4. MAGNETIC STORAGE MEDIA

Magnetic storage encompasses a wide range of media, from mini cassette tapes to terabyte-sized file servers.

Some new media types have emerged as major storage categories in the last 5 years, including digital videocassettes, audio MiniDiscs, and flash memory. Meanwhile hard disk drives are finding new applications in consumer products such as personal video recorders and video game boxes.

Other magnetic storage media have declined since the 2000 study but remained in demand, despite predictions to the contrary. For example, relatively old-fashioned tape mechanisms still play a major role in safeguarding large amounts of data. PC manufacturers like Dell plan to eliminate floppy disk drives from their personal computers, yet worldwide demand for floppy disks has not disappeared entirely.

In this section we review the production statistics for magnetic media and we estimate the percentages of original information stored on each.

Overall, we estimate that the amount of original data stored annually on magnetic media has increased dramatically—it has nearly doubled since our 2000 study.

<table>
<thead>
<tr>
<th>Magnetic storage types— 2003 Sources</th>
<th></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Media Type</th>
<th>Unique Items per Year (World)</th>
<th>Conversion Factor</th>
<th>Total Annual Petabytes (World)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video tape (VHS and camcorder)</td>
<td>220,000,000</td>
<td>4 GB per tape (MPEG-2 compression)</td>
<td>1,340</td>
</tr>
<tr>
<td>Audio tape (analog)</td>
<td>128,800,000</td>
<td>1 GB per tape (CD audio format - no compression)</td>
<td>128.8</td>
</tr>
<tr>
<td>Digital tape</td>
<td>5,000,000</td>
<td>Varies</td>
<td>250</td>
</tr>
<tr>
<td>Mini-DV</td>
<td>115,000,000</td>
<td>11 GB per tape</td>
<td>1,265</td>
</tr>
<tr>
<td>Floppy disks</td>
<td>55,000,000</td>
<td>1.44 MB per disk</td>
<td>0.08</td>
</tr>
<tr>
<td>Zip disks</td>
<td>1,400,000</td>
<td>250 MB per disk</td>
<td>0.35</td>
</tr>
<tr>
<td>Audio MiniDisks</td>
<td>10,450,000</td>
<td>160 MB per disk</td>
<td>1.7</td>
</tr>
<tr>
<td>Flash memory</td>
<td>43,000,000</td>
<td>Varies</td>
<td>1.2</td>
</tr>
<tr>
<td>Hard disk drives</td>
<td>43,928,000</td>
<td>Varies</td>
<td>1,986</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5187.13</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: How much information 2003

**Table 4.2: Comparison of production of original information for the major magnetic media types - 2000 sources vs. 2003 sources**

<table>
<thead>
<tr>
<th>Media Type</th>
<th>% change</th>
<th>Year</th>
<th>Unique Items per Year (World)</th>
<th>PB per Year (World)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Video tape (VHS and camcorder)</td>
<td>-6%</td>
<td>2000</td>
<td>355,000,000</td>
<td>1,420</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2003</td>
<td>220,000,000</td>
<td>1,340</td>
</tr>
<tr>
<td>Audio tape (analog)</td>
<td>-30%</td>
<td>2000</td>
<td>184,200,000</td>
<td>184.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2003</td>
<td>128,800,000</td>
<td>128.8</td>
</tr>
<tr>
<td>Digital tape [???]</td>
<td>0</td>
<td>2000</td>
<td>5,000,000</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2003</td>
<td>5,000,000</td>
<td>250</td>
</tr>
<tr>
<td>Floppy disks</td>
<td>-27%</td>
<td>1999</td>
<td>75,000,000</td>
<td>0.11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2003</td>
<td>55,000,000</td>
<td>0.08</td>
</tr>
<tr>
<td>Zip disks</td>
<td>-68%</td>
<td>2000</td>
<td>4,400,000</td>
<td>1.69</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2003</td>
<td>1,400,000</td>
<td>0.35</td>
</tr>
<tr>
<td>Flash memory</td>
<td></td>
<td>2000</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2003</td>
<td>43,000,000</td>
<td>1.2</td>
</tr>
<tr>
<td>Hard disk drives</td>
<td>114%</td>
<td>2000</td>
<td>39,918,000</td>
<td>926</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2003</td>
<td>43,928,000</td>
<td>1,986</td>
</tr>
</tbody>
</table>
I. VIDEO TAPE (ANALOG)

Analog video tapes include the standard VHS tapes using in video cassette recorders (VCRs) as well as the 8 mm video camcorder tapes.

