A TeraByte in Your Pocket and a PetaByte in your Home

Trends and Opportunities for Data Storage

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Coughlin Associates
Outline

• A Quick Discussion of the HDD Industry
• New Applications for HDD
• Home storage hierarchies, how to choose the proper storage for an application
• New roles for HDDs in CE applications
• Home storage networks and the home storage utility

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Quick Update on HDD Industry
2005 Total Drive Percentages

- Seagate: 29%
- Western Digital: 17%
- Maxtor: 15%
- Samsung: 14%
- Toshiba: 9%
- Hitachi: 9%
- Fujitsu: 6%
- Others: 1%

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By 2010 CE and Mobile Computers will dominate in disk drive unit volume
HDD Form Factor Projections

By 2010 2.5-inch and smaller HDD will provide over half of total disk drive volume
<table>
<thead>
<tr>
<th></th>
<th>2004</th>
<th>2005</th>
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<td>HDD</td>
<td>305,603</td>
<td>379,900</td>
<td>442,537</td>
<td>513,002</td>
<td>587,232</td>
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<td>Heads</td>
<td>837,800</td>
<td>1,139,020</td>
<td>1,371,863</td>
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<td>Disks</td>
<td>488,200</td>
<td>604,300</td>
<td>690,357</td>
<td>790,023</td>
<td>892,593</td>
<td>1,000,487</td>
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<td>SPM</td>
<td>323,939</td>
<td>400,869</td>
<td>469,089</td>
<td>543,782</td>
<td>622,466</td>
<td>707,011</td>
<td>798,346</td>
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<table>
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<th>2008</th>
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<tr>
<td>HEAD/HDD</td>
<td>2.74</td>
<td>3.01</td>
<td>3.10</td>
<td>3.05</td>
<td>3.00</td>
<td>2.95</td>
<td>2.90</td>
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<td>1.58</td>
<td>1.56</td>
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<td>1.52</td>
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<td>SPM</td>
<td>1.06</td>
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<tr>
<td>Head/Media</td>
<td>1.72</td>
<td>1.90</td>
<td>1.99</td>
<td>1.98</td>
<td>1.97</td>
<td>1.97</td>
<td>1.96</td>
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AVERAGE DRIVE PRICE TREND FOR SEAGATE, WESTERN DIGITAL AND MAXTOR (Q4 '98 to Q1 '06)
Comparison of Product Announcement Trends vs. Areal Density Rates

There is no CAGR. Growth rate of technology introductions varies with time.
What will your life be like in 2010?

• 5 TB of first-instance content digital capacity in a tech savvy home
• As much as double this amount of digital storage including copies of content
• 100+ GB mobile devices (using fuel cells to remove many power limitations?)
• Higher definition content available boasting storage requirements
• Consumer applications integrated in storage devices to reduce costs and resulting prices
• Beginning of integrated home storage pool with in-home data analysis and metadata tagging
Cumulative Original-Instance Home Storage Capacity

Almost 5 TB of combined personal reference data and home commercial content by 2010
Consumer Products Using HDDs
HDDs for Consumer Applications, Units Shipments

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Consumer Electronics Storage Hierarchies
Storage Hierarchy

• Ordering storage options by some criteria important to the application
• The important characteristics become clear as the application matures
• Sometimes advantages for overall system performance comes from combining multiple memory options in a device: e.g. DRAM and HDD mass storage in a computer or flash memory in a hybrid HDD
– Radial line is a system design
Mobile Storage Hierarchy

- **Flash**
  - Cost: $38/GB
  - Write Speed: 14 MB/s

- **SFF HDD**
  - Cost: $8/GB
  - Write Speed: 20 MB/s

- **Optical Disk**
  - Cost: ~$0.2/GB

Additional metrics:
- **Write Life**
- **Environmental Resistance**
- **Read Speed**
- **Multi-tasking**
Comparative Prices Flash and Various Form Factor HDDs

[Sources: E. Grochowski (HDD to 2003), Coughlin Associates (HDD 2003+) and Semico for Flash]
Comparison of Price vs. Capacity of HDDs and Flash in 2005

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Minimum 1-Inch Drive Capacity (one head) and Flash vs. HDD Cross-Over Price Point vs. Time

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Weight Comparisons of SD Flash & SFF HDDs

