A TeraByte in Your Pocket and a PetaByte in your Home
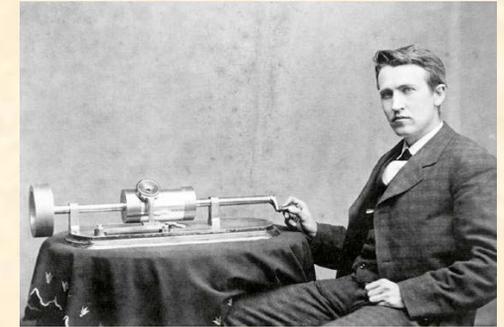
Trends and Opportunities for Data Storage
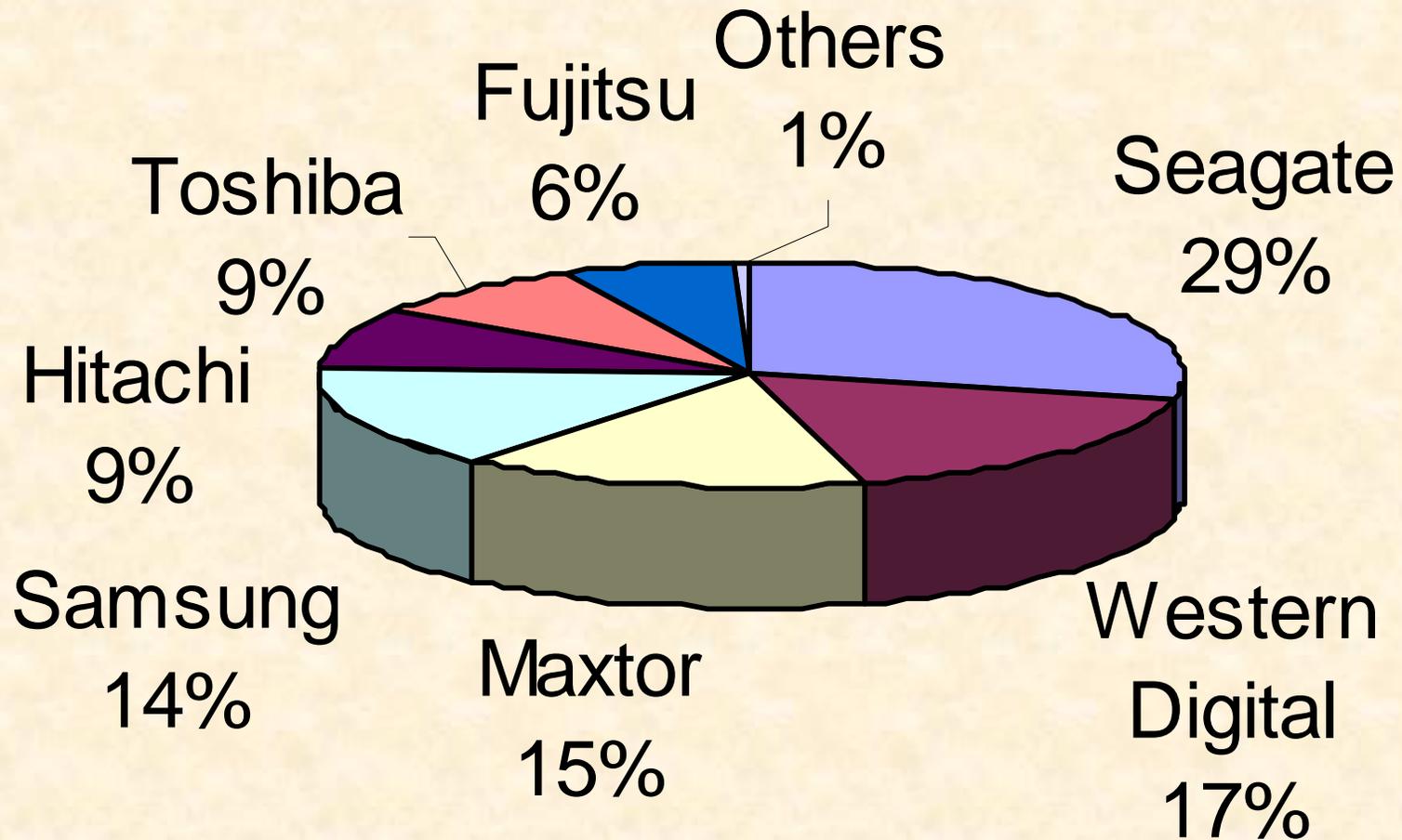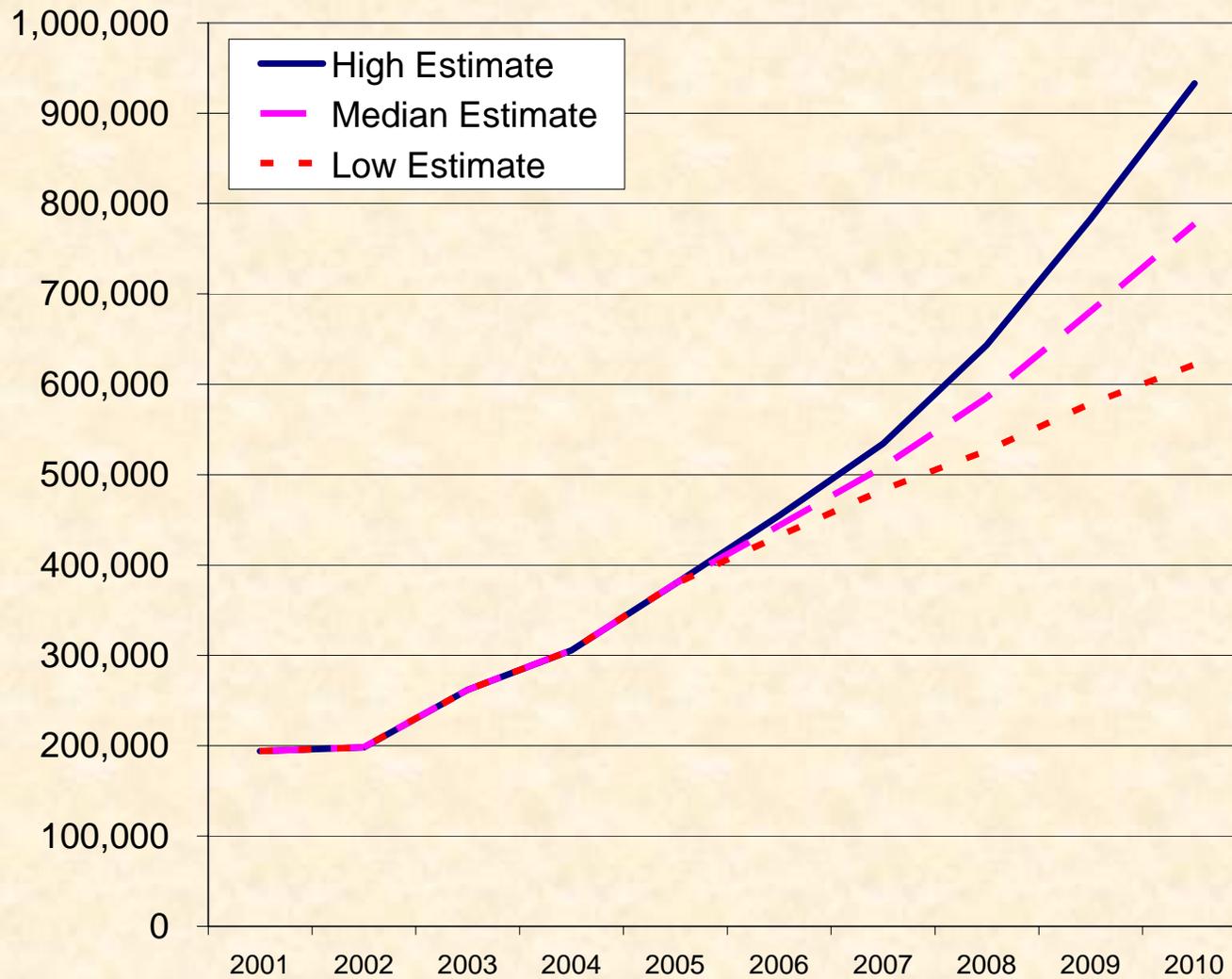
Tom Coughlin

Coughlin Associates

Outline

- A Quick Discussion of the HDD Industry
- New Applications for HDD
- Home storage hierarchies, how to choose the proper storage for an application
- New roles for HDDs in CE applications
- Home storage networks and the home storage utility

Quick Update on HDD Industry

2005 Total Drive Percentages

