Storage Device Trends
HEC FSIO Conference AUG 2008

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Seagate Technology

Seagate Technology - Safe Harbor

Today's presentation may include predictions, estimates or other information that might be considered forward-looking. While these forward-looking statements represent our current judgment on what the future holds, they are subject to risks and uncertainties that could cause actual results to differ materially. Throughout today's discussion, we will attempt to present some important factors relating to our business that may affect our predictions. Please review our current SEC filings for a more complete discussion of our risk factors.

Outline

Company & Research Overview

Magnetic Recording Trends

Hard Disc Drive Trends

Hybrid & SSD

Summary

Seagate: Storage Leader

Seagate is the world's leading provider of hard disc drives

- Q4 FY2008*: 43M drives shipped; revenue of $2.9B
- FY2008: 183M drives shipped; revenue of $12.7B

Provides storage solutions for Enterprise, Desktop, Mobile Computing, Consumer Electronics and Retail markets

- Share leader in Desktop, Enterprise and Consumer Electronics
- 33% overall market share: highest in the industry
- Broadest product offering in the industry – Largest customer base

Ownership and vertical integration of critical technologies: heads, media and motors

Approximately 54,000** employees worldwide

Acquired MetaLINCS

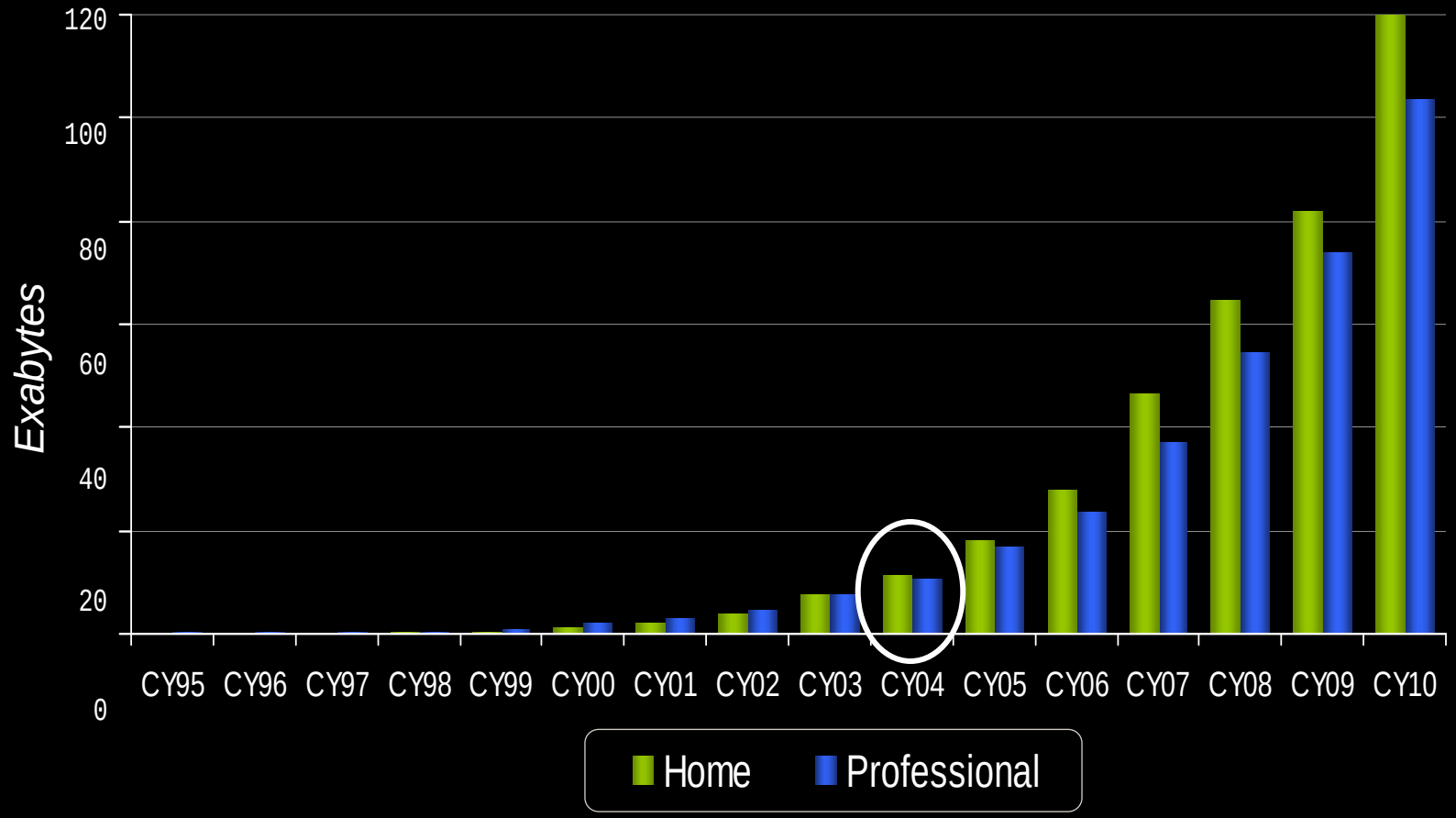
Shipped billionth drive April 2008

* For third fiscal quarter ended June 27, 2008
** Includes interns, contractors, and agency temps

Seagate's Global Presence

- Drives and Components
- Regional HQ's and Sales
- Design
- Customer Support
- Seagate Services Headquarters

Storage Demand Growth



Source: Seagate Market & Competitive Intelligence

Seagate

Seagate Research in Pittsburgh

New building officially Opened in August, 2002

- 154 Employees
- 135 Scientists and Engineers from 27 countries
- 100 PhD's from 60 universities
- 40,000 sq. ft. of class 10 – 100 cleanrooms

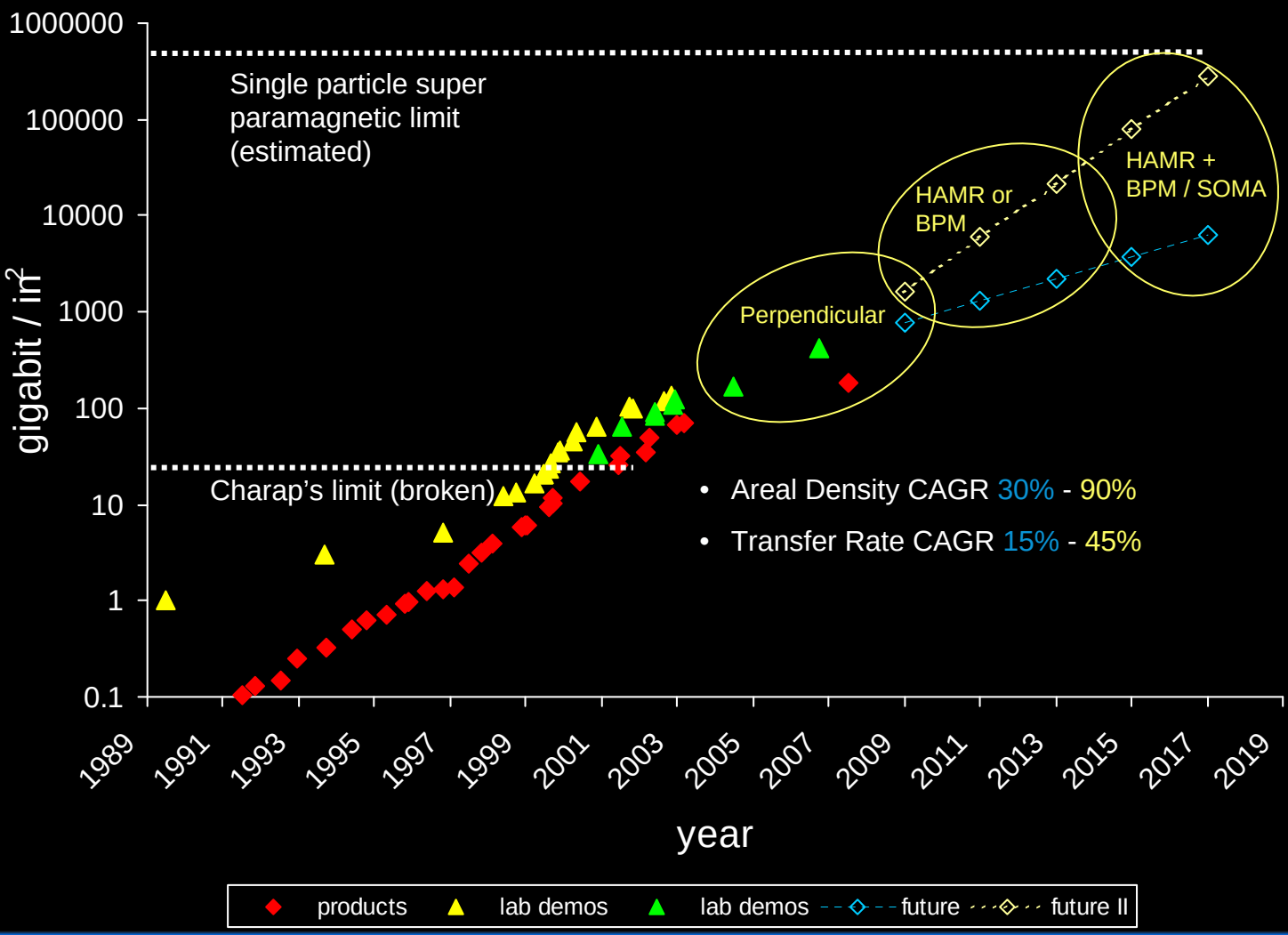
Seagate Research Mission

To develop and evaluate advanced materials, processes, technologies and systems for future storage products that will address market and customer needs 4-10 years in the future.

