

MEDIA TRAINING GUIDE

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MEDIA TRAINING GUIDE

Purpose

The purpose of the Media Training Guide is to provide a detailed understanding of information management specific to data storage technology. This guide begins with an overview of the two major technologies that support electronic data storage in digital form. Following this is a review of the most common forms of data storage media prevalent in the marketplace, including detailed specifications, likely future trends, and common applications.

Magnetic and Optical Data Technology

The most commonly known components of computers include the hard drive, floppy drive, and CD-ROM drive. Since their inception during the early development of computer technology, they have become the standard for *data storage* in almost every computer environment. These devices store and retrieve data electronically through the two types of technology: *magnetic* and *optical*. Together, they provide physical methods of holding information that allow for varying storage capacity, data transfer rates, and portability.

Drive Components

At first glance, the different types of drives found in computers appear very similar. They all rely on storage media in the form of a disk upon which data can be stored, or *written*, and retrieved, or *read*. From this comes the name *read-write device*. Standard hard drives and floppy drives use magnetic technology to read and write information, while CD-ROM drives use optical technology to do so. Therefore, they are referred to respectively as *magnetic storage devices* and *optical storage devices*. All types of drives have similar internal components to accomplish their jobs. They typically consist of three main parts:

1. A logic board receives commands from the computer's operating system to activate the drive.
2. A motor rotates the disk to enable data access.
3. A *read-write mechanism* does the job of transferring data to and from the disk.

Differences Between Magnetic and Optical Drives

Differences in the way the read-write mechanism works determines whether a drive is using magnetic or optical technology. Floppy and hard drives use a small magnetic head to magnetize areas on the disk surface to store data, and the same head allows for easy retrieval of data. CD-ROM drives use a low-power laser to read data stored on the disk surface. Because of the established understanding of magnetics and its prevalent use in a variety of technologies,

magnetic storage devices have typically been constructed to both read and write data. However, because laser technology is a newer science and certain media limitations exist, it is only recently that optical storage devices with the ability to write data have reached the consumer market.

Digital Technology

The way drives translate data to disk-based media seems quite complicated to many, but it is actually founded upon a very simple concept. No matter how data may appear onscreen or printed out, computers always rely on *binary code* at the most basic level. This simply means that a computer understands everything in terms of the numbers one and zero. Putting this elementary concept in the context of media storage, it becomes very easy to understand how a disk holds information. The use of two digits allows for only two possible conditions. Therefore, magnetic storage devices use an electrical charge to magnetize areas of the disk to create positive charge, which translates to a one, or negative charge, which translates to a zero. Similarly, with optical storage devices a *pit* is pressed into an area of a compact disc through a manufacturing process, or burned in by a laser, which translates to a one. An area that is left level with the rest of the disc surface, which translates to a zero, is referred to as a *land*. Reading data is even easier because the read-write mechanisms determine the presence of either a positive or negative magnetic charge, or the presence or absence of a pit, on the media surface.

So what do all of these ones and zeroes add up to? Again, the premise is very simple. Binary code uses up to eight digits to represent alphanumeric characters. These are called *bits*. From this, basic math determines that eight bits make up one unit of data, now universally known as a *byte*. Together with the devices that enable their manipulation, bits and bytes create *digital technology*, a term that is so widely used yet often rarely understood.

Units of Data Measurement

Now that the origin of digital technology is clear, another mystery can be solved: units of data measurement. Usually, we are taught that a thousand bytes make one *kilobyte* (KB), a thousand kilobytes make one *megabyte* (MB), and a thousand megabytes make one *gigabyte* (GB). It is a fairly easy mathematical process. Then you run into more observant people who ask the question “If I have a file that takes up one megabyte, how come my computer says it takes up 1,024 kilobytes instead of 1,000?” The answer takes us back to the basics of binary code. Since one character is comprised of eight binary bits, each with one of two possible values, the units of data measurement will always be multiples of two. Therefore, one kilobyte is actually equal to 1,024 bytes, each an individual character of alphanumeric data. Because data multiplies so quickly, the spare characters add up quickly as well. It may be convenient to round off the units of data measurement, but in the end media capacity is never truly a multiple of ten.

To understand the units of data measurement more concretely, consider that an average typewritten page requires about two kilobytes of space to store. This is extremely small relative to the amount of digital storage readily available to the average consumer or professional. In the tape-based media section below, we will see that a high-end 8mm tape can provide 25 gigabytes

of backup space. Just one of these tapes has the capacity to store 12.5 million typewritten pages, which is equivalent to 1,250 four-drawer file cabinets. Seen from this perspective, it is easy to realize how truly revolutionary electronic data storage is.

Given the apparent excessive capacity of current media, it is easy to stop understanding units of data measurement at gigabytes because the question arises “who is ever going to need this much space?” But technology is evolving at a pace unimagined by most. It was less than five years ago that hard drives with the capacity of hundreds of megabytes were hailed as cutting-edge storage devices. Today, we regularly use media with storage capacity approaching hundreds of gigabytes, with literally thousands of times the capacity of their predecessors. Measurement in terabytes, petabytes, and exabytes is just around the corner. Following is a snapshot of current data capacity naming standards:

<i>Rounded Capacity</i>		<i>Unit Name</i>	<i>Abbreviation</i>	<i>Actual Capacity (in bytes)</i>
1,000 bytes	=	1 kilobyte	KB	1,024
1,000 kilobytes	=	1 megabyte	MB	1,048,576
1,000 megabytes	=	1 gigabyte	GB	1,073,741,824
1,000 gigabytes	=	1 terabyte	TB	2^{40}
1,000 terabytes	=	1 petabyte	PB	2^{50}
1,000 petabytes	=	1 exabyte	EB	2^{60}

Tape Drives

A much older magnetic storage device, the tape drive, predates considerably the development and use of disk-based media. Magnetic tape is actually one of the original media developed in the early history of computer technology for data storage. It has been used for decades in large-scale government and industrial settings. It was popularized early in the consumer market when it began supplanting vinyl records in the music industry. Although audio tape has met the same fate as vinyl in the face of compact disc technology, it has always retained its foothold in the computer industry. Tape drives and tape-based media have risen again in recent years as a prevalent form of magnetic storage in the computer industry, thanks to their low cost and small size. Proving that everything old is new again, magnetic tape technology has been refined and developed, and is now used innovatively to provide high-capacity data storage primarily for backup purposes.

How They Work

As with other magnetic data technology, tape drives operate on the same basic premise. Rather than spinning a magnetic disk, the drive motor spools the magnetic tape within a *cartridge* from one spindle to another. While in motion, the read-write mechanism, or *tape head*, magnetizes portions of the tape with a positive or negative charge to write data. Again, reading is easy as the head determines the type of magnetic charge to read data.

Differences and Limitations

One of the primary differences between tape-based and disk-based media devices is the mobility of the read-write mechanism. With disk-based media, both magnetic and optical, the read-write mechanism moves across the surface of the disk while it rotates, making disk drives a *direct access* device. Conversely, with tape-based media the read-write mechanism remains stationary as the tape is moved across it, making tape drives a *sequential access* device. Put simply, when you want information from disk-based media, the read-write mechanism can go directly to its location on the disk. This has caused it to be more commonly known as a *random access* device, because its direct access capability enables the retrieval of randomly located information on the disk. However, when you want information from tape-based media, the tape must be moved forward or backward to its location for the read-write mechanism to retrieve a specific section of data, moving sequentially through all other data on the tape.

Traditionally, this has made the process of reading data much slower on tape-based media than on disk-based media. On the other hand, writing data to tape has always been comparable in speed, as data is quickly laid down while the tape streams by. Together, these two characteristics have made magnetic tape a natural choice for backup. Tape drives store data quickly and easily to low-cost, high-capacity, portable media that can be reused systematically. Data retrieval becomes necessary only in emergency situations when hard drives become damaged or fail.

The Big Gray Area

Much of the information presented so far not only reflects historical trends in the development of information technology, but also provides a framework to keep concepts, terms, and processes clear. However, two definite things can be said about the computer industry: 1) It is undoubtedly the fastest growing sector of the marketplace, and 2) it relies upon some of the most complex technological developments in the history of mankind.

It follows, then, that the speed at which the market grows creates a highly competitive atmosphere, which in turn floods the market with proprietary technology. Devices are frequently developed independently by major companies or *corporate alliances* that achieve the same ends via different means. This generally creates an initial glut on the market of similar technologies, with a variety of social and economic forces determining a “winner” later on that is adopted as an industry standard. These characteristics of our economy work in tandem with the constant discovery and innovation of new technology, creating a symbiotic relationship between the two: Market demand fuels the research and development of new technology, while research and development create new technology that fuels market demand.

What does this all mean? Unfortunately, it means there is a tremendous amount of overlap in available technology, a big gray area, which frequently creates quite a bit of confusion in understanding various products. Often, this dynamic dictates that what you learn about today may disappear tomorrow. There have been many casualties on the technology market battlefield. However, certain trends always remain, and some foundational concepts never change. As you review the more detailed aspects of data storage devices and media outlined in this guide, keep in

mind the broader directions in which technology flows, and the established underpinnings that continue to support it.

