New Markets for Storage Products

Tom Coughlin
Data Storage Consultant
PRESENTATION OVERVIEW

- STORAGE APPLICATION DRIVERS
- AREAL DENSITY GROWTH DRIVES APPLICATIONS
- NEW STORAGE APPLICATIONS
- INDUSTRY FORECASTS FOR NEW APPLICATIONS 2000-2004
- MAKING DRIVES PROFITABLE AGAIN
A little perspective...

- Our memories define our past and enable the accumulation of capability that drives our technological civilization.

- The major business of our age is to pass accumulated experiences, beliefs, and observations to future generations. Data storage is how we will pass on this legacy.

- That means lots of storage, and for all levels of users!
Drivers for Storage Applications

Data Storage Costs:

- “…storage has more price elasticity than bandwidth and silicon chips. What this means is that for any 1 percent reduction in cost, there’s a 4 percent increase in usage. Bandwidth only gets a 2.5 percent increase in usage for each 1 percent reduction in price. And the silicon chips that supply computers with the brains to process data only get a 1.5 percent demand increase for every percent in price a CPU drops.”
  - Lee Bruno in Disk Driven Technology (Red Herring, March 2000):

Data Storage Performance:

- capacity increases by >100% AGR.
- lower storage cost means more applications for digital storage
- decreasing cost per GB makes smaller form factors drives with useful capacities.
- In a free society information must be available to all!
### Trend Doubling Periods

<table>
<thead>
<tr>
<th>Category</th>
<th>Period</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semiconductor performance</td>
<td>18 months</td>
<td>(Moore’s Law)</td>
</tr>
<tr>
<td>Computer performance/dollar</td>
<td>21 months</td>
<td>(Roberts Law)</td>
</tr>
<tr>
<td>Communications- bits/dollar &lt; 1995</td>
<td>79 months</td>
<td></td>
</tr>
<tr>
<td>Communications- bits/dollar w/DWDM</td>
<td>12 months</td>
<td></td>
</tr>
<tr>
<td>Max. Internet Trunk Speed in service</td>
<td>22 months</td>
<td></td>
</tr>
<tr>
<td>Internet Traffic Growth 1969-1982</td>
<td>21 months</td>
<td></td>
</tr>
<tr>
<td>Internet Traffic Growth 1983-1997</td>
<td>9 months</td>
<td></td>
</tr>
<tr>
<td>Internet Traffic Growth 1997-2008</td>
<td>6 months</td>
<td></td>
</tr>
<tr>
<td>Internet Router/Switch Max Speed &lt;1997</td>
<td>22 months</td>
<td></td>
</tr>
<tr>
<td>Internet Router/Switch Max Speed &gt; 1997</td>
<td>6 months</td>
<td></td>
</tr>
</tbody>
</table>
Computer Networks Drive Storage Demand

- In 2000 EMC estimated that within a year, some dot-coms will need an exabyte of storage capacity.
- A UC Berkeley study at the end of 2000 predicted that while it took 300k years to accumulate the first 12 EB of data it will only take 2.5 years to double this.
- New wireless technologies will connect a billion cell phones, laptops and personal organizers to the Internet within three years (The Yankee Group).
Ubiquitous Computers = more storage!

Decreasing cost of computers makes them available for more applications, and where there’s computers there’s storage!

- Storage must to tailored to the cost/requirements of the application

**Advanced Applications Driving Storage Development:**

- genome mapping
- protein modeling
- digital movies
- bomb modeling
- weather and seismic modeling
- backing up the web…a never ending job

Source: When Things Start to Think, Neil Gershenfeld
As we hook up communication to the web...

...its all stored on disk drives and tape!

Next, the wireless internet!

New Devices will even bring smell files to the web.
High Resolution Images-A BIG Driver

- High End Customer are initial drivers
  - medical file transfer
  - movie distribution
  - interactive collaborations
  - physical simulation

<table>
<thead>
<tr>
<th></th>
<th>Bandwidth Requirements (MB/sec)</th>
<th>Storage Requirements (GB/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPEG-1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>MPEG-2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Broadcast TV (ITU-R601)</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>HD TV (1080i)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>35mm Film (4KX4K)</td>
<td>1000</td>
<td>1000</td>
</tr>
</tbody>
</table>
The Future is Storage-Centric

Stored Data is the heart of a modern network.