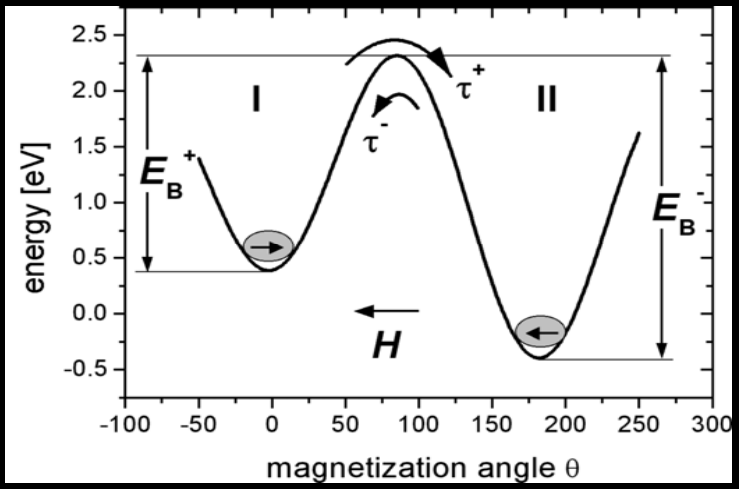
Magnetic Recording Trends

Areal Density Growth

- Late 1990s – super paramagnetic limit demonstrated through modeling
- Longitudinal recording has reached areal density limits
- Perpendicular expected to extend to 0.5-1 Tb/in^2
- Additional innovations required at that point
  - heat-assisted recording
  - bit patterned media recording

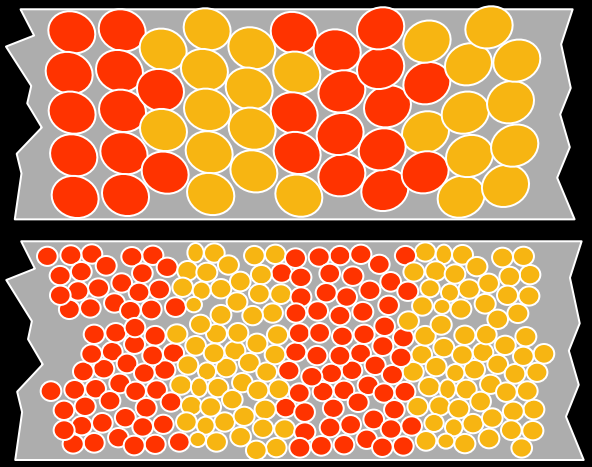


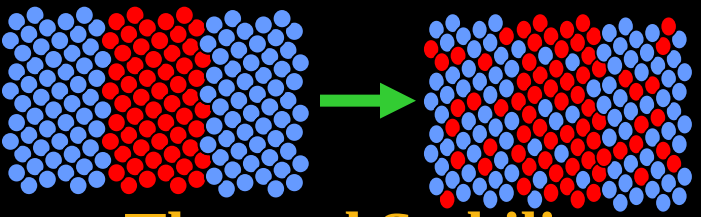
The Fundamental Problem



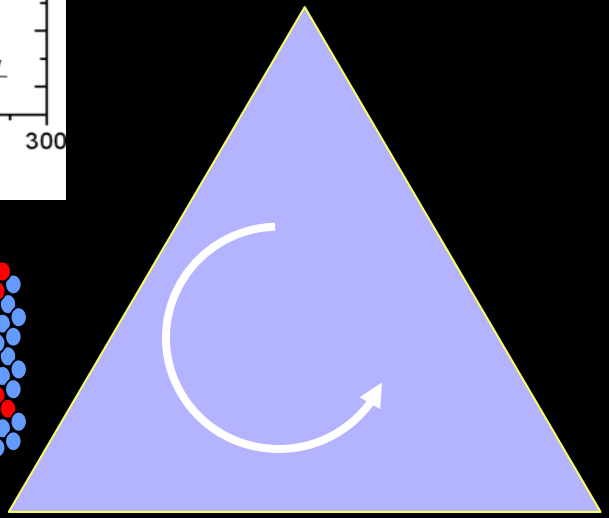
Media SNR

Small Grains (V)





Thermal Stability



Writability

$$E_B \cong K_u V \cdot \left[1 - \frac{|H_d|}{H_0}\right]^{3/2}$$

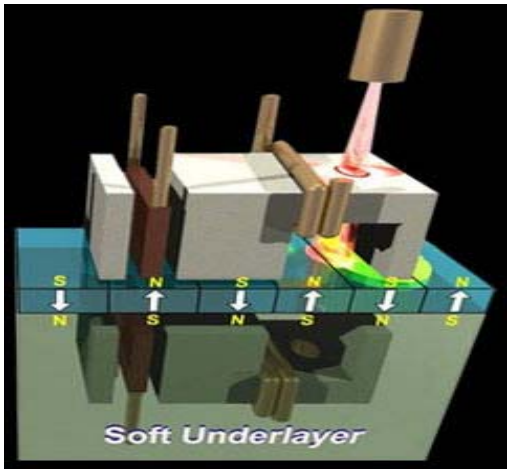
$$H_0 = \alpha \cdot \frac{2 \cdot K_u}{M_S} - N_{eff} \cdot M_S$$

K_uV = 40-60 $k_BT \equiv \eta_o\ k_BT$

H_0 < Head Field

Beyond a Terabit…

HAMR

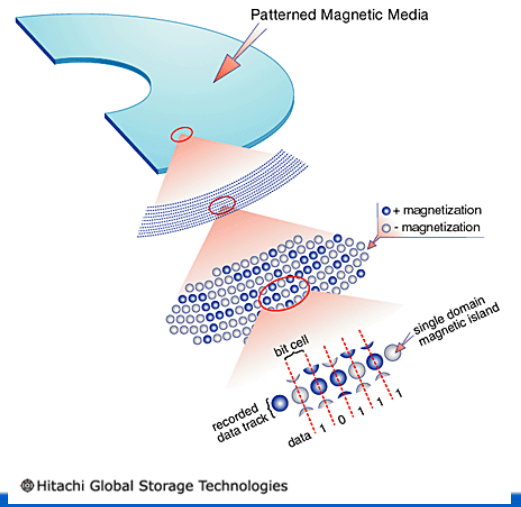


Increase **K**

K • V

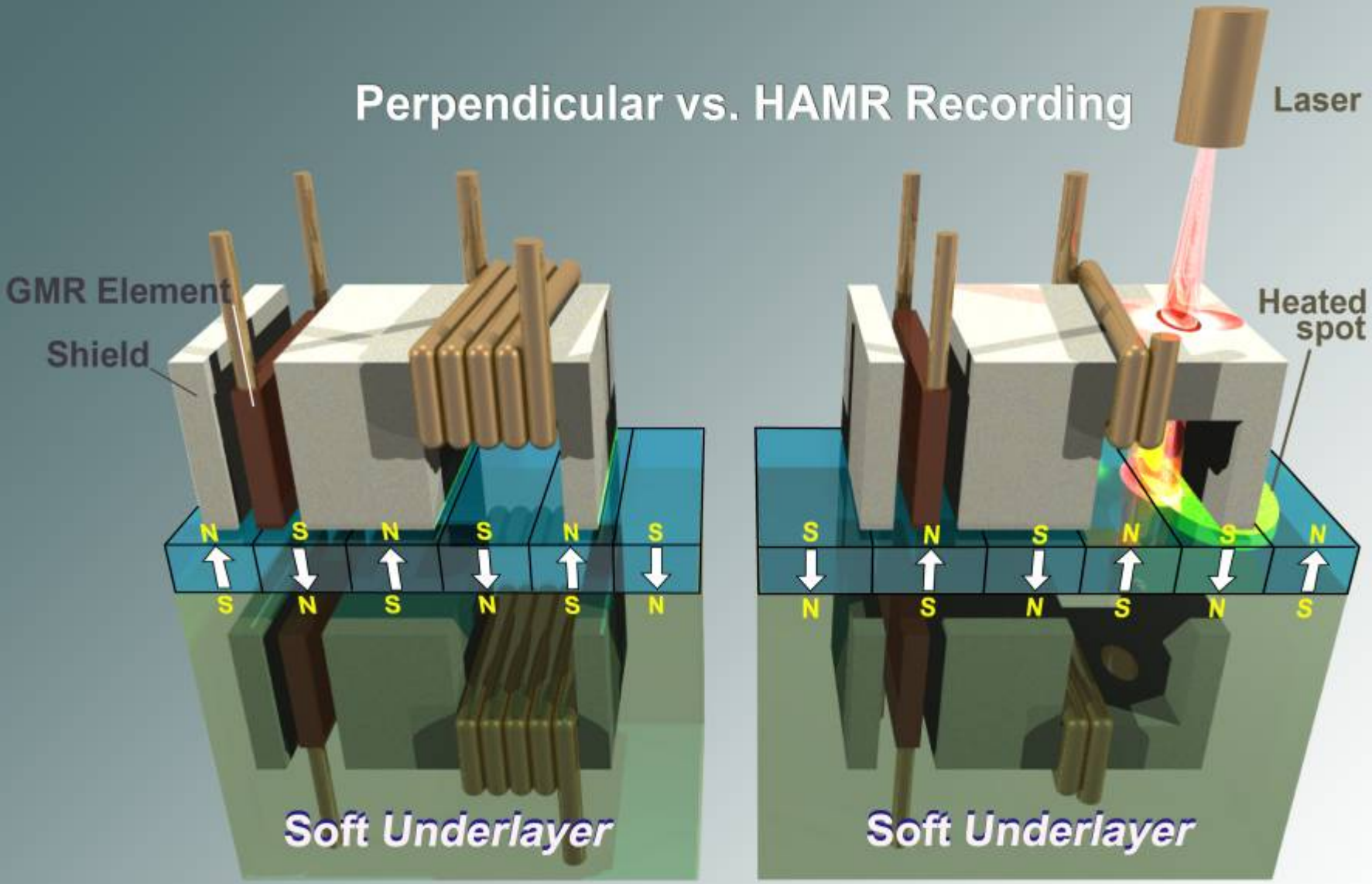
Increase **V**

BPM



Current Hardware Research Activities

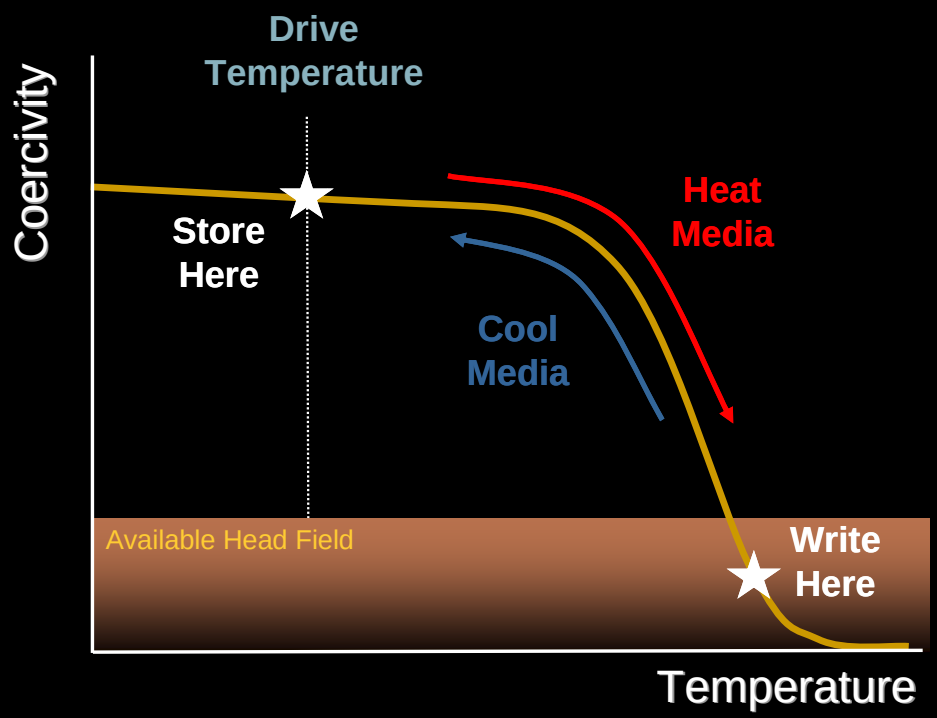
Perpendicular vs. HAMR Recording



Writability with High Anisotropy Media

With HAMR

- we can write on high anisotropy media
- maintain thermal stability with reduced grain size
- extend the areal density growth curve