Tape-Based Media

Overview

As discussed in the introduction, tape-based media are types of storage that rely on magnetic data technology to read and write information. Traditionally, tape has been easy to write data to, but difficult to read data from, because tape drives are sequential access devices. However, tape has consistently maintained its status as a low-cost, high-capacity, portable means of storing information, and therefore is almost exclusively used for *backup* purposes. A backup provides redundant copies of any type of electronically stored information that can be used to restore original files if they are lost, accidentally deleted, or destroyed. Backup procedures are very important for most organizations because primary systems can fail for a variety of reasons, often resulting in the loss of critical data.

Typically, the first step in matching tape technology to a given PC environment involves assessing storage capacity needs for the data being backed up. This is just one of many considerations for tape users, however. For some, data transfer rates are more important because of limited time frames during which file access can be provided for backup. For many, tape drives provide the best of both automation and convenience. Most software allows for scheduled, automatic backup based on almost any configuration of time, date, and frequency. Also, tape is generally the only media that can support a complete hard drive backup without being swapped out.

In this section, when learning about the innovative ways information is now stored to tape, keep in mind a few precedents. From its inception, data has not only been stored to tape sequentially, but also in a *linear* fashion across *tracks* on the tape, very much like painting lanes on a highway. Because of this, the common trends in expanding tape technology have been to make tapes longer to accommodate more data, or wider to allow for more tracks. You will learn below that this convention has been improved upon quite a bit in recent years.

Current Technology

For the purpose of this discussion, we will examine seven predominant types of tape-based media:

1. Data Cartridges, including QIC and Travan standards
2. 8mm Tape
3. Digital Audio Tape (DAT)
4. Digital Linear Tape (DLT), including Super DLT
5. Half-Inch Tape
6. Scalable Linear Recording (SLR)
7. Linear Tape Open (LTO), including Accelis and Ultrium

Each of these media is used for backup purposes. They each exploit different means of physically storing data, and they each possess varying capabilities in terms of storage capacity and data transfer rates.

Data Cartridges – QIC and Travan

One of the first standards created in tape-based media is the *quarter-inch tape cartridge*, abbreviated *QIC* and pronounced the same as *quick*. This type of *data cartridge* was developed by 3M in the early 1970s. As with other forms of tape, QIC has retained its foothold in the market for so long because of its capacity and cost. QICs look similar to audio tapes, and the drives that support them use the standard linear recording technique along parallel tracks, with the number of tracks primarily determining the tape capacity.

QICs come in two sizes, the DC600 full-size cartridge and the DC2000 mini-cartridge, with the mini-cartridge more prevalent in the marketplace. The drives use a read-write mechanism similar to standard home audio equipment, which writes data sequentially, one track at a time in one direction. Once the end of the tape is reached, the direction reverses and the data recording process begins again with the next track, continuing through all tracks in a similar fashion.

Terms you may hear applied to the way data is written to tape include *ECC*, which stands for *error correction code*, and *CRC*, which stands for *cyclic redundancy check*. It is important to understand that the binary code that comprises the data stored on a tape is not the only information recorded. Tape drives use both mechanical and software techniques to check the accuracy of data written to tape, which includes supplemental recorded information that ensures the integrity of the data and helps eliminate errors in the writing process. Tape drives also store a *directory track* that maps out the location of data on the tape to maintain a *directory structure* for later data retrieval.

Standards and Formats

Developments of the QIC to accommodate more data have included increasing its length and width (which ironically no longer makes it a quarter-inch tape) to create room for more data and more tracks. Another method involves adding more tape heads so that writing can be done concurrently on more than one track.

These developments soon required the establishment of *QIC Standards* so that tape formats could be unified and made compatible. Following are common QIC parameters:

- Widths of either 0.25 inches or 0.315 inches.
- Total tracks between 28 and 72.
- Storage capacity as low as 80 MB and as high as 4 GB.

Keep in mind that the storage sizes represent what is called *native capacity*, which means the minimum amount of data storage possible with the tape. Many types of backup software utilize

data compression techniques that can often dramatically increase the total amount of capacity, called *compressed capacity*, but almost always reduce data transfer rates to and from the tape.

Travan

Unfortunately, because of the rapid and uneven development of technology, QIC Standards were not enough to keep things straight, nor was compatibility ever complete between standards. Therefore, a format called *Travan* was introduced to create a new standard that allowed not only for higher tape capacity, but also for compatibility with existing QIC standards. Following is a snapshot of current Travan standard formats:

Name	<i>Travan-1</i>	<i>Travan-2</i>	<i>Travan-3</i>	<i>HP Colorado*</i>	<i>Travan-4</i>	<i>Travan-5</i>
Native Capacity	400 MB	800 MB	1.6 GB	2.5 GB	4 GB	10 GB
Compressed Capacity	800 MB	1.6 GB	3.2 GB	5 GB	8 GB	20 GB
Data Transfer Rate	62.5 – 125 KB per second	62.5 – 125 KB per second	125 – 250 KB per second	502 KB – 1 MB per second	1 – 1.17 MB per second	1 – 1.83 MB per second

* *The 5 GB version of the Travan standard was developed by Hewlett-Packard for use on its Colorado tape drive systems, hence the break in naming sequence.*

Travan NS

The Travan format has been augmented recently by the *Travan NS* format, with NS standing for network series. This was developed by Imation in 1997 with the aim of creating a higher performance standard for larger scale network applications, and also to compete with the 8mm and DAT technologies outlined below. Travan NS drives and cartridges are designed to use *read-while-write* data recording, which means data is verified as it is written to prevent errors. Prior technologies relied on a second pass of the read-write head as part of the data verification process. Elimination of this with read-while-write recording typically cuts backup time in half. Additionally, improved hardware-based data compression significantly improves data transfer rates. Following are the current Travan NS standard formats:

Name	<i>Travan NS 8</i>	<i>Travan NS 20</i>	<i>Travan NS 30</i>
Native Capacity	4 GB	10 GB	15 GB
Compressed Capacity	8 GB	20 GB	30 GB
Data Transfer Rate	600 KB per second	1 MB per second	3 MB per second

8mm Tape

The eight millimeter tape was originally developed by the video industry to provide a high-quality medium that was small enough to be designed into both professional and consumer grade cameras. They are used widely by many camcorders on the market today, and for video formats are commonly called *Hi-8* tapes. This format was adapted by the computer industry to allow for even higher capacity storage than QIC and Travan formats. When used as a backup media, these tapes are simply referred to as *8mm*.

Data Writing Innovation

Eight millimeter tape drives use an innovative data writing technology called *helical scan*, which allows for much greater data storage on tapes of comparable width and length as other formats of tape. As with the 8mm media, this data writing method was also adapted from the video industry and is based on the same recording principle used in both professional and consumer grade VCRs.

When writing data, tape drives that use the helical scan system pull the tape along a complicated path so that it can be wrapped against a cylindrical drum, containing two pairs of read and write heads. This cylinder is tilted at an angle to the tape so that it can write diagonal tracks of data across its width. Not only do the two write heads lay down data concurrently at an angle to the streaming tape, but at two different angles to one another. Therefore, their tracks can overlap, but are magnetically encoded so that their companion read heads only pick up the data written by their respective recording twin. This ingenious method allows for considerable *data density*, meaning that much more information can be stored in much less tape space.

Unfortunately, there is a major drawback to this recording technique. The requirement that the tape be wrapped halfway around the read-write mechanism creates a complicated tape path, which in turn generates much greater wear and tear on both the tape heads and the tape itself. Almost everyone has experienced his or her VCR eating a VHS tape. The danger is the same for 8mm backup systems. Because of the problems inherent in the data writing process, the life of both 8mm drives and the 8mm tape medium is significantly less than that of other drive and tape types. Based on this, 8mm tape is most appropriate for applications where storage capacity is the primary determining factor.

Standards and Formats

There are two major standards prevalent in 8mm tape-based media. Exabyte Corporation supports a *Standard 8mm* tape and a companion format called *Mammoth*. Seagate Technology and Sony Corporation support a format called *Advanced Intelligent Tape*, abbreviated *AIT*. Following is a summary of the parameters of these formats:

Name	<i>Standard 8 mm (low end)</i>	<i>Standard 8mm (high end)</i>	<i>Mammoth</i>	<i>AIT-1</i>	<i>AIT-2</i>
Native Capacity	3.5 GB	7 GB	20 GB	25 GB	50 GB
Compressed Capacity	7 GB	14 GB	40 GB	50 GB	100 GB
Data Transfer Rate	530 KB per second	1 MB per second	6 MB per second	6 MB per second	12 MB per second

Digital Audio Tape (DAT)

Digital Audio Tape, abbreviated as *DAT*, has a story remarkably similar to that of 8mm tape, although it is only half the width at 4mm. Instead of being borrowed from the video industry, as its name implies the DAT was borrowed from the music industry. It was originally developed to rival compact disc technology in audio quality, while retaining magnetic data storage techniques. In 1998, Hewlett-Packard and Sony Corporation defined a *Digital Data Storage* standard, abbreviated *DDS*, which created a format enabling the use of DAT tapes for data storage. There is a competitive standard called DataDAT, which is a less prevalent format than DDS.

