

An aerial photograph of a mountain range with a river valley. The mountains are rugged and brownish-grey, with a dark river winding through the valley. The sky is overcast and grey.

Perpendicular Magnetic Recording and Other New Technologies Drive Capital Spending

Thomas Coughlin
Coughlin Associates
www.tomcoughlin.com

Abstract

- Perpendicular magnetic recording will completely displace longitudinal recording in HDDs by 2009. Along with unit volume increases to meet demand for new and established applications manufacturing of PMR and other new technologies to meet areal density growth needs over the next few years will fuel industry capital spending that will exceed \$20 B between 2005 and 2010. This presentation will describe the impact of the PMR conversion in terms of drive and component shipments and capital equipment spending. It will also discuss component and drive technology developments and the capital equipment that will be required to make them manufacturable.

Outline

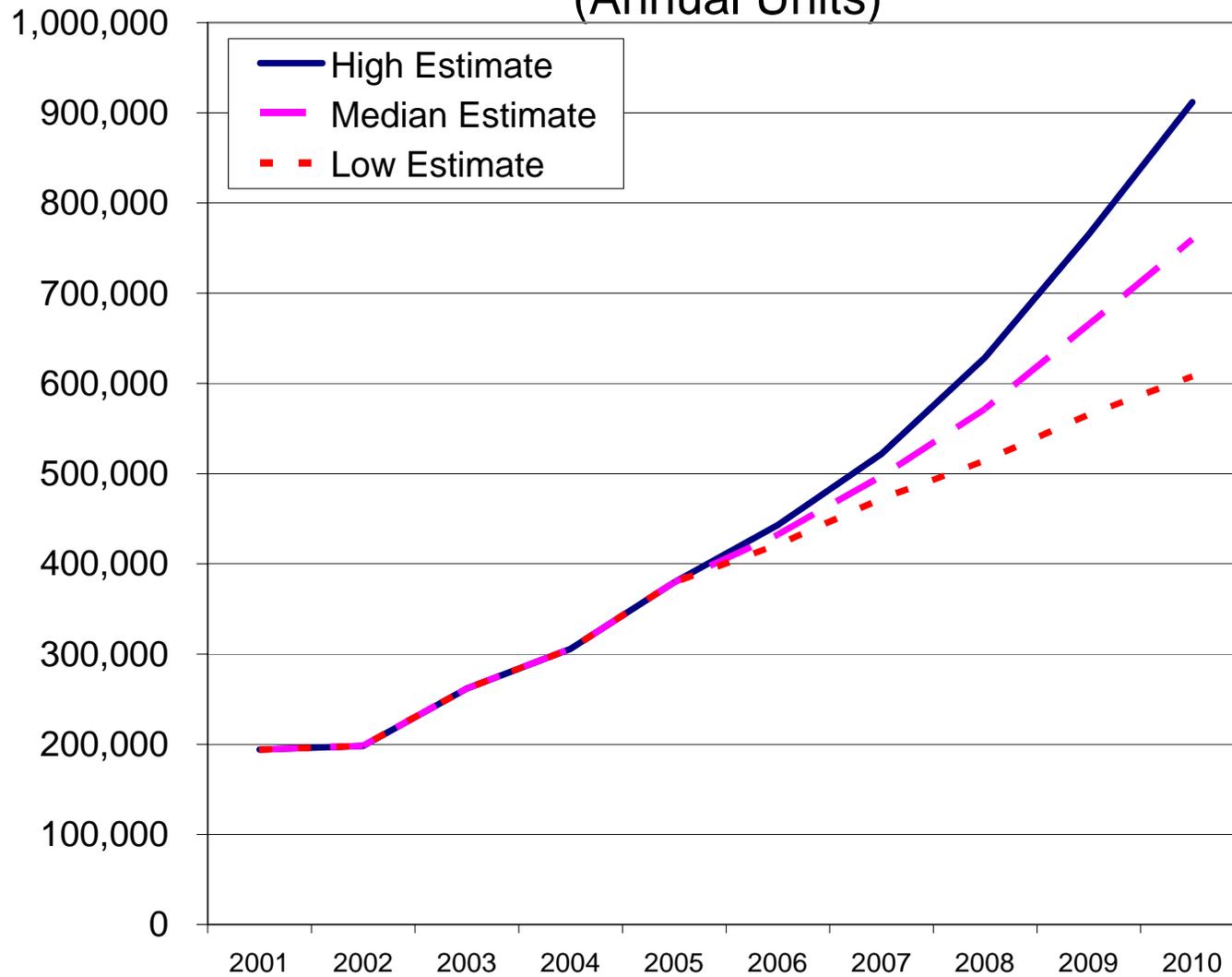
- Industry Market Trends
- Technology Projections
- Capital Spending Trends
- Conclusions



HDD Industry Market Trends

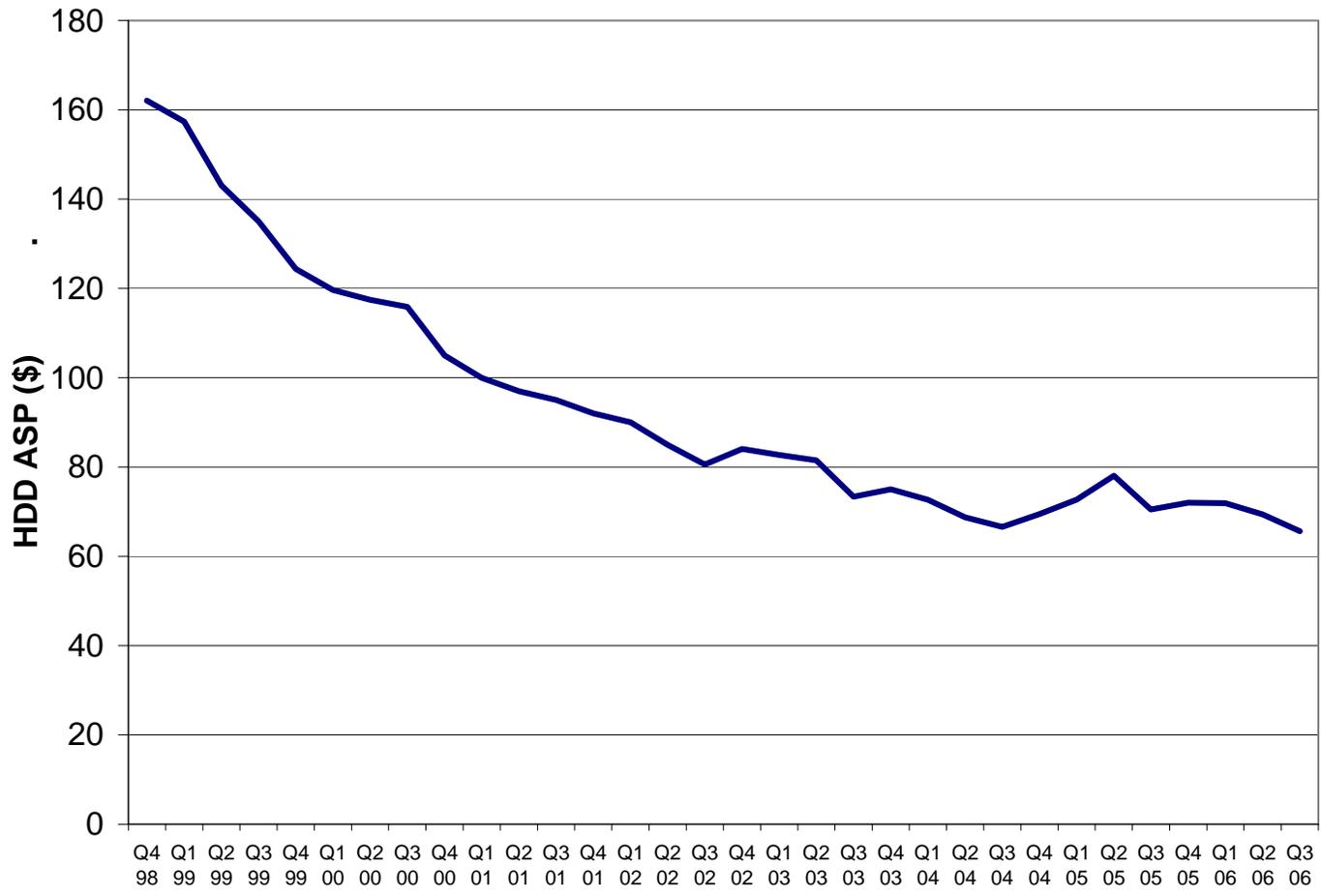
Banded Hard Drive Volume Projections

(Annual Units)



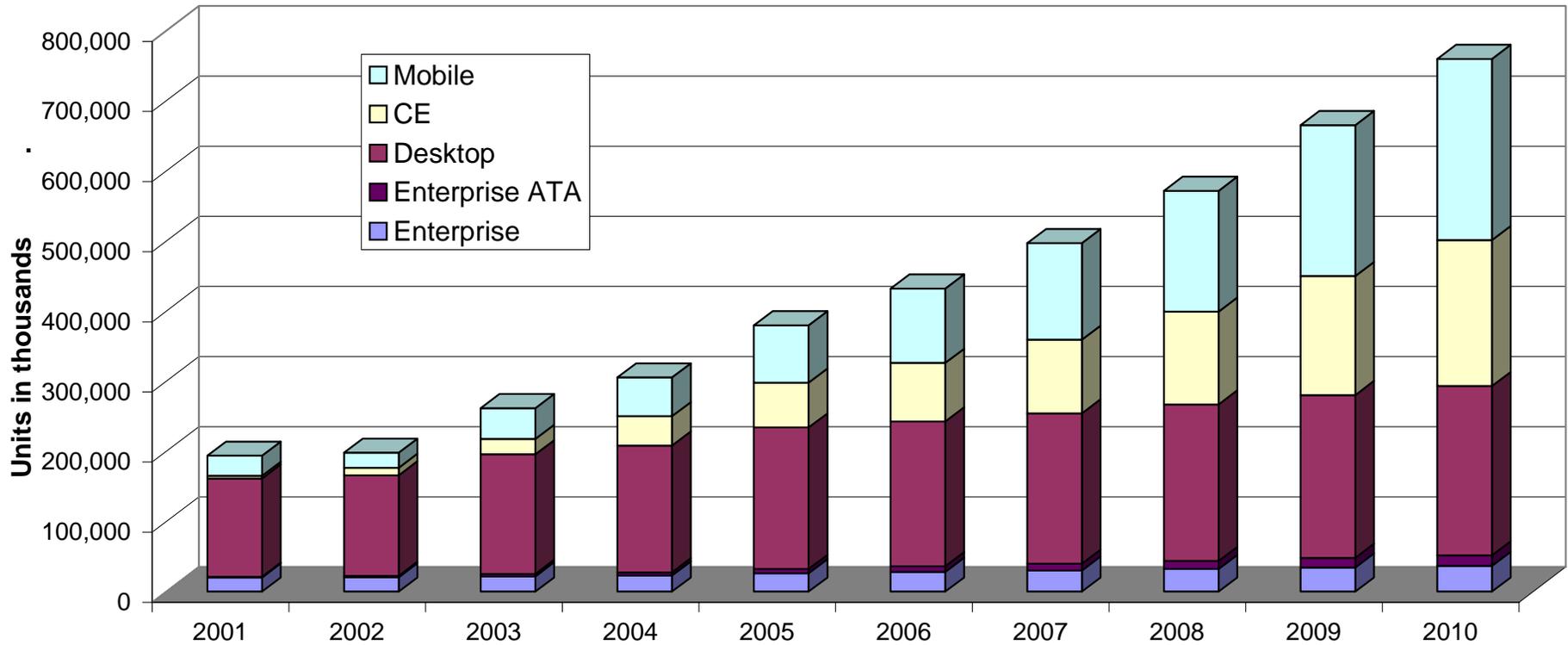
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AVERAGE DRIVE PRICE TREND FOR SEAGATE, WESTERN DIGITAL AND MAXTOR (Q4 '98 to Q2 '06)



