

## A Media Maniac's Guide to Removable Mass Storage Media

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### Background

The electronic imaging world has been changing. For over a dozen years, users and customers have been the target of presentations providing the incentive to get them to buy into the concept of electronic document handling. Initially, these systems incorporated the revolutionary 12-inch WORM (write once, read many) optical disks that were supposed to replace file cabinets and microfilm repositories. In 1984, it was new, it was scary and it was threatening to data processing managers who had long been the keepers of the corporate data. Once the technology behind the optical disk industry became more familiar, systems hit the marketplace with a variety of shapes, sizes, capacities, and characteristics. Choices became confusing and the presentation to management changed from "should we buy" to "what should we buy?"

Just when laws began to back optical for its non-erasability, that very feature was seen as an impediment to progress. Buyers were looking for the erasable features to allow them to get more long-term usage out of their investment in the systems. Instead of replacing file cabinets, they wanted to replace expensive hard drives — and WORM media was not a suitable candidate. To meet a growing market demand, erasable disks were introduced in 1988-89.

Early systems, dating back to 1983-84, cost over \$1,000,000. Potential users were faced with a sticker shock that was tough to argue. There were no components of an imaging systems that did not shock a procurement official. The drives, media, autoloaders, scanners, monitors, printers — everything! Monitors to display images were different from those to display normal data, so high resolution image viewers had to be purchased. Expensive scanners were used to digitize the documents because all previous image capture functions had been performed with cameras in film-based systems. Printers that had been turning out 2-Kilobyte (KB) ASCII reports or word processing files, were now being asked to generate high resolution 50-KB document images. Speed and user contention were serious matters for these departmental workhorses. The first media cost close to \$1,000 for 1,000 megabytes (MB) of capacity. This industry was a tough one to launch!

Meanwhile, the scientific community was developing tapes for customers such as NASA, NOAA, and CIA to record digital data. Some of the first high capacity media to offer a reasonable price to the digital storage industry was the digital VHS tape made by Honeywell. In 1986, when the 12 inch optical boasted a capacity of 2 gigabytes (GBs), the VHS tape could hold 5.2 GBs. The \$35 price for tape compared to the disk's price of \$1000 gave Honeywell an impetus to enter the document imaging market. They had to create a buffer strategy to change from capturing streaming instrumentation data to handling packets of data called images, but once that was established, their breakthrough had an extensive impact on other vendors offering tape solutions. These vendors included Exabyte, Ampex, Sony, Storage Technology (STK) and IBM. The movement of the tape industry to support the document image industry, began in late 1989 when groups such as the Tape Head Interface Committee (THIC) were exposed to new business opportunities. These groups became instrumental in providing a pathway for vendors with systems that offered a higher transfer rate, lower per megabyte cost and higher per unit density, to address those areas of the electronic document industry where they were best suited. To complete the offering from the tape industry, Creo manufactured a drive to record data on a non-erasable reel of optical tape from ICI ImageData. A single 12.5 inch reel holds 1,000 GBs or 1 terabyte (TB).

The compact disc (CD), was beginning to enter the market place carrying not only published music, but published data. As early as 1986, vendors could demonstrate interactive Compact Disc-Read Only Memory discs (CD-ROMs) on \$10,000 systems. These systems were not ready for the massive consumer market, but they certainly could point toward the future. Published reference materials or marketable information databases became some of the first to be available on this new media. Entire industry consortiums sprung up in support of the 650 MB disc that could be duplicated from a master tape for under \$5 and sold at a tremendous profit. The next logical step in the evolution of the CD was to sell recorders to the public so end users could create their own masters. These recording systems were introduced at \$15,000 and are predicted to soon fall under \$700.

The first 12 inch optical platter in 1984, held 1 GB of data. A dozen years later, the commercial capacity is 12 GB. Tape formats have also increased. VHS started out at 5.2 GB and now can store up to 50 GB. The recordable 650 MB CD will not improve in data storage capacity until 1998-99 when it is projected to reach 2.6 GB.

## **Introduction**

This paper addresses at a high level, the many individual technologies available today in the removable storage arena including removable magnetic tapes, magnetic floppies, optical disks and optical tape. Tape recorders represented below discuss longitudinal, serpentine, longitudinal serpentine, and helical scan technologies. The magnetic floppies discussed will be used for personal electronic in-box applications.

Optical disks still fill the role for dense long-term storage. The media capacities quoted are for native data. In some cases, 2 KB ASCII pages or 50 KB document images will be referenced.