As with 8mm tape, DAT uses the same helical scan data writing process described above. Because of this, the same drawback applies: greater wear and tear on both the tape and read-write mechanism. DAT media are approximately in the middle between QIC/Travan and 8mm tapes in terms of storage capacity. Following is a snapshot of current DAT format capacities:

Name	<i>DDS</i>	<i>DDS-1</i>	<i>DDS-2</i>	<i>DDS-3</i>	<i>DDS-4</i>
Native Capacity	2 GB	2 GB	4 GB	12 GB	20 GB
Compressed Capacity	-	4 GB	8 GB	24 GB	40 GB
Data transfer rates	55 KB per second	0.55 – 1.1 MB per second	0.55 – 1.1 MB per second	1.1 – 2.2 MB per second	1.1 – 3.0 MB per second

Digital Linear Tape (DLT)

The *Digital Linear Tape*, abbreviated *DLT*, was originally developed by Digital Equipment Corporation in the 1980s, and came into its current form after the technology was acquired by Quantum Corporation in 1994. The discussion of this tape-based media was saved for the end because it represents the combination of a variety of tape technologies and developments so far

presented. In this way, DLT not only attempts to be a jack of all trades, but a master of all as well.

For starters, the DLT is a half-inch wide, greater in width than all other tape types. This naturally allows for a high number of tracks to be laid on the tape. The tape streaming concept used by DLT drives is actually modeled from the old reel-to-reel concept: DLT cartridges contain only one reel of tape, which is then wound onto a second reel contained within the DLT tape drive. The path the tape takes is along a carefully constructed, boomerang-like arc, where it passes by the read-write mechanism, and then smoothly wraps around the drive uptake reel. This patented design dramatically decreases the wear and tear associated with helical scan systems, greatly extending the life of the tape heads and greatly reducing tape contact.

Beyond the mechanical improvements, DLT also capitalizes on advanced data writing techniques, essentially combining linear and helical scan recording methods. Data tracks are laid down in parallel pairs, using a serpentine pattern that runs the entire length of the tape. As with linear systems, the tape runs all the way to the end, then reverses to begin laying the next pair of tracks. As the tracks are layered on the tape, however, they are placed at an angle as with the helical scan method, creating a herringbone pattern. The combined method is known as *Symmetric Phase Recording*, or *SPR*.

Overall, DLT takes the best features of existing technologies to yield an extremely high-capacity tape with much greater data integrity and data transfer rates. Along with these innovations comes a hefty price tag, making DLT one of the most expensive backup options. As with other tape-based media, DLT has its own standard with varying capacity formats:

Name	<i>DLT 2000</i>	<i>DLT 4000</i>	<i>DLT 7000</i>
Native Capacity	15 GB	20 GB	35 GB
Compressed Capacity	30 GB	40 GB	70 GB
Data Transfer Rate	1.25 – 2.5 MB per second	1.5 – 3 MB per second	5 – 10 MB per second

Super DLT

Quantum will release a follow-up DLT format in 2000 called *Super DLT*. The new drives supporting this format use a combination of optical and magnetic data storage technology called *laser guided magnetic recording*, or *LGMR*. With this recording method, a laser precisely guides the magnetic tape heads so that Super DLT tapes will not have to be preformatted. This decreases cost and increases convenience.

Super DLT drives also use a data writing technique called *Partial Response Maximum Likelihood*, or *PRML*, which is variation of a method originally developed for hard disk drives. This technique is used to differentiate between valid data and *noise* during the writing process.

Noise is any kind of electrical interference that occurs when the tape heads write data. Taken together, LGMR and PRML enable major increases in capacity and data transfer rates. The PRML technique is also used by scalable linear recording drives, discussed below.

Storage capacity for Super DLT media will likely exceed 100 GB, with the goal of approaching 500 GB. Data transfer rates will be 10 MB per second at baseline, with plans to reach an incredible 40 MB per second.

Half-Inch Tape

As discussed in the previous section, DLT and Super DLT are half-inch formats that capitalize on some of the best aspects of existing technology. Other manufacturers are seeking to continually create competitive products in the tape-based media market through similar means. Because the constant recombination of tape widths, lengths, and technologies is often confusing, it is important to be reminded of the big gray area. Keep in mind that the market will continue to be flooded with proprietary technology, and the resulting technological overlap will likewise grow. It is best to remember that no matter how many ways the wheel is reinvented, it is still, at root, a wheel. The basic concepts of data storage will remain the same, and the details of data storage advancements can always be placed in the context of larger trends.

Capitalizing on the advantages of the half-inch format, Imation in conjunction with StorageTek released in 1999 what they call the *Black Watch 9840* tape cartridge for use in StorageTek's 9840 tape drive. The media is designed for decreased data access speeds, currently rated at an average of eight seconds for first access to data. Storage capacity for the Black Watch 9840 cartridge is 20 GB native, up to 80 GB compressed. Data transfer rates are 10 MB per second native, 20 MB per second compressed. The 9840 cartridge is backward compatible with a smaller capacity cartridge called the Black Watch 3490E. This media has considerably less space at 810 MB.

Scalable Linear Recording (SLR)

Another entry into the field of proprietary technology is the *scalable linear recording* drive, abbreviated *SLR*, developed by Tandberg Data. Imation manufactures compatible media. This iteration of tape technology again combines a variety of technological elements to compete with many of the other tape types. SLR tape drives and cartridges are based on linear recording technology, which provides significant reliability advantages over helical drives and media such as 8mm and DAT. With SLR, the tape path is contained entirely within the cartridge, reducing tape stress, ensuring data integrity, and increasing cartridge reliability.

As with the Travan NS drives and media, SLR offers read-while-write data recording, thus decreasing backup time and increasing data transfer rates. Additionally, SLR boasts a technology called *Variable Rate Randomizer*, or *VR2*. This technology was originally developed by Overland Data, and it relies on the Partial Response Maximum Likelihood data writing

technique used by Super DLT drives. This proprietary form of PRML achieves the same goal as Super DLT by significantly increasing capacity and data transfer rates.

Following are the current SLR media types and capacities:

Name	<i>SLR-5</i>	<i>SLR-24</i>	<i>SLR-32</i>	<i>SLR-50</i>	<i>SLR-100</i>
Native Capacity	4 GB	12 GB	16 GB	25 GB	50 GB
Compressed Capacity	8 GB	24 GB	32 GB	50 GB	100 GB
Data Transfer Rate	380 KB per second	1.2 – 2.4 MB per second	1.5 – 3 MB per second	2 – 4 MB per second	6 – 10 MB per second

Linear Tape Open (LTO)

To compete with Quantum’s DLT and Super DLT format, Hewlett-Packard, IBM, and Seagate have joined forces to develop a new standard called *linear tape open*, or *LTO*. LTO technology uses enhanced linear data reading and writing techniques, improved servo technology, data compression, track layout, and error correction code to further push the bounds of capacity, performance, and reliability. As with the DLT tape medium, LTO cartridges contain a single reel, with the drives providing a companion uptake reel to mirror the reel-to-reel concept.

This technology supports two different formats: *Accelis* and *Ultrium*. The Accelis format is focused primarily on decreasing access time, currently rated at under 10 seconds, along with higher data transfer rates. The Ultrium format is focused primarily on increasing storage capacity, also providing higher data transfer rates. Capacities for this format are 100 GB native, 200 GB compressed. Data transfer rates are 10 to 20 GB per second native, 20 to 40 GB per second compressed.

Future Developments

Beyond making tapes longer and wider, there are a variety of innovations that manufacturers are capitalizing on to push the boundaries of capacity and reliability. Tape drives are now being designed with fewer moving parts, reduced tape tension, advanced heat protection, and integrated circuitry that enhances drive calibration, accuracy, and error correction.

The tape materials themselves and the metallic coatings applied can make great differences in all aspects of performance. Exabyte’s Mammoth drives support an emerging medium called *advanced metal evaporated* tape, or *AME*. This tape can store more data, and has anti-corrosive properties to increase durability and push expected archival ratings of 30 years. This better grade of tape also reduces wear on the read-write mechanism, thus increasing head life.

Sony's AIT tape technology incorporates a unique feature called *Memory-In-Cassette*, or *MIC*. This technology relies on a special *EEPROM chip* built into the tape cartridge, which stands for *erasable electrical programmable read-only memory*. This chip stores the tape's directory structure and indexing information, which allows for data retrieval up to 150 times the normal read speeds of traditional cartridges. In this way, developers like Sony are attempting to overcome the limitations of sequential access media.