The main use of blank VHS tape is the consumer's use to record television programs. It is estimated that a very large share of the users of VCRs do so for time-shifting of viewing programs. A challenge to this market comes from new time-shifting devices employing hard disk drives—personal video recorders (PVRs) such as TiVo and Replay. The market for such drives is currently small, but growing fast, according to a report released in 2002 by market research company InStat/MDR. The company predicts that the market for PVRs will jump from 1.2 million units in 2001 to over 6 million in 2003; this trend along with the popularity of DVD recorders is likely to cause further declines in the popularity of the VHS tape.

A. Original Information Stored/Published on Video Tape

1. Annual Production of Titles

World. In 2003, 1.1 billion blank VHS video tapes will be produced for the entire world, according to the International Recording Media Association. This statistic is confirmed by the Japanese Recording-Media Industries Association (JRIA). If all these tapes were filled to their 120 minute capacity and then converted to digital using MPEG-2 compression, there would be approximately 4 gigabytes of data per tape. One year’s production of blank video tape, therefore, provides storage space adequate for 4,400 petabytes of data. The vast majority of this is used for recording television programs; a minority is used in video cameras.

Assuming twenty percent of this tape is used for the storage of original data, the annual flow of new data stored on analog VHS video tape would be **880 petabytes**.

As of 2002, video camcorder tapes (all formats except VHS) are consumed at the rate of 230 million per year worldwide, according to JRIA. Almost all of this tape is used for the storage of original data. Assuming one hour per tape in MPEG-2 format yields **460 petabytes** annually.

The production of video tapes has declined by 21 percent since 2000, when 1.4 billion video tapes were produced for the world. In contrast, the production of video camcorder tapes has increased by 50 percent since 2000.

United States. In 2003, 310 million blank VHS video tapes will be produced for the entire world according to IRMA.

2. Accumulated Stock

World. About 8 billion blank video cassettes have been sold since 1998, according to IRMA. If twenty percent of this tape is used for the storage of original data, the total accumulated stock would be **6,400 petabytes**.

One billion camcorder format tapes have also been added over the same period. This would be equivalent to 3 billion hours of stored original video which, if digitally encoded, would produce a stock of about **6,000 petabytes** of original video taped data.

B. Copies of Information Stored/Published on Video Tape

1. Annual Production of Titles

World. In the year 2003, 1.2 billion prerecorded video tapes will be distributed worldwide according to the International Recording Media Association. This entire production will be copies, principally of feature films. If converted to digital using MPEG-2 compression, prerecorded video tape would consume **4,800 petabytes** per year.
If 80 percent of the blank video tape distributed per year were used for copies, this would constitute a digital equivalent of 3,520 petabytes.

The total yearly world production of copied data on analog video tape, therefore, is 8,320 petabytes. This represents a 30% decrease from our 2000 study; significantly fewer copies are being stored on analog video tapes.

2. Accumulated Stock

World. Since 1998, about 9 billion prerecorded videocassettes have been sold worldwide, according to IRMA. If converted to digital using MPEG-2 compression, prerecorded video tapes would consume 36,700 petabytes.

IRMA also reports that about 8 billion blank video cassettes have been sold since 1998. If 80 percent of this tape is used for the storage of copies, the total accumulated stock of copies would be 25,700 petabytes.

Therefore the total world stock of copied data on video tape is 62,351 petabytes.

II. AUDIO TAPE (ANALOG)

The distribution of prerecorded music is one of the most common uses of analog audio tape cassettes. The sales of music in this format, however, are now much smaller than they have been historically and are generally expected to continue to decline as digital media become more prevalent and convenient.

The International Recording Media Association (IRMA) no longer tracks audio cassette manufacturing because, according to the organization, this medium is a dying business. According to the Japanese Recording-Media Industries Association, “the global blank audio cassette market in 2003 continues to contract significantly by 16% to 644 million units. The decline in demand is largely attributed to the shift to digital processing in the audio recording technology resulting in the growing popularity of alternate media such as the MiniDisk and CD-R for audio use.” Worldwide, the compound annual decline rate for duplicated audiocassettes is 10 percent.

In North America, the rate of decline was only 5 percent, due in large part to the growth of "books on tape" (or audiobooks). This segment, with over 726 million cassettes dubbed, accounted for more than 77 percent of all audio cassettes duplicated in North America in 2000, according to IRMA. In 2001, sales of audiobooks in the United States reached 801 million units and increases about 10 – 12% each year, according to the Audio Publishers’ Association (APA).

At the same time, the use of CDs for audiobooks increased dramatically from 2000 to 2001. In fact, the APA reports that the average number of hours per week audiobooks are listened to on CD currently almost equals the use of audiobooks on cassettes. This may perhaps be attributed to a shift in car audio systems: audiobook listeners spend most of their time listening to books in the car and 64% of new cars are sold with CD players (as opposed to 42% sold with cassette players).