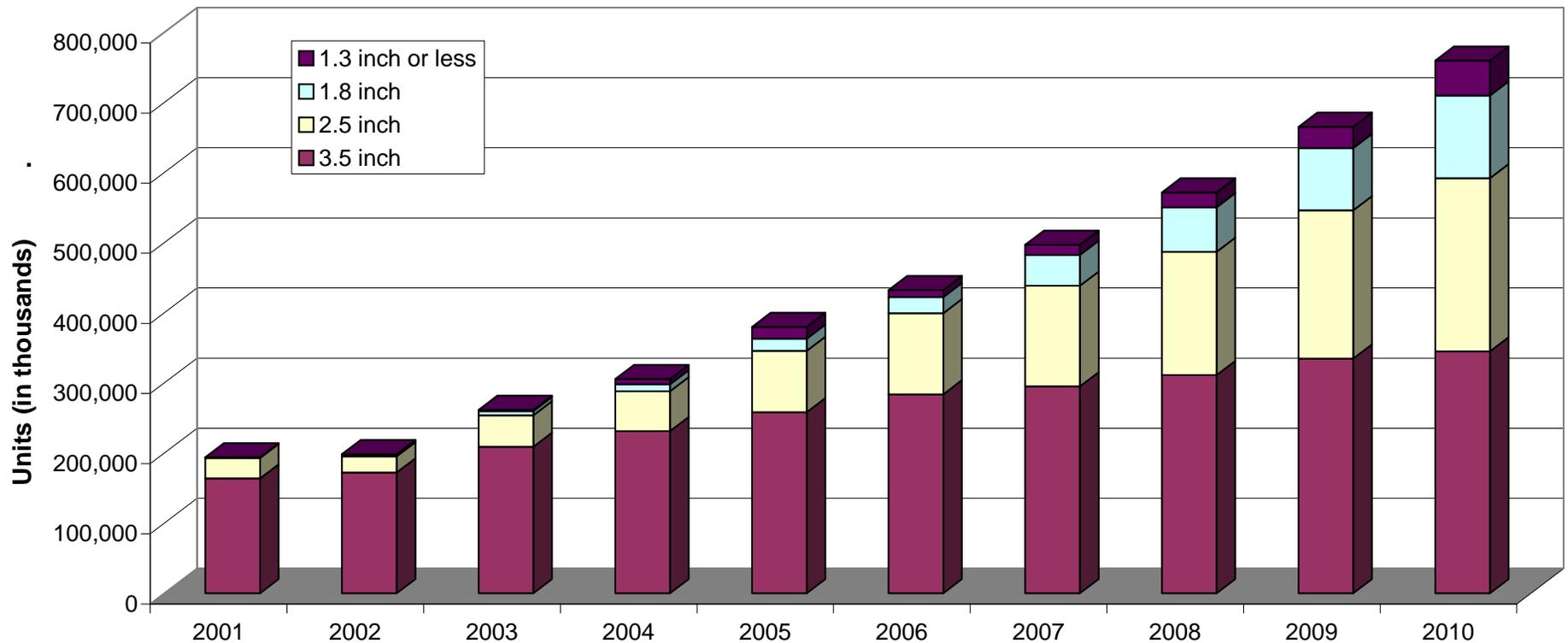
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HDD Market Niche Projections



By 2010 CE and Mobile Computers will dominate in disk drive unit volume

HDD Form Factor Projections



By 2010 2.5-inch and smaller HDD will provide over half of total disk drive volume

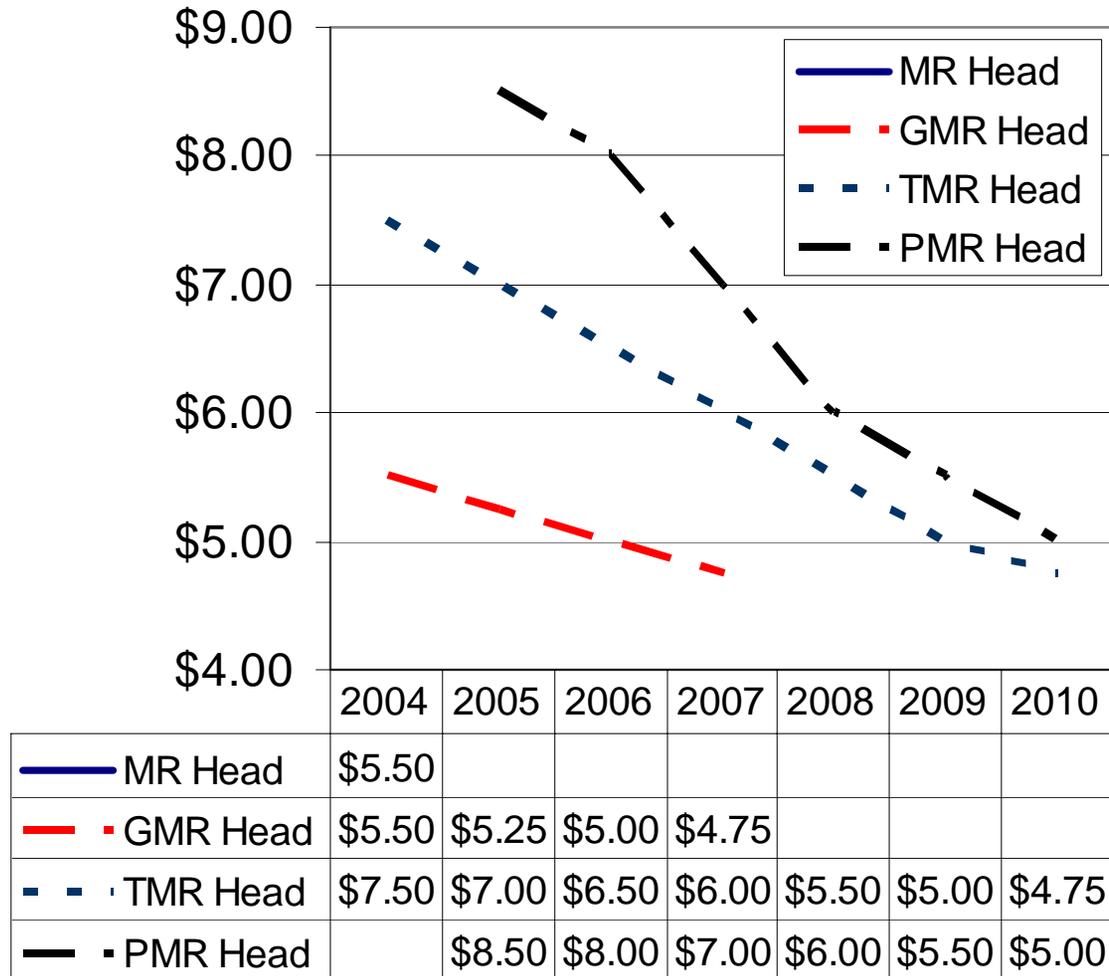
Head Shipment Projections

	2004	2005	2006	2007	2008	2009	2010
3.5 INCH	577,808	594,090	596,054	589,908	622,093	669,333	689,747
2.5 INCH	176,858	278,720	370,093	445,009	527,427	633,654	716,529
1.8> INCH	27,886	65,360	58,937	99,530	144,034	203,031	285,381
TOTALS	782,552	938,170	1,025,084	1,134,447	1,293,553	1,506,018	1,691,658