HAMR Recording System

Three Light Delivery Components:

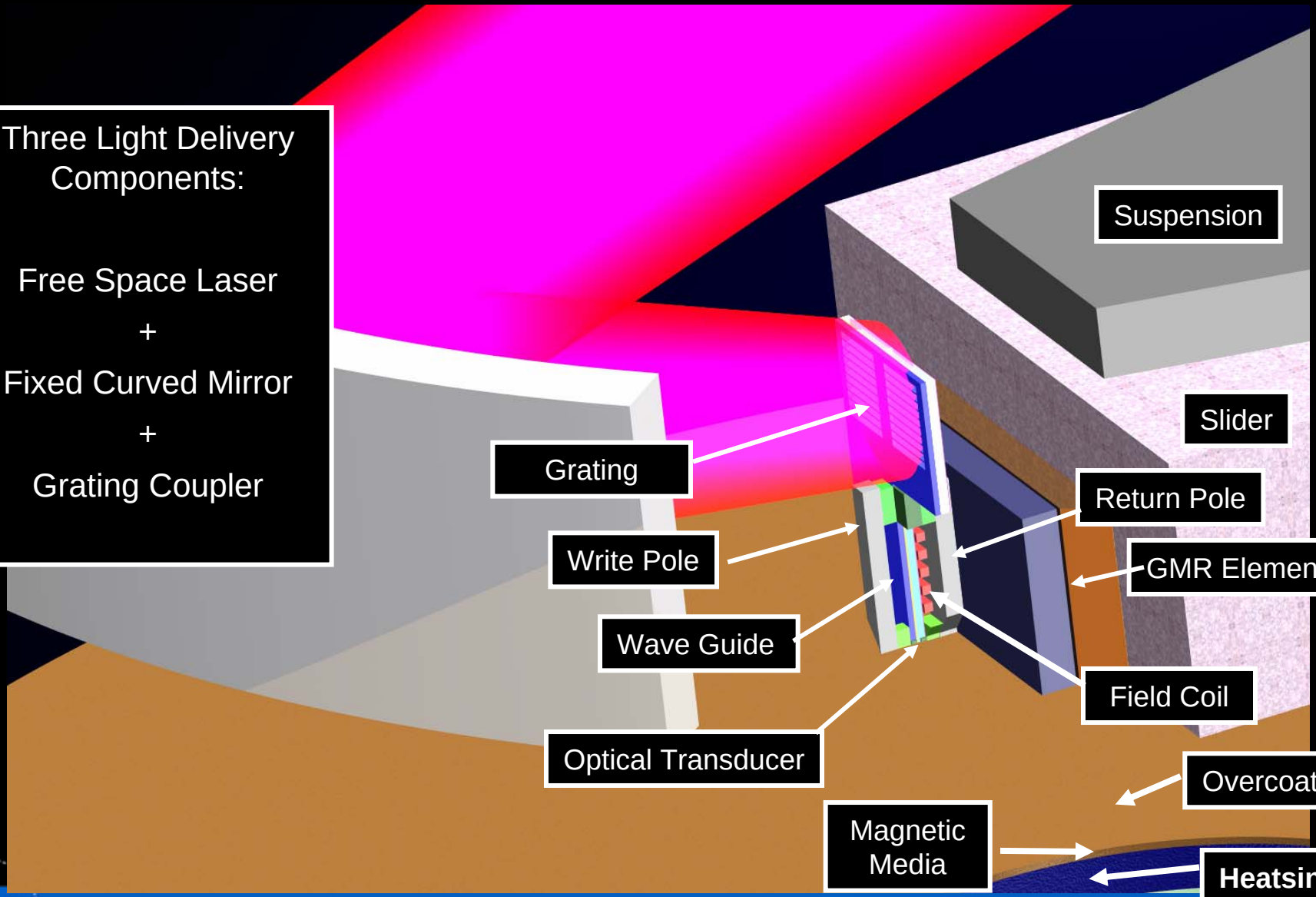
Free Space Laser

+

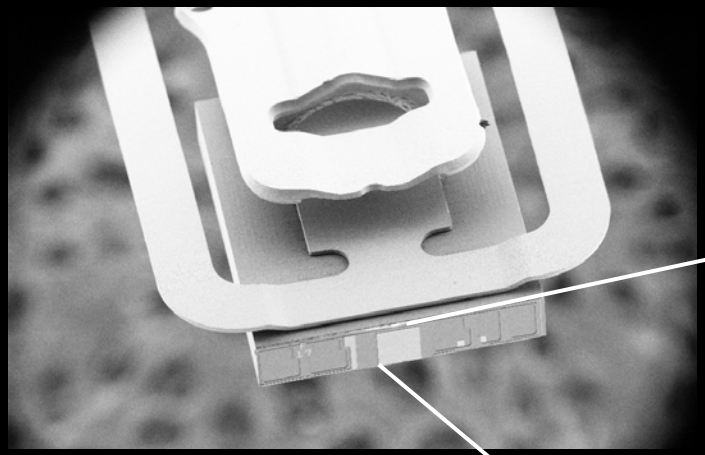
Fixed Curved Mirror

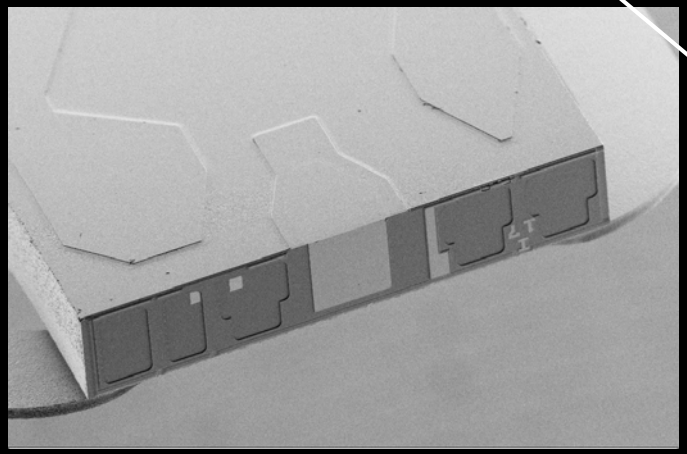
+

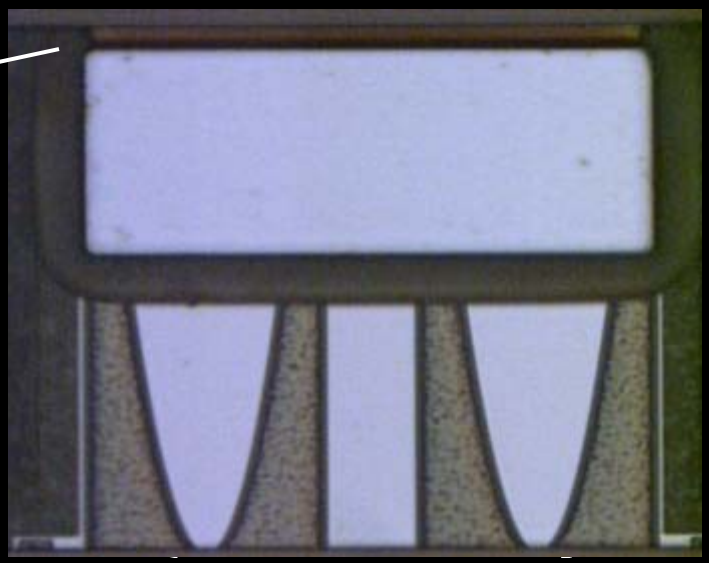
Grating Coupler



Completed Optical Heads







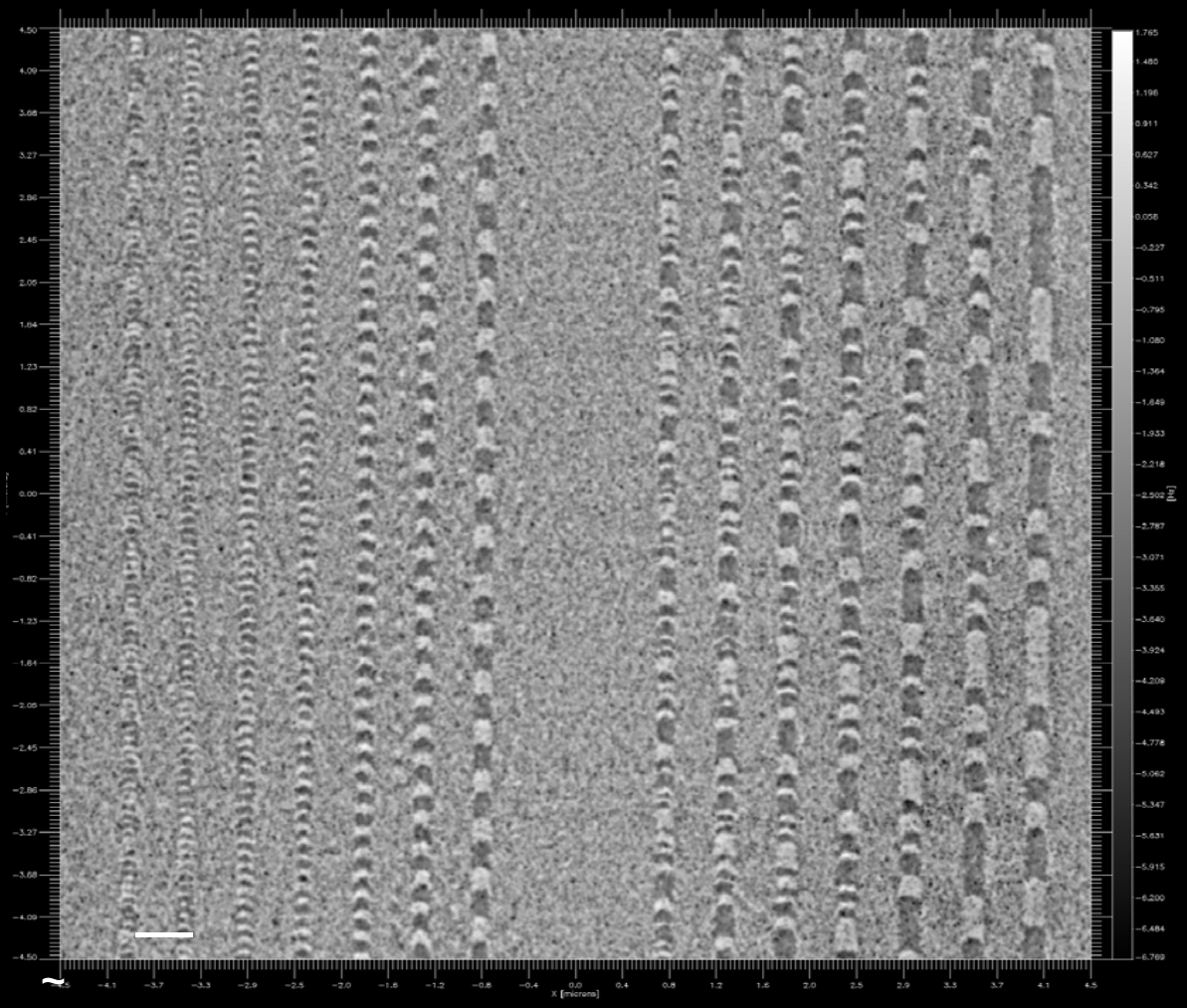
MFM images of recorded tracks

Fully Integrated HAMR Head

HAMR Unique Media

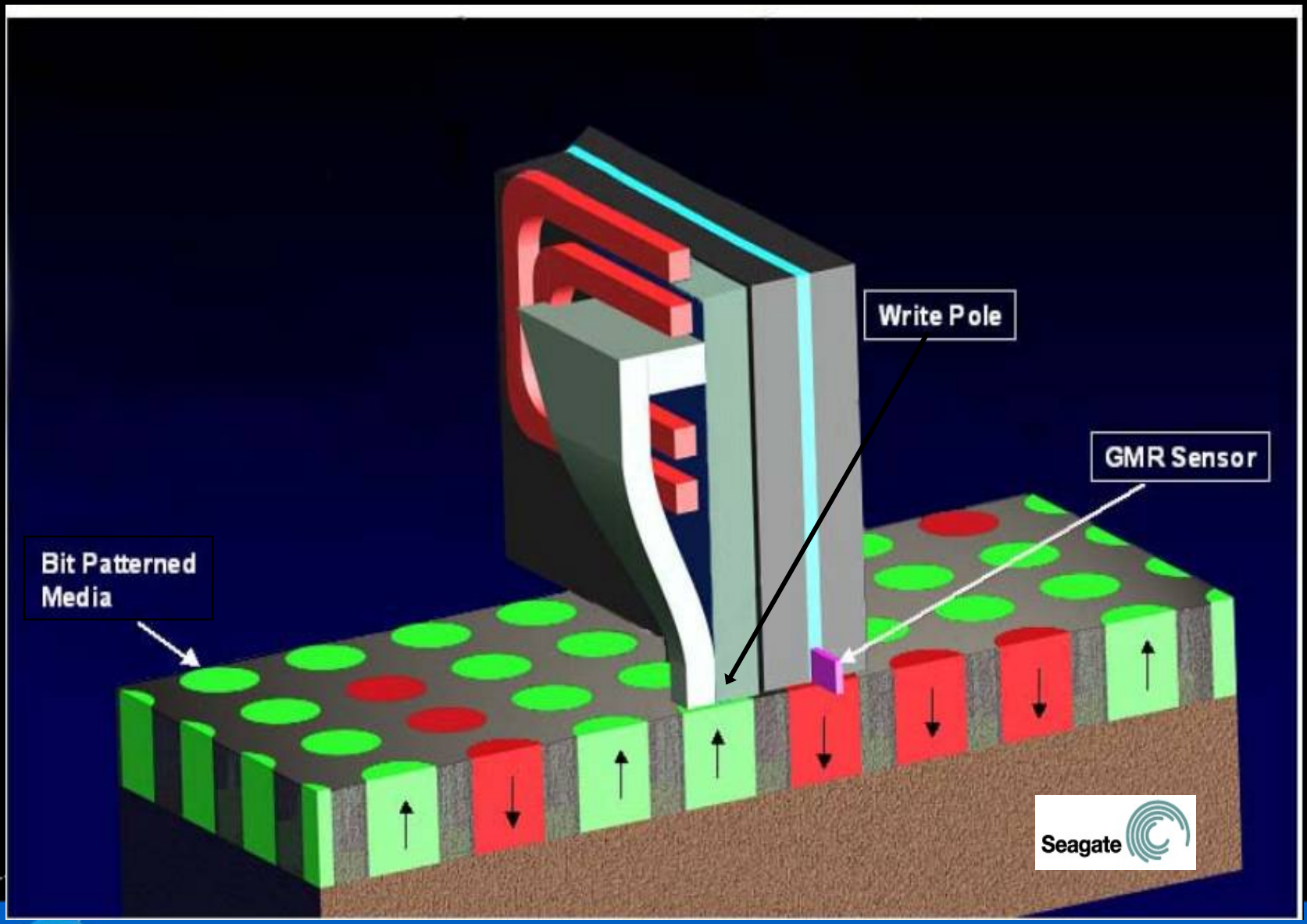