Even with these declines, in 2002 the analog audio tape cassette was one of only four recording formats with production of over one billion units. According to Magnetic Media Information Services (MMIS), “demand for cassettes has long since peaked, but it remains strong despite the advanced age of the format” (it was first introduced in 1964). The biggest market for music cassettes is Asia, which represents 48% of all sales. Other markets with potential for growth include Latin America, the Middle East, Russia, Eastern Europe, and India, according to Optical Disk Systems magazine.

No one really knows just how large the pirated music cassette business was in 2002 (or any other year), but it is probably close to or even over one billion pieces last year. Much of the demand for these pirated music cassettes is in Asia, and especially in China, Vietnam, Cambodia, Indonesia, and the Philippines, according to MMIS.

A. Original Information Stored/Published on Audio Tape

1. Annual Production of Titles

In 2003, 644 million blank audio tape cassettes will be produced for the entire world, according to the JRIA.
each tape was filled to its 120 minute capacity and then converted to digital using the common CD audio format, there would be approximately 1 gigabyte of data per tape, for a total of 644 petabytes. Assuming 20 percent of this tape is used for the storage of original data, the flow of new data stored on analog audio tape would be 128.8 petabytes.

The flow of audio tape cassettes has declined by 30% since 2000, when 921 million blank cassettes were produced annually. This corresponds to an increase in the use of optical recording media (See Optical section).

2. Accumulated Stock
The total stock of original audio content stored on tape may be estimated by assuming 20 percent of five years’ production of blank cassette tapes contains original content. The digital equivalent of this audio information is 1,000 petabytes.

B. Copies of Information Stored/Published on Audio Tape

1. Annual Production of Titles

World. According to the Syndicat de l'Edition Phonographique, worldwide sales of prerecorded audio cassettes totalled 800.9 million units in 2000. If converted to digital using audio CD format, and assuming about one hour of music per tape, this would result in 801 petabytes of data.

If 80 percent of the 644 million blank audio tapes distributed per year worldwide were used for copies, this would constitute a digital equivalent of 515 petabytes.

The total yearly production of copied data on analog audio tape, therefore, is 1.3 exabytes. This represents a 30% decrease from our previous study; significantly fewer copies are being stored on analog audio tapes.

United States. In the year 2000, 76 million prerecorded audio cassette tapes were distributed in the United States according to the Recording Industry Association of America. This is less than 10% of the world sales of prerecorded audio cassettes. As of 2002, the figures are even lower: only 31 million tapes sold in the United States, equivalent to 31 petabytes.

2. Accumulated Stock
The world production of blank audio tape for the past five years is approximately billion units. During that period, there has also been sales of prerecorded audio tapes of 434 million units. Assuming that 80 percent of the blank audio tape has been used for the storage of copied data, the overall stock of copies of audio data on tape is petabytes on blank tape and 434 petabytes on prerecorded tape. Therefore, there is a total stock of petabytes of copies of audio data on magnetic tape.

III. DIGITAL TAPE
There are 25 million computer tape drives installed in the world at present. These drives provide storage capacity for a range of computers - from desktop personal computers to the most mammoth supercomputers. Storage expert Fred Moore, of Horison Information Strategies, estimates that the amount of data stored on tape is between 4 and 15 times the amount of enterprise data on disks and that there is almost US$1 billion of computer tape media sold each year worldwide. Digital tape types include super tape drives with more than 100 GB capacity such as SuperDLT, LTO (Linear Tape Open), and AIT (Advanced Intelligent Tape), as well as lower-capacity tape formats such as DAT (digital audio tape), QIC (quarter-inch cartridge tape), 8mm, Mammoth, DLT (Digital Linear Tape), ADR, and VXA. The super drive formats are in greater demand than the desktop and entry level drives, as organizations gradually shift from desktop backup to network backup.

There are two sides in the debate over the status and future of digital tape. On one side, there are those who view tape as a throwback technology, advocating instead newer disk-based technologies for backup and archiving. The main advantage of these systems is speed and flexibility: restoring from tape requires a minimum of one hour per terabyte while with disk-to-disk mirroring, one can quickly switch over from failed disk to working disk and keep applications...
Magnetic storage is constantly in service. Relatively inexpensive secondary disk storage is gaining a significant foothold in corporate data centers, according to a 2003 survey of more than 1,000 IT managers conducted by Peripheral Concepts consulting firm. Another indicator of tape’s decline relative to disk is noted by StorageSearch, a leading portal for enterprise storage buyers since 1998, with over 0.5 million readers. In April 2003 reader pageviews for disk-to-disk backup on STORAGEsearch overtook pageviews for tape backup for the first time.