Disk Shipment Projections

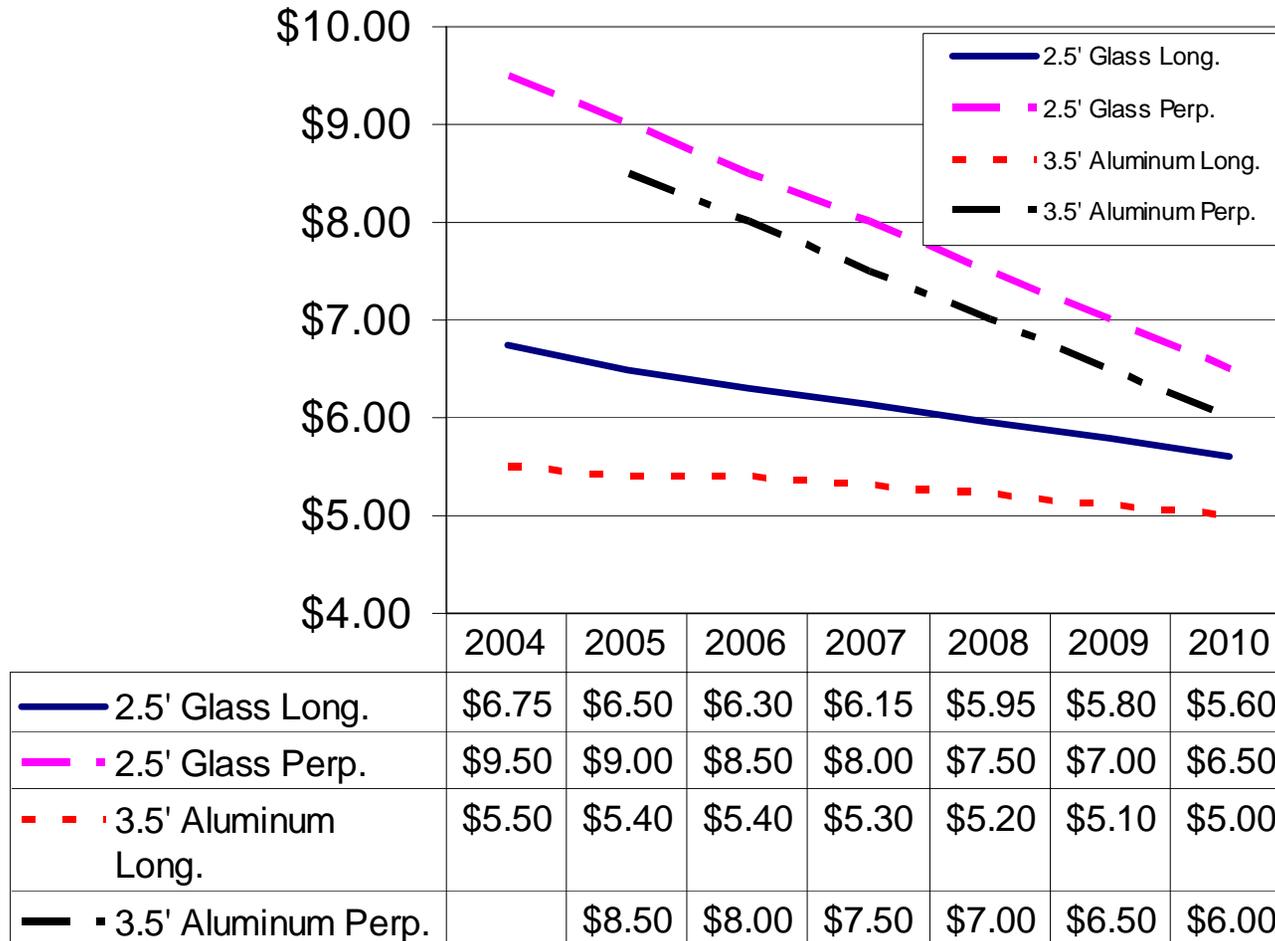
	2004	2005	2006	2007	2008	2009	2010
3.5 INCH	361,384	373,773	397,369	418,835	438,576	468,533	482,823
2.5 INCH	114,102	174,200	231,308	279,925	334,037	390,753	444,742
1.8> INCH	17,708	34,627	32,808	58,606	84,810	119,550	168,039
TOTALS	493,194	582,600	661,485	757,365	857,423	978,836	1,095,604

Market HGA Pricing Trends



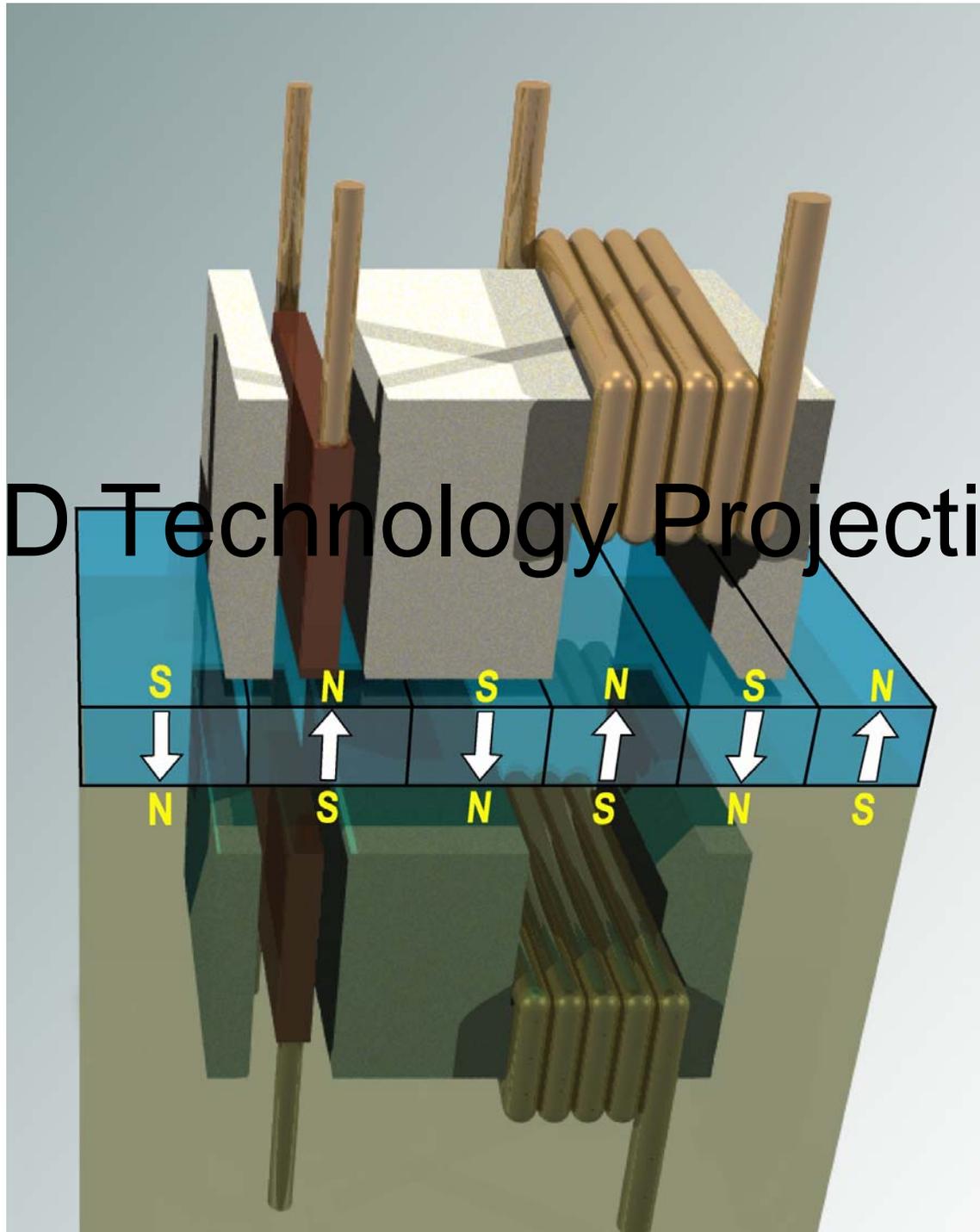
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Market Magnetic Disk Pricing Trends



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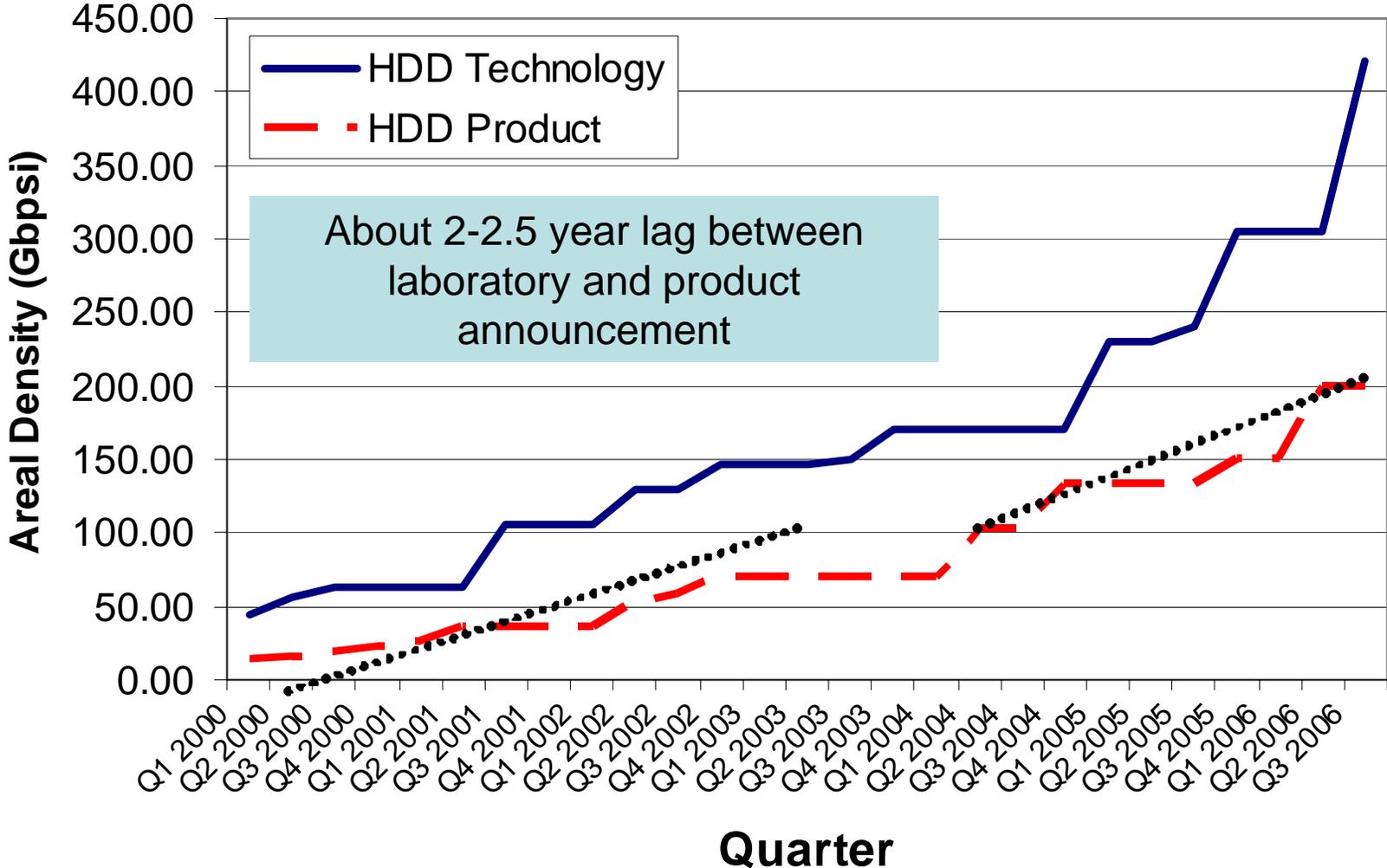
HDD Technology Projections