- High Anisotropy
- Proper Heatsinking

Both single tone & PRBS have been recorded



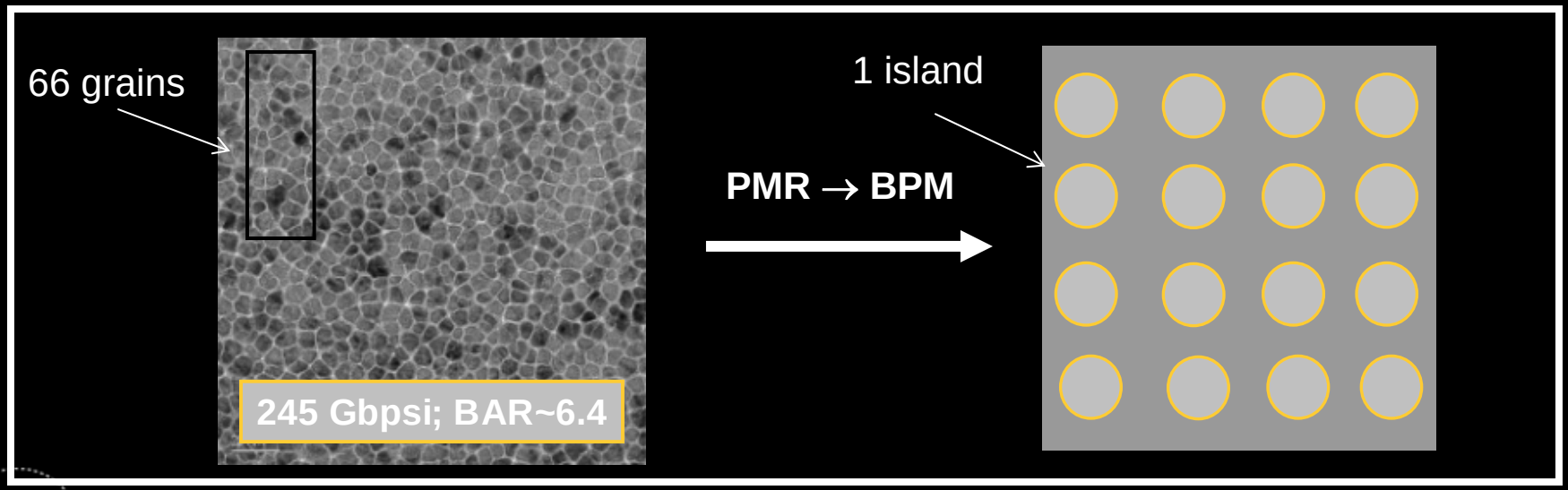
Xiaobin Zhu, Tim Rausch

Bit Patterned Media (BPM)

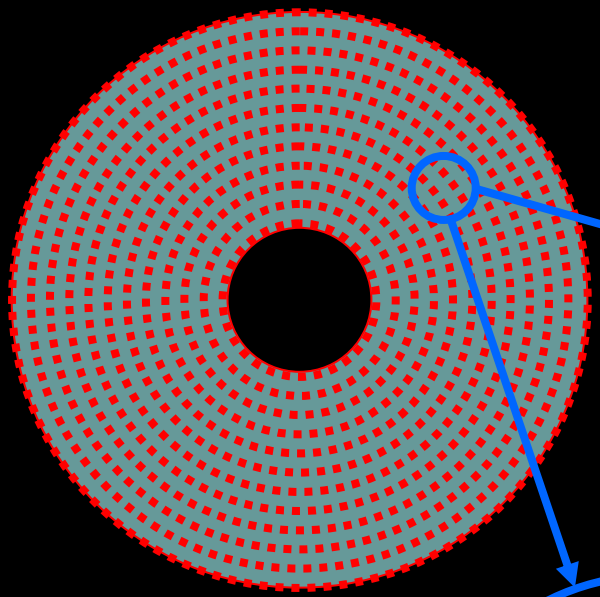


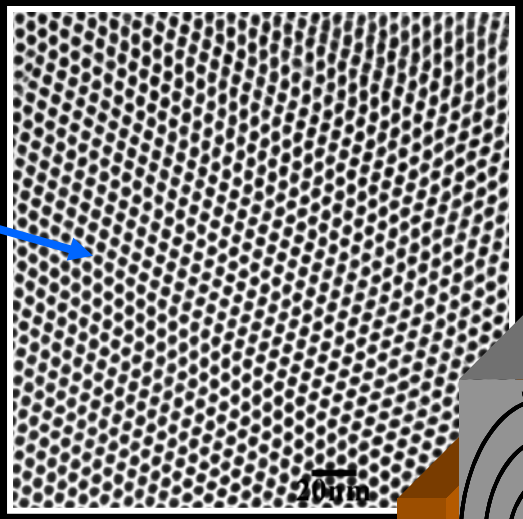
BPM Overview

- "Large", well positioned grain in a single recording bit
- Critical to control position, size and magnetic sigma
- Bit/Pitch Size: 500G 18/36 nm
  1T 12.5/25 nm
  2T 9/18 nm