Specific Applications

The following shows suggested PC environments in which each of the tape-based media discussed above may be appropriate:

Tape/Drive	Format	Capacity (native – compressed)	Environment
Data Cartridge	Travan-3	1.6 GB – 3.2 GB	<ul style="list-style-type: none"> • Stand-alone PC
	Travan-4	4 GB – 8 GB	<ul style="list-style-type: none"> • Stand-alone PC • LAN Server
	Travan-5	10 GB – 20GB	<ul style="list-style-type: none"> • LAN Server • Small network • Mid-size network
	Travan NS 8	4 GB – 8 GB	<ul style="list-style-type: none"> • Stand-alone PC • LAN Server
	Travan NS 20	10 GB – 20GB	<ul style="list-style-type: none"> • LAN Server • Small network • Mid-size network
	Travan NS 30	15 GB – 30GB	<ul style="list-style-type: none"> • LAN Server • Small network • Mid-size network
8mm	Standard 8mm (low end)	3.5 GB – 7 GB	<ul style="list-style-type: none"> • Stand-alone PC • LAN Server
	Standard 8mm (high end)	7 GB – 14 GB	<ul style="list-style-type: none"> • Stand-alone PC • LAN Server
	Mammoth	20 GB – 40 GB	<ul style="list-style-type: none"> • Mid-size network • Large network
	AIT-1	25 GB – 50 GB	<ul style="list-style-type: none"> • Mid-size network • Large network

Tape/Drive	Format	Capacity (native – compressed)	Environment
	AIT-2	50 GB – 100 GB	<ul style="list-style-type: none"> • Mid-size network • Large network
DAT	DDS-1	2 GB – 4 GB	<ul style="list-style-type: none"> • Stand-alone PC • LAN Server
	DDS-2	4 GB – 8GB	<ul style="list-style-type: none"> • Stand-alone PC • LAN Server
	DDS-3	12 GB – 24 GB	<ul style="list-style-type: none"> • LAN Server • Small network • Mid-size network
	DDS-4	20 GB – 40 GB	<ul style="list-style-type: none"> • LAN Server • Small network • Mid-size network
DLT	DLT 2000	15 GB – 30 GB	<ul style="list-style-type: none"> • LAN Server • Small network • Mid-size network
	DLT 4000	20 GB – 40 GB	<ul style="list-style-type: none"> • Mid-size network • Large network
	DLT 7000	35 GB – 70 GB	<ul style="list-style-type: none"> • Mid-size network • Large network
Half-Inch Tape	Black Watch 9840	20 GB – 80GB	<ul style="list-style-type: none"> • Mid-size network • Large network
SLR	SLR-5	4 GB – 8 GB	<ul style="list-style-type: none"> • Stand-alone PC • LAN Server
	SLR-24	12 GB – 24 GB	<ul style="list-style-type: none"> • LAN Server • Small network • Mid-size network
	SLR-32	16 GB – 32 GB	<ul style="list-style-type: none"> • LAN Server • Small network • Mid-size network
	SLR-50	25 GB – 50 GB	<ul style="list-style-type: none"> • Mid-size network • Large network
	SLR-100	50 GB – 100 GB	<ul style="list-style-type: none"> • Mid-size network

Tape/Drive	Format	Capacity (native – compressed)	Environment
LTO	Accelis/Ultrium	100 GB – 200 GB	<ul style="list-style-type: none"> • Large network <ul style="list-style-type: none"> • Mid-size network • Large network

Disk-Based Media

Overview

As discussed in the introduction, disk-based media are types of storage that rely on both magnetic and optical data technology to read and write information. The earlier and more familiar magnetic media, in the form of hard disks and floppy disks, were part of the technology explosion that facilitated the advent of personal computing in the early 1980s. Although the PC was well established by the time optical storage devices became widely available, they are just as important in the scheme of media development as their magnetic partners. Together, both forms of disk-based media provide the foundation upon which all modern computing is accomplished.

The most important feature of any removable disk, whether magnetic or optical, is its portability. The primary reason removable media are so popular is because they can be taken anywhere. Although from a market standpoint they are competing varieties of media, magnetic and optical removable disks offer similar advantages to all types of users. The price of most magnetic drives, including newer high capacity types discussed below, remains consistently low relative to standard peripheral costs. Writable and rewritable optical drives are still somewhat higher in cost than many magnetic drives, but they generally reach consumer level pricing soon after they are introduced. Media prices between the two are very close, providing affordable options in a wide range of capacities and formats.

The prevalence of media types is very important to both professional and home users as well. Some newer types of high capacity magnetic drives and high-end optical drives are becoming standard equipment on many new PCs. Prevalence boosts compatibility, with more and more backward-compatible and cross-compatible formats being established. Most enterprises managing data in digital form are able to accommodate almost any type of disk-based media in order to maintain their competitive edge with customers and colleagues.

As with tape-based media, there are many innovative ways information is now stored to disk, and it is important to keep in mind the precedents of data reading and writing for these media. With magnetic technology, binary code is written to a disk while it spins by means of a mobile read-write mechanism that magnetizes areas on the disk. With optical technology, binary code is also written to a disc while it spins by means of a mobile read-write mechanism, in this case a laser that burns a pattern of pits into the disk surface, leaving level areas called lands. Reading in both cases is accomplished by establishing the presence of magnetized areas and pits on the respective disk types.

Current Technology

For the purpose of this discussion, we will examine four predominant types of disk-based media:

1. Compact Disc (CD)
2. Digital Versatile Disc (DVD)
3. Magneto Optical Disc (MO)
4. Diskettes including Zip, SuperDisk, and HiFD

There are some types of disks that will not be covered in this discussion of disk-based media, although it is important to be familiar with them. On the magnetic end of the spectrum, hard drives are the obvious missing element. Hard drives are more precisely referred to as *fixed disks*, in comparison with *removable disks*, which include all of the types listed in the above four categories. On the optical end of the spectrum, the predecessor to the magneto optical technology discussed below is known as a *WORM drive*, meaning *Write Once Read Many*. These drives are used in a variety of large-scale, often proprietary systems that emerged in the late 1980s for optical imaging of large amounts of data in storage intensive settings. They operate on the same premise as the CD-R technology discussed below.

Compact Disc (CD)

The *compact disc*, or *CD*, was invented by Sony and Philips and introduced to the consumer music market in 1982. Its phenomenal success ever since that time is due to the CD's unmatched audio quality, random access capability, and durability. A data version for PCs, called the *CD-ROM*, meaning *compact disc-read only memory*, was introduced two years later in 1984, but it took some time before it became prevalent in the computer industry. As discussed in the first overview, optical storage devices have traditionally had read capability well before having write capability. In the case of the early years of the CD and CD-ROM, discs were pressed from molds, creating the data-bearing pits by means of manufacturing. This is obviously still the case with large-scale releases of audio CDs and software CD-ROMs. It is only recently that the ability to *burn* CDs individually has been made possible with the newer lasers found in write-capable optical drives.

Disc Capacity

The audio CD was originally designed to hold up to 74 minutes of music. The CD-ROM was adapted to hold up to 650 MB of data, and more recently 74 minutes of full-motion video and audio with picture and sound quality comparable to standard VHS tapes.

Disc Speed

The primary distinguishing factor between CD-ROM drives is the data transfer rate, or *speed* of the drive. The original single-speed CD-ROM drive reads data at a rate of 150,000 bytes per

second, or roughly 150 KB. This is the benchmark from which all succeeding drives are measured. Soon after the single-speed drive came the double-speed (2X), triple-speed (3X), and quadruple-speed (4X) models. After this, speed ratings grew in even numbers, such as 6X, 8X, 10X, 12X, etc. Current drive speeds from a variety of manufacturers are standard at 32X, which enables a transfer rate of 4.8 MB per second. Newer 48X drives are capable of transfer rates of 7.2 MB per second.

CD-Recordable (CD-R)

WORM drives for large-scale data archiving implementations were developed in the late 1980s, but a comparable consumer product was not available until 1993 when Philips became the first to market the *compact disc-recordable* disc, or *CD-R*. Data on a standard CD is placed on a spiral track that winds from the center outwards. This spiral track is preformed on blank CD-Rs when they are manufactured to ensure that data is written along the same path, so it can be read the same way as a standard CD.

Recording Process

In the CD manufacturing process, pits and lands representing data are pressed into the disc by a mold. A manufactured CD, then, always has its trademark silver color because of the aluminum layer into which the data pattern is pressed. To replicate this process on an individual basis with a write-capable drive, a CD-R incorporates a layer of *organic dye* between the standard metallic layer and the clear protective layer. It is this layer of dye that is burned by the laser in the drive, replicating the pits and lands of a manufactured CD, which in the case of a CD-R are actually burned and unburned areas of the dye layer. Together with the reflective attributes of the metallic layer, the burned and unburned areas of the dye layer reflect light almost identically to pressed pits and lands, enabling compatibility between drives so that standard CDs and CD-Rs are read in the same manner.

Because CD-Rs require an organic dye layer and a reflective layer to work together to emulate the laser light reflection created by manufactured CDs, there are only a few standard dyes in use. Along with the two types of reflective layers, gold and silver, a total of four CD-R dye color schemes exist that are readily recognizable to consumers:

1. gold/green
2. gold/gold
3. silver/blue
4. silver/silver

Although color may seem a relatively unimportant aspect, it is always representational of the chemistry behind the organic dyes that enable the writing process to work. CD-Rs with a gold/green reflective layer get their color from an organic dye called cyanine. This dye has high light sensitivity, and is therefore writable by a wider range of laser powers, increasing compatibility across different drive manufacturers. The archival rating of these discs is about 50

years. CD-Rs with a gold/gold reflective layer use a dye called pthalocyanine. The gold/gold combination enables a higher archival rating, currently projected at up to 100 years. However, pthalocyanine is less light sensitive, which sometimes causes compatibility problems with certain rewritable drive types.

Silver/blue discs get their color from a dye called azo, manufactured by Mitsubishi Chemical Company. These discs have competitive archival ratings approaching 100 years. CD-Rs with a silver reflective layer are typically less expensive to produce.

Disc Capacity

CD-Rs are currently available in formats that allow for two different data and audio/video storage capacities:

Name	CD-R	CD-R
Data Capacity	650 MB	700 MB
Audio/Video Capacity	74 minutes	80 minutes

It is important to remember that all of the data written to a CD-R may not be readable by all CD-ROM drives, depending on the number of times data is written to the CD-R. If the data is stored all at once, or in a *single session*, then compatibility is ensured across all drives. However, if the data is stored across a *multi-session* recording process, some older CD-ROM drives will not be able to read data written after the first recording session. Most newer CD-ROM drives are multi-session compatible.