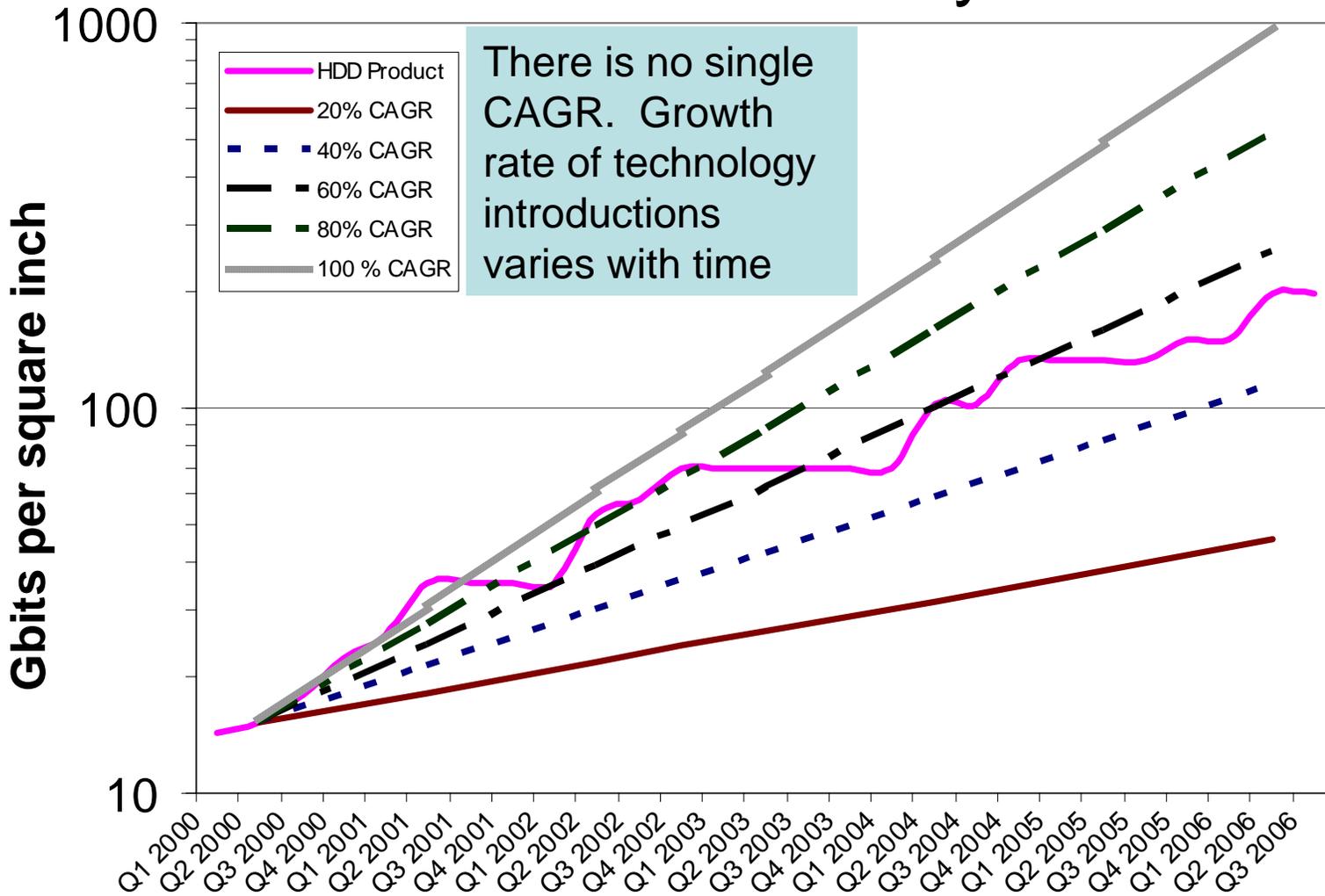
Observations regarding Technology Introductions

- Technology introductions occur erratically in a monotonically increasing fashion, driven by the pace of technical discovery as well as introductions timed for maximum advantage to the introducing company
- Once a technology is introduced it must go through a learning cycle until yield and performance issues are resolved and then follows a rapid adoption that displaces other technologies
- There may be more than one approach that creates at least a short term solution to a given technological problem

HDD Quarter by Quarter Public Technology Demonstrations and Product Announcements

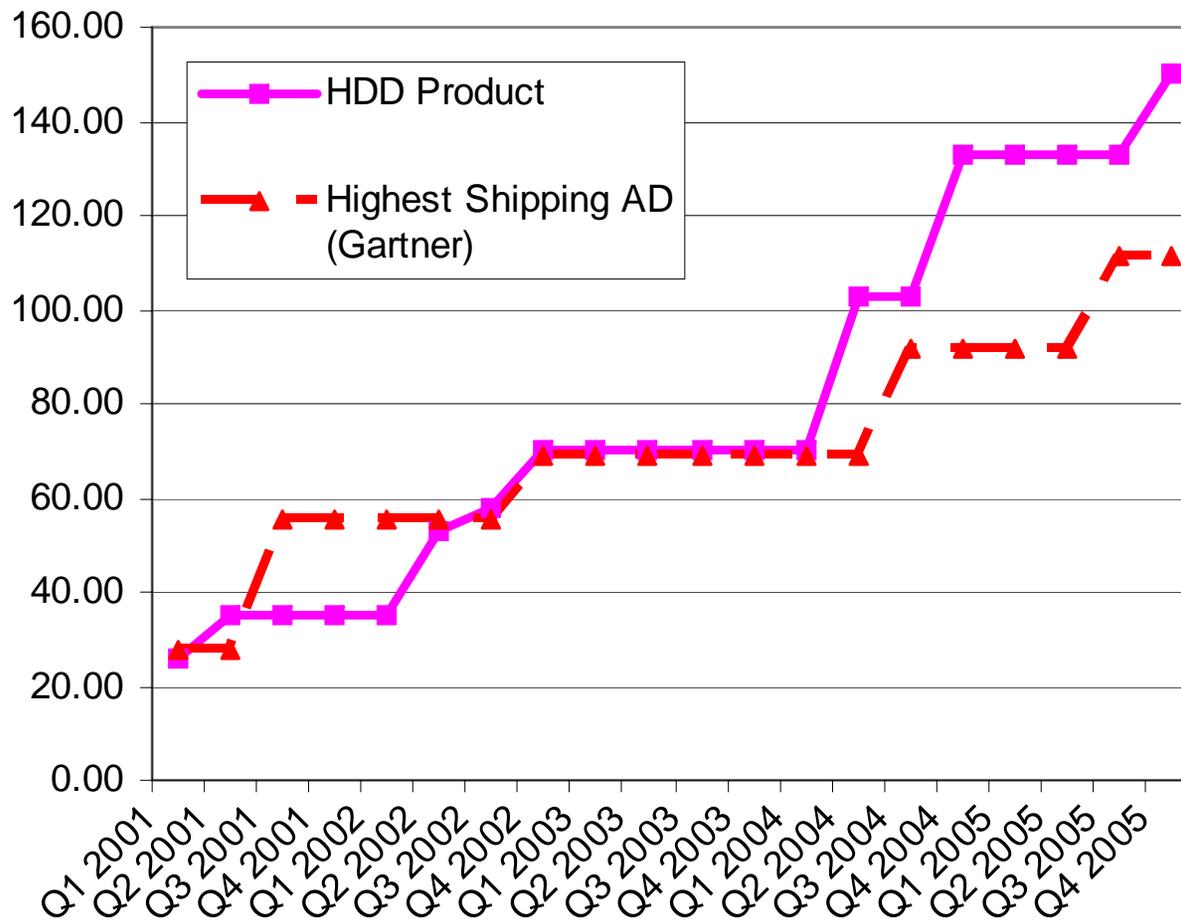


Comparison of Product Announcement Trends vs. Areal Density Rates



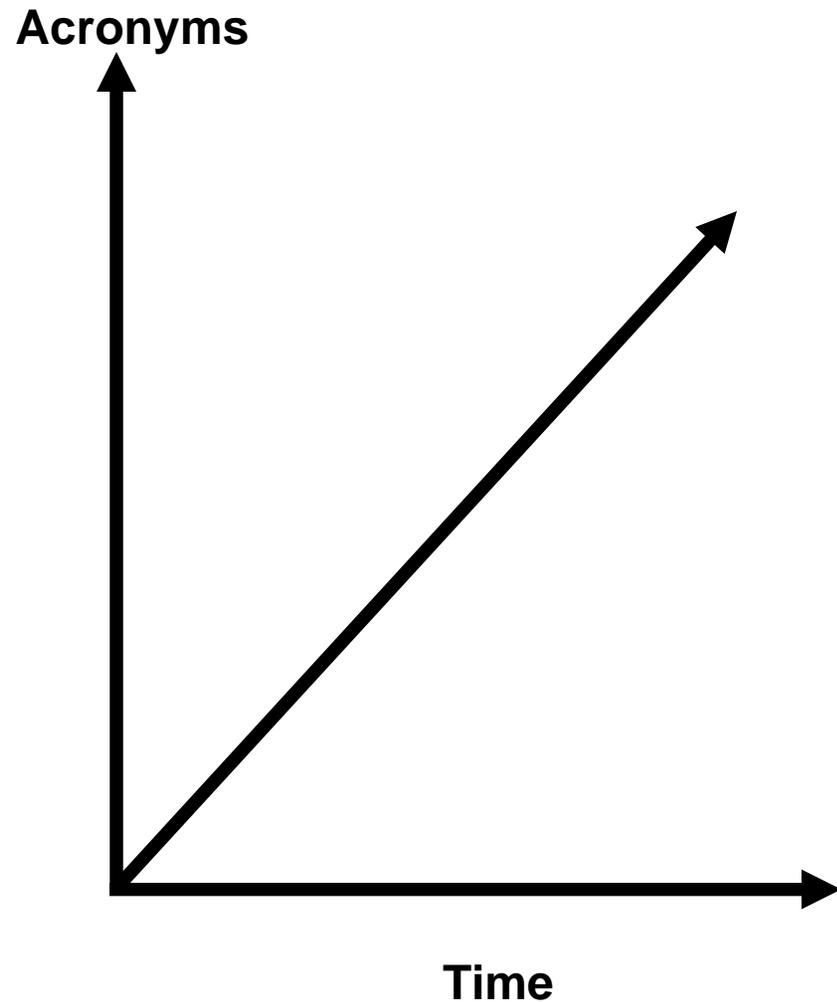
There is no single CAGR. Growth rate of technology introductions varies with time

Comparison of Announcements to Highest Shipping Areal Density (2001-2005)