### **Longitudinal Recorders**

The first "industrial strength" tape recorders used longitudinal recorders that moved tape in a single pass across stationary heads to read or write the length of the tape. The closer the heads are to each other, the denser the recording. Futurists predict reaching a 1,000-head recorder. Early longitudinal recorders stored 180 MB on open reel 9-track tapes. These were replaced in 1986-87 by 200 MB cartridges which could be managed in automated libraries. Over 90% of the world's data centers use the half-inch 3480-type tape cartridges. STK has developed and sold over 7,500 circular library units, commonly called silos, which can house up to 6,000 cartridges. Using the newest 800 MB cartridges provides 4.8 TB of robotically-addressable storage. The silos have a footprint of 121 square feet and are large enough to allow a technician to walk inside to provide necessary service. The drives can transfer data at 52 Megabits per second (Mbps). Up to 16 libraries can be linked to offer 76.8 TB of data storage. The current generation of the silo, PowderHorn, provides two robotic arms to retrieve and load cartridges up to 350 times per hour.

### **Serpentine Recorders**

Serpentine recorders write a single track from end to end on the tape and then reverses directions to write the second track in the opposite direction. The back and forth recording continues until all data is recorded. The quarter inch cartridge (QIC) tape format cartridge is 4 inches by 6 inches and stores 13 GB as a result of a cooperative effort between Tandberg, IBM and 3M. The data rate has reached 12 Mbps. Vendors expect the storage capacity to go to 25 GB by 1997 with the adoption of thin film media, 50 GB in 1998-99 using barium ferrite technology and 180-200 GB per tape by 2000 using multi-channel drives on thin film media. By then, the data rates should be close to 56 Mbps. There are currently 8 million QIC drives in use today. In the spring of 1996, Tandberg introduced three autoloaders to accommodate 10, 20 or 30 tape cartridges.

The QIC mini-cartridge offers 4 GB in a cartridge which is 2.5 by 3.5 inches. Following the same improvement path as the full sized QIC and using multi-channel tape and thin film technology, the capacity for this unit should reach 30 GB by 2000 and the data transfer rate is expected to reach 56 Mbps. There are no autoloaders for this media.

The newest small tape format to enter the market is 3M's Travan. It was introduced in April of 1995 with a capacity of 400 MB, and by June the capacity had reached 800 MB. By December 1995, Travan could store 1.3 GB and the current capacity is 4 GB. Vendors predict that by 1997, the capacity should be 15 GB. Drives are made by HP, Conner, Iomega and AIWA. The tape is manufactured by Sony or 3M and the autoloaders are scheduled to come out from Exabyte or Conner. The Travan drive will accept the mini-cartridge as well as all previous generations of Travan tapes.

Quantum bought the storage products division of Digital Equipment Corp. and now offers their internal data cartridge as a removable storage media. In early 1996, the native capacity was increased from 20 GB to 35 GB on the half inch tape. With a data transfer rate of 24 Mbps and Bit Error Rate (BER) of E-17, this tape format should provide an interesting addition to the storage hierarchy. EMC is currently offering this media as the disaster recovery solution to support their warehousing projects. The future introduction of thin film media should provide storage of 100 GB before 2000. The data transfer rates are due to increase to 80 Mbps. The available multiple-cartridge units include a stackloader of 7 cartridges on the low end, and a broad selection of autoloaders supporting 28, 48, 60, 264, 360, or 900 tapes on the high end. The 900 tape unit comes from MountainGate and offers 31.5 TB in 18 square feet (1,750 GB per square foot). The maximum of 20 drives provides access to 700 GB of mounted data. The AML/2 from EMASS supports 32,720 DLT tapes for a potential capacity of 1,145.2 TB in 1300 square feet (881 GB per square foot).

### **Longitudinal Serpentine Recorders**

These recorders combine the two previous technologies to record one set of multiple tracks down the length of the tape, then reverse direction to record another set of tracks back toward the beginning of the tape. The new longitudinal serpentine head assembly designed by IBM can read or write 16 tracks at a time. The media is formatted to hold eight sets of the 16 tracks resulting in data on a total of 128 tracks. IBM's 10 GB subsystem is called Magstar and it can support a 72 Mbps data transfer rate. The largest IBM library (model 3495) is 92 feet long and uses a robot on a rail to move tapes from the slots to the drives. The library can store up to 18,920 cartridges for a potential storage of 189.2 TB. The smaller model 3494 library can store between 210 and 3,040 cartridges and support a maximum of 30.4 TB using the Magstar, or 2.4 TB using the 800 MB cartridges.