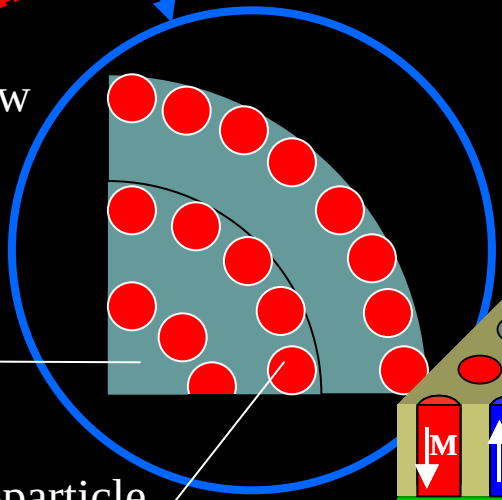


HAMR + Patterned Media



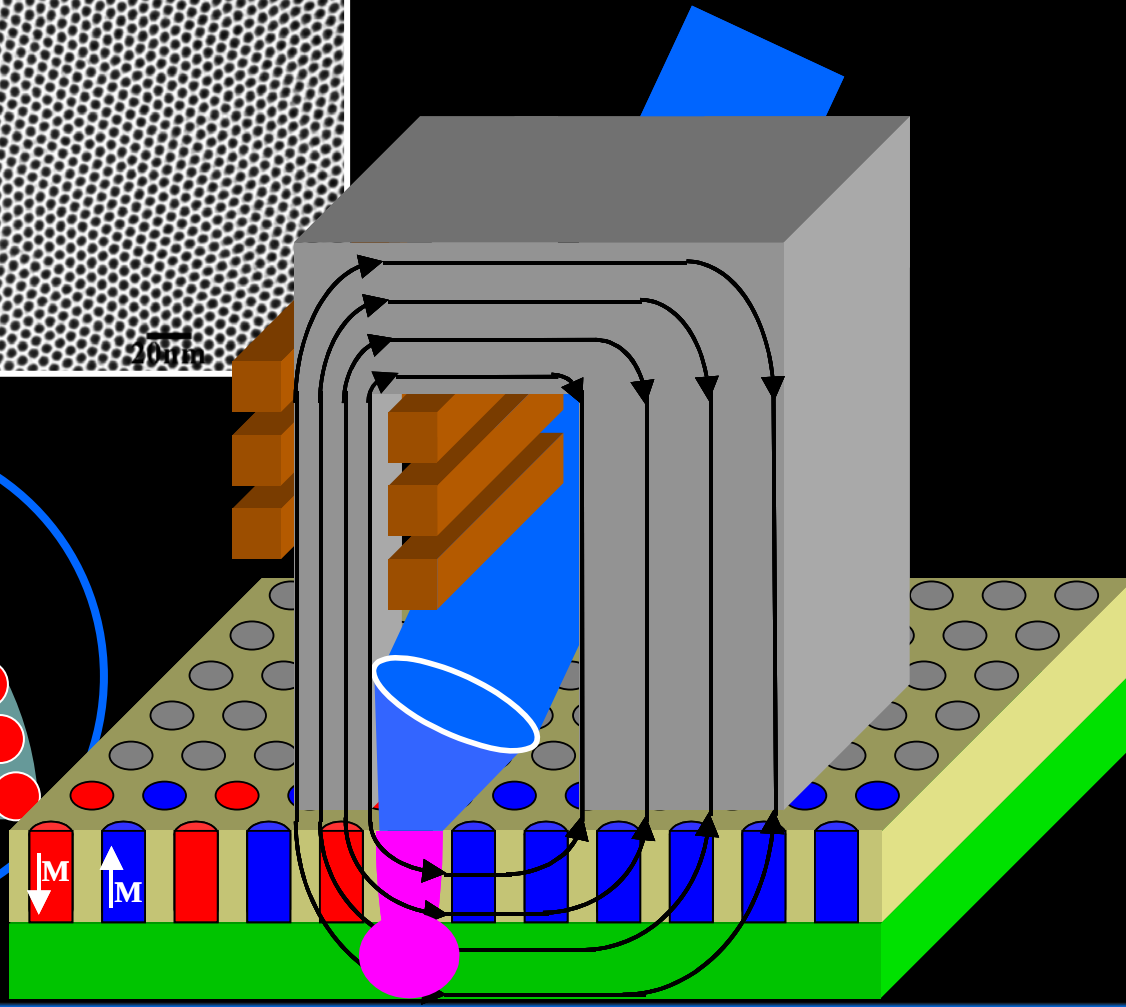


Cross-sectional View



Non-Magnetic
Filler

Magnetic Nano-particle
Diameter ~ 4 nm



Estimate of Ultimate Limit of HAMR/BPM

To increase areal density [AD]

- HAMR to raise medium magnetic anisotropy
- Single domain patterned bit media

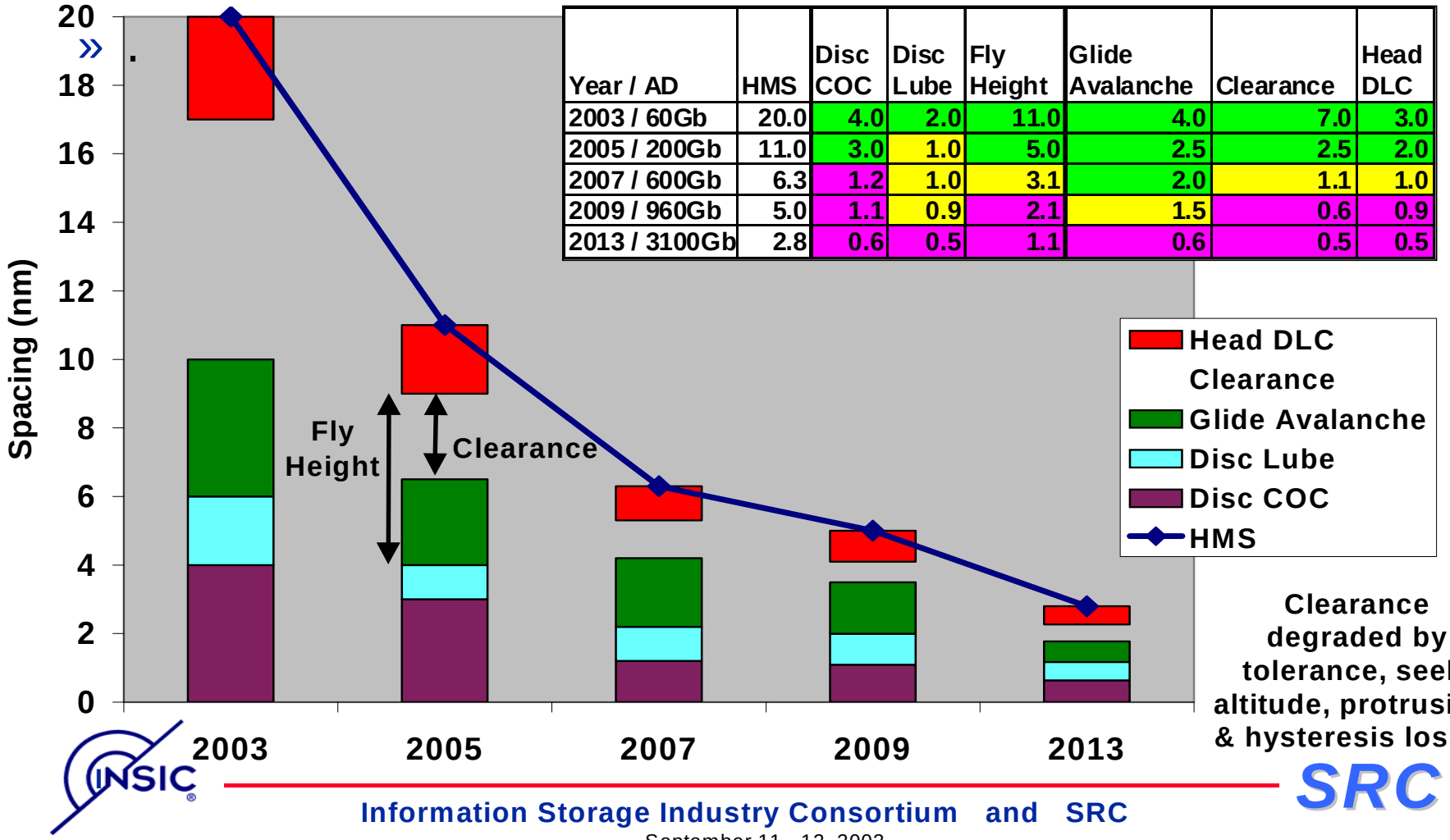
Based on thermal stability arguments, project ultimate AD's roughly in the range 40 – 100 Tb/in^2 (~10^3 X current AD)

NOTE: 50 Tb/in2 provides storage of the current printed content of the U.S. Library of Congress on a single disk the size of a 30mm diameter coin (~10 TB)

Tribology – Challenges For Flying Interface

"Flying" Interface includes current, wear-in, controlled proximity

Year / AD	HMS	Disc COC	Disc Lube	Fly Height	Glide Avalanche	Clearance	Head DLC
2003 / 60Gb	20.0	4.0	2.0	11.0	4.0	7.0	3.0
2005 / 200Gb	11.0	3.0	1.0	5.0	2.5	2.5	2.0
2007 / 600Gb	6.3	1.2	1.0	3.1	2.0	1.1	1.0
2009 / 960Gb	5.0	1.1	0.9	2.1	1.5	0.6	0.9
2013 / 3100Gb	2.8	0.6	0.5	1.1	0.6	0.5	0.5



Clearance degraded by tolerance, seek, altitude, protrusion, & hysteresis losses

INSIC

SRC

Information Storage Industry Consortium and SRC

September 11 - 12, 2003

Magnetic Recording Summary

Conventional perpendicular recording appears limited to 500-1000 Gbpsi

HAMR could extend the areal density by an order of magnitude

Bit patterned media/SOMA, combined with HAMR could, in principle, extend the areal density to perhaps 50 Tbpsi

A key obstacle is magnetic head-media spacing

Some of this work was performed as part of the Information Storage Industry Consortium (INSIC) program in Heat Assisted Magnetic Recording (HAMR), with the support of the U. S. Department of Commerce, National Institute of Standards and Technology, Advanced Technology Program, Cooperative Agreement Number 70NANB1H3056