Disc Speed

Relative to standard CD speeds, writing data to CD-R is a much slower process than reading it. Originally, writable drives were only able to support 1X write speed. Current drives have reached 8X write speeds. In most cases, the read speed of a writable drive is also reduced somewhat, currently in combinations of 8X write speeds and 16X/20X read speeds.

CD-Rewritable (CD-RW)

The *compact disc-rewritable*, or *CD-RW*, was introduced in 1997 through a collaboration between Hewlett-Packard, Mitsubishi, Philips, Ricoh, and Sony. While CD-Rs and WORMs can be characterized as identical twins, CD-RWs and MOs are more like fraternal twins. The MO drive and discs, as the name implies, rely on a combination of magnetic and optical technology to facilitate a rewritable media. The CD-RW drive and discs, however, employ no magnetic techniques and together remain an entirely optical form of data storage, unlike their professional counterpart.

Recording Process

As with CD-Rs, CD-RWs are preformed with a spiral track to create a data path from which CD-RW drives are able to read and write data. Also like CD-Rs, CD-RWs have a special layer upon which data can be written. What makes it possible to erase and rewrite data repeatedly on this layer is the use of *phase change* technology. Through this unique innovation, the recordable layer of the disc is composed of a special *phase-change medium*, which manifests different properties depending upon the temperature to which it is heated. When heated to a lower temperature, the medium cools down to a *crystalline* state. When heated to a higher temperature, it cools down to an *amorphous* state.

What does this mean, exactly? Put simply, the phase-change medium can be thermally altered with the laser of the drive to create either crystalline or amorphous areas on the disc, which again ingeniously replicate the pits and lands of the original CD-ROM. Here is a summary of what happens:

Laser Power	Description	Phase Change	Result
High	Write Power	Amorphous	Imitates a pit
Medium	Erase Power	Crystalline	Imitates a land
Low	Read Power	-	Standard data reading

Although this remarkable process very closely approximates the data written in both the manufacturing and CD-R recording processes, the reflectivity of the disc is actually less than standard CDs and CD-Rs. Therefore, the wavelength of the laser that reads a CD-RW is different than the lasers that read CDs and CD-Rs. To accommodate this difference, drives that support CD-RW discs are designed to meet a standard called *MultiRead*. This specification is found on both drives and CDs that support this reading capability.

Disc Capacity

CD-RWs are available in the standard 650MB capacity for data storage. However, because of the file structure used to place and manage data on the disc, the useable space is actually closer to 500 MB. There are a variety of format challenges relating to the location and relocation of data on the disc that require high overhead for file allocation information, significantly reducing total capacity. Since CD-RWs are rewritable by design, there is no distinction between single and multi-session recording as with CD-Rs. However, as stated above, drives must support MultiRead capability to read data from CD-RWs. Therefore, many existing CD-ROM drives are not able to read this type of disc.

Disc Speed

As with CD-Rs, writing data to CD-RW is much slower relative to read speeds. Current drives have reached 8X write speeds. Again, the read speed of a writable drive is also reduced somewhat, currently in combinations of 8X write speeds and 16X/20X read speeds.

Digital Versatile Disc (DVD)

The original concept of evolving compact disc technology to the next level was spearheaded by the motion picture and video industry, therefore *DVD* originally stood for digital video disc. However, as with the CD, it was obvious that a crossover to the computer industry was guaranteed. Therefore, the name was revised to *digital versatile disc*.

As with the development of almost all other computer technology and its associated media, there was considerable disagreement about the specifications and standards for DVD. Rather than let these disagreements play out in the marketplace, another alliance of manufacturers was formed called the *DVD Forum*. This group includes expected major players such as Sony, Philips, Toshiba, and Matsushita. Together, the Forum compromised on a set of formats that began reaching the market in 1997, but are still under debate.

DVD Formats

Currently, there are five varieties, called *books*, of DVD:

Name	Description
DVD-ROM	Designed for data storage
DVD-Video	Designed for motion pictures
DVD-Audio	Designed as an audio-only format similar to CDs
DVD-R	A WORM type disc similar to CD-Rs
DVD-RAM	A rewritable DVD similar to CD-RWs

The last variety, DVD-RAM, is a major bone of contention within the DVD Forum right now and the battle has just recently moved to the marketplace. A competitive product called DVD+RW, now just called +RW, is in the works. This format struggle will be expanded upon in the Future Developments section.

Disc Capacity

The DVD-ROM disc comes in several different formats, manifesting differences in physical production that provide varying storage capacities:

Name	Type	Capacity
DVD-5	Single-sided, single-layer	4.7 GB
DVD-9	Single-sided, double-layer	8.5 GB
DVD-10	Double-sided, single-layer	9.4 GB
DVD-18	Double-sided, double-layer	17 GB

The remarkable increase in storage capacity for DVDs has been achieved largely through improved manufacturing techniques and by expanding precedents set by standard CDs. For starters, the minimum pit length required for data reading has been reduced by more than half that of traditional CDs, creating room for more pits, thus automatically increasing capacity. Creating double-sided discs enables the DVD to be turned over, opening up twice as much room for data. More unique is the addition of another data layer to create *double-layer discs*. With this advancement, a *semi-transparent data layer* is added. This enables the drive's laser to "see through" the semi-transparent layer to focus on the main data layer, then refocus on the semi-transparent layer where essentially another disc's worth of data resides.

Disc Speed

The manufacturing advancements that increase capacity have also enabled greatly increased data transfer rates, defining new disc speeds for DVD drives. While the 1X benchmark for standard CDs is 150 KB per second, the new 1X benchmark set by DVDs is an amazing 1,250 KB (1.25 MB) per second. This is a major speed increase, matching closely the speed of an 8X standard CD. Currently, multi-speed DVD drives are entering the market that will progress along a similar growth path as standard CD drives.

Digital Versatile Disc-Recordable (DVD-R)

A writable version of the DVD follows the same CD naming convention and is therefore called the *digital versatile disc-recordable*, or *DVD-R*. It was introduced shortly after the DVD-ROM in 1997. The DVD-R relies upon the same technology as the CD-R, with information burned onto an organic dye layer within the disc. However, initial limitations reduced capacity to 3.95 GB. DVD-Rs that are equal in capacity to DVD-ROMs at the full 4.7 GB are becoming available now.

Magneto Optical (MO)

Magneto optical, or *MO drives*, use a hybrid of magnetic and optical technologies to store and retrieve data from the MO disks used in the drive systems. A laser is used to read data from the disks, and used again in combination with a magnetic head to write data to the disks.

As outlined in the introduction, magnetic storage devices magnetize areas of a disk to represent binary code. More specifically, this process actually changes the *polarity* of areas of a disk. Any magnetic disk media, whether a hard, MO, or floppy disk, is coated with magnetic particles that are only a few millionths of an inch thick. The drive divides the particles into microscopic areas called *domains*. Each domain serves as a small magnet, which can be polarized to physically represent the ones and zeroes of binary code. The domains are either positively or negatively polarized so that the molecule is turned one direction or the other within its domain. What this means is that the polarity of the particles is actually directional, and so the molecule is flipped back and forth so that the orientation of the particle in the domain translates to binary code as a one or a zero.

With hard drives, the disk media contained inside can be magnetized and the polarity of its domains changed at any temperature. However, what is unique about MO disks is that the magnetic coating used on the media is designed to be stable at room temperature, which makes the data unchangeable in this state. More importantly, contrary to hard disks, it makes the data unsusceptible to magnetic fields, giving MO disks the greatest reliability of almost any removable media.

In order to magnetize or write to areas on the disk, the medium's alloy layer must be heated to a high temperature of approximately 200 degrees centigrade. This is known as the *Curie point*, which is the temperature at which the magnetic properties of a given substance can be changed. To write data, MO drives use a laser to target and heat the domains of magnetic particles. Once heated to the Curie point, the read-write head can easily change the polarity, or direction, of the particle. The accuracy of the technique allows for high data density on the disks, complemented by the data stability once the alloy medium is cooled.

Once written, data is read using a lower power laser, as with CD technology, that relies on the *Kerr effect*. This is a principle by which the laser light is reflected according to the polarity of the magnetic particles. Positively and negatively polarized particles will reflect the laser light differently, enabling the reading of binary code.

In 1997, magneto optical technology took a major leap forward with the development of *LIMDOW* technology, enabling a considerable increase in the level of performance over previous MO drives. LIMDOW stands for *Light Intensity Modulated Direct Overwrite*. LIMDOW disks and drives work on the same principle outlined above, but instead of using a read-write head to magnetize areas of the disk media, the magnets are built into the disk itself. The original MO data writing process required two passes to create data, one to heat the target area of the disk to the Curie point, and another to magnetize the media. LIMDOW disks, however, contain two magnetic layers behind the reflective writing surface of the disk. When heated to a lower temperature, the write surface takes its polarity from one of the magnetic layers, but when heated to a higher temperature, the write surface takes its polarity from the other magnetic layer. Through this, the difference in positive and negative polarity is achieved without applying a magnetic charge by means of a read-write head. Therefore, rather than requiring two passes to write data, LIMDOW technology only requires the drive's laser to pulse between two power levels. The results in a single pass for data writing, bringing data transfer rates to around 4 MB

per second, which is competitive with the low-end of data transfer rates of standard hard disk drives.