• By 2004, companies will have to manage 10 times as much data as they do today (Meta Group)

• System vendors see storage eclipsing server sales in the near future

Figure from Shugart Technology
World Wide Storage Capacity of Disk Memory
(In PetaBytes, Source: Disk/Trend plus projection to 2004)

Mega: $10^6$
Giga: $10^9$
Tera: $10^{12}$
Peta: $10^{15}$
Exa: $10^{18}$
Zetta: $10^{21}$
Yotta: $10^{24}$
NEW APPLICATIONS / STORAGE

- AUTOMOBILE MAPPING SYSTEMS
- GPS NAVIGATION SYSTEMS
- DIGITAL CAMERA SYSTEMS
- DIGITAL VIDEO SYSTEMS
- T.V. SET TOP BOXES (U.S. AND JAPAN)
- MULTIFUNCTIONAL COPY MACHINES
- AIRLINE ENTERATINMENT SYSTEMS
- INTERACTIVE HOME ENTERTAINMENT (WEB-TV/TiVo)
- MODELING AND ANIMATION MASTERING
- MOVIE AND IMAGE DISTRIBUTION
- MUSIC STORAGE AND DISTRIBUTION
- E-MAIL INTERNET STORAGE
- STORAGE SERVICE PROVIDERS
- GAMING MACHINES, SLOT, POKER
- APPLIANCES- SEWING MACHINES
Increased Areal Density makes VERY BIG Desktop and Mobile Drives

Disk Drive Data Capacity Growth (Double-Sided)

Year

Disk Capacity (GB)

- 95-mm
- 65-mm
- 27 mm
Increased Areal Density makes Smaller Form Factors USEFUL

27-mm Disk Drive Capacity Growth

- Single Sided (GB)
- Double Sided (GB)

Courtesy of International Business Machines Corporation. Unauthorized use not permitted.
Increased capacity creates useful small form factor data storage.

MIT Wearable Computer Group

Compaq PDA with Compact Flash Slot

Samsung Watchphone

The watchphone has no keypad. Instead, proprietary, speaker-independent, continuous-speech technology from Conversa is embedded so users can make and receive phone calls simply by speaking in their natural voice. Users can program frequently called numbers by voice. The watchphone will also include a function that will read out e-mail messages.
Mobile Computer Memory Hierarchy

Cost/Speed

- RAM/ROM: $2.00/MB, 5 ms
- Compact Flash (removable): $0.50/MB, 5 ms
- Tiny Optical ROM (removable): $0.50/MB, 5 ms
- Micro or Pico HDD: Mass Storage (removable or embedded, personal server): $0.10/MB, 15 ms

Capacity

Volatile Storage

Non-Volatile Storage
<table>
<thead>
<tr>
<th>Device</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer Handheld</td>
<td>Equipped with keyboard, Internet access, organizer and operating system i.e., Windows CE with information services and web browser.</td>
</tr>
<tr>
<td>Computer Handheld Wireless</td>
<td>The same features as the Handheld, but it has the additional ability to perform e-mails and web services by wireless radio links.</td>
</tr>
<tr>
<td>Interactive Pagers</td>
<td>Features personal organizer, interactive services; it can be worn like a pager and with mini-QWERTY keyboard can provide instant wireless e-mail connectivity.</td>
</tr>
<tr>
<td>Smart Phones</td>
<td>Phones that feature personal organizer, voice mail and digital voice recording.</td>
</tr>
<tr>
<td>Screen Phones</td>
<td>Phones with high quality LCD displays that emulate the same functions and web connectivity as the wireless handheld computer.</td>
</tr>
<tr>
<td>Digital Cameras</td>
<td>Cameras that record and store images digitally offering a substantial challenge to film. Recently, affordable digital cameras have progressed from typically 13 mega pixels in 1998 to 2.1 mega pixels in 1999, competing with ASA-400 and 200 film quality.</td>
</tr>
<tr>
<td>Global Positioning Systems</td>
<td>GPS systems are available as handheld portable or automobile in-dash devices. They are used for navigation as well as tracking. Introduce in 1989 as optional equipment in some automobiles, the popularity of these devices will continue to penetrate the automobile markets. A substantial potential exists for the handheld GPS device in military applications.</td>
</tr>
<tr>
<td>Digital Voice Recorders</td>
<td>Artificial Intelligence Voice recording has been successfully introduced in the personal computer marketplace. Low cost memory will enable its application to palmtops and handhelds that can use the mini-keyboards.</td>
</tr>
<tr>
<td>Digital Sound (MP3)</td>
<td>MP3 technically is MPEG 1 layer 3. It has become a popular de facto standard for quality through high bit resolution sound. With the new MP3 players, one can record and compress music digitally by copying CDs, DVDs, or downloading music from the Internet. It does not take a trained musician to do even the improvement this format offers.</td>
</tr>
<tr>
<td>Warehouse Inventory</td>
<td>Handheld RF devices, usually enabled with barcode.</td>
</tr>
<tr>
<td>Wearable Computers</td>
<td>Wearable computers are used for on-site maintenance with auto manufacturers and aircraft industries leading the early Adapters. Some apply wearable single-eye displays that allow the individual to coordinate mechanisms with schematics and pictorial assemblies.</td>
</tr>
<tr>
<td>Portable Games</td>
<td>Downloadable games that for use with the handheld and laptop computers and CE-based handhelds.</td>
</tr>
</tbody>
</table>