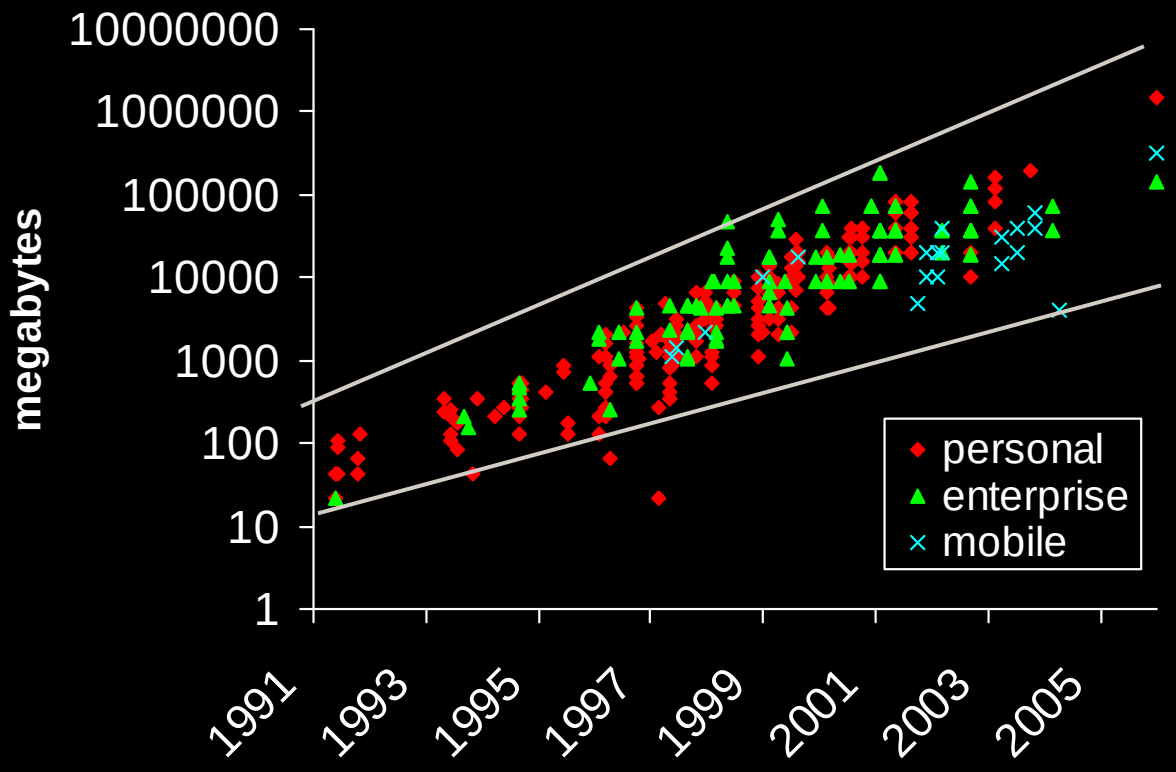
HDD Trends

Seagate

We turn on ideas

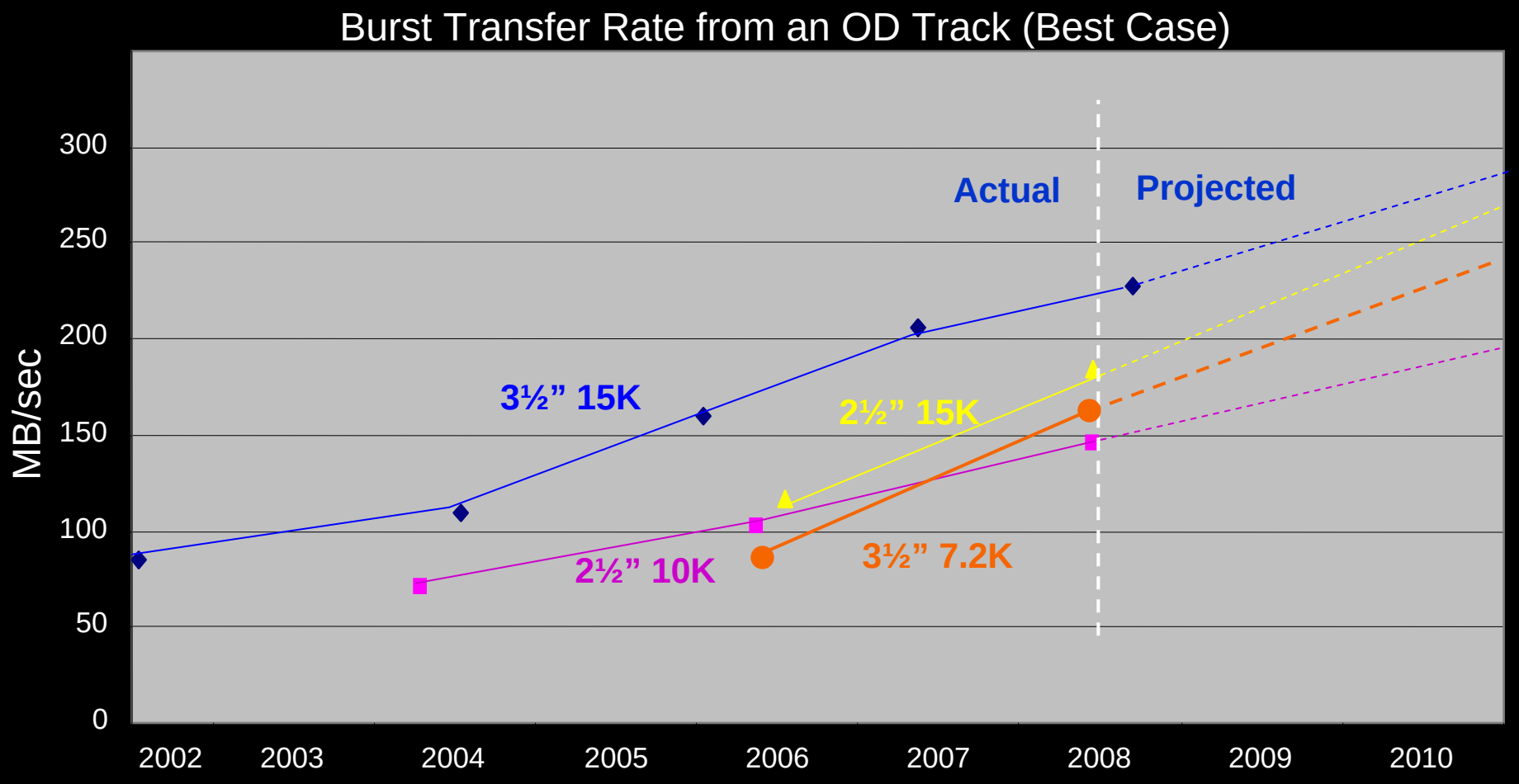
Capacity

- Range of available capacities is widening with inclusion of drives for hand-held applications
  - 60 – 1500 GB today
- Note that highest capacity was always in the enterprise market, until 2003
  - consumer uses (especially DVR) now push capacity



product information for Seagate disc drives introduced since 1991, mobile includes Toshiba drives since 1997

Projected Drive Transfer Rate through 2010

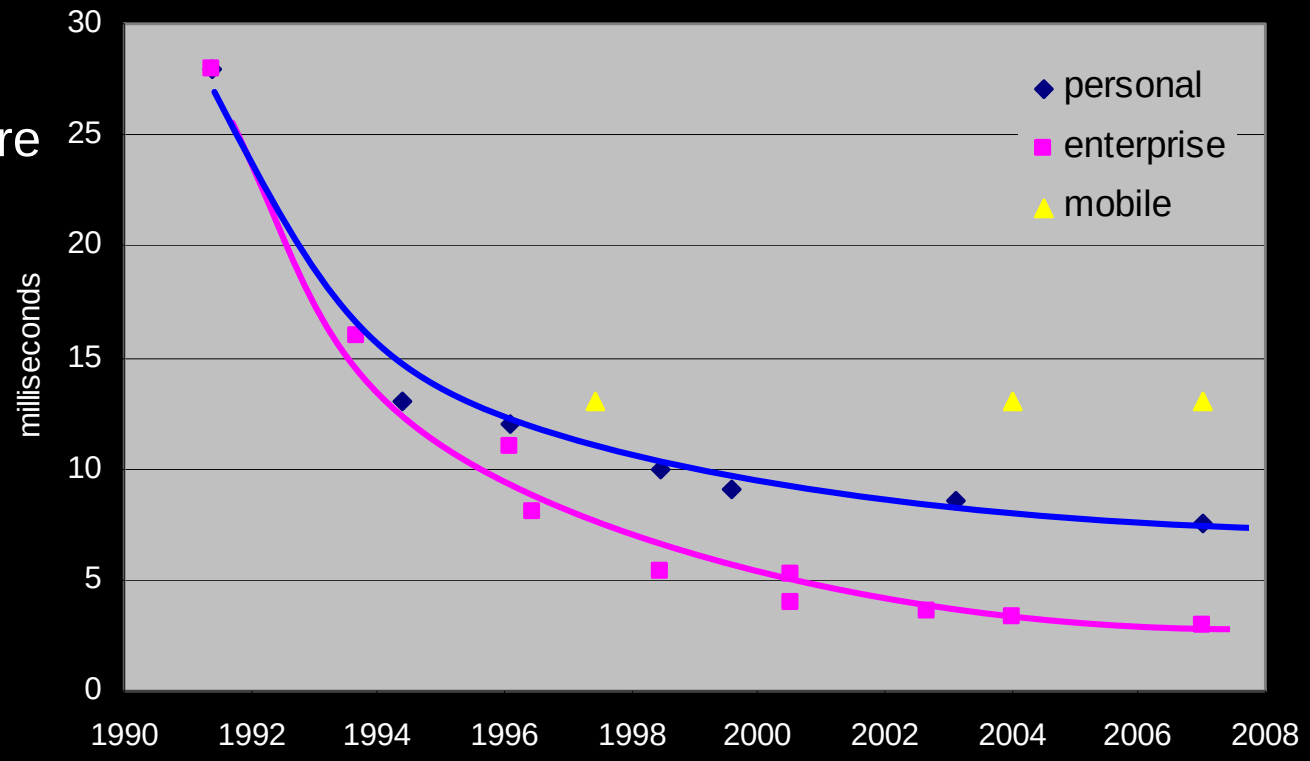


Data rate into the drive buffer from an Outer Diameter Track

- No Seeks involved
- Format efficiency taken into account

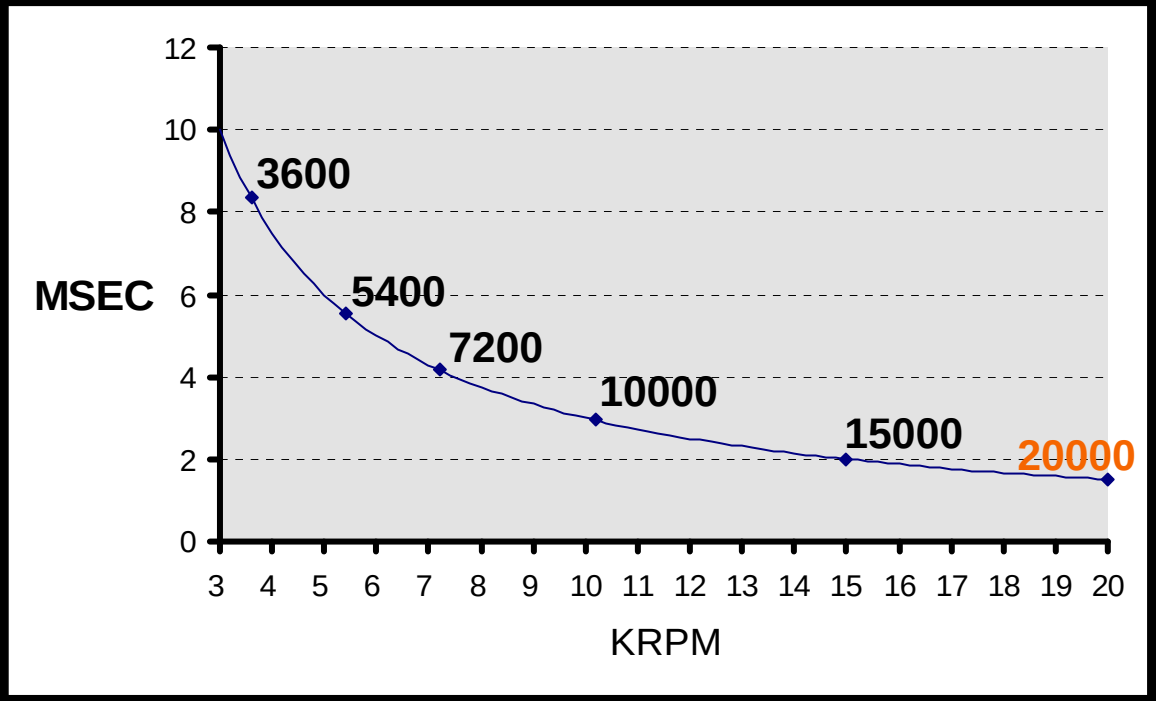
Seek Time

- trend is toward further separation
  - enterprise always more aggressive on seek performance
- little change in mobile
- seek time sensitive to both mechanics and signal processing
  - moving arm fast enough (starting)
  - staying on track (stopping)