MO Media

As explained above, MO disks are manufactured with a special metal alloy layer that reflects laser light at different angles depending on the polarity of the magnetized area of the disk. Protective films cover the alloy write layer that serve to enhance the polarization angle of reflected laser light, thus helping the optical read mechanism to detect the Kerr effect. An additional reflective film is added that also improves the efficiency of data reading, and gives MO disks their characteristic rainbow coloring.

MO disks come in 3.5-inch and 5.25-inch form factors, and are available in write-once and rewritable formats. Typical 3.5-inch disks range in capacity from 640 MB to 1.3 GB. Typical 5.25-inch disks range in capacity from 600 MB to 5.2 GB.

Most importantly, MO disks are extremely reliable. Because data is written and erased optically, and only possible at controlled high temperatures, MO disks are not susceptible to magnetic fields. There is no physical contact between the disk surface and drive head, so there is no possibility of data loss through a head crash as with magnetic disk technologies.

Multiple MO disks are typically employed in *jukeboxes* to provide long-term, durable, permanent storage of unusually high amounts of data, ranging from hundreds of gigabytes to several terabytes of data. This makes MO technology ideal in a variety of storage-intensive industries, including accounting, banking, customer service, healthcare, legal, and government applications.

Diskettes

When personal computing began in earnest during the 1980s, hard drives were typically available with tens of megabytes. At the time, a drive exceeding 100 MB was a cutting-edge, modern luxury. It followed, then, that the original 5.25-inch floppy disks, holding up to 1.2 MB of information, were a very roomy removable disk. The 3.5-inch floppy was a revolution when drives that supported it were introduced in 1984. At 720 KB, they were smaller, tougher, yet still a sizeable storage media. In 1987, the available space doubled to 1.44 MB, where it has remained ever since.

Several forces have kept the floppy at this capacity level. For starters, it is still a useable format. Even today, with the tremendous growth in file sizes and the availability of many alternatives, you can easily save small files such as word-processing documents and spreadsheets to a 3.5-inch floppy. The expansion of optical technology has also overshadowed the push for a larger standard floppy. Used in combination with a hard drive, optical technology in the form of CDs and DVDs has met the storage capacity needs of many varieties of users.

However, removable optical media have never won out over removable magnetic media for one big reason: writability has always been built in. While consumers have had to wait and suffer through the growing pains of writable optical technology, the diskette has always offered quick, easy read-write capability and portability.

Additionally, the computer market is immense and there is still plenty of room for devices that support removable magnetic storage, which rival the capacity, portability, and reliability of optical products. Just as the need for greater storage capacity has continually driven the expansion of the removable optical media market, the same demand has driven the expansion of removable magnetic media. There have been many developments in this market over the years, and here we will examine the most common seen on the market today. These include the following:

1. Zip drive
2. SuperDisk drive
3. High-Capacity Floppy Disk (HiFD) drive

Zip Drive

Omega Corporation introduced the *Zip drive* and its accompanying medium, the *Zip disk*, in 1995. When introduced, this technology provided 100 MB of storage space on a custom disk designed for compatibility with the drive, with formatted capacity more accurately at 94 MB. The external model of the drive allowed for tremendous portability between machines and geographic locations, promoting widespread acceptance and use of the format. In just the past few years, the Zip disk has become the most popular removable magnetic storage media next to the original 3.5-inch floppy disk. An internal version of the drive has positioned it as a possible replacement for the standard floppy drive. However, its lack of compatibility with standard floppies will likely prevent the fulfillment of this prediction.

In response to the competing SuperDisk and HiFD drives and disks outlined below, in 1999 Iomega released a 250 MB version of its Zip drive, with formatted capacity of the new Zip disks at approximately 237 MB. Not only does this up the ante for the competition, but Iomega has made this drive backward compatible with the 100 MB version, making the transition smooth for current Zip drive and disk users.

SuperDisk Drive

To compete with the stronghold Iomega has established in the market, Imation in collaboration with Panasonic introduced a new 3.5-inch drive in 1998 called the *SuperDisk*. This drive incorporates optical technology called *laser servo* that enables much faster data transfer and efficient use of space. This innovation has two distinct advantages over Iomega's Zip drive and Zip disks: capacity and compatibility. The diskette used by the SuperDisk drive has room for 120 MB. Taking its name from the technology of the drive and its capacity, the SuperDisk diskette is called an *LS-120 disk*. Not only do these disks look very similar in appearance to a

standard 3.5-inch floppy, but the SuperDrive is backward compatible with existing 3.5-inch floppies in 720 KB and 1.44 MB formats. An additional advantage tied in with its backward compatibility is that the SuperDisk drive, like a standard floppy drive, can serve as a boot device for PCs.

High-Capacity Floppy Disk (HiFD) Drive

Further expanding the competitive market for removable magnetic storage, Sony in collaboration with Fuji introduced a new drive and accompanying medium in 1999 called the *High-Capacity Floppy Disk drive*, or *HiFD drive*. Like the original Zip drive, this is an external device. Like the SuperDisk, it provides backward compatibility with 720 KB and 1.44 MB formats. Surpassing both the original Zip disk and LS-120 disk, the *HiFD disk* provides storage capacity of 200 MB. Sony plans to market an internal version of the HiFD drive soon. Unfortunately for Sony, early models of the drive have read-write head alignment problems that are plaguing its acceptance by retailers.

Future Developments

Compact Disc Technology

There are a variety of methods being employed to improve the performance of CD drives, the most common being attempts to spin the disc faster while retaining its stability, thus increasing its speed. Also being explored is advancing methods by which the laser reads data, also increasing data transfer rates. A new development pioneered by Zen Research, called *TrueX technology*, focuses on the latter. This drive design enables the laser beam to be split so that it can focus on and read multiple tracks concurrently. At this point in the development of TrueX technology, seven beams can be focused simultaneously, reading the same number of tracks. By capitalizing on the way the laser reads information, disc rotation speeds remain low and promote greater spin stability. Currently, the TrueX approach has facilitated drive speeds of 40X, 52X, and even 60X.

DVD Technology

The development of a rewritable DVD is currently plagued by a battle over standards within the DVD Forum, yielding two different types: DVD-RAM and DVD+RW, now called only +RW as a result of the struggle over the technology. The first DVD-RAM drives were manufactured by Panasonic and Hitachi, based on modified phase change technologies yielding capacities of 2.6 GB on either side of the discs. Hitachi is working to release a disc with 4.7 GB capacity soon. The primary difference seen in DVD-RAM discs is that this medium is encased in a cartridge, causing obvious compatibility problems with existing DVD drives.

The opposing DVD+RW technology, forced by the DVD Forum to drop the DVD name so that it is now referred to as +RW, also relies on modified phase change technologies. There are several important specification differences that led the backers of +RW, Sony and Philips, to introduce this product even though they remain members of the DVD Forum. For starters, +RW offers better data transfer rates and greater capacity at 3 GB per side. The most important difference, however, is the lack of a cartridge. This is the main battle being fought out between members of the DVD Forum. The +RW advocates argue that DVD-RAM's necessary cartridge will add to the serious compatibility problems that already exist in the DVD realm, and force too many drive design and manufacturing changes. Currently, the data formats on DVD-RAMs and +RWs are not compatible with one another, and so the divisiveness remains.

CD and DVD Compatibility Issues

The manufacture of DVD drives that provide varying compatibility across different CD and DVD formats is referred to as the *generation* of the drive. Unfortunately for DVD, the technology has had a rocky beginning. First generation DVD drives will not read CD-R and CD-RW discs, although this has been corrected in second generation drives by the MultiRead standard discussed above. However, while most CD compatibility problems were solved in the second generation, these drives are not able to read any rewritable DVD, whether it be DVD-RAM or +RW. This is supposed to be remedied in a third generation drive, although the standards war will likely complicate compatibility issues rather than mitigate them in the near future.

Optical Technology

The current Holy Grail of optical storage technology is called the *blue laser*, and promises the possibility to dramatically increase disc capacity in the near future. This variety of laser has a significantly smaller wavelength than standard lasers used in contemporary drives. This smaller wavelength translates into the possibility for a much narrower beam. A narrower beam, in turn, would allow for even smaller pits on the disc surface. And, as with the transition from CD to DVD, smaller pits enable much greater data storage capacity. Right now, the industry is facing serious challenges in developing the blue laser for the mass market. The components used to produce blue lasers in laboratories today are very large, and the laser has extremely high power requirements. However, if perfected and fit into a standard drive size with reasonable power limits, it is estimated that a single disc layer could hold 15 GB. Using current DVD designs, double-layer discs could hold up to 25 GB, and double-sided discs up to 30 GB. It is likely that the data demands of the future will create a large market for disk-based optical media with capacities such as this.