**Images:**
- MP3
- Digital Camera
- RF Pager
- Handheld
- Wearable
## Storage for Wearable/Handheld Computers

<table>
<thead>
<tr>
<th>Application</th>
<th>Min. MB</th>
<th>Avg. MB (2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mapping/Directions</td>
<td>5</td>
<td>1,000</td>
</tr>
<tr>
<td>Face Recognition</td>
<td>500</td>
<td>2,000</td>
</tr>
<tr>
<td>Camera</td>
<td>100</td>
<td>1,000</td>
</tr>
<tr>
<td>Phone Book, Dialer</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>Calendar</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Email</td>
<td>1</td>
<td>500</td>
</tr>
<tr>
<td>Fax</td>
<td>1</td>
<td>200</td>
</tr>
<tr>
<td>To Do List</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Memo</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Speech Recognition/Output</td>
<td>200</td>
<td>500</td>
</tr>
<tr>
<td>News</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>Market Quotes</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Entertainment: Games/Video/Spoken Books</td>
<td>2</td>
<td>5,000</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>816</strong></td>
<td><strong>10,528</strong></td>
</tr>
</tbody>
</table>
Projected Capacity Range for $150 with Compact Flash and Microdrive

- HDD
- CF
Microdrive Market Penetration

Units Sold (M)

- Microdrive Enabled
- Rest of Market

~10% Market Penetration by 2005
Networked Storage

Network Attached Storage (NAS)
- Storage connects directly to the LAN
- Allows user to access data without server intervention
- Simple to install and manage
- Concurrent multi-OS support

Storage Area Network (SAN)
- Separate network from LAN/WAN
- Storage consolidation by connecting to switches and servers
- High-speed FC tape backups
- More complex installation
SAN/NAS - Applications

Horizontal
- Backup
- Archiving
- Data Replication
- Disaster Protection
- Data Sharing
- Data Warehousing

Vertical
- OLTP
- ERP Business
- E-Commerce
- Broadcasting
- Pre-Press
- Geophysics
APPLICATIONS

Source: Peripheral Concepts, Inc
• These are the back-bone of e-commerce and the internet
• Driving the market for high end disk drives
• Performance and reliability are key
<table>
<thead>
<tr>
<th>Sector Based</th>
<th>Object Based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blocks</td>
<td>Fixed sized sectors</td>
</tr>
<tr>
<td>Naming</td>
<td>Represents fixed physical place</td>
</tr>
<tr>
<td>Partitioning</td>
<td>Partitioned into sets of contiguous spaces</td>
</tr>
<tr>
<td>Access Unit</td>
<td>One or more blocks</td>
</tr>
<tr>
<td>Arbitrary Accesses</td>
<td>Scheduled by host (queue tags)</td>
</tr>
<tr>
<td>Zoning</td>
<td>Physical zones differentiate peak bandwidth</td>
</tr>
</tbody>
</table>

**Higher Bandwidth**

![Graph showing application throughput vs. number of disks](chart)

Source: InfoStor, Sept. 2000
**Storage Service Providers**

- The visible and hidden costs of storage management represent about half of IT costs
- **SSP = Storage as a utility, lease as much as you want, when you want it without having to maintain it**
- Allows a company to focus on its core competency
- 411% CAGR expected to 2003 (Soloman Smith Barney)
- Enterprise Storage Group projects SSP sales of $11.2B by 2004
- No clear winner(s) yet in this category

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**Storage Service Provider Supplier Market Share (1999),**

Source: IDC

- **Sun** 1%
- **EMC** 2%
- **IBM** 17%
- **Compaq** 4%
- **Veritas** 0%
- **StorageTek** 3%
- **HP** 5%
- **Other** 68%
Worldwide Storage Device Forecast
(Units Millions)