### **Helical Scan Recorders**

Helical scan technology uses multiple read/write heads to record data on tracks at a slant across the tape. This track, known as a swiipe, is slanted such that the angle between the track and bottom of the tape is between 4 and 7 degrees. Some helical drives yield 15 MB per square inch or 16 KB per swiipe. Major helical scan drive

components were brought back after WWII by Bing Crosby and Ampex was the first company to demonstrate this technology in 1955.

### **Four-mm formats**

Several companies offer the Digital Audio Tape (DAT) tape format that holds 4 GB of uncompressed data on 120 meters of 4-mm tape housed in a standard cassette measuring 2.9 inches by 2.1 inches. In the fall of 1995, HP announced the DDS3 standard format which can store 12 GB by recording on longer tape with smaller tracks. The data transfer rate is 6.2 Mbps and the seek time is 40 seconds. In 1997, the DDS4 standard should be introduced and provide a native capacity of 24 GB using metal evaporated tape and a data transfer rate of 8 Mbps. Due in part to the Forward Error Correction (FEC) technology which promises a BER of E-15, this tape format has been used for CD-ROM mastering, COM (computer output to microfilm) replacement, and image storage. For automated applications, autoloaders are available to manage a variety of cassettes in several formats including carousel, vertical and horizontal configurations. The largest automated handler for this size media is available from Exabyte and holds 218 units for a potential capacity of 2.6 TB.

### **Eight-mm formats**

The 8-mm format is primarily available from Exabyte. March 1996 brought the long awaited release of the Mammoth drive. Data can be recorded at a transfer rate of 24 Mbps. The 8-mm cassette of advanced metal evaporated tape holds 20 GB of uncompressed data. To put this capacity into perspective, the first 12-inch optical disks held a ground-breaking 1 GB. Numerous vendors are supporting this technology. Mass storage libraries have come from the back-up storage and video broadcast industry and hold 10, 40, or 80 cassettes. The EMASS model AML/2 library sets the record for highest number of tapes in a single autoloader. The maximum load would be 58,880 tapes providing 1,177.6 TB. The BER has improved from E-15 to E-17. In 1997-98, the capacity should double to 40 GB and the rate should reach 32 Mbps. By 2000, the capacity will double again to 80 GB and the transfer rate should reach 48 Mbps.

A recent entrant to the 8 mm market is coming out from Sony. This product was originally promised in June 1996 to come out in late summer at 25 GB. The drive fits into a 3.5-inch slot, smaller than the 5.25-inch Exabyte slot. A design advantage that contributes to performance, is the location of the index on a chip on the cartridge. This intelligence will allow the drive to reject the cassette without having to spend precious moments rewinding the tape. When the dust settles, the tape could be released with a native capacity of 35 GB. Time and the market will tell.

### **Half inch formats**

The most recent tape format to enter this market is the digital tape format (DTF) manufactured by Sony. The two sizes available are the 12 GB and the 42 GB capacities. Several libraries are available from Sony to support this media. The smaller one holds 35 large tapes (1.5 TB) or 70 small tapes (840 GB) with one drive. The BER is E-17 and the transfer rate is 96 Mbps. As demand grows for capacity, other autoloaders may become available and the capacity could extend into the Petabyte range.

A long-awaited helical scan recorder was shipped by STK in 1995. The new Redwood drives store 50 GB on a single 4 inch square cartridge and raise the capacity of their silo from 4.8 TB using 800 MB cartridges, to 300 TB and 4.8 Petabytes per 16-unit cluster. The transfer rate is 96 Mbps.

MountainGate offers the VHS drive that was originally modified from broadcast industry-developed technologies by Honeywell, then Metrum Information Storage. The RSP-2150i drive can record 21 GB using T-180 tape format in a VHS cassette. For data processing purposes, 21 GB could replace 117 reels of 6250 tape. An autochanger with a footprint of 18 square feet, can accommodate 600 cassettes and provide an automated storage capacity of 12.6 TB. Legacy Storage Systems used the PRML (partial response, maximum likelihood) recording technology to store 50 GB on a T-180 VHS cassette. The origin of this system is the radio astrology industry. Currently, the company supports ganging drives together to meet customer needs rather than putting tapes into robotic handlers. With the right software, the system appears to the host as a mounted disk drive. The current transfer rate is 16 Mbps, but they have a short term goal of reaching 32 Mbps by the end of 1996. By then, they plan for the capacity to be 100 GB per cassette.