- **1.8-inch HDD**
- **1.0-inch HDD**
- **SD Flash**

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Weight (gm)</th>
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<tbody>
<tr>
<td>128 MB</td>
<td>1</td>
</tr>
<tr>
<td>256 MB</td>
<td>1</td>
</tr>
<tr>
<td>1 GB</td>
<td>2.5</td>
</tr>
<tr>
<td>2 GB</td>
<td>5.0</td>
</tr>
<tr>
<td>4 GB</td>
<td>10</td>
</tr>
<tr>
<td>8 GB</td>
<td>20</td>
</tr>
<tr>
<td>16 GB</td>
<td>40</td>
</tr>
<tr>
<td>32 GB</td>
<td>80</td>
</tr>
<tr>
<td>64 GB</td>
<td>160</td>
</tr>
<tr>
<td>128 GB</td>
<td>320</td>
</tr>
<tr>
<td>256 GB</td>
<td>640</td>
</tr>
<tr>
<td>512 GB</td>
<td>1280</td>
</tr>
<tr>
<td>1 TB</td>
<td>2560</td>
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</table>

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Volumetric Comparisons of SD Flash & SFF HDDs

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Mobile Storage Hierarchy

- MP3 is a lossy format meant to allow OK audio on small capacity storage if used in a noisy environment with lower quality headphones, if storage capacity increases then we could go to richer music formats.
- Video storage and playback or higher resolution audio could really generate larger files.
- Larger files favor small form factor HDDs that can deliver higher storage capacity for lower prices than flash at any given point in time.
- MusicGiants launched first loss-less compressed music download service—thus more storage for a portable music player.
- Hybrid devices with a mass storage device such as a HDD and removable storage such as flash and/or optical could create a higher end differentiated product for mobile devices just as they are doing for fixed CE devices.
- Could optical media eventually stake a larger role for richer media distribution to avoid BW bottlenecks?
Higher Resolution Mobile Device Storage Needs  
(HDD’s Still Have a Role)

• A pure 4-MPixel photo viewer with 20,000 maximum images has 20 GB
• A combination camera and photo viewer with 8 MPixel Resolution and 20,000 images has 40 GB
• A 10,000 song MP3 player has 40 GB
• A 10,000 song loss-less compression player has 140 GB
• A 10,000 CD quality song player has 280 GB
• A 100 movie player at VGA resolution has 70 GB
• A 100 movie player at DVD resolution has 417 GB

• A combination 20k 4-Mpixel photo, 10k MP3 song, 100 VGA movie player has 130 GB
• A combination 20k 8-Mpixel photo, 10k loss-less compressed song, 100 DVD movie player has 597 GB
i-Pod Portability vs. Song Capacity

Portability is inversely proportional to the physical size, volume or weight

Source: Semico Research Corp., June 2006

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1 Disk/2 Head Capacity vs. HDD Form Factor (50% A.D. CAGR) and Flash Memory for ~$55 OEM

- 48-mm HDD
- 34-mm HDD
- 27-mm HDD
- Embedded Flash

- 10,000 Song MP3 Player
- 10,000 Lossless Compressed Music Player

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Capacity, Price and Requirement for 2010 Personal Media Players

HDDs Cheaper than Flash Memory

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Hours of MPEG-2 Video for ~$60 of Storage Capacity

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CE Storage Demand vs. Available Technology Capacity—Cell Phones

Price vs. Capacity, 27mm HDD vs Flash Memory, Year 2005

Price vs. Capacity, 27mm HDD vs Flash Memory, Year 2010

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Cell Phone Market Niches

Market Volume

Flash Only
- Lower storage needs

Flash or HDD
- Moderate storage needs
- Features and environmental factor trade-offs

HDD Only
- Rich media
- Convergence device
- High storage needs
- Highest margins

Price/Features

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Small form factor HDDs will provide mass storage for higher end portable devices.
Personal Life Recorder
Storage Requirements on Hyperdrive

• **Memex**, As We May Think, Vannevar Bush, 1945
  “A memex is a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility”

• Don Norman speculated about a “**Personal Life Recorder**” (PLR) type of device in his 1992 book “Turn Signals Are The Facial Expression of Automobiles”. He theorized that these PLR’s would start out as a device given to young children, called the “Teddy.” The "Teddy" would record all of your personal life moments, and as you mature, the data could be transferred to new devices that matched your maturity level.

• **MyLifeBits**, Gordon Bell at Microsoft is digitizing his life

• **Memory Prosthesis**, Presentations given by David Thompson in 2001 on how such a device could be used to improve our memories
### Filling a terabyte in a year

<table>
<thead>
<tr>
<th>Item</th>
<th>Items/TB</th>
<th>Items/day</th>
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</thead>
<tbody>
<tr>
<td>300 KB JPEG</td>
<td>3 M</td>
<td>9,800</td>
</tr>
<tr>
<td>1 MB Doc</td>
<td>1 M</td>
<td>2,900</td>
</tr>
<tr>
<td>1 hour 256 kb/s MP3 audio</td>
<td>9 K</td>
<td>24</td>
</tr>
<tr>
<td>1 hour 1.411 Mbps CD audio</td>
<td>1.6K</td>
<td>5</td>
</tr>
<tr>
<td>1 hour 1.5 Mbp/s MPEG video</td>
<td>290</td>
<td>0.8</td>
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</table>