Spindle Speed

- Only interest was enterprise
  - (SAS, FC)
  - Greater interest in 2.5”
- Little performance benefit
- Huge cost:
  - Power~ RPM^5
  - Negative effect on magnetic recording
    - Increase NRRO
    - Vibration
    - Data rate



HDD Trends…

3.5 inch Consumer	2007 (Perp)	2010 (Perp)	2014 (HAMR/BPM)
Drive Capacity (GB)	1,000	2,200 – 6,800	6,300 – 89,000
Number of Discs	4	4	4
Capacity (GB/disc)	250	550 – 1,700	1,575 – 22,250
Product Areal Density (Gbpsi)	180	395 – 1,235	1,129 – 16,090
Transfer Rate (Mb/sec)	1,030	1,560 – 3,140	2,740 – 13,880
RPM	7,200	7,200	7,200
Power (Idle / Consumer DVR Profile)	9.3 / 9.4	9.3 / 9.4	9.3 / 9.4
3.5 inch Enterprise	**2007 (Perp)**	**2010 (Perp)**	
Drive Capacity (GB)	300	650 – 2,000	
Number of Discs	4	4	
Capacity (GB/disc)	75	163 - 500	
Product Areal Density (Gbpsi)	133	292 - 912	
Transfer Rate (Mb/sec)	1,200	1,820 – 3,650	
RPM	15,000	15,000	
Power (Idle / Enterprise Profile)	13.7 / 18.8	13.7 / 18.8	
2.5 inch Enterprise	**2007 (Perp)**	**2010 (Perp)**	**2014 (HAMR/BPM)**
Drive Capacity (GB)	73.4	160 - 500	460 – 6,550
Number of Discs	2	2	2
Capacity (GB/disc)	36.7	80 - 250	230 – 3,275
Product Areal Density (Gbpsi)	133	292 - 912	835 – 11,888
Transfer Rate (Mb/sec)	896	1,360 – 2,730	2,380 – 12,750
RPM	15,000	15,000	15,000
Power (Idle / Enterprise Profile)	5.8 / 7.9	5.8 / 7.9	5.8 / 7.9

Capacity, Areal Density (AD), and Transfer Rate ranges assume a 30% to 90% AD CAGR

Hybrid & SSD

Hybrid: HDD + Flash

Seagate introduced a Hybrid disk drive in Fall 2007 for laptop computers

- 2.5-in. 160 MB; 5,400-rpm
- 256MB flash cache memory

Potential benefits:

- Reduced Power: spin down motor & operate out of flash memory
- Higher Performance: boot quicker & resume from hibernation
- Improve Reliability: spinning drive down creates less mechanical movement

Hybrid technology will be introduced across other product lines as customer requirements demand

- Enterprise
- Desktop
- Consumer

SSD

Seagate plans to deliver first SSD products in early 2009

Initially focus on Enterprise environments

- Tier 0 – Provide small pool of high performance storage used by most demanding application - requires highest level of endurance, data integrity & scalability
- Server Caching – used as read/write caching devices as a layer of cache between RAM and Hard Drives
- Server main storage – used as local storage in workstations, blades, and other servers as a performance enhancer for applications

Standardization required

- Describe & measure, in real-world environments - endurance, performance & reliability for SLC/MLC
- Seagate actively leading industry standards efforts to establish standards for SSD's through JEDEC, SNIA, etc.
  - Effort includes defining requirements for test & qualification processes

Summary

Based on thermal stability arguments, 2D AD growth opportunity ~ 3 OOM

- 3D next frontier?

HDD

- Performance improvements continue, albeit at lower rates than capacity increases
  - Enterprise performance class models transitioning to smaller form factors
- High demand remains in all markets for high capacity drives

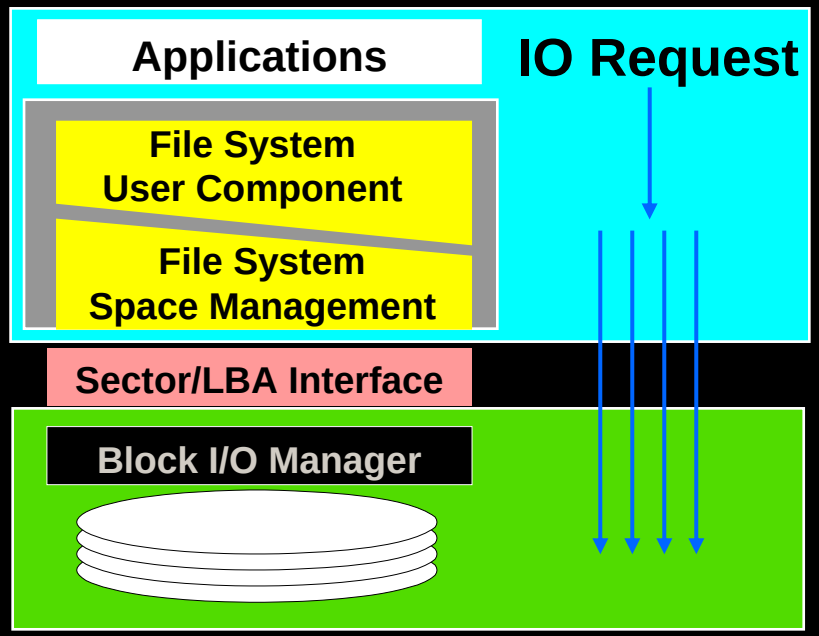
Hybrid & SSD

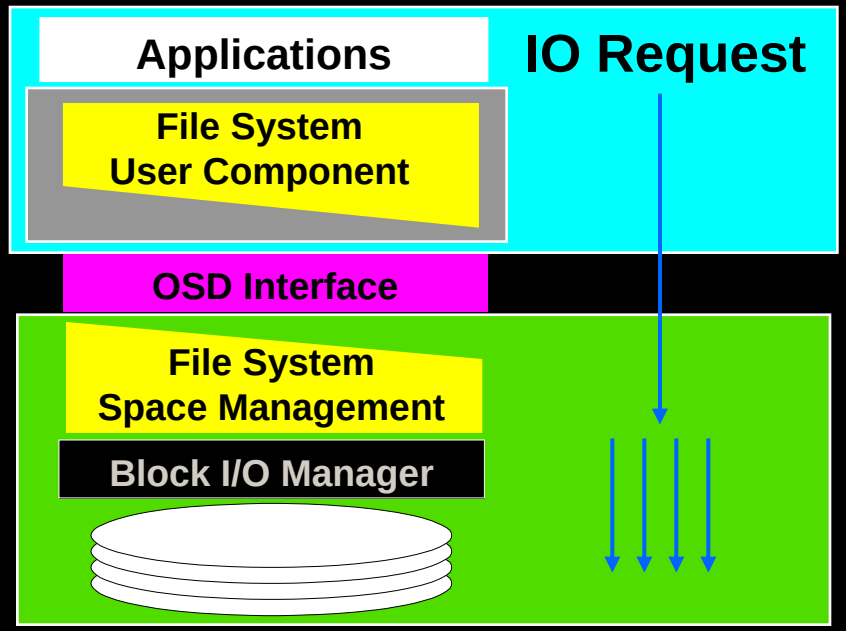
- New storage device classes that enable interesting new opportunities to improve performance, reliability & power savings

Storage Systems

Seagate

OSD


Applications
IO Request
File System
User Component
File System
Space Management
Sector/LBA Interface
Block I/O Manager


Applications
IO Request
File System
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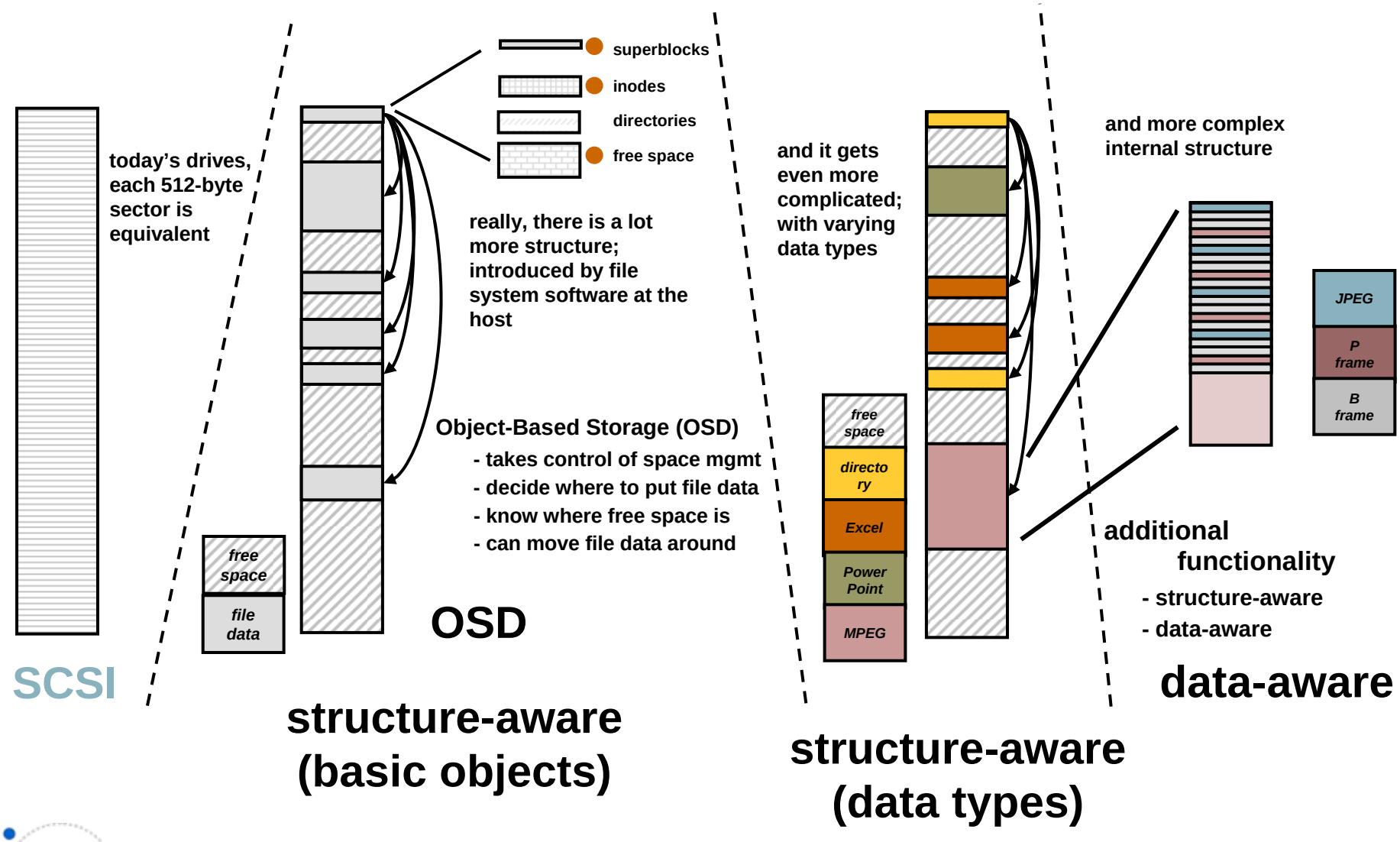
Structure of data – what happens next