On the other side are those who point to the advantages of tape storage, including cost and capacity. Costs associated with tape are generally lower than with other storage formats. The Gartner Group claims that the typical cost of enterprise disk storage amounts to US$110 per gigabyte, whereas tape costs $11 per gigabyte. Gartner predicts an 80 percent possibility that this disparity will remain until 2007. Analysts at International Data Corp (IDC) insist that disk prices will never approach the levels of tape. "The cost per gigabyte for tape is so low and getting lower with improving capacity," said Martin Wijaya, senior analyst for storage at IDC Asia-Pacific, quoted at ITWorld.com. "It's also more expensive to manufacture a disk that reaches the density level of tape." The densities of digital tape continue to increase. On March 24, 2003, Sony Electronics announced a new series of PetaSite tape library systems based on SAIT drive technology with a native capacity of up to 1.2 petabytes. Other advantages noted by analysts and advocates include longer lifecycles, high rates of reliability, less vulnerability to hacking, and portability. Lou Hirsh at the NewsFactor Network writes, "The newest tape technologies will become increasingly important for such storage-hungry corporate functions as data mining and archiving. Also facing increased storage needs are corporate and university researchers in disciplines ranging from geophysics to life sciences. Academic studies, in particular, require systems that allow long-term, repeated access to data, with the ability to make multiple copies and easily transport it to various sites."

Despite major advances in disk technologies, tape continues to be the mainstay of most companies’ backup and archival efforts. Secondary disk storage typically involves less than one-fifth of a company's total data, said Farid Neema, president and chief executive officer of Peripheral Concepts, as quoted at ComputerWorld.com. Furthermore, only a small percentage of the data backed up on disks does not get moved to tape devices for archiving, Neema said, "Tape remains by far the most popular medium and does not seem to want to go away."

### WORLD'S LARGEST DATABASE

In 1997, the largest database was Knight Ridder's DIALOG, a text database, with 7 terabytes of storage, according to SearchDatabase.com.

As of 2002, the world’s largest database is at the Stanford Linear Accelerator Center which stores 500 terabytes of experiment data.

### A. Original Information Stored/Published on Digital Tape

1. **Annual Production of Titles**

   The digital tape shipped in 2002 has a total storage capacity of about 2,500 petabytes. However, in all but the largest computer applications, digital tape is generally used solely for backup of data already stored on hard disk drives. Quantum, the manufacturer of DLT tape, the most popular format for enterprise storage, estimates that 90 percent of the tape capacity in that format is used for backup. Fred Moore also points out that it is more and more common for multiple copies of data to now be stored on tape.

   If it is assumed that ten percent of the total amount of data stored on tape is original data of the sort generated by scientific experiments in high-energy physics or by observational earth satellites or archival storage on tape where the data is no longer stored on disk, original data on magnetic tape is about 250 petabytes.

   250 petabytes is also generally consistent with estimates derived by use of forecasts of producer revenue of around US$3.4 billion for tape media and an average cost of around US$11 per gigabyte of tape storage.
2. Accumulated Stock

The stock of original data on magnetic tape may be approximated by adding the yearly flow of original data over the course of the expected lifetime of the medium. Some unfortunate experiences with the loss of computer data stored on magnetic tape has led to the practice of continuous migration of this data to new media every five to ten years. This process leads to the reduction in the number of tape cartridges that need to be managed as tape capacity inexorably rises, as well as insuring modernization of the tape format.

Therefore, the stock of original data on magnetic tape may be taken as five years’ worth of original data flow: 1,250 petabytes.

B. Copies of Information Stored/Published on Digital Tape

1. Annual Production of Copies

If 90% of the computer tape distributed annually were used for copies, this would constitute 2,250 petabytes of copied data for the year 2002. Similar trends will most likely be seen in the amount of data stored on tape, particularly as it becomes more common to make multiple tape copies of data.

2. Accumulated Stock

The stock of copied data on magnetic tape may be taken as five years’ worth of copied data flow: 11,250 petabytes.

IV. (MINI) DIGITAL VIDEOCASSETTES

Digital video is recorded on a tape called a Mini DV Cassette (DVC) that occupies less than half the volume of a 8mm cassette and holds one hour of video—11 GB of data on a tape 65 meters long. This small cassette size makes possible much smaller and more portable camcorders. Mini DVC represents 50% of the overall camcorder video cassette market, according to the Japanese Recording-Media Industries Association (JRIA).

A. Original Information Stored/Published on Mini DV

1. Annual Production of Titles

Magnetic Media Information Services estimates that DVC digital camcorder mini-cassettes reached sales of 72 million in 2001 and 88 million in 2002. In 2003, JRIA projects that mini-DV will grow by 19% to 115 million units worldwide. If all the tape produced in 2003 were used to store original information, the total storage would be 1,265 petabytes.

2. Accumulated Stock

Mini DV was first introduced in 1998. However, we only have sales figures for the last 3 years: 275 million units have been sold. This is equivalent to 3,025 petabytes of storage.

B. Copies of Information Stored/Published on Digital Tape

Mini DV is used primarily for the storage of original information.