Specific Applications

The following shows suggested PC environments in which each of the disk-based media discussed above may be appropriate:

Drive/Type	Format	Capacity	Environment
CD-ROM	Read only	650 MB data 74 minutes audio/video	<ul style="list-style-type: none"> • Stand-alone PC
CD-R	WORM (write once read many)	650 MB data 74 minutes audio/video 700 MB data 80 minutes audio/video	<ul style="list-style-type: none"> • Stand-alone PC
CD-RW	Read, write, and rewrite capability	650 MB data 74 minutes audio/video	<ul style="list-style-type: none"> • Stand-alone PC
DVD-ROM	Single-sided, single-layer	4.7 GB data 133 minutes audio/video	<ul style="list-style-type: none"> • Stand-alone PC • LAN Server
	Single-sided, double-layer	8.5 GB data 240 minutes audio/video	<ul style="list-style-type: none"> • Stand-alone PC • LAN Server
	Double-sided, single-layer	9.4 GB data 266 minutes audio/video	<ul style="list-style-type: none"> • Stand-alone PC • LAN Server
	Double-sided, double-layer	17 GB data	<ul style="list-style-type: none"> • Stand-alone PC • LAN Server • Mid-size network
MO	Read, write, and rewrite capability	640 MB – 1.3 GB	<ul style="list-style-type: none"> • Large scale archives
Zip drive	Zip disk (old)	100 MB	<ul style="list-style-type: none"> • Stand-alone PC
	Zip disk (new)	250 MB	<ul style="list-style-type: none"> • Stand-alone PC
SuperDisk	LS-120 disk	120 MB	<ul style="list-style-type: none"> • Stand-alone PC
Hi-FD drive	Hi-FD disk	200 MB	<ul style="list-style-type: none"> • Stand-alone PC

CD-Rs and DVD-Rs

WORM media such as CD-Rs and DVD-Rs provide small-scale archival capability that has a variety of applications in the consumer and professional market. Software upgrades downloaded from the Internet are obvious candidates for write-once media, as they often take up many megabytes of space. If consumers or professionals own a certain version of software on CD and are able to download free updates from manufacturer websites, they can create companion CDs that permanently store the accompanying software upgrades.

Consolidation of specific information requiring a permanent archive in office settings is another great use for CD-Rs and DVD-Rs. A law firm, for instance, may want all information pertaining to a specific case stored in one place and filed with paper-based records. Correspondence, legal briefs, and support documentation could easily add up to several hundred megabytes.

Software developers are also heavy users of write-once media. As different beta-versions are developed, they need to be permanently archived. Also, many smaller companies do not have the resources to release beta versions of software that are pressed at a manufacturing plant. It is far more cost effective to generate a handful of copies in-house for distribution to potential beta testers.

Multimedia presentations are another major storage demand for CD-Rs and DVD-Rs. More and more, sales and marketing professionals generate high-end presentations in applications such as Microsoft PowerPoint that incorporate large amounts of data, graphics, and frequently sound and full-motion video. Completed presentations, particularly with video, may take up hundreds of megabytes, or even gigabytes, of space. The portability required when presenting these materials with laptops and projection equipment makes write-once media an ideal storage choice.

CD-RWs

All of the above applications can be enhanced with the rewritable capability of CD-RWs, particularly when it comes to *file sharing*. A team of developers, for instance, could have a working copy of a software program on CD-RW, with separate modules being added or deleted at will. IT professionals may use rewritable media for a variety of network administration purposes. Virus updates, which periodically change, could be stored and deleted as needed, without outdated information taking up unnecessary space. Overall, the flexibility of adding and deleting files enhances the appeal of the CD-RW medium.

MOs

The advantages of MO disks are many. They offer per megabyte storage costs that are competitive with other removable storage media. Many vendors rate data rewrite capability for MO disks at a minimum of a million times, and data read capability at a minimum of 10 million times. Additionally, MO disks are permanently fixed in durable cartridge housings manufactured to high shock-tolerance standards. Archival ratings for MO disks are listed at a minimum of 30 years for most brands. Some manufacturers even claim media life of 50 or even

100 years. Altogether, the features of MO technology and media make them ideal for large scale archiving in storage-intensive settings. As outlined above, these include industries such as accounting, banking, customer service, healthcare, legal, and government.

Diskettes

High-capacity diskettes also offer small-scale archival and file sharing capabilities identical to those of CD and DVD options. The Zip disk has been a favorite in the desktop publishing and printing industry for quite some time. Finished publications saved in four-color print format typically take up many megabytes of space, and need to be easily transported or mailed to printing houses for production. Support graphics, scanned images, and photo-quality pictures themselves typically take up many megabytes of space also, and are usually received from a variety of sources including clients, advertising agencies, and libraries.

Media Type by Manufacturer

<i>Media</i>	<i>BASF</i>	<i>Fuji</i>	<i>Hewlett-Packard</i>	<i>Imation</i>	<i>Iomega</i>	<i>Kodak</i>	<i>Maxell</i>	<i>Mitsui</i>	<i>Quantum</i>	<i>Sony</i>	<i>TDK</i>	<i>Verbatim</i>
Data Cartridges, Travan		X	X	X			X			X		X
8mm, DAT	X	X	X	X			X			X	X	X
DLT		X	X	X			X		X	X		X
Half-Inch Tape	X			X								X
CD-R, CD-RW, DVD	X			X		X	X	X		X	X	X
MO Disks			X	X			X			X		X
Diskettes	X	X		X			X			X	X	X
Zip Disks		X			X		X					

Manufacturer Websites

<i>Manufacturer</i>	<i>Website</i>
Fuji	www.fujifilmmediasource.com
Hewlett Packard	www.hp.com
Imation	www.imation.com
Iomega	www.iomega.com
Kodak	www.kodak.com
Maxell	www.maxell.com
Mitsui	www.mitsuigold.com
Sony	www.sel.sony.com/products
TDK	www.tdk.com
Verbatim	www.verbatim.com

Glossary

<i>8mm</i>	The market name for magnetic tapes used in data storage, based on the width of the media.
<i>Accelis</i>	A linear tape open format focused on decreasing access time and increasing data transfer rates in tape-based media.
<i>AIT</i>	<i>Advanced Intelligent Tape</i> : An 8 mm tape format developed by Sony for data storage.
<i>AME</i>	<i>Advanced Metal Evaporated</i> : A tape medium physically designed to allow for greater data density, protection from corrosion, and increased durability.
<i>amorphous</i>	In the phase-change medium, the material property that results after heating in order to imitate a land for optical data storage.
<i>backup</i>	Redundant copies of any type of electronically stored information that can be used to restore original files if they are lost, accidentally deleted, or destroyed.
<i>binary code</i>	A number system that uses only the digits one and zero. This allows the representation of two possible conditions, which can be used to create an electronic record of information.
<i>bit</i>	A single digit in binary code, either a one or a zero.
<i>Black Watch 9840</i>	A half-inch tape format developed by Imation for use in StorageTek's proprietary 9840 drives.
<i>blue laser</i>	A small wavelength, blue laser that may allow for significant advancements in optical technology.
<i>book</i>	In DVD terminology, the format of a type of disc.
<i>burn</i>	A term used to refer to the optical writing process for writable CDs and DVDs, in which a laser burns pits into the surface of the disc.
<i>byte</i>	A single unit of data, usually an alphanumeric character, comprised of eight bits of binary code.
<i>cartridge</i>	In tape-based media, the housing unit designed to hold magnetic reels of tape, providing access to the tape while protecting and storing it at the

same time.

<i>CD</i>	<i>Compact disc</i> : An optical, disk-based medium invented by Sony and Philips to provide a high-quality storage medium for music recording.
<i>CD-R</i>	<i>Compact disc-recordable</i> : A writable version of CD that enables data to be written to the disc with a laser one time, with almost limitless future retrieval.
<i>CD-ROM</i>	<i>Compact disc-read only memory</i> : An adaptation of the CD from the music industry to provide an optical, disk-based medium for data storage.
<i>CD-RW</i>	<i>Compact disc-rewritable</i> : A rewritable version of CD that enables data to be written to the disc with a laser many times over, with almost limitless future retrieval.
<i>compressed capacity</i>	The maximum amount of data storage possible on a given medium using data compression techniques.
<i>corporate alliances</i>	Partnerships formed by corporations, usually to promote the research and development of technology and the unification of standards used to bring it to the market.
<i>CRC</i>	<i>Cyclic redundancy check</i> : A software-based method of correcting writing errors as data is stored to magnetic tape.
<i>crystalline</i>	In the phase-change medium, the material property that results after heating in order to imitate a pit for optical data storage.
<i>Curie point</i>	The temperature at which the magnetic properties of a given substance can be changed.
<i>DAT</i>	<i>Digital Audio Tape</i> : A 4 mm tape adapted from the music industry to use for data storage.
<i>data cartridge</i>	A magnetic tape medium used for storing information electronically.
<i>data compression</i>	Software-based, logical techniques to reduce the amount of information physically required in the writing process to represent the original data being stored.
<i>data density</i>	The amount of information that can be stored in a given space on a given media type.

<i>data storage</i>	The process of storing and retrieving data electronically, usually by means of magnetic or optical technology.
<i>DDS</i>	<i>Digital Data Storage</i> : A standard format developed to enable the use of DAT tapes for data storage.
<i>digital technology</i>	Electronic mechanisms, devices, and systems that rely on the use of binary code to manipulate information.
<i>direct-access device</i>	A data storage device with the ability to read or write data directly located on specific areas of the information medium.
<i>directory structure</i>	The way information is arranged in logical groups for data storage.
<i>directory track</i>	A track of data on a tape that stores directory structure and indexing information about all other data stored on the tape.
<i>DLT</i>	<i>Digital Linear Tape</i> : A tape format that combines a variety of technologies to enable large storage capacity and extended tape life.
<i>domain</i>	The smallest unit recognized by a magnetic storage device, consisting of a microscopic magnetic particle on the disk medium that physically represents binary code.
<i>double-layer discs</i>	DVDs that contain two sandwiched data layers.
<i>DVD</i>	Originally digital video disc, later adapted to <i>digital versatile disc</i> : An evolution of CD technology that allows for much greater data storage capacity.
<i>DVD Forum</i>	A corporate alliance of manufacturers joined to establish a set of standard formats for DVD technology.
<i>DVD-R</i>	<i>Digital versatile disc-recordable</i> : A writable version of DVD that enables data to be written to the disc with a laser one time, with almost limitless future retrieval.
<i>ECC</i>	<i>Error correction code</i> : A software-based method of correcting writing errors as data is stored to magnetic tape.
<i>EEPROM chip</i>	<i>Erasable electrical programmable read-only memory</i> : A chip that provides supplementary information storage in Sony's 8mm AIT tapes, used to implement the Memory-In-Cassette feature.
<i>file sharing</i>	The use of the same electronically stored data file(s) by several different people within an organization.