Security - DriveTrust

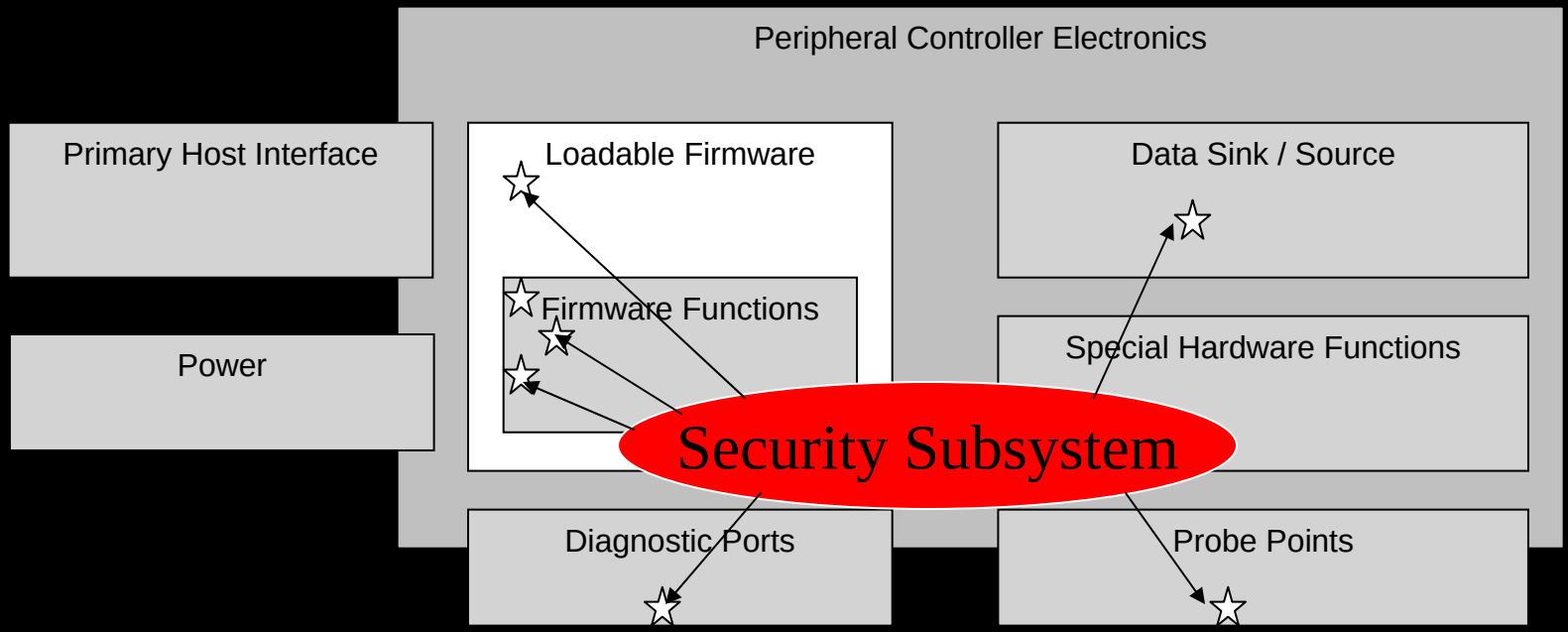
A Storage Device ***will soon*** have a built in sophisticated

ACCESS CONTROL SUBSYSTEM

E.G., Windows has an ACCESS CONTROL SUBSYSTEM called “GINA” – your username – password or smartcard, etc. that let’s you ‘log in’ and gives selected access to Windows objects

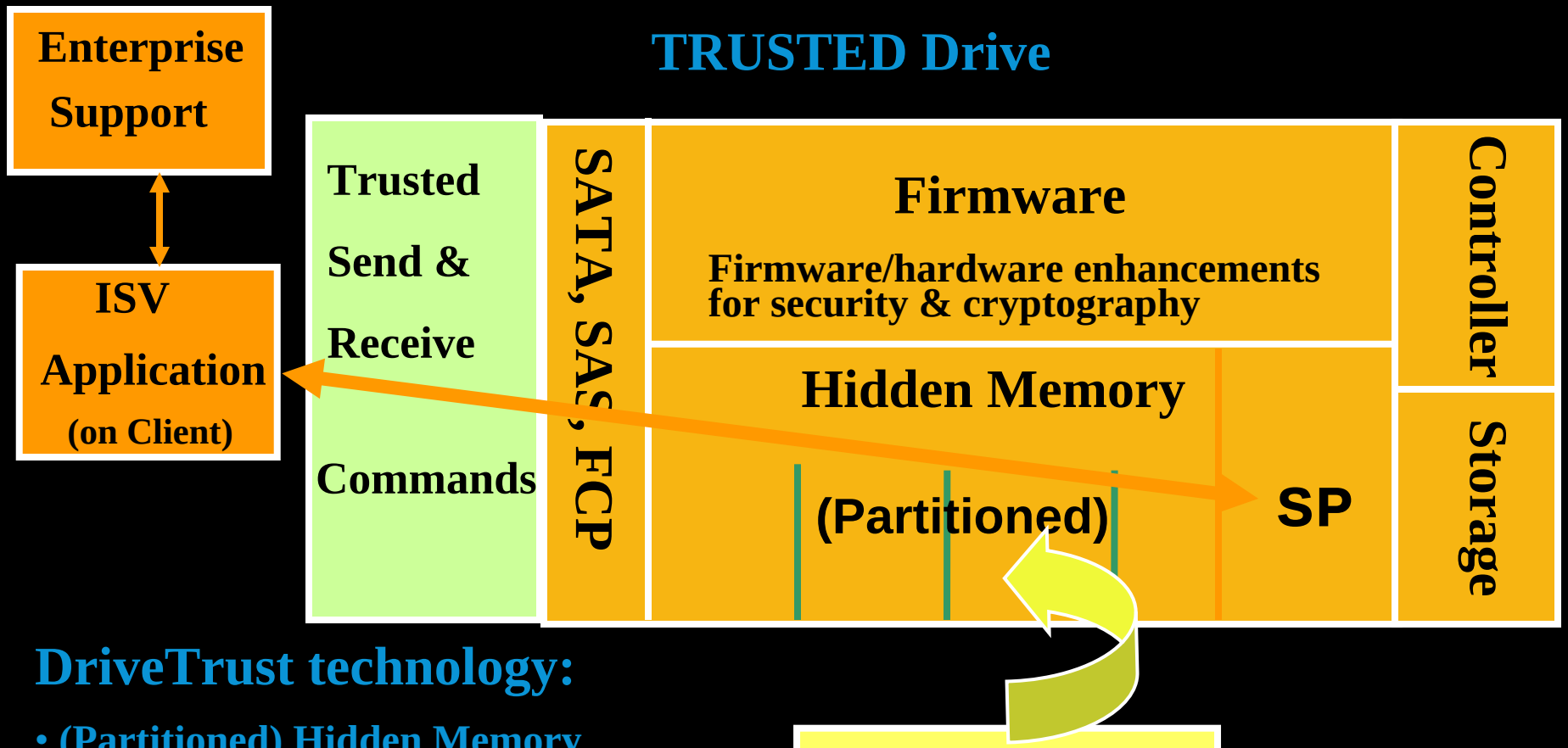
So in the immediate and long-term future the Device ITSELF refuses to give up data in the wrong situations.

Security Access Control Subsystem



From Thibadeau, R. "Trusted Computing for Disk Drives and Other Peripherals" IEEE Security and Privacy, Oct 2006.

Seagate DriveTrust Technology



DriveTrust technology:

- (Partitioned) Hidden Memory
- Security firmware/hardware
- Trusted Send/Receive Commands
- Assign Hidden Memory to Applications

Primary Applications & Uses for DriveTrust

Theft & Disposal

- Protecting data at rest in the event of system or drive loss or disposal
- Corporate Data: laptops, desktop drives, storage and servers, removable
- HIPAA (US), Personal Information Protection Law (Japan)

Content Protection

- Personal Information Privacy
- HIPAA, Personal Information Protection Law
- Protection against piracy
- Software, Entertainment, Enterprise Software
- Enforcing Content Policy such as number of copies, time limited use

Forensic Logging

- Creating and protecting logs for file access and modification
- Sarbanes Oxley, HIPAA, Government

Network Attack

- Protecting against malware that typically arrives via network attack. Can also arrive via sneaker net.
- Corporate data, Consumer identity: Stronger solutions

DriveTrust Summary

Fast disk disposal/repurposing

Protection of all data against computer theft

Is *independent of operating system*

Lock individual drives to particular machines *makes a hard drive useless to a drive thief*

Fastest FDE security solution combines Windows XP/Vista OS with a Seagate DriveTrust hard drive with FDE

With TCG's TPM, a very secure, private, and easy to use Laptop, PC, Server, or USB Attached Drive

Enables *numerous primary use cases including:*

- *Content Protection*
- *Forensic Logging*
- *Network Attack Protection*