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%

© 2008 Seagate Technology. All rights reserved.
Heat Assisted Magnetic Recording (HAMR)

Perpendicular Recording

HAMR

GMR Element

Shield

Soft Underlayer

Laser

Heated Spot
# 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>
<td></td>
<td></td>
</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>
</tr>
<tr>
<td>Capacity (GB/disc)</td>
<td>187</td>
<td>670</td>
<td>2,670</td>
</tr>
<tr>
<td>Product Areal Density (Gbpsi)</td>
<td>133</td>
<td>500</td>
<td>1,800</td>
</tr>
<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>
</tr>
<tr>
<td><strong>3.5 inch Enterprise</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drive Capacity (GB)</td>
<td>300</td>
<td>600</td>
<td>2,400</td>
</tr>
<tr>
<td>Number of Discs</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Capacity (GB/disc)</td>
<td>75</td>
<td>150</td>
<td>600</td>
</tr>
<tr>
<td>Product Areal Density (Gbpsi)</td>
<td>108</td>
<td>250</td>
<td>1,000</td>
</tr>
<tr>
<td>Transfer Rate (Mb/sec)</td>
<td>975</td>
<td>2,000</td>
<td>4,000</td>
</tr>
<tr>
<td>RPM</td>
<td>15,000</td>
<td>15,000</td>
<td>15,000</td>
</tr>
<tr>
<td>Read Seek Time (ms)</td>
<td>3.7</td>
<td>3.3</td>
<td>2.8</td>
</tr>
</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
HDD Intelligence: Self Encrypting Disk Drives

**Purposes**
- Protect data from exposure due to equipment loss
- Enable instant, secure erase of HDD

**Closed encryption device**
- Dedicated engine for full interface speed encryption
- Key generated in the drive
- Encryption cannot be turned off
- Encryption Key never leaves the drive
- Drive exposes an open interface for management

**NSA support**
- Publicly spoken on encryption embedded in the hard drive
- Actively participating in TCG Storage Security work group
- Submitted its security requirements for inclusion in TCG spec
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 interface thinking

4K sectors
- Strong push by drive suppliers
- Requires tough infrastructure changes

Power becoming an ever bigger issue
- Enterprise storage moving to 2.5”
- Ramp load/unload for power saving flexibility
Summary

- Technology identified for ~100x capacity growth
- HDDs will continue to be primary storage in most systems
- SSD use more likely than higher RPM drives
- Drive-based security examples of added drive intelligence
- Power becoming more a important consideration