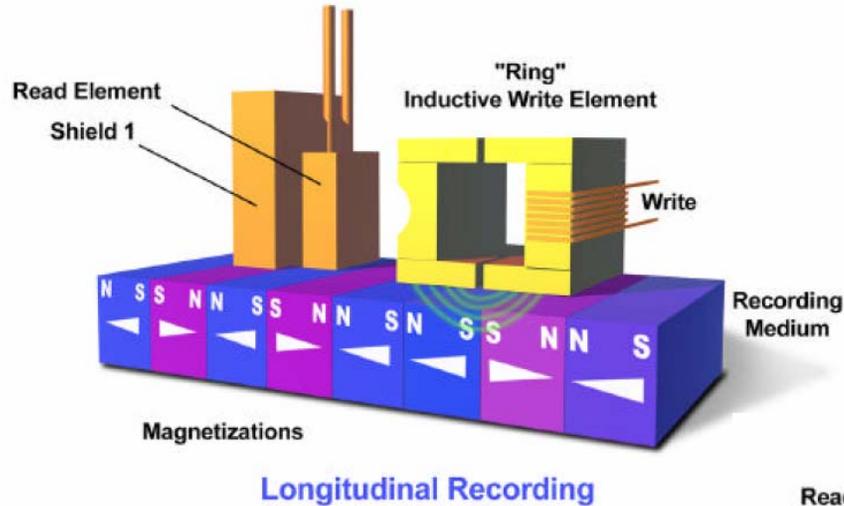


CAAGR

- However one facet of magnetic recording that appears to show steady growth is the growth of acronyms.
- Cumulative Annual Acronym Growth Rate (CAAGR) increases as shorthand for greater technology complexity

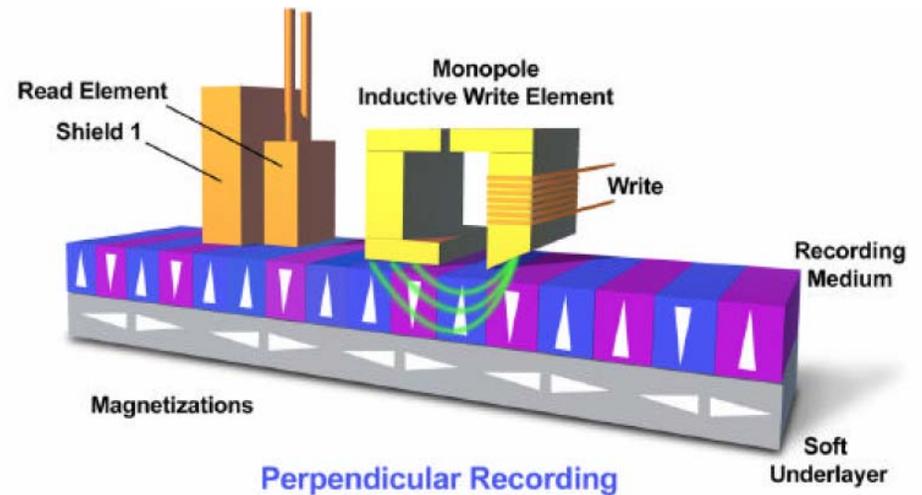


Transition from LMR to PMR

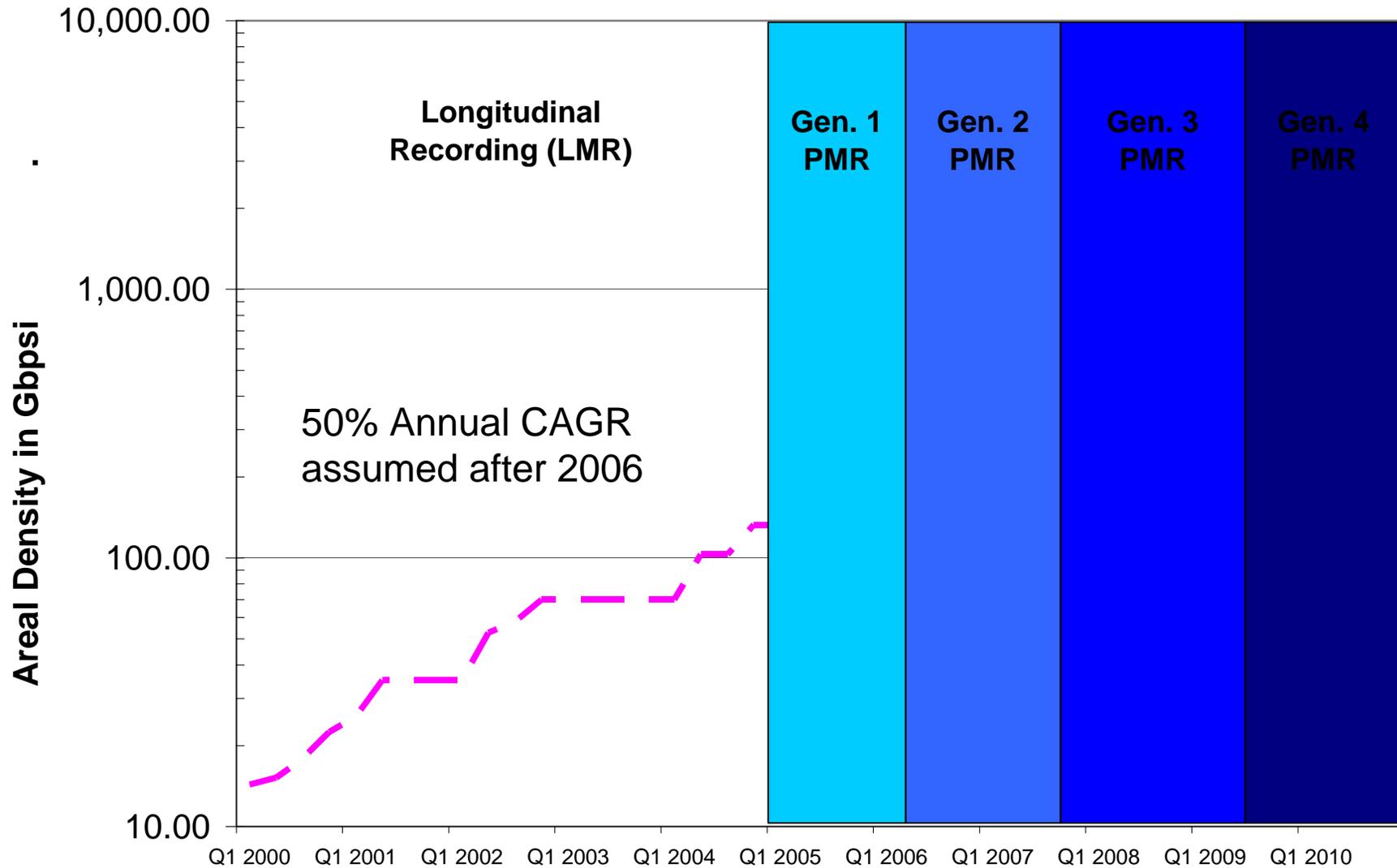


Longitudinal Recording

Perpendicular Recording



Generations of PMR Announced Products

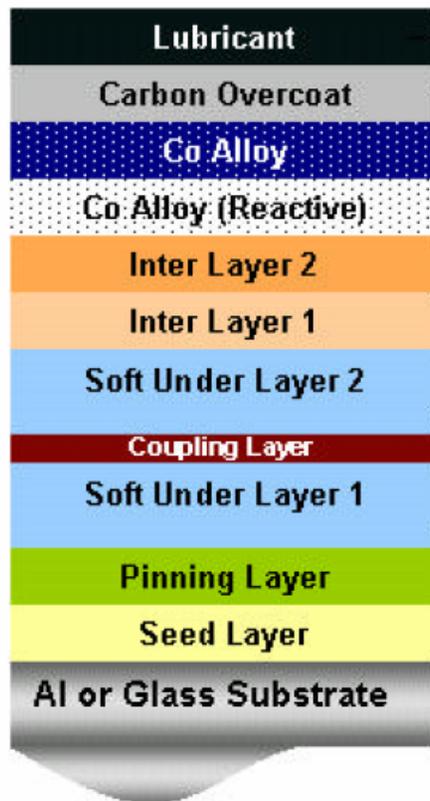


Definitions of PMR Generations

- Generation 1: Initial product introductions by Toshiba and then Seagate
- Generation 2: Current product generation—incremental improvements in PMR, greater use of TMR readers
- Generation 3: Further improvements including discrete track and/or dual-stage actuator
- Generation 4: TAR/HAMR or Patterned Media with more advanced read sensors, dual-stage actuators

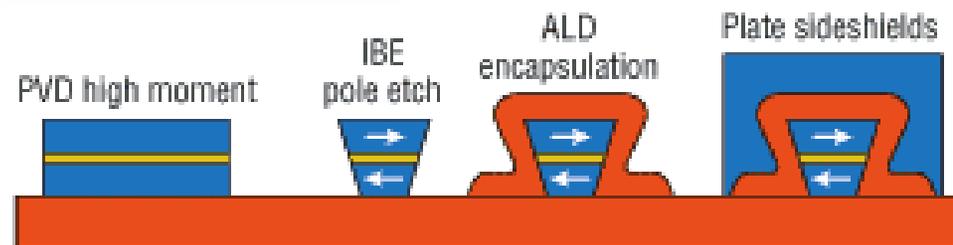
2nd Generation PMR

Key Requirements



- Surface Smoothness
- Corrosion Protection, Density
- Composition (Reactive)
- Surface & Grain Control
- Magnetic Domain Uniformity

