Areal Density Growth

- Late 1990s – superparamagnetic limit demonstrated through modeling
- Perpendicular expected to extend to 0.5-1 Tb/in²
- Additional innovations required at that point
  - heat-assisted recording
  - bit patterned media recording

- Areal Density CAGR 40%
- Transfer Rate CAGR 20%

![Graph showing areal density growth with key points and technologies]
## HDD Technology Trend

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2009</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>3.5 inch Consumer</strong></td>
<td></td>
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</tr>
<tr>
<td>Drive Capacity (GB)</td>
<td>750</td>
<td>2,000</td>
<td>8,000</td>
</tr>
<tr>
<td>Number of Discs</td>
<td>4</td>
<td>3</td>
<td>3</td>
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<tr>
<td>Capacity (GB/disc)</td>
<td>187</td>
<td>670</td>
<td>2,670</td>
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<tr>
<td>Product Areal Density (Gbpsi)</td>
<td>133</td>
<td>500</td>
<td>1,800</td>
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<tr>
<td>Transfer Rate (Mb/sec)</td>
<td>930</td>
<td>2,000</td>
<td>5,000</td>
</tr>
<tr>
<td>RPM</td>
<td>7,200</td>
<td>7,200</td>
<td>10,000</td>
</tr>
<tr>
<td>Read Seek Time (ms)</td>
<td>8</td>
<td>7.2</td>
<td>6.5</td>
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<tr>
<td><strong>3.5 inch Enterprise</strong></td>
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<tr>
<td>Drive Capacity (GB)</td>
<td>300</td>
<td>600</td>
<td>2,400</td>
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<tr>
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<tr>
<td>Capacity (GB/disc)</td>
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<td>150</td>
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<tr>
<td>Product Areal Density (Gbpsi)</td>
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<td>Transfer Rate (Mb/sec)</td>
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<td>4,000</td>
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<tr>
<td>RPM</td>
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<td>15,000</td>
<td>15,000</td>
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<tr>
<td>Read Seek Time (ms)</td>
<td>3.7</td>
<td>3.3</td>
<td>2.8</td>
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</tbody>
</table>
Solid State Disks

**SSD Value Prop**
- Lower command latency
- Access Density (IOPS/GB)
- Power (IOPS/WATT)

**Inhibitors to Broader Adoption**
- Price
- Endurance concerns
- Immature failure mode understanding

**Industry Work Needed**
- Centralized standards activity
- Performance standards
- Endurance standards

**Take Aways**
- SSD Enable Growth
- SSD will co-exist with HDD
- Industry Standards work needed
Other Topics

Interfaces: Serial reigns!

- 6 Gbit SAS & SATA deployed in 2010
- FC continues for enterprise storage, but no 8 Gb/s on a drive
- SSD may lead to new (direct attached) interface thinking
- USB-3 will be considered as client drive interface
- PI will provide end to end integrity checking (SAS)

Power becoming an ever bigger issue

- Enterprise storage moving to 2.5”

Security will in or available on all drives

Form Factor transition?

- Laptops displacing desktops as mainstream client
- High capacity 3.5” drives based on low cost desktop market
Summary

- HDDs will continue to be primary storage in most systems
- SSD use more likely than higher RPM drives
- Power becoming more a important consideration
- Mainstream form factor trends bear watching