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gbell wag: 67 yr, 25Kday life
a Personal Petabyte (~2003)

Lifetime Storage

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A Terabyte in the Pocket and a Petabyte in the Home

• Estimated Areal density required for 1-TB 2-sided disk vs. FF (Gpbsi)

<table>
<thead>
<tr>
<th></th>
<th>1.8-inch</th>
<th>1.3-inch</th>
<th>1.0-inch</th>
<th>0.85-inch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>3,160</td>
<td>7,100</td>
<td>11,300</td>
<td>19,400</td>
</tr>
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</table>

• With 19.4 Tbpsi areal density we could have a ~25 TB 2-sided 3.5-inch disk so a 4-disk drive would be 100 TB. A 10-drive array would be 1 PB.
Application Integration into HDDs
## Comparison of Consumer Device and Component Storage Costs

<table>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>DVR</td>
<td>250</td>
<td>$450</td>
<td>$200</td>
<td>$80</td>
<td>40%</td>
<td>HDD</td>
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<tr>
<td>Game System Ext.</td>
<td>20</td>
<td>$90</td>
<td>$80</td>
<td>$65</td>
<td>89%</td>
<td>HDD</td>
</tr>
<tr>
<td>Personal Video Player</td>
<td>60</td>
<td>$390</td>
<td>$195</td>
<td>$130</td>
<td>67%</td>
<td>HDD</td>
</tr>
<tr>
<td>MP3 Player</td>
<td>4</td>
<td>$240</td>
<td>$190</td>
<td>$140</td>
<td>74%</td>
<td>Flash</td>
</tr>
</tbody>
</table>

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The Next Level of Disk Drive Integration

- Requires high performance common interface standards (ATA)
- Requires common application command standards (UHAPI, others)
- Requires greater electronic integration so CE applications can be placed on the circuit board of the HDD (Moore’s Law)
- Requires business agreements with CE companies to make HDD companies ODMs for the CE industry (Up to You!)
Integration of Applications on Storage Device Circuit Board.

- Digital storage is often the single most expensive component in a CE device, thus reducing this cost is key to reducing total cost.
- Digital storage devices have their own circuitry and application circuitry could be integrated into it as these applications mature.
- There are considerable savings in manufacturing, test, and inventory/distribution by having CE applications built into storage devices and activated by proprietary firmware by the CE company—I estimate at least 15% manufacturing cost savings to CE company.

Hard disk SoC with separate CPU and custom logic for CE applications.

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Example of a Personal Media Player (PMP) implemented on a Hard Disk Drive

- Disk Drive SoC (CPU, Elec. Channel, ECC, Servo and Interface Control)
- Other Electronics and Drive Connections
- Motor and VCM Control Electronics
- Analog Application Electronics (Antenna Interface, Display Driver and Human Interface)
- Flash Memory and Proprietary PMP Program (Possible 2nd CPU, CE Interface)
- ATA Interface
- CE Interfaces
- Power
The Home Storage Utility
Pivotal Role for Home Storage Network (Where you store your PB)
Drivers for Home Network Storage

- Growth in various networking technologies in the home
- Growth in home reference data (personal, non-commercial content) is growing and this needs backup—easy 2 TB by 2010–1 PB by 2020?
- Increased need to back-up data in the home and perhaps outside the home for disaster recovery
- Greater use of PVR/DVR, MP3 and other content in the home leads to a greater desire to share this content within the home
- Need to centralize and organize home content
Home Storage Utility

• Discovers any digital storage device in the home that is on the network
• Once detected a storage device is made part of the home storage pool
• The storage pool managing functions such as backup, synchronization and content distribution as well as traffic control
• Organizes and tags all data in storage pool
• Watches your use of content anticipating your needs and prepositioning material for you.
• Protects itself from outsiders

Source: 2005 Integration of Storage in Consumer Electronics Coughlin Associates

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Conclusions

• Huge growth for all types of Storage for Mobile and fixed Consumer applications!
• As CE mobile (and fixed) applications mature they create digital storage hierarchies that help design in the appropriate storage based on capacity, price and environmental sensitivity.
• More than a single storage component may be used to create CE product differentiation
• Storage demand for CE applications is unlimited—1 TB in your pocket and 1 PB in your home by 2020!
• Economic forces will drive increased electronic integration of digital storage and CE applications
• The need for ease of use, low cost and reliability will lead to the creation of a home storage utility linking all storage devices in the home into a single digital storage entity
Sources

- Presentations at **2006 Storage Visions Conference**, [www.storagevisions.com](http://www.storagevisions.com)

For more information go to the tech papers section of [www.tomcoughlin.com](http://www.tomcoughlin.com)

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