PMR Magnetic Medium



Perpendicular Head Write Pole Formation

Tending to be TMR Heads with PMR

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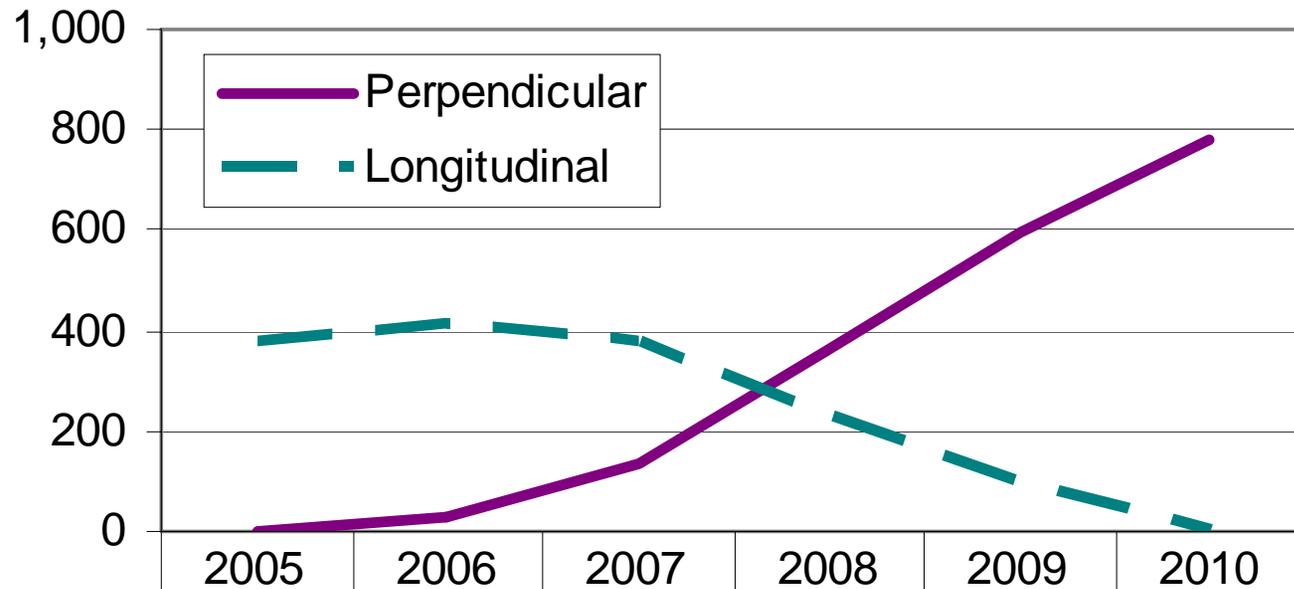
Generation 3 and 4 PMR

- Generation 3 Technology Candidates:
 - New PMR Media
 - exchange coupled composite media (ECC)
 - Exchange Spring Media (ESM)
 - Discrete track recording could also be used to increase TPI
 - Head Technologies
 - Adjustable spacing heads
 - Secondary actuator heads (cost model must improve)
 - At least TMR, maybe CPP GMR?
- Generation 4 Technology Candidates:
 - By generation 4 some companies may be incorporating initial elements of TAR/HAMR or some form of patterned media
 - Use of secondary actuators may be used to increase TPI if cost can be reduced
 - Improved read sensors such as CPP GMR or even more sensitive technologies
 - Improved encoding to recover signals with lower SNR

PMR vs. Form Factor

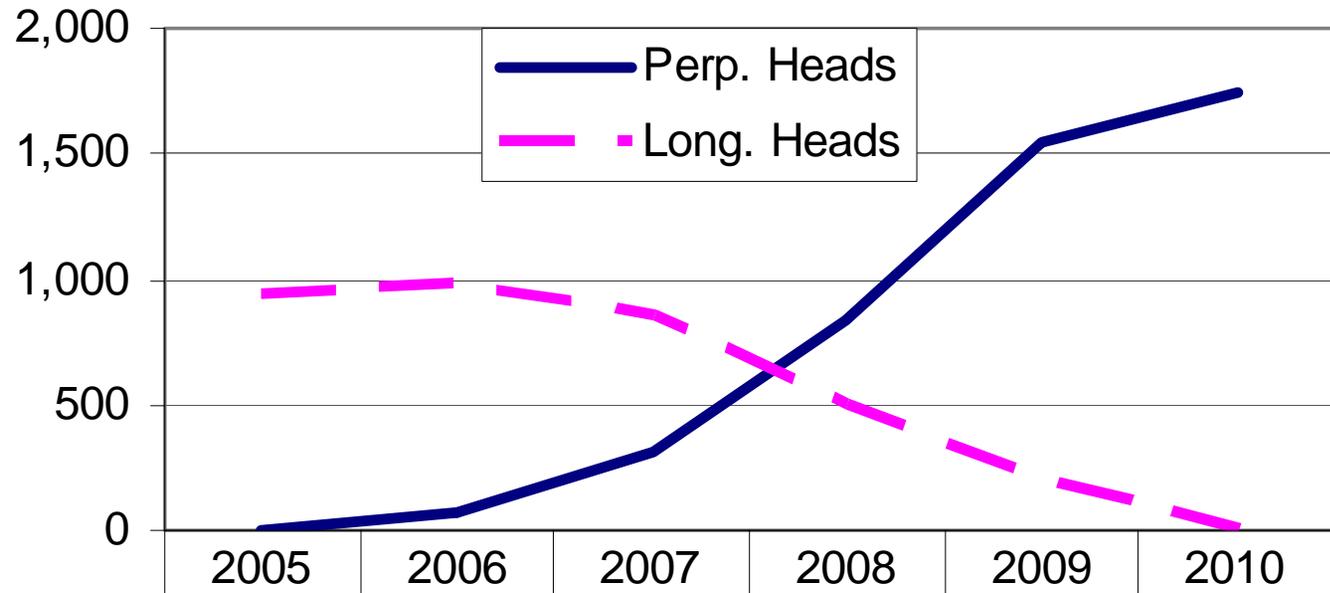
Year	2005	2006	2007	2008	2009	2010
</=1.3 inch	0.1%	10.0%	60.0%	85.0%	100.0%	100.0%
1.8 inch	1.0%	15.0%	50.0%	90.0%	100.0%	100.0%
2.5 inch	2.0%	10.0%	30.0%	70.0%	90.0%	100.0%
3.5 inch	0.0%	5.0%	20.0%	50.0%	80.0%	100.0%
Total	0.5%	7.0%	26.7%	62.0%	86.8%	100.0%

PMR vs. LMR Disk Drives (Millions)



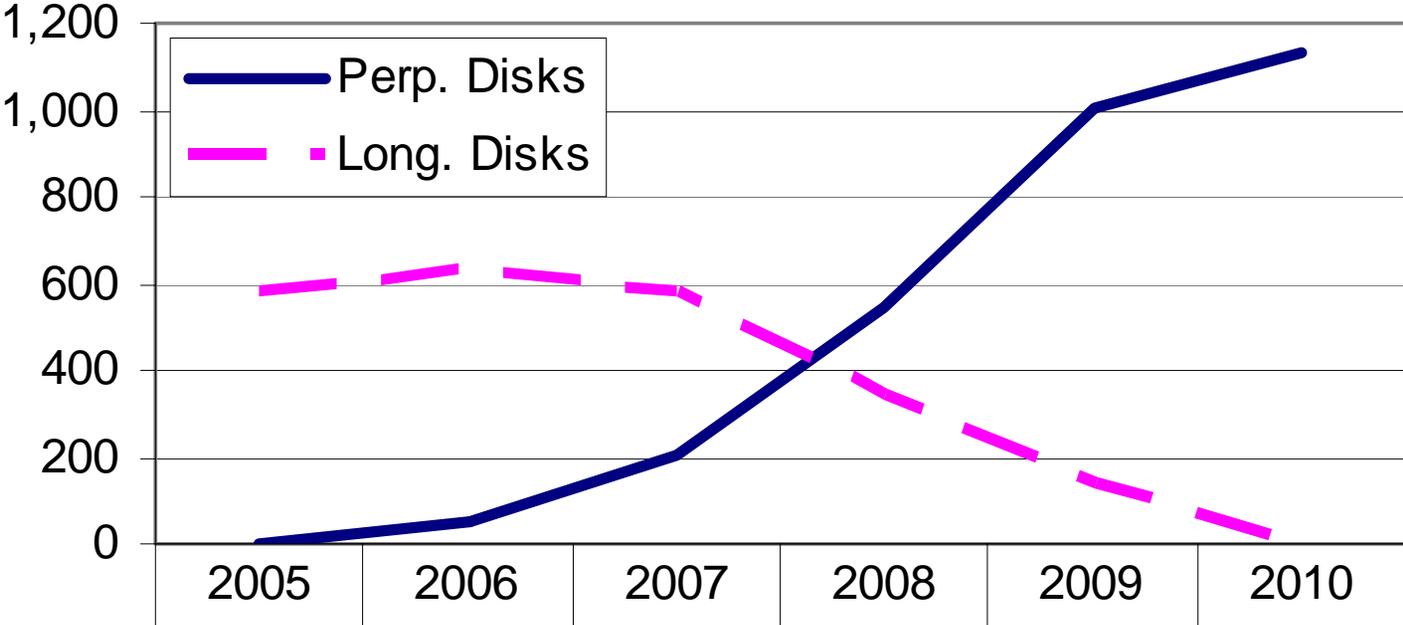
— Perpendicular	2	31	137	365	594	782
— Longitudinal	378	414	375	224	90	0

PMR and LMR Heads (Millions)



 Perp. Heads	6	77	314	834	1,552	1,742
 Long. Heads	933	980	856	499	203	0

PMR and LMR Disks (Millions)