### **Nineteen-mm formats**

The DD (Digital Data)-1 or DD-2 tape formats are available in the small, medium or large 19 mm cassettes. These cassettes are used by the broadcast industry to store TV data, by the scientific community to store instrumentation data, and by the computing community to store computer data. The drives used to record data from scientific instruments are called ID-1 (Instrumentation Data 1) and the tapes can be recorded at rates up to 400 Mbps per drive. Four drives can operate simultaneously to provide a data capture rate of 1600 Mbps. Loral, Lockheed Martin, DATATAPE, Penny & Giles, and Sony, are building these drives. The standard for the ID-1 tape was established by the ANSI X3B.6 committee and other committees are currently meeting to develop standards for the DD-1 and DD-2 formats as well. The suppliers of 19 mm tapes include Hitachi, BASF, Sony, Fuji, 3M, TDK, DATATAPE, Penny & Giles, Maxell, and Quantegy. The DD-1 tape format offers a BER of E-13 while the DD-2

format has recently been improved to E-17. The storage capacities of the six tape formats are shown below.

•DD-1S	16 GB	•DD-2S	50 GB*
•DD-1M	40 GB	•DD-2M	150 GB*
•DD-1L	96 GB	•DD-2L	330 GB*

\* These doubled capacities are currently in Beta test.

Ampex currently offers a 7 square foot library that holds 7 DD-2L for a capacity of 2.3 TB. Another autochanger is available that will hold 256 DD-2S cassettes for a capacity of 12.8 TB. The DD-2 drives can reach a transfer rate of 120 Mbps. EMASS offers three sizes of autoloaders, the AML/J, AML/E and AML/2. The AML/2 has the largest capacity and could support either 16,896 DD-2S tapes for a total of 845 TB, or 10,752 DD-2M for a total of 1,613 TB in 1300 square feet. Using the DD-2 M tape would result in 1,240 GB per square foot. To relate this to a paper volume, 1,613 TB represents 32.3 billion 50 KB document images which could fill 3,226,000 file cabinets covering 753 football fields.

The Sony DD-1 drives have a recording speed of 128 Mbps. Sony offers a cassette tower which can hold all three sizes of DD-1 cassettes and either one or two drives providing a storage capacity ranging from 512 GB to 2.2 TB in less than 8 square feet. There are two larger libraries which hold 320 DD-1M cassettes for 12.8 TB capacity, or 736 DD-1M cassettes for a total capacity of 29.4 TB.

### **Optical Cards**

Requirements for personal storage that need to be met by high density storage systems may incorporate the low-cost option offered by numerous vendors supporting the 4.6 MB optical card invented and patented by J. Drexler. This credit-card sized optical storage media can store 2,300 ASCII text documents or 92 document images using WORM technology on a media carrying a 10-year life expectancy. These cards are being used for individual medical record storage, personal registration data, and financial transactions. A test is being conducted at the border between Canada and the U.S. Soon, frequent travelers may be able to use their Canon optical registration card in addition to a fingerprint scanner to speed processing through customs.

### **Compact Disc Read Only Memory**

One of the least expensive media for mass distribution of reference-type database information is the Compact Disc-Read Only Memory (CD-ROM). The first compact discs were introduced in 1981 to replace 8 mm audio tape cassettes with high quality digital sound discs. By 1987-88, published data became available on these systems and an alternative printing industry was born. The 12 cm, 650 MB disc can hold

325,000 2-KB pages of ASCII text. To print this many pages would require 1.9 tons of paper. There are numerous library units to house CD-ROMs. One of the interesting jukeboxes on the market can hold 240 disks in a spiral configuration. Four of these "slinky-looking" units can be connected to provide access to 960 discs. A different type of library unit holds eight rows of eight drives providing simultaneous on-line access to 64 discs. Other libraries offer larger capacities ranging from 500 discs in a Pioneer jukebox to 1478 discs in a DISC jukebox.

New CD applications include multi-media which support full motion entertainment or instructional video storage. By early 1996, the price of a drive to record a CD-R (recordable) dropped from an opening price in 1991 of \$15,000 to less than \$1,000. Affordability and availability allows the media to be used for small departmental or desktop storage applications. It has also opened new doors for small publishers to create and distribute documentation. Drives to record and erase data on the compact disc are due out before the end of 1996.

There is considerable controversy in the industry today about the forthcoming Digital Video Disc (DVD). At a minimum, the DVD should:

- 1) Record a full length feature movie
- 2) Offer picture quality better than video discs
- 3) Provide audio in three to five languages
- 4) Build in a copy-protection system
- 5) Support choices between subtitles or dubs
- 6) Insure parental-lockout features.