V. FLOPPY DISKS

Many industry analysts have declared the micro-floppy disk (MFD) format essentially dead. Dell, the world’s largest PC manufacturer, has already eliminated the floppy from its higher-priced desktops and will drop the floppy from most models in 2003, citing two reasons: “computer buyers have become more sophisticated about using their computers, and new technology such as portable USB storage devices and CD-rewritable drives have come down in price over the last few years” (reported at ZDNet, Feb. 2003). Many computer users in the United States, the EU, and Japan haven’t used a floppy disk in years, still less purchased new floppy disks. Certainly the statistics show a sharp decline in worldwide demand over the past 7 years, from 4.5 billion diskettes at the peak of the market in 1995 to 1.3 billion in 2002.

However, in many parts of the world such as Latin America, China, and India, the MFD remains a widely-used recording medium, according to Magnetic Media Information Services. The demand for MFDs remained above one billion units in...
2002, and it is predicted to stay near that level in 2003 as well. For some companies, the production of MFDs is still a sizable and profitable business. Imation, the world's largest producer, accounts for one-third of the world's total floppy production and claims to produce about two million MFDs a day, both for itself and for other companies still active in selling diskettes.

A. Original Information Stored on Floppy Disks

1. Annual Production of Titles

In 2003, JRIA forecasts that the global market for floppy disks will decrease to 1.1 billion disks, down 15% from 2002 (1.3 billion disks) but up 15% since 1999. If each floppy disk can store 1.44 megabytes, this is an aggregate storage capacity of 1.58 petabytes. If [???] five percent of this is original data, new data per year on floppy disk would be 0.08 petabytes.

2. Accumulated Stock

The useful life of a floppy disk is estimated to be about three years. The amount of original data stored on roughly 4 billion floppies produced over the course of the past three years is around 5 percent of the total data on those disks, or 0.4 petabytes.

B. Copies of Information Stored/Published on Floppy Disks

1. Annual Production of Copies

If 95 [???] percent of the 1.6 petabytes of annual floppy disk storage were used for copies of data, this would add 1.52 petabytes to the stock of digital data stored on floppy disks.

2. Accumulated Stock

The useful life of a floppy disk is estimated to be about three years. The amount of copied data stored on roughly 4 billion floppies produced over the course of the past three years is around 95 percent of the total data on those disks, or 7.6 petabytes.

VI. ZIP DISKS

The general trend for low-end disk (capacity of around 100 to 250 megabytes) is downward, according to Iomega president and CEO Werner Heid. At the peak of the format's popularity in 1999, Iomega shipped more than 11 million Zip drives and 64 million Zip disks. In 2002 Iomega Zip disk unit sales were 28.2 million units, representing a decrease of 6.2 million units from 2001. This 18% decline has been attributed to the advent of recordable CDs.

In order to provide the dedicated Zip user with a format that matches the capacity of a recordable CD, in 2002 Iomega introduced the Zip 750MB drive. Initially available as an external USB device, Iomega claims the Zip 750 “offers better-than-CD recordable performance, with media designed to be rugged and user friendly.” However, Zip disks lack the universal compatibility of a CD.

A. Original Information Stored on Zip Disks

1. Annual Production of Titles

Iomega Zip disks are primarily used for backup, transfer of files or video or image editing. If each Zip disk sold in 2002 was filled to capacity, that would equal about 7 petabytes. If five [???] percent of this is original data, new data per year stored on Zip disks would be 0.35 petabytes.

2. Accumulated Stock

Since the Zip drive was introduced in March 1995, Iomega has shipped more than 48 million drives and 300 million disks. This translates to 75 petabytes in all, with about 3.8 petabytes of original data. (The lifespan of a disk, in heavy use, is about 5 years.)

B. Copies of Information Stored/Published on Zip Disks
1. Annual Production of Copies

If 95[???] percent of the 7 petabytes of annual removable disk storage were used for copies of data, this would add 6.7 petabytes to the stock of digital data stored on removable disks.

2. Accumulated Stock

The 300 million disks shipped since 1995 have a total storage capacity of 75 petabytes. About 71.2 petabytes of the storage is used for copies of data.

VII. AUDIO MINIDISCS

The audio MiniDisc, developed by Sony, was first introduced in 1991. This format’s main features are random access, good sound quality, easy song editing, and compact size. There are two physically distinct types of discs: Premastered MDs, similar to CDs in operation and manufacture, and Recordable MDs, which can be recorded on repeatedly and employ magneto-optical technology. The disc itself is enclosed in a small (7cm x 7cm) cartridge. According to Sony, each disc can be recorded and erased 1 million times.

