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PMR: Innovation Achieved

Implications for a New Era of Hard Disk Drive Technology

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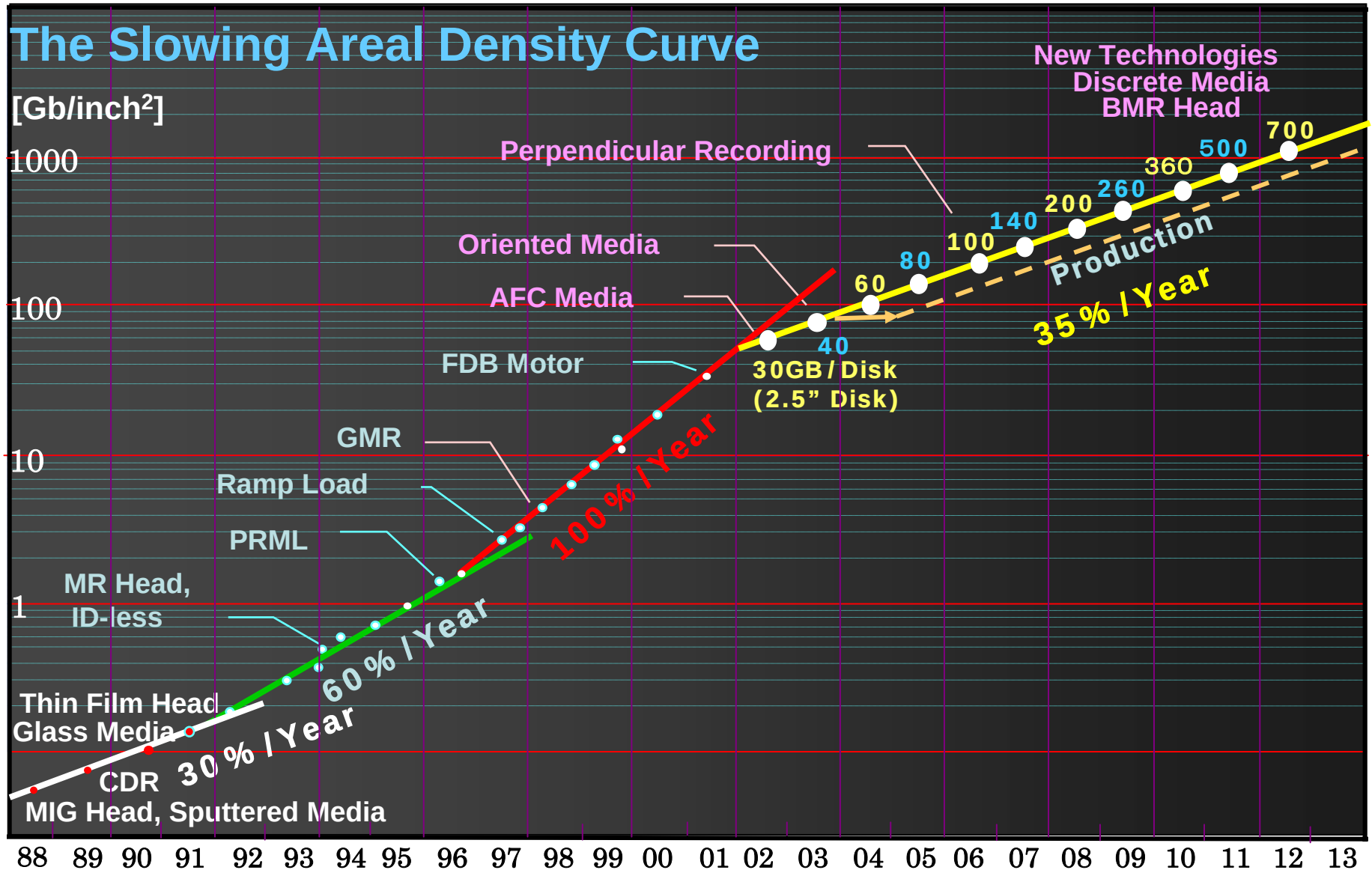
Computers Come and Go, But Data Remains …

- 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

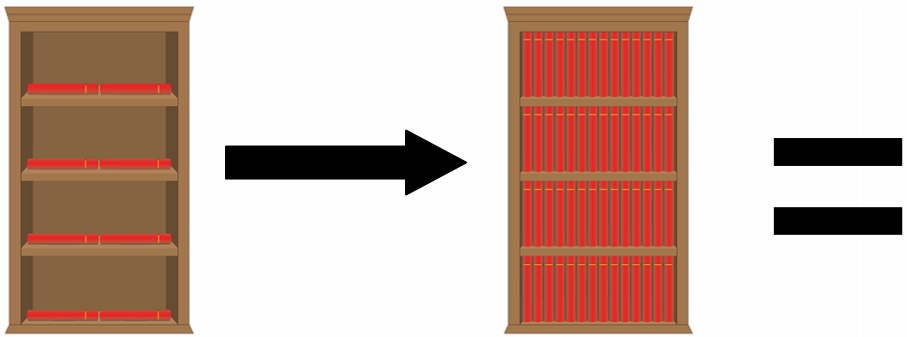
- **The path to innovation in the HDD industry previously followed an *evolutionary* curve:**
  - Capacity increases with improved areal density
  - Adjustments to media and head technology
  - MR to GMR to TMR
- **Unfortunately, recording technology would eventually run out of room**
  - End of AD road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


The Slowing Areal Density Curve
[Gb/inch²]
1000
100
10
1
New Technologies
Discrete Media
BMR Head
Perpendicular Recording
Oriented Media
AFC Media
FDB Motor
GMR
Ramp Load
PRML
MR Head,
ID-less
Thin Film Head
Glass Media
CDR
MIG Head, Sputtered Media
30 % / Year
60 % / Year
100 % / Year
35 % / Year
Production
40
60
80
100
140
200
260
360
500
700
30GB / Disk
(2.5" Disk)
88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13

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



Longitudinal Bit Alignment

Perpendicular Bit Alignment

More Music

More Photos

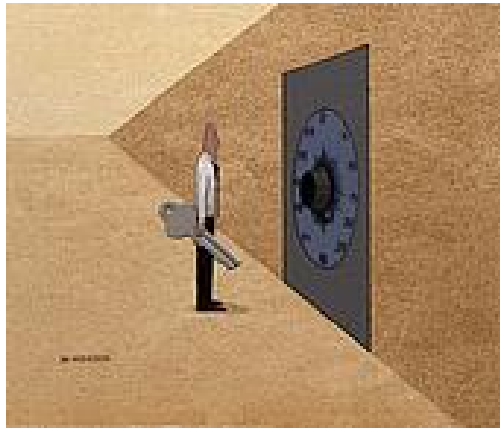
More Fun

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

Mobile Class	2007	2010	2015
2.5-inch GB/platter	120	250	760
1.8-inch GB/platter	80	150	500
1.0-inch GB/platter	20	35	60

Source: IDC

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PMR puts SFF HDDs Ahead in the Race

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

VS.

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

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HDD Technology: Enabling the Digital World

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Thank You.

Questions and Discussion