<i>fixed disk</i>	A data storage device, such as a hard drive, containing non-removable disk-based media that store data electronically.
<i>generation</i>	In DVD technology, the manufacture of drives that provide varying compatibility across different CD and DVD formats.
<i>gigabyte</i>	A unit of data measurement comprised of 1,000 megabytes (rounded) of information.
<i>helical scan</i>	A recording technique used by 8mm tape drives in which data is written at an angle to the tape, allowing for greater data density.
<i>Hi-8</i>	The market name for 8mm tapes used in video recording.
<i>HiFD disk</i>	<i>High-Capacity Floppy Disk</i> : A magnetic, disk-based medium that provides 200 MB of storage space for use with HiFD drives.
<i>HiFD drive</i>	<i>High-Capacity Floppy Disk drive</i> : A 3.5-inch drive introduced by Sony that allows for backward compatibility with standard 3.5-inch floppies, and provides 200 MB of storage space in its companion HiFD disk.
<i>jukeboxes</i>	Magneto optical storage devices that employ an array of MO disks to facilitate large scale data storage, ranging from hundreds of gigabytes to several terabytes of data.
<i>Kerr effect</i>	A principle by which laser light is reflected according to the polarity of the magnetic particles upon which it is focused.
<i>kilobyte</i>	A unit of data measurement comprised of 1,024 alphanumeric characters, or bytes.
<i>land</i>	The area of a compact disc left level to represent, in binary code, the number zero.
<i>laser servo</i>	A read-write mechanism enhancement in SuperDisk drives that incorporates optical technology to allow for faster data transfer and storage capacity.
<i>LGMR</i>	<i>Laser guided magnetic recording</i> : A recording method that combines magnetic and optical technologies by using a laser to precisely guide the magnetic tape heads in Super DLT drives.
<i>LIMDOW</i>	<i>Light Intensity Modulated Direct Overwrite</i> : A magneto optical technology in which the MO disks are designed with two magnetic layers such that their polarity can be changed by a laser alone, without

	the need for a magnetic read-write mechanism.
<i>linear</i>	In a straight line.
<i>LS-120 disk</i>	A magnetic, disk-based medium that provides 120 MB of storage space for use with SuperDisk drives.
<i>LTO</i>	<i>Linear tape open:</i> A new standard being developed by a corporate alliance between Hewlett-Packard, IBM, and Seagate to compete with Quantum's DLT format; this standard supports two new formats called Accelis and Ultrium.
<i>magnetic</i>	Involving the use of an electrical field that creates polarity in magnetic materials. In the case of data storage, the polarity of the magnetic materials can be used to represent binary code.
<i>magnetic storage devices</i>	Data storage devices that rely on magnetic technology to store and retrieve information electronically.
<i>Mammoth</i>	An 8mm tape format developed by Exabyte for data storage.
<i>megabyte</i>	A unit of data measurement comprised of 1,000 kilobytes (rounded) of information.
<i>MIC</i>	<i>Memory-In-Cassette:</i> A feature of Sony's 8mm AIT tapes that relies on an EEPROM chip built into the data cartridge to store the tape's directory structure and indexing information.
<i>MO drives</i>	<i>Magneto-optical</i> data storage devices that use a combination of magnetic and optical technology to store information to disk-based media; usually proprietary systems used in storage-intensive settings.
<i>MultiRead</i>	A standard developed to accommodate lower reflectivity in optical discs that use a rewritable phase change medium; this standard creates compatibility between optical drives to enable the reading of most types of CDs and DVDs on the market.
<i>multi-session</i>	A process during which data is stored to an optical disc across several recording periods.
<i>native capacity</i>	The minimum amount of data storage possible on a given medium with standard methods of writing information.
<i>noise</i>	Any kind of electrical interference that occurs when a magnetic read-write mechanism writes data.

<i>optical</i>	Involving the visual perception of light through the eye or a lens. In the case of data storage, a laser is focused through a lens in order to read information represented as binary code.
<i>optical storage devices</i>	Data storage devices that rely on optical technology to store and retrieve information electronically.
<i>organic dye</i>	A compound used to create the recording layer of write once CDs and DVDs, which allows for the laser of the drive to burn pits into the disc surface.
<i>phase change</i>	A physical process in which a given medium is altered, usually with heat, to produce different properties after a change force has been applied; this process is used in rewritable CDs and DVDs.
<i>phase-change medium</i>	A medium that can be altered, usually with heat, to produce different properties after a change force has been applied; this medium is used in rewritable CDs and DVDs.
<i>pit</i>	The area of a compact disc that has been pressed through manufacturing or burned by a laser to represent, in binary code, the number one.
<i>polarity</i>	The condition of being positive or negative with respect to magnetic state or electrical charge.
<i>PRML</i>	<i>Partial Response Maximum Likelihood</i> : A data writing technique used to differentiate between valid data and noise during the data writing process.
<i>QIC</i>	<i>Quarter-inch tape cartridge</i> : A data cartridge that relies on standard linear recording techniques to store information magnetically.
<i>QIC standards</i>	An attempt to unify and define the means by which QIC tapes were manufactured and the methods by which data was stored to them.
<i>random-access device</i>	A data storage device that relies on direct-access methods to read or write data non-sequentially; more common name for direct-access device.
<i>read</i>	In data storage, the means by which a device understands representational units of data, usually through either magnetic or optical technology.
<i>read-while-write</i>	A tape-based media recording process in which data is verified as it is written to prevent errors. Prior technologies relied on a second pass of the read-write head as part of the data verification process. Elimination

	of this greatly increases recording speed.
<i>read-write device</i>	A data storage mechanism that has the ability to both store and retrieve information electronically.
<i>read-write mechanism</i>	The component of a data storage device that actually transfers data to and from a tape, disk, or other medium.
<i>removable disk</i>	A data storage device that accepts removable disk-based media that store data electronically.
<i>semi-transparent data layer</i>	In double-layer DVDs, the see-through data layer that gives the drive's laser access to both itself and the main data layer.
<i>sequential-access device</i>	A data storage device that can read data only by passing through all existing data on the information medium until the desired location is reached, based on the logical order of the information originally stored.
<i>single session</i>	A process during which data is stored to an optical disc all at once.
<i>SLR</i>	<i>Scalable linear recording:</i> A tape storage technology developed by Tandberg data, with companion media by Imation, which combines a variety of technologies to enable larger storage capacity and higher tape reliability.
<i>speed</i>	A term used to refer to the data transfer rates of CD and DVD drives.
<i>SPR</i>	<i>Symmetric Phase Recording:</i> An innovative data writing method used by DAT tape drives that combines standard linear and helical scan recording techniques, yielding greater data density to allow for higher capacity storage.
<i>Standard 8mm</i>	An 8mm tape format developed by Exabyte for data storage.
<i>Super DLT</i>	A follow-up DLT format that relies on a combination of magnetic and optical data storage technology in the tape drive, called laser guided magnetic recording (LGMR), which enables greatly increased storage capacity and data transfer rates.
<i>SuperDisk drive</i>	A 3.5-inch drive introduced by Imation that allows for backward compatibility with standard 3.5-inch floppies, and provides 120 MB of storage space in its companion LS-120 disk.
<i>tape head</i>	In a tape drive, the read-write mechanism that magnetizes or demagnetizes portions of the tape.

<i>tracks</i>	Parallel lines of magnetically stored information across the width of a tape, which also run the entire length of the tape.
<i>Travan</i>	A format used to further correct the original QIC standards allowing for higher storage capacity and backward compatibility.
<i>Travan NS</i>	A Travan format, called network series (NS), developed to improve upon current Travan formats, enabling greater storage capacity.
<i>TrueX technology</i>	An optical technology innovation developed by Zen Research that splits the laser beam used for data reading in CD-ROM drives in order to increase the data transfer rate, or speed of the drive.
<i>Ultrium</i>	A linear tape open format focused on increasing data storage capacity in tape-based media.
<i>VR2</i>	<i>Variable Rate Randomizer</i> : A technology developed by Overland Data used in SLR tape storage that relies on the PRML data writing technique to increase tape capacity and data transfer rates.
<i>WORM drives</i>	<i>Write once read many</i> data storage devices that enable one-time writing of information with almost limitless future retrieval; usually proprietary systems used in storage-intensive settings.
<i>write</i>	In data storage, the means by which a device creates representational units of data, usually through either magnetic or optical technology.
<i>Zip disk</i>	A magnetic, disk-based medium that provides 100 MB of storage space in the original release of the product, 250 MB in the new release, for use with Zip drives.
<i>Zip drive</i>	A proprietary disk drive developed by Iomega Corporation to provide the capability for greater data storage capacity through its companion Zip disk.