Confusion over the MiniDisc's intended purpose plus early technical limitations and high cost made its initial acceptance slow outside of Japan. In 1994, Sony sent 1.1 million MD samplers to Rolling Stone subscribers and in 1997, lowered the prices on players and discs. However, the MD market remains a niche market, a presence established primarily in Japan, accounting for 70% of the world demand. It also has a fairly strong and growing presence in Europe. This is one of the few storage media types where there is not a sizable U.S. market—only 5% of the 274 million discs sold in 2001. In 2002, according to the Magnetic Media Information Services, industry analysts expect some 321 million MiniDiscs to be sold worldwide, of which about a third (100 million) will be sold outside of Japan.

A. Original Information Stored on Audio MiniDiscs

1. Annual Production of Titles

Recordable. Japanese Recording-Media Industries Association (JRIA) estimates that the global market for recordable audio MDs will be 209 million units in 2003; this represents a decline of about 5% from 2002. Each MiniDisc can hold 140MB in data mode or 160MB for 74 minutes in audio mode. This results in a total annual production of about 33 petabytes, assuming that most discs are used for recording audio. If five[???] percent of data stored on recordable MDs is original data, this would equal 1.7 petabytes per year.

Prerecorded. Sony is the only manufacturer currently producing titles on premastered MD; there are currently 531 titles in the Sony MD catalog. There are no titles issued on MD that are not also available on CD; therefore to avoid double-counting, we do not report this format under original information.

2. Accumulated Stock

Estimates of worldwide MD sales vary somewhat and we do not have data for every production year. For the years 1999 – 2002, we estimate that a total of 1 billion blank minidiscs were produced. This results in a total storage capacity of about 160 petabytes. If 5% of this storage is used for original data, this would equal about 8 petabytes.

B. Copies of Information Stored/Published on Audio MiniDiscs

1. Annual Production of Copies

Recordable. If 95% of data stored on recordable MDs each year are copies, this would equal approximately 31.3 petabytes.

Premastered. IFPI first reported on international sales of premastered audio MiniDiscs in 1999. At that time, IFPI stated “in total one million units were sold worldwide, the biggest market being the UK where sales totalled just under 500,000. Minidisc sales were also reported in Austria, Belgium, Denmark, Finland, France, Germany, Norway, Sweden and Japan.”

However the following year, in 2000, only 700,000 premastered MiniDiscs were sold worldwide, a decline of...
Magnetic 

34% from 1999. We do not have production statistics for 2001 and 2002, but the premastered MiniDiscs sold in 2000 equal **0.11 petabytes**.

2. Accumulated Stock

*Recordable*. If 95% of data stored on all recordable MDs are copies, this would equal approximately **152 petabytes**.

*Premastered*. The two years for which we have sales data (1999 and 2000) total **0.29 petabytes**.

VIII. FLASH MEMORY

Flash memory is used for information storage in devices such as mobile phones, digital cameras, MP3 players, personal digital assistants, tablet PCs, home video game consoles and even the Aibo robotic dog from Sony. Here are some examples of flash memory:

- A computer's BIOS chip
- CompactFlash (most often found in digital cameras)
- SmartMedia (most often found in digital cameras)
- Memory Stick (most often found in digital cameras)
- PCMCIA Type I and Type II memory cards (used as solid-state disks in laptops)
- Memory cards for video game consoles

Intel invented flash memory in 1988. In April 2003, Intel said it had shipped over 2 billion flash memory units. It took Intel 12 years to ship its first billion discrete flash units and only three more years to ship the next billion.

In 2002, the largest flash memory manufacturers after Intel were Samsung, Toshiba, AMD (Advanced Micro Devices) and Fujitsu.

According to Techweb (March 11, 2003), flash memory sales in 2002 were driven by continuing demand for digital still cameras and for data storage applications, such as other products, like MP3 players. At the same time, demand for the flash memory used in cell phones and PCs decreased sharply.

Overall, flash unit shipments are expected to increase 21% to 1.8 billion units in 2003, according to IC Insights.

The capacity of flash memory units varies; most memory cards today are 200 megabytes or less, but high-capacity versions just released by SanDisk can hold 2 GB or 4 GB of data.

SMART CARDS

Smart cards currently in deployment have a capacity ranging from a few kilobytes to 224 MB. There is an annual growth rate of about 28% in the number of smart cards produced and sold yearly. There may be anywhere between 4 and 10 billion smart cards in the world by 2006. This figure might get a huge boost if cards that do not need separate readers get mass produced (thus the card plugs directly into the Universal Serial Bus (USB) port on a PC via a passive adapter). The reason this is important is that credit card companies will then shift to smart cards from magnetic cards. Currently, the amount of information on your average magnetic strip credit card is negligible, partly because there is greater reliance on the network (in which case we have already accounted for that in our Magnetic statistics) - this dependence changes with chip-enabled cards. In the near future the government of China plans to have all its citizens carry smart cards, as do the Philippines, Cambodia and several nations in the Persian Gulf as well. The U.S. government alone plans to buy several million smart cards (the Department of Defense has already implemented the first phase for its own employees). In the future, when biometric information is stored on these
A. Original Information Stored on Flash Memory

1. Annual Production of Originals

Currently, the majority of original information stored in flash memory is found in digital cameras; digital cameras account for about two-thirds of all shipments of flash memory cards, according to IDC figures reported at CNET.com. In 2002, about 27 million digital cameras were purchased worldwide. The average memory per card as of 2002 is 42 megabytes, but by 2006 the average will increase to about 83 MB per card. If the memory in every camera were filled to capacity, the annual flow of original information would be about 1.1 petabytes, all of which is original.