Source: Peripheral Research Corp.
<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>1999</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>RIGID DISK DRIVES</td>
<td>33.4</td>
<td>37.2</td>
<td>43.9</td>
<td>51.3</td>
<td>54.0</td>
<td>61.1</td>
</tr>
<tr>
<td>OPTICAL DRIVES</td>
<td>7.5</td>
<td>7.7</td>
<td>8.9</td>
<td>9.3</td>
<td>9.8</td>
<td>10.3</td>
</tr>
<tr>
<td>TAPE DRIVES</td>
<td>4.6</td>
<td>4.8</td>
<td>5.0</td>
<td>4.8</td>
<td>4.4</td>
<td>4.0</td>
</tr>
<tr>
<td>FLEXIBLE DRIVES</td>
<td>2.5</td>
<td>2.4</td>
<td>2.4</td>
<td>2.3</td>
<td>1.9</td>
<td>1.7</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>48.0</strong></td>
<td><strong>52.1</strong></td>
<td><strong>60.2</strong></td>
<td><strong>67.7</strong></td>
<td><strong>70.1</strong></td>
<td><strong>77.1</strong></td>
</tr>
</tbody>
</table>

Source: Peripheral Research Corp.
Computer Disk Storage / Non-Computer Disk Storage Markets
(Units Millions)

Source: Peripheral Research Corp.
## Emerging Non-PC HDD Storage Markets
(Units OOO)

<table>
<thead>
<tr>
<th>SEGMENT</th>
<th>2000</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
</tr>
</thead>
<tbody>
<tr>
<td>LASER PRINTERS</td>
<td>1,380</td>
<td>1,905</td>
<td>2,787</td>
<td>3,159</td>
<td>3,602</td>
</tr>
<tr>
<td>GPS SYSTEMS</td>
<td>300</td>
<td>700</td>
<td>940</td>
<td>1,300</td>
<td>1,400</td>
</tr>
<tr>
<td>SET TOP BOXES</td>
<td>8,000</td>
<td>12,100</td>
<td>18,700</td>
<td>26,400</td>
<td>29,870</td>
</tr>
<tr>
<td>DIGITAL CAMERA</td>
<td>16,420</td>
<td>27,590</td>
<td>42,860</td>
<td>68,600</td>
<td>79,800</td>
</tr>
<tr>
<td>GAMING INDUSTRY</td>
<td>2.4</td>
<td>3.7</td>
<td>4.8</td>
<td>5.6</td>
<td>6.0</td>
</tr>
<tr>
<td>AUDIO/APPLIANCE</td>
<td>1,420</td>
<td>3,570</td>
<td>5,965</td>
<td>7,414</td>
<td>8,215</td>
</tr>
<tr>
<td>OTHER</td>
<td>37</td>
<td>45</td>
<td>70</td>
<td>75</td>
<td>80</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td>33,730</td>
<td>61,183</td>
<td>81,867</td>
<td>106,953</td>
<td>122,973</td>
</tr>
</tbody>
</table>

Source: Peripheral Research Corp.
Biggest Current Limitations to Storage are Economic, not Technical

- Continued price pressure has caused considerable consolidation in the industry.
- Remaining companies may be sustainable but only if their profitability improves.
- Drive and component companies must make better profits in order to finance capital improvements and retain technical talent needed to sustain the data areal density growth.
  - Current capital equipment for heads and media cannot go above 100 Gb/in²!
  - With higher TPI, how will photolithographic equipment become available on time to meet track-width needs?
  - Drive and component companies will run out of gas in 2-3 years without new investments!
- Growth of storage systems and the Internet itself is dependent on continued increases in storage capacity.
### Some Comparisons of Storage Company Categories

<table>
<thead>
<tr>
<th>Storage Food Chain</th>
<th>Drive Company</th>
<th>SAN/NAS Company</th>
<th>Storage System Provider</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Annual Price ($/GB)</strong></td>
<td>2.5</td>
<td>60</td>
<td>636 ($53/GB/mo, managed storage)</td>
</tr>
<tr>
<td><strong>Gross Margin (%)</strong></td>
<td>12</td>
<td>&gt;45</td>
<td>&gt;60</td>
</tr>
</tbody>
</table>
Opportunities for Drive Companies

With various form factors and applications perhaps there is an opportunity for drive companies to segment the market

Move from data storage to information management.

Build new intelligence into the drive

Specialize, become the best-in-class for particular types of storage

Improve margins by differentiation and bringing greater functionality into drives

Share margins with storage system companies

Use improved margins to reward investors & employees and provide capitalization for technical improvements e.g. areal density increases
Storage for the Next Generation