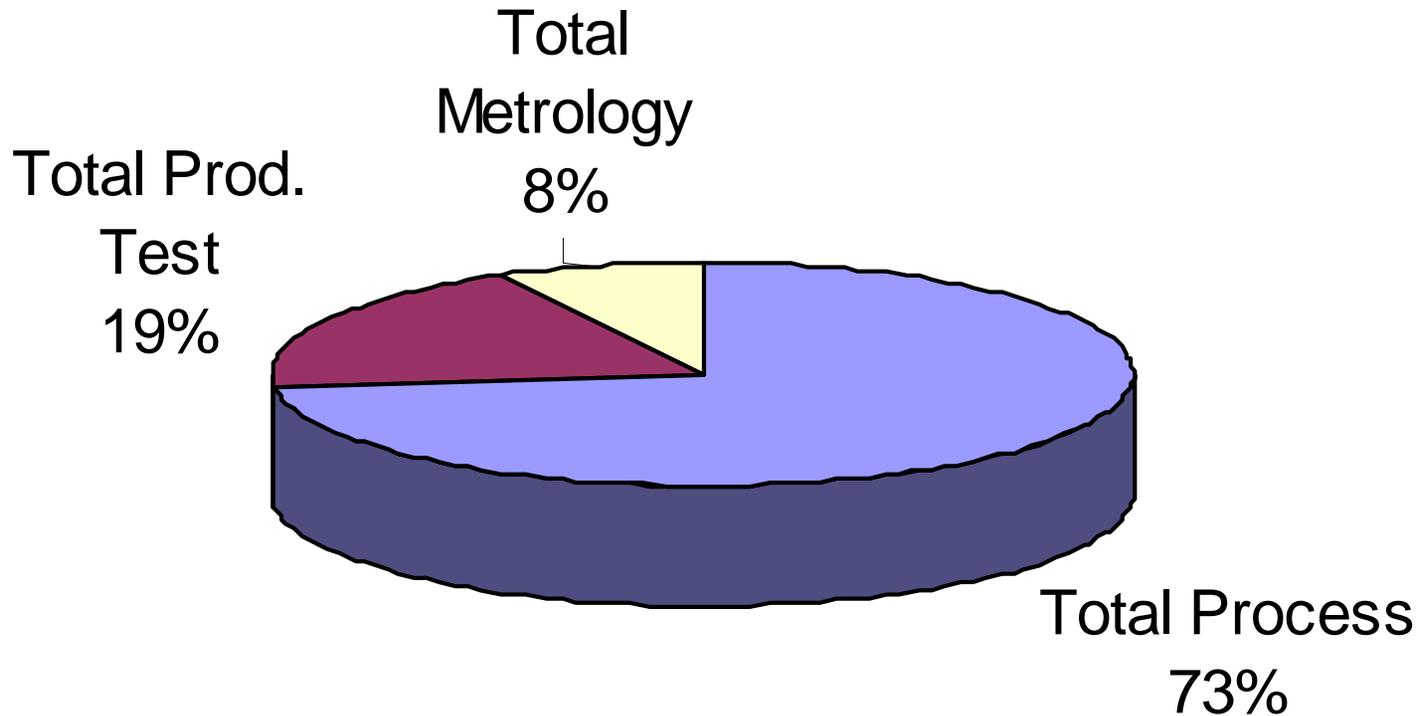


— Perp. Disks	4	49	205	545	1,008	1,128
- - Long. Disks	579	633	576	338	136	0



HDD Capital Spending Trends

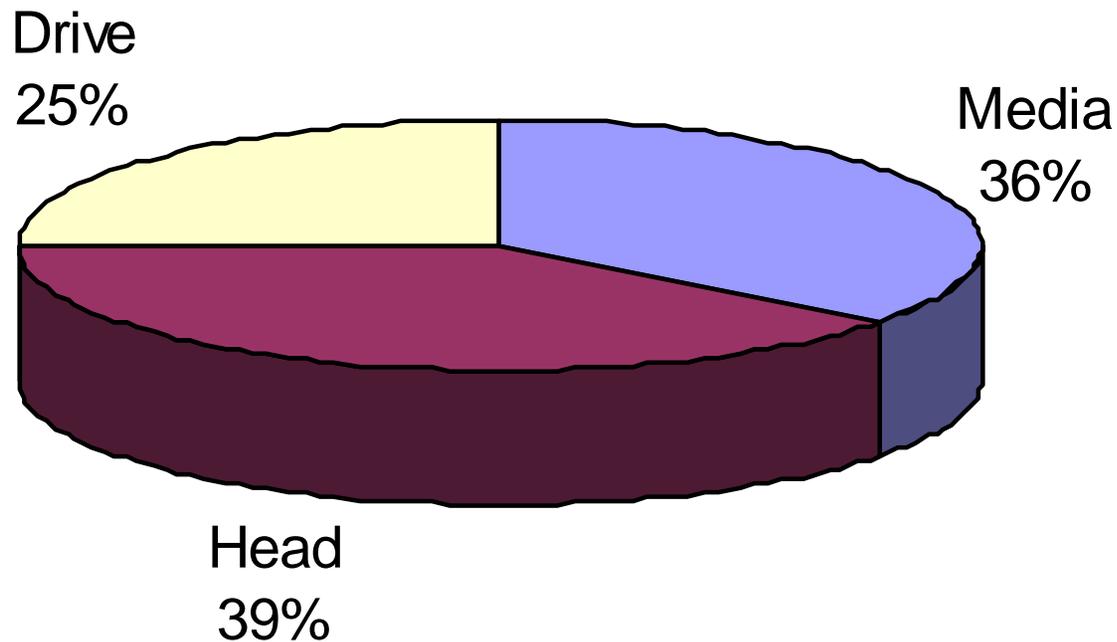
2005 Capital Equipment Spending Breakdown



Total 2005 Capital Equipment Spending ~\$2.2 B

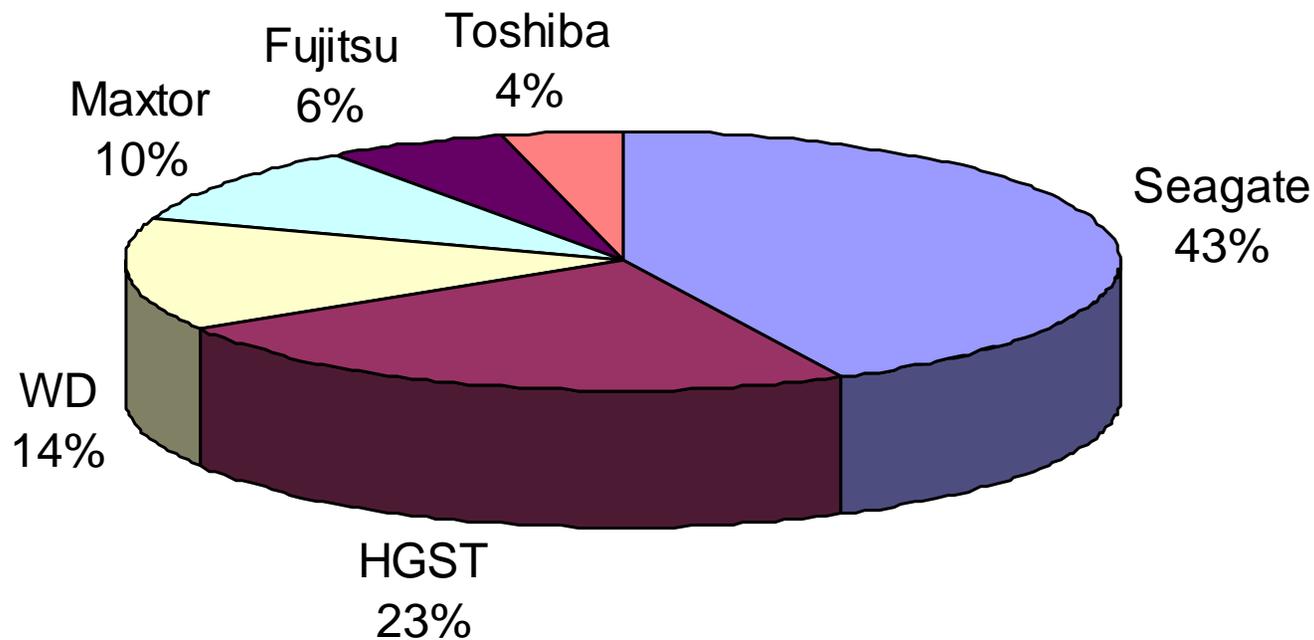
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2005 Capital Equipment Spending by Component Market Segment



Total Capital Equipment Spending ~\$2.2 B

2005 HDD Company Capital Equipment Spending Estimates (Percentage of Whole) (includes media/head capital equipment)



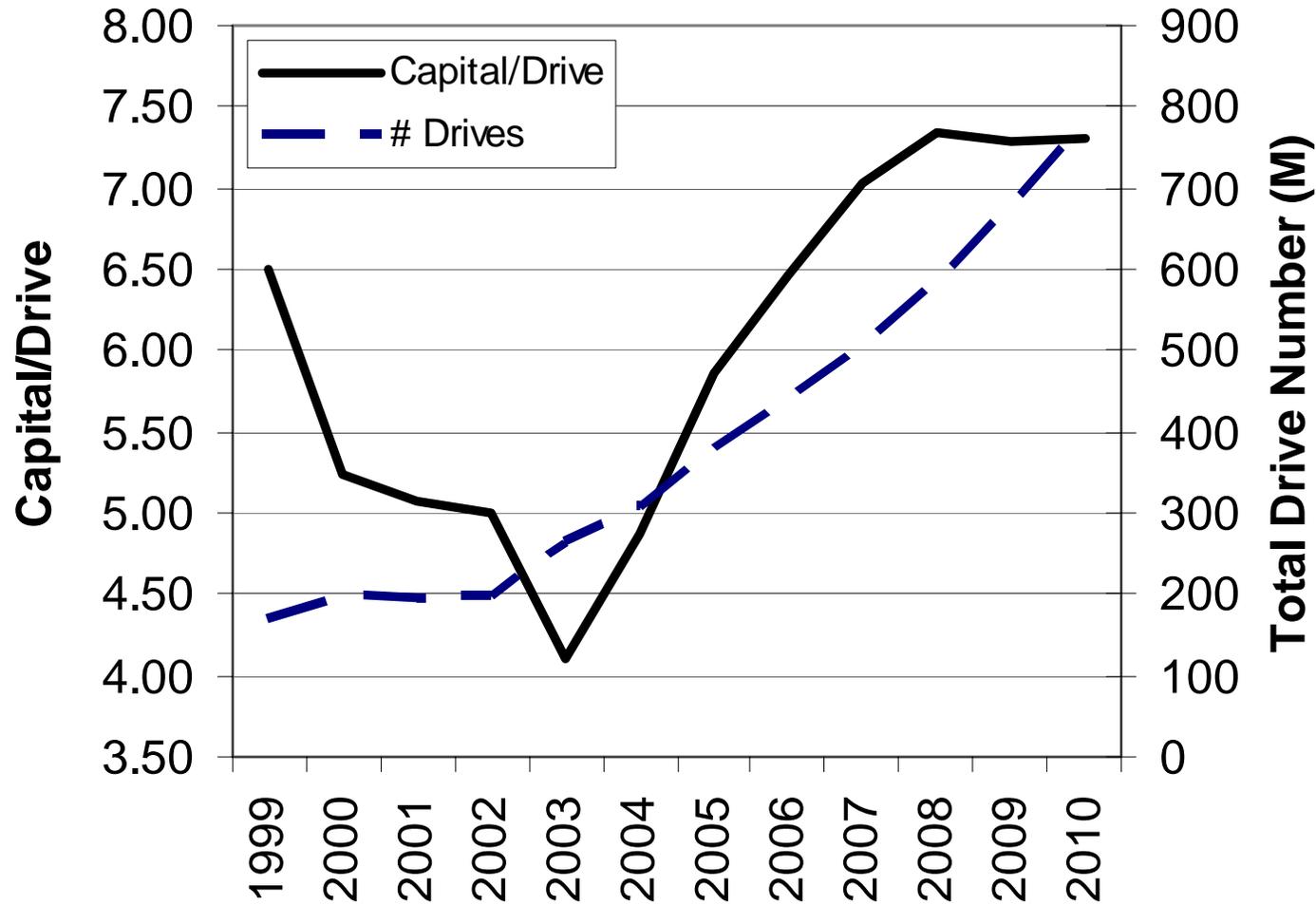
Drivers for Capital Equipment Spending to 2010