High-end cell phones enabled to store data and images also use flash memory for original information. Roughly 16 million such phones were sold worldwide in 2002, the vast majority (96%) in Japan and Korea. If each phone has an average of 128 megabits of flash memory, this adds up to about 0.1 petabyte of data.

2. Accumulated Stock

As of 2002, there are about 53 million digital cameras in the world. This represents a total possible capacity of about 2 petabytes, all of which is original.

These results also allow us to estimate the maximum number of photographs stored on digital cameras. If a 42 MB card can store, on average, 80 photographs at a resolution of 2 megapixels, then the total potential stock is 4.2 billion digital photographs.

B. Copies of Information Stored/Published on Flash Memory

1. Annual Production of Copies

Flash memory is used for storage of copies on MP3 players. The average amount of memory that comes with a player is 64 MB. About 7 million MP3 players were sold in 2002, for a total possible capacity of about 0.4 petabytes.

2. Accumulated Stock

About 30 million MP3 players have been sold worldwide since the technology was introduced in 1999. With an average of 64 MB of flash memory per player, this equals a total of about 2 petabytes of copied data.

IX. HARD DISK DRIVES (HDD)

Worldwide shipment of hard drives dipped to 196 million in 2001 and rose to 213 million in 2002. Worldwide PC unit shipments grew by 2.7 percent in 2002 from 2001. In spite of two consecutive quarters of growth, Gartner reports the market has yet to show evidence of a significant upturn.

To estimate total capacity, we look at the hard drive sales statistics in combination with the storage capacity per drive. In 2002, 10.85 exabytes of hard drive storage were sold.

<table>
<thead>
<tr>
<th>Year</th>
<th>Disks Sold (Thousands)</th>
<th>Storage Capacity (Petabytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>42,000</td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>89,054</td>
<td>104.8</td>
</tr>
</tbody>
</table>
Magnetic

<table>
<thead>
<tr>
<th>Year</th>
<th>Units Shipped</th>
<th>Total Storage (in TB)</th>
<th>Est. % Original</th>
<th>Total Original (in TB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>105,686</td>
<td>183.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>129,281</td>
<td>343.63</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>143,649</td>
<td>724.36</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>165,857</td>
<td>1394.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>200,000 (IDEMA)</td>
<td>4,630.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>196,000 (Gartner)</td>
<td>7,279.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>213,000 (Gartner projection)</td>
<td>10,849.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>235,000</td>
<td>15,892.24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>1,519,527 (1.5 billion drives)</td>
<td>41,402.73 (41 exabytes)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Raw data, various sources. Chart, How much information 2003

A. Original Information Stored on Hard Drives

1. Annual Production of Titles

The amount of original data stored on hard disks is most likely to vary according to the computing environment in which the disks are deployed. It is possible to divide all hard disk storage into two major categories:

- **Single-user computers** (personal computer, laptop, or workstation). This type of computer is responsible for approximately 90% of the computer disk storage capacity currently shipped.

- **Servers** (typically used with mainframe or network file servers). This class of computer is responsible for about 10% of the overall storage market.

The amount of original data stored on the computers in each is probably substantially different.

**Single-user computers** and the applications software usually found on them are not suited for the production of large amounts of original data. A recent study (McKenzie, “Microsoft’s Applications Barrier to Entry: The Missing 70,000 programs”) found that most people used only a few applications other than those found in the Microsoft Office application suite. These applications are usually text-based, such as word-processing or spreadsheets, and so require minimal storage space. Most personal computers now sold come with hard disk storage capacity in the range of 20 gigabytes. 200 megabytes of original data constitutes 1% of disk capacity, which is the estimate for this category of computer disk.

**Servers** are commonly found in business, government, educational, or other organizational settings. These servers provide disk space for a group of users, who all contribute to the production of organizational data. Aside from the databases and spreadsheets, there may be product catalogs and other graphic intensive marketing material, PowerPoint presentations and so on. An estimate of the original data stored in these hard disks is 35%.