The proposed DVD format exceeds all of these requirements.

Agreements that are in place meet these specifications:

1. Backward compatibility with current CD media. This will protect the software vendors who have in hundreds of programs on this media. It will also protect consumers who own disc collections.
2. Two substrates - each 0.6 mm thick, with a data layer capable of holding up to 4.7 GB - bonded together to form a 1.2 mm thick disc.
3. EFM Plus signal modulation. This scheme is simpler to implement and yields a more robust and stable product, a desirable feature for the entertainment industry.
4. Reed Solomon Product Code (RS-PC) error correction. This error correction code is similar to that on the magnetic and optical media, rather than that used in CD-R. This is important because CD-Rs are not ideal for computer applications. Data cannot be placed arbitrarily on the disc, it has to chain each recording session to the end of the last session. Moving to RS-PC, allows a random, block-oriented kind of recording anywhere on the disc surface. The DVD format that will be available for recording data, will not be available to consumers until 1998-99 and the capacity will be 2.6 GB.



## **Rewritable Magnetic Disks**

In 1995, the new Zip drive was introduced by Iomega. The price is under \$200 and the removable magnetic media is available in 25 MB (\$10) or 100 MB (\$20) capacities. The drive has since taken the personal data storage industry by storm and led to the development of an entire market for personal storage media. This demand has been encouraged by the electronic in-box revolution taking place in reaction to the ease of downloading documentation from the Internet. Other available disks offer capacities of 120 MB (3M's drive that can also read the 3.5 inch 1.44 MB floppies), 135 MB (SyQuest EZ135), 170 MB (Avatar APS 170 PB), or 1 GB (Iomega Jaz).

SyQuest offers removable magnetic drives with associated removable floppies. These magnetic drives cost between \$500 and \$700. A 2.5 inch floppy is available with a 42.8 MB capacity. A 1.8 inch floppy is also available which holds 80 MB. These media are commonly used in the printing industry to exchange color prints because a digitized color image requires roughly 20 MB of capacity.

The Bernoulli disk from Iomega, is based on barium ferrite media. The current storage capacity of 230 MB is spread over two platters that can be accessed simultaneously. These two disks are back-to-back in the cartridge and as they spin, the air between them forces them away from each other and toward the recording heads. They are often used in rugged environments because if there is an interruption in power, the media falls away from the heads to avoid any head damage to the disk or loss of data. This media is also a favorite of some security-oriented organizations because the media can be shredded.

## **Rewritable Optical Disks**

Magneto-optic (MO) technology uses optical properties and some principles of magnetic storage to store data on 2.5-, 3.5-, 5.25-, 12- and 14-inch optical disks. To replace data on a MO disk requires the first head pass over the disk to erase the data, a second pass to let the track cool, and the a third pass to record the new data.

Desktop requirements will soon be met by the 2.5 or 3.5 inch optical disk. Sony offers the 2.5 inch MD-Data disk that holds 140 MB, the equivalent of 15 minutes of video (using MPEG-1 compression). The current capacity of the 3.5 inch disk is 640 MB. These disks can spin faster and provide shorter seek times than their 5.35 inch counterparts. A desktop jukebox was introduced by Fujitsu at the 1996 AIIM show. It can hold up to 35 of the 3.5 inch disks and up to two optical drives providing 22.4 GB of storage.

The 5.25 inch disk currently holds 2.6 GB. This size of disk has become the media of choice for network and jukebox applications. Multifunction drives have been introduced by numerous vendors that will write to either 5.25 inch WORM or erasable platters.

Phase change technology can write directly over the data on a track and replace it with new data, therefore saving time required by the MO drives. The popularity of phase change media is expected to grow. In the fall of 1994, Matsushita introduced the phase change dual (PD) drive. This drive is being considered a standard in the European community. This drive records on a rewritable 4.72 inch phase change disk but it can also read a 4X CD-ROM to serve a dual purpose for the consumer. Two new jukeboxes are available from Pioneer. The 50 platter unit provides 32.5 GB and the 100-platter unit provides 65 GB.

Nikon has combined the two technologies (MO and phase-change) and is bringing a direct overwrite MO disk to the market. They market a 12 inch disk with the storage capacity of 8 GB. The transfer rate is 1.1 Mbps and the cost is \$1,100 per disk. This disk and drive can be installed in the ATG Cygnet jukebox and there are customers in Korea who are interested in using this system for the management of governmental records. Currently, Lockheed Martin is developing a 14 inch disk that can hold 12 GB and meet Mil Standard E-5400. It is not known when or if this product will be made commercially available. Kodak is also working to bring an erasable disk to the market before 2000.

