Terabytes, Petabytes and Beyond --
Data Storage Strategies

Mike Leonhardt
Storage Technology Corporation
2270 S. 88th St.
Louisville, CO 80028-6100

phone:+1-303-673-5627; fax:+1-303-673-7967
e-mail: michael_leonhardt@storagetek.com

Presented at the THIC meeting at the Amberley Suite Hotel, Albuquerque, NM
April 21, 1998
Outline

• Data Storage Building Blocks
  – Storage Technology Overview
  – Magnetic Tape
  – Magnetic Disk

• Data Storage Archive
Storage Trends

- Magnetic disk is the areal density leader with 60%/year growth
- “Optically assisted” approaches are in development to continue magnetic disk’s growth past “2003 technology limit”
- Optical disk using “near-field” technology (e.g. SIL) could regain areal density lead
- Distinction between magnetic and optical recording will become “blurred”
- Major technical challenges remain for holography
- Tape’s “third dimension” gives it a volumetric storage efficiency advantage (30-50%/year growth)
  - 2 - 10x over disk drives
  - > 3x over optical media
- Magnetic tape vendors will get (are getting) more aggressive
  Recent announcements - more expected
Magnetic Tape Technology Trends
StorageTek

GA Year vs Capacity

28% CAGR

parallel track longitudinal:

narrow track longitudinal:

helical scan:
GA Year vs Data Rate

Data Rate (MB/s) vs GA Year

- Parallel track
- Longitudinal: ▲
- Narrow track longitudinal: ◆
- Helical scan: □

25% CAGR
GA Year vs Cost per MB

Cost is for 1 drive + 100 tapes (OEM/equivalent)

-48% CAGR
-30% CAGR
Areal Density

(Linear Density vs. Track Density)

Parallel track
 longitudinal:

Narrow track
 longitudinal:

Helical scan:

## Areal Density

Linear Density (Kb/in)

Track Density (TPI)

- 1 Mb/in²
- 10 Mb/in²
- 100 Mb/in²
Storage Architecture as a Tape Technology Extension

Data Rate (MB/s)

Capacity (GB)
Tape Array Background

Functions

- Capacity multiplying
- Data rate multiplying -- cost-performance benefits
  - Emulation
  - “Super-performance”
- Fault tolerance
  - Enhanced archive data integrity
- Data reconstruction
**Enabling Events -- Magnetic Tape**

- Magnetic disk drive development “spin-off” technologies
  - Head, media, channel, servo, system architecture
    - MR, GMR, thin film heads
    - PRML (partial response-maximum likelihood) recording channels
    - Track following servo systems
    - ME (metal evaporated) thin film media
    - RAID (array) configurations
- Greatest opportunity for areal density growth is in track density
  - Magnetic disk track density is 4-12x tape track density
  - Media, head, servo, tape path, channels issues to overcome
- Array configurations (RAIT) as a technology extension
- Consumer product driven technologies
  - Helical scan tape from VCRs, camcorders
  - Competition from Digital Versatile Disk (DVD), recordable CD’s
Magnetic Disk Technology Trends
**Disk Storage Issues**

- Disk areal density growth continues at 60% per year and drives the storage technology infrastructure.
- Will disk run out of steam?
  - Super paramagnetic limit will cause data retention problem by year 2003 if 60% areal density growth continues
- Solutions
  - Manage data, i.e. backup to tape or cycle data
  - Patterned media or new magnetic material
  - Thermally assisted write technologies
  - Other new technologies (holographic, probe)
Optically Assisted Magnetic Recording

- “Optically assisted” magnetic write -- thermal assist
- Not “near field” optical
- Optical track following servo -- factory optical servo patterns on disk
- Maintains magnetic disk’s areal density growth path
- High track density
- First products expected within a year
Storage Subsystem Cost Trends

- **Disk Drives**
- **Tape Drives**
- **Tape Drives + 100 Tapes**
- **Tape Media Only**
- **Performance Disk Subsystems**

Cost (OEM/Integrator - $/GB) vs. GA year (1994-2008)
Storage Outlook

- Magnetic Tape -- largely maintaining $/MB advantage over other storage types
  - Disk subsystems = 6-30x performance tape subsystem costs
  - Arrays -- data rate performance, archive enhancing fault tolerance, data reconstruction
- Magnetic Disk -- technology leader, aggressive growth
  - “Optical assisted” magnetic technology extension
  - Watch for removable media product advances
- Optical Disk -- costs down, performance up
  - Watch for DVD, CD-R driven products
  - Watch for “near field” (e.g. solid immersion lens) progress
- Holographic -- potential storage efficiency but...significant inventions required
- Optical Tape -- no drive, media products; limited development
Removable Media Archiving
Data Archive

- Media lifetimes
  - Environmental control
  - Data migration
  - Role of data storage fault tolerance (e.g. array architecture)
  - Management
- Technology lifetimes typically < media lifetimes
- Lifetimes are economics driven
  - Magnetic tape has lifetime potential > 30 years
Recommended Storage Conditions for Magnetic Tape

September 1997 by National Technology Alliance

"With moderate care, most magnetic tapes used for digital data storage will last for 10 years. With special storage and handling [see chart] digital magnetic tape formats can reliably store information for 30 years or more. The longevity of magnetic tapes can be significantly increased by storing the tapes at lower temperatures and humidities"

ref: http://www.nml.org
Archive Strategy

Goal:

• Archive 1 exabyte of data ($10^{18}$ bytes)

• Capture 1 petabyte/day ($10^{15}$ bytes)
## Scale of the Problem -- 1 Petabyte/day - Today

*RedWood drives, Powerhorn libraries*

<table>
<thead>
<tr>
<th>Capacity (TB)</th>
<th>Daily</th>
<th>Quarterly</th>
<th>Yearly</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,000</td>
<td>91,250</td>
<td>365,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cartridges (50GB)</th>
<th>Daily</th>
<th>Quarterly</th>
<th>Yearly</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20,000</td>
<td>1,825,000</td>
<td>7,300,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Silos (5600 Slots)</th>
<th>Daily</th>
<th>Quarterly</th>
<th>Yearly</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.0</td>
<td>326</td>
<td>1,304</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Floor Space (Sq.Ft)</th>
<th>Daily</th>
<th>Quarterly</th>
<th>Yearly</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>576</td>
<td>46,929</td>
<td>187,776</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Floor Space</th>
<th>Daily</th>
<th>Quarterly</th>
<th>Yearly</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lg. Room</td>
<td>Football field</td>
<td>4 Acres</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Req’d BandWidth;</th>
<th>8 Hr</th>
<th>16 Hr</th>
<th>24 Hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>GB/HR;</td>
<td>125,000</td>
<td>62,500</td>
<td>41,667</td>
</tr>
<tr>
<td>MB/SEC;</td>
<td>34,722</td>
<td>17,361</td>
<td>11,574</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transports (11.1 MB/s)</th>
<th>8 Hr</th>
<th>16 Hr</th>
<th>24 Hr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3,129</td>
<td>1,565</td>
<td>1,043</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Power</th>
<th>kWh</th>
<th>8 Hr</th>
<th>16 Hr</th>
<th>24 Hr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17,522</td>
<td>17,528</td>
<td>17,522</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Power Cost</th>
<th>8 Hr</th>
<th>16 Hr</th>
<th>24 Hr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>998.78</td>
<td>999.10</td>
<td>998.78</td>
</tr>
</tbody>
</table>
Data Capture Rate Ramp
to 1 petabyte/day

Growth = 1.5x/quarter

437,267 TB

Daily Capacity (TB).

Quarters
1 Petabyte/day - Today’s Technology

Transports

Transports @ 16Hr.Capture

Quarter

Number of transports

- 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

1,600 1,400 1,200 1,000 800 600 400 200

1 Petabyte/day - Today’s Technology

Transports
Data Capture Profile

Exabyte Archive

1,157,267 TB
Exabyte Archive - Today’s Technology

Libraries
# Projected Trend Tape Product Family

<table>
<thead>
<tr>
<th></th>
<th>Capacity</th>
<th>Data Rate</th>
<th>GA</th>
</tr>
</thead>
<tbody>
<tr>
<td>RedWood</td>
<td>50 GB</td>
<td>11.1 MB/s</td>
<td>Now</td>
</tr>
<tr>
<td>PT1</td>
<td>100</td>
<td>25</td>
<td>3Q99</td>
</tr>
<tr>
<td>PT2</td>
<td>150</td>
<td>40</td>
<td>1Q01</td>
</tr>
<tr>
<td>PT3</td>
<td>250</td>
<td>50</td>
<td>3Q02</td>
</tr>
<tr>
<td>PT4</td>
<td>400</td>
<td>70</td>
<td>1Q04</td>
</tr>
</tbody>
</table>
Exabyte Archive - Trend Technology

Libraries

SILOS

Cum Silos
Silos/Q

Number of Silos

Quarter

1 3 5 7 9 11 13 15 17 19 21 23 25 27
Exabyte Archive - Trend Technology

Media

Carts in Use

Number of carts

Quarter

300 GB
150 GB
100 GB
50 GB

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
## Summary

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity 7 Years (TB)</td>
<td>1,157,267</td>
</tr>
<tr>
<td>GB/Hr.</td>
<td>62,500</td>
</tr>
<tr>
<td>MB/Sec.</td>
<td>17,361</td>
</tr>
<tr>
<td>Transports Capture</td>
<td>435</td>
</tr>
<tr>
<td>Capture Silos</td>
<td>27</td>
</tr>
<tr>
<td>Daily Carts (300 GB)</td>
<td>3334</td>
</tr>
<tr>
<td>Total Carts (300 GB)</td>
<td>3,857,557</td>
</tr>
<tr>
<td>Total Silos</td>
<td>689</td>
</tr>
<tr>
<td>Total Sq.Ft. (Silos)</td>
<td>99,216</td>
</tr>
<tr>
<td>Total Sq.Ft. (Silos)</td>
<td>2 Acres</td>
</tr>
</tbody>
</table>
Conclusion

• Magnetic tape based data archive can meet exabyte capacity, petabyte/day rate goals
  Offers cost advantage over other storage types
  Media is “medium to long term” archive capable
  Tape technology will support continual performance enhancements

• Questions remain for a comprehensive archive model
  Transport-Library ratios
  Recall activity
  Usage patterns
  Data retirement
  Technology adoption