<table>
<thead>
<tr>
<th>Drive type</th>
<th>Est. Units Shipped 2002</th>
<th>Total Storage (in TB)</th>
<th>Est. % Original</th>
<th>Total Original (in TB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-user (PC, laptop, and workstation)</td>
<td>200 million</td>
<td>9 million TB</td>
<td>1%</td>
<td>90,000 TB</td>
</tr>
<tr>
<td>Server (midrange and enterprise)</td>
<td>20 million</td>
<td>0.9 million TB</td>
<td>35%</td>
<td>313,000 TB</td>
</tr>
</tbody>
</table>
Using these calculations, approximately **403 petabytes** of the total hard disk drive capacity each year is used to store original (user-created) data.

If, instead of assuming 1% original information on PCs and 35% on servers, we estimate 20% original across all hard disk storage, we arrive at an upper bound of **1,986 petabytes**. Clearly, the factor we use in the "% original" estimate has a strong effect on the final result. We hope our investigation of how individuals use storage on their personal computers will provide a more solid foundation for this tentative calculation.

2. Accumulated Stock

Over the past 3 years, hard disk capacity of about 23,000 petabytes has been produced. If 20 [?] percent of that capacity has been used to store original content, the stock in that format is now **4,600 petabytes**.

### GENOMIC DATA

One growing source of original information that human genomic sequence information. As of 2002, there are 22 billion sequences stored in the GenBank; this number has grown exponentially since it was started in 1982. If each sequence occupies 10 bytes, this currently represents **220 GB** of information (and growing).

### B. Copies of Information Stored/Published on Hard Drives

1. Annual Production of Copies

   If 80 [?] percent of the 10,849 petabytes of annual hard disk storage were used for copies of data, this would add **8,679 petabytes** to the stock of digital data stored on hard disks.

2. Accumulated Stock

   Over the past 3 years, hard disk capacity of about 23,000 petabytes has been produced. If 80 [?] percent of that capacity has been used to store original content, the stock in that format is now **18,400 petabytes**.

## NEW USES FOR DISK DRIVES

Applications for hard disk storage have extended beyond conventional computing uses. As reported in IDEMA Insight Magazine, IDC expects over 50 million drives to ship into consumer applications, representing about 13 percent of all HDDs shipped in 2005. New categories for disk drives include:

- Personal video recorders (IDC expects over 1.5 million units will be sold this year and grow to over 25 million in 2005)
- Video game boxes
- Portable digital music players that integrate hard disks. (Led by models like the iPod and the Rio Riot, worldwide unit shipments are forecasted by In-Stat/MDR to increase from 230,000 in 2001 to over 950,000 in 2003, as reported by MacCentral.)

### Interesting Facts about Magnetic Media

- As of February 2003, the cost of disk-drive capacity has dropped below US$1 per gigabyte. (Reported at
Magnetic

SiliconValley.com)

- Hard drives now come in packages almost as small as a quarter. IBM Corp.'s 1-gigabyte Microdrive holds the equivalent of 700 floppy disks in a half-ounce, one-inch package. Credit-card sized hard drives in laptops can now hold 20 GB of data. (Reported in the San Francisco Examiner, July 29, 2002)

- The typical American consumer now generates some 100 gigabytes of data during his or her lifetime, including medical, educational, insurance, and credit-history data, EMC's Rothnie says. Multiply that by 100 million consumers and you get 10,000 petabytes of data. (Reported in Information Week, Feb. 11, 2002)

Notes on Conversion Decisions

Video tape

In making assumptions about the size of analog video tape stores we have chosen to make conversions assuming the use of MPEG-2 video compression standard. In the case of video tape, the use of this conversion factor is seen as appropriate because it was designed as a generic format for digital multimedia and includes coding schema for both video and audio.

In the case of video, the massive amount of data generated requires that for any practical purpose some compression scheme must be used. MPEG-2 is now the international standard for video storage. Compression is achieved in two ways: spatial compression and temporal compression. The spatial compression is achieved by reducing the number of bits used to represent a single frame. Temporal compression, where the bulk of the savings come, attempts to encode only the bits that represent the portions of a frame that have changed from the previous frame.

The actual amount of compression that can be achieved with MPEG-2 varies quite a bit, we have assumed that 2 gigabytes is adequate to represent 1 hour of high-fidelity audio and high-definition video data.

Audio tape

In translating the vast quantity of audio information available on cassette tape into its digital equivalent, we have chosen to use the CD format, linear PCM audio at a 16-bit word length and 44.1kHz sample rate. Although, professional recording studios use a sampling rate of 96kHz, the vast majority of tape recorded audio material is music for consumer use and the CD format is the digital format of choice for this application. The amount of data generated by this format is easily calculated. There are 44,100 16-bit samples taken each second for two tracks. Thus,1.4 million bits per second and 5.08 gigabits per hour are generated. The conversion to bytes yields 605 mBs per hour. (1 mByte = 1,048,576 bytes). This data is not compressed and yields a reasonable representation of music for most people.

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