### **WORM Optical Media**

Non-erasable WORM media is available in 5.25-, 12-, or 14-inch sizes. By the end of 1995, the 5.25 inch platter held an average of 2.6 GB. There are numerous jukeboxes that are available to accommodate this size media. These vary in size from 10 to 1,054 platters.

Philips LMSI offers a 12-inch WORM drive that operates with a dual-head so that each side of the disk is available to the user simultaneously. The user is provided with 12 GB of storage without the need to flip the disk in a standalone environment. To compliment this drive, a 6-platter magazine fits as a single unit into a modified version of the drive providing 72 GB of storage with a disk swap time of less than 3 seconds. The removable magazine can easily be vaulted for security.

In 1995, Sony announced a 15 GB disk and dual-head drive that should be shipping by the third quarter in 1996. The drives will be available in one of two different jukebox configurations. For every drive, the jukebox frees up space for 10 platters. The smaller jukebox will handle from 1 drive and 76 platters, to 4 drives and 46 disks. The trade-off ratio is the same for the larger jukebox. The drive/disk combination will run

from 2 drives and 156 disks to 6 drives and 116 platters. Disks in 6 drives will provide the user with 90 GB on-line simultaneously.

Kodak's latest 14 inch optical platter has the capacity of 14.8 GB and incorporates a non-erasable form of phase-change technology. The 132 platter Kodak jukebox provides access to 1.9 TB. The new dual-sided 25 GB disk and drive is due out in the fall of 1996. That introduction will take the large jukebox to a 3.3 TB capacity.

## **Optical Tape**

This media is one of the most exciting and versatile on the market today. It was originally introduced into the U.S. in 1986-87 by ICI Imagedata. A 12.5 inch open reel can hold 1 TB of data. As with other open reel systems, there is no way to automate the system as it stands today. The tape must be mounted on a floor-model drive that occupies 6 square feet. Transverse recording writes data perpendicular to the length of the tape. Of interest: if you were to print out 1 TB of ASCII data, the paper requirements would consume 42,500 trees. A single TB would accommodate either 1 million 500 page books, or 1600 CDs, or 2000-4 drawer file cabinets, or 5,000 9-track tapes. There are systems in UK, Canada, Republic of South Africa, and Australia in addition to the U.S. Applications include satellite data, oil data, medical images, transaction processing and document archives.

Other vendors, including Kodak and Dow Chemical, developed different types of optical tape. There are also several vendors working to perfect an optical tape cartridge or cassette subsystem. Most of these are members of the Optical Tape Study Group lead by Fernando Podio at NIST. The subsystem closest to commercialization will be coming from LOTS Technology. The engineers at this company are building their own drive to read Kodak optical tape in a 3480-sized cartridge. This drive will fit into any of the autoloaders which uses the 3480-type cartridge. The drive can record up to 1 TB on a single unit at 120 Mbps. LOTS Technology could expand STK's 6000-unit 3480-type library capacity to 6 PB. Sixteen libraries would provide 96,000 TB or 96 Petabytes of robotically-addressable storage. The 96 PB could replace 1,920 billion image documents -- roughly equal to the volume of pages in 9,600 Library of Congress buildings. Beta units should be available by the close of 1996.

## **Thin Film Media**

The NT-1 cassette from Sony contains thin film media which is only 2.5 mm wide and 4.8 microns thick. The tape can record 45, 60, 90 or 120 minutes of digital music, up to 53 minutes more than an audio CD. The length of tape is 20 meters and it has already been specked out for data — 612 MB! The digital data tape would replace 3.4 9-track tapes, 4 file drawers holding 12,240 document images, or 306,000 ASCII pages that would take 3,570 pounds of paper to print.

Unfortunately, the system was withdrawn from the marketplace in late April, 1996. Only time will tell if it reemerges or not.

### **Conclusion**

The abstract for this paper was submitted in February. Changes were made to the body of the paper when it was revised in early May. The July revision, was made due to the technology advances since that point in time. By the time this paper appears in the proceedings for September, more products will have been introduced, some vendors will drop out and other vendors will enter the market. If you have updates to add, give me a call and I will reflect them in future releases of my book. If you want to check what has changed since this paper was released, I invite you to contact me!

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