- Annual drive volumes increasing ~2X by 2010 from 2005
- Form factors ratio changes: 2.5-inch and smaller HDDs to dominate by 2010
- New HDD applications may require new manufacturing capital equipment and process changes
- Transition to perpendicular recording making much older equipment obsolete
- Lower flying heights and smaller bits increasing metrology requirements, contamination control, as well as tightening of head and disk specifications
- By 2009 and 2010 to continue areal density increases the industry must introduce new technologies such as HAMR, discrete track media or fully patterned media

Capital Equipment Spending Estimates vs. Total Disk Drive Revenue

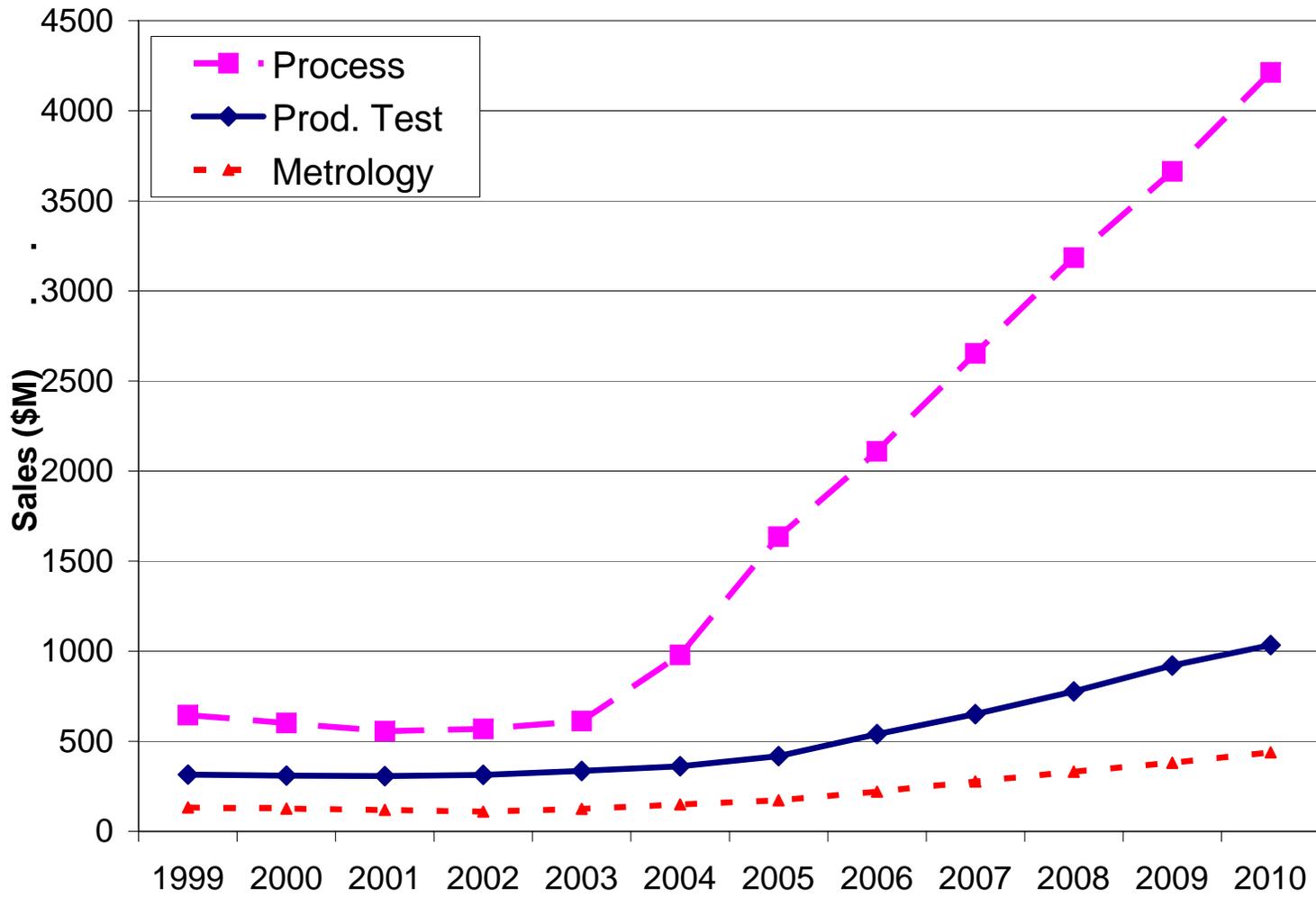
Year	Total HDD Company Est. Revenue	Total HDD Industry Capital Est. Equipment Spending	Percentage Capital Equipment Spending/ Revenue
2005	\$28.1 B	\$2.23 B	7.9%
2006	\$32.4 B	\$2.87 B	8.9%
2007	\$36.6 B	\$3.62 B	9.9%
2008	\$41.5 B	\$4.29 B	10.3%
2009	\$47.7 B	\$4.96 B	10.4%
2010	\$53.6 B	\$5.68 B	10.6%
Total (2006- 2010)	\$239.9 B	\$23.65 B	10.1% (avg.)

Capital Equipment Spending and Number of Drives Trends



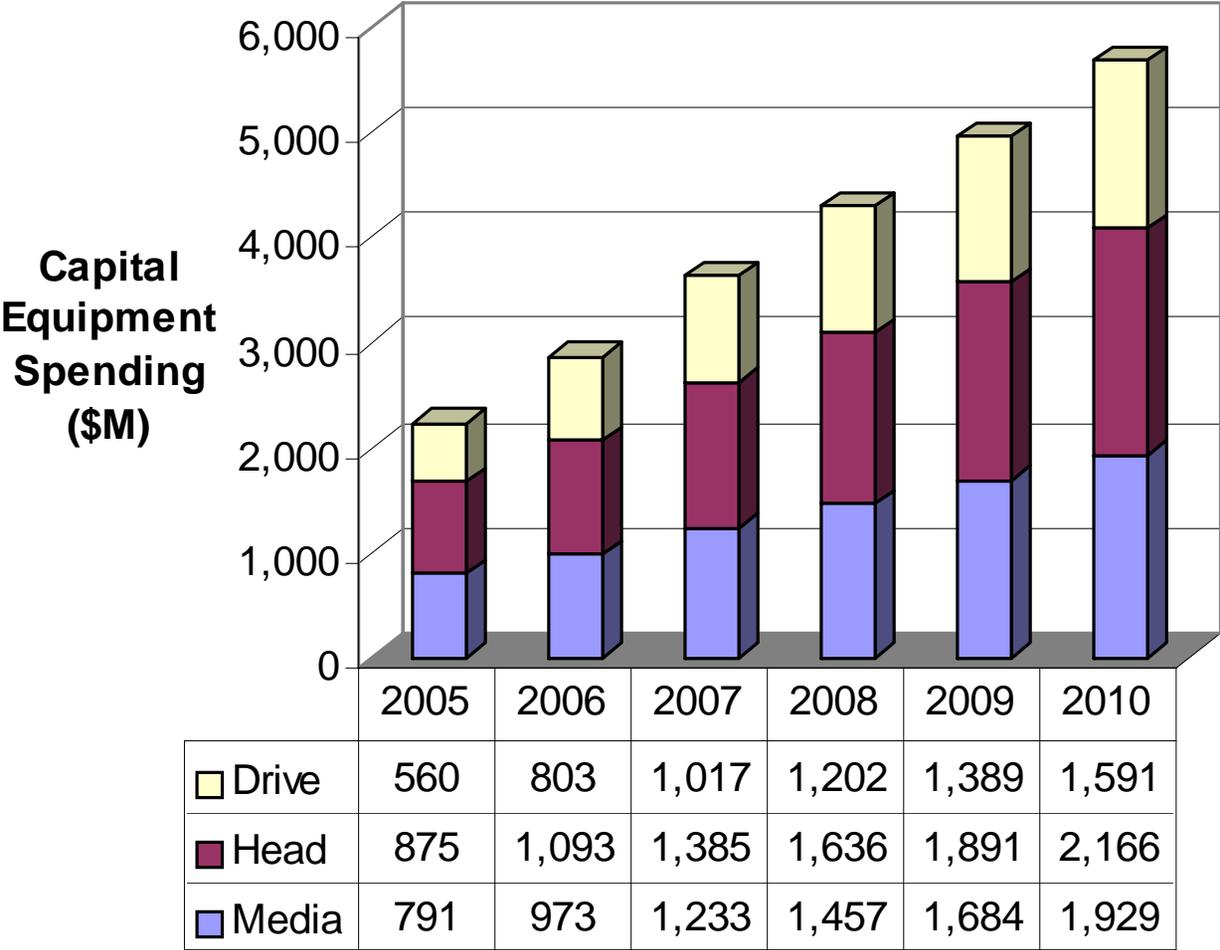
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Capital Equipment Spending Projection Summary



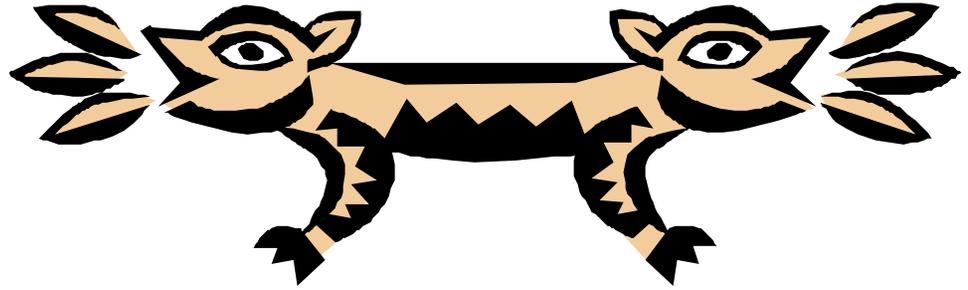
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HDD Capital Equipment Spending Projections



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Conclusions



- Projecting 445 M HDDs in 2006
- We project strong growth in HDDs through 2010 and a significant increase in the percentage of HDDs that are used for CE and mobile computer applications as well as smaller form factors
- Areal density product growth is an irregular process
- Areal density growth using perpendicular recording will drive four generations of products by 2010.
- All HDDs expected to use PMR by the end of 2009
- Technology transitions will drive about \$23 B capital spending by the industry by 2010

Sources

- **2006 Hard Disk Drive Capital Equipment Market and Technology Report, Coughlin Associates**

For more information go to the tech papers section of www.tomcoughlin.com



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