PMR: Innovation Achieved
Implications for a New Era
of Hard Disk Drive Technology

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September 28, 2005
Computers Come and Go, But Data Remains …

- University of California at Berkeley Study, 2003
  - 800 megabytes per person per year of “personal data”
  - 100 gigabytes per person per lifetime of “personal data”
  - 75 petabytes of broadcast television per year
  - 400 petabytes of e-mail generated each year
  - In 2002, 5 exabytes of data were recorded magnetically

- No matter how you calculate the global extent of “storage,” it is obvious that the “digitization” of our corporate and cultural artifacts is still in its infancy. It is also obvious that HDDs will be able to store whatever we create and enable greater data mobility

Source: Gartner 2005
From Evolution to Revolution: The Road to PMR

- The path to innovation in the HDD industry previously followed an evolutionary curve:
  - Capacity increases with improved areal density
  - Adjustments to media and head technology
  - MR to GMR to TMR
- Unfortunately, recording technology would eventually run out of room
  - End of AD road predicted within two years
  - Super-paramagnetic effect
  - Bits fluctuate due to thermal agitation
The Slowing Areal Density Curve

- Thin Film Head, Glass Media
- GMR, 60%/Year
- MR Head, ID-less
- PRML, 30% / Year
- FDB Motor
- AFC Media
- Oriented Media
- Perpendicular Recording
- CDR
- MIG Head, Sputtered Media
- BMR Head, New Technologies

- 35% / Year
- Production
- 30GB/Disk (2.5” Disk)

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From Evolution to Revolution: The Road to PMR

The HDD industry had to be revolutionary

- New approach to laying data down on the disk
- Magnetic bits stand on end, reinforcing magnetic coupling
Benefits of PMR

• **Primary:** Pack more data on increasingly smaller disks
  – Stable, higher recording densities
  – Up to 10 times greater capacity than longitudinal recording

• **Bonuses:** More robust product, improved quality
  – Better recording efficiency
  – Higher BPI is possible
  – Decreased rate of thermal decay - improved stability
  – Write performance in wider temperature ranges than longitudinal recording
  – Thermal reliability

FIRST PMR HDD SHIPS 8/05
40GB, single platter
1.8-inch HDD
133 gibabits per square inch
High Barriers to Entry

PMR Challenges

• **Cost**
  – Tremendous R&D investment
  – New manufacturing and testing equipment

• **Technology curve**
  – Complicated head/media system
  – Overcome technology challenges (pole erasure, SUL domain suppression, new media process)

• **Manufacturing obstacles**
  – Producing viable yields
  – Greater demand for components
Forecast for PMR Deployment: Kicking Capacity Up a Notch

<table>
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<th>Mobile Class</th>
<th>2007</th>
<th>2010</th>
<th>2015</th>
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<tr>
<td>2.5-inch GB/platter</td>
<td>120</td>
<td>250</td>
<td>760</td>
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<td>1.8-inch GB/platter</td>
<td>80</td>
<td>150</td>
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<tr>
<td>1.0-inch GB/platter</td>
<td>20</td>
<td>35</td>
<td>60</td>
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Source: IDC
## SFF HDD (0.85-inch – 1.0-inch)

**Benefits**
- Higher capacity
- Multiple form factors
- Fast read/write
  - Lower cost per GB
  - Faster data transfer rates
  - Better life for rewriting data

**Challenges**
- Fixed form factors
- Long development cycle for new technologies

## Flash

**Benefits**
- Small size for integration into portable devices
- Power management
- Shock tolerance (although 0.85-inch HDD has a similar shock spec)

**Challenges**
- Capacity limit of 8GB
- Slower read/write times
- Limited number of erase and rewrite cycles
- High cost per GB
Impact to the HDD Industry

• Enormous R&D expenditures will be required to stay competitive
• Production over-capacity, capacity constraints and technology transitions will drive complex consolidations in 2005 and 2006
• Unlike recent generations of HDD technology, evolving HDD technologies may not be freely or generally available to all suppliers
• The real test may come when the industry begins to shift in earnest to perpendicular recording technologies (mid-06?)
  – Only the largest, richest, most-efficient and mercilessly cunning drive makers will survive this transition
Implications: New Opportunities for HDDs

Higher capacity in small form factors brings new applications

• **Digital cameras (sub-one inch)**
  – Potential for built-in storage in addition to removable

• **Cell phones** (sub one-inch)
  – Converged devices: music, video, games, photos

• **Notebook (1.8-inch)**
  – Greater capacity delivers multimedia functionality
  – Able to maintain “ultra” portability with increased capacity
  – Notebooks poised to proliferate in the home

• **DVR (2.5-inch)**
  – PMR brings right capacity to application
  – Better acoustics than 3.5-inch

• **Desktop (2.5-inch)**
  – Mobile drives now viable for desktop applications
  – Potential as the home server for entertainment and content distribution

• **Automotive (2.5-inch)**
  – Multimedia moves to the car
  – GPS, rear-seat entertainment, music
Conclusions: PMR Will Alter the Landscape of the HDD Industry

- Provides tremendous growth opportunities for HDD manufacturers
- A “must-have” not a value-add to do business in the HDD industry
- Fuels the continued drive to smaller form factor HDDs
- Opportunity to address pricing issues related to the value of higher capacity, especially in SFF CE devices
- A truly digital world: Innovation opens new consumer electronics and computing markets
HDD Technology: Enabling the Digital World
Thank You.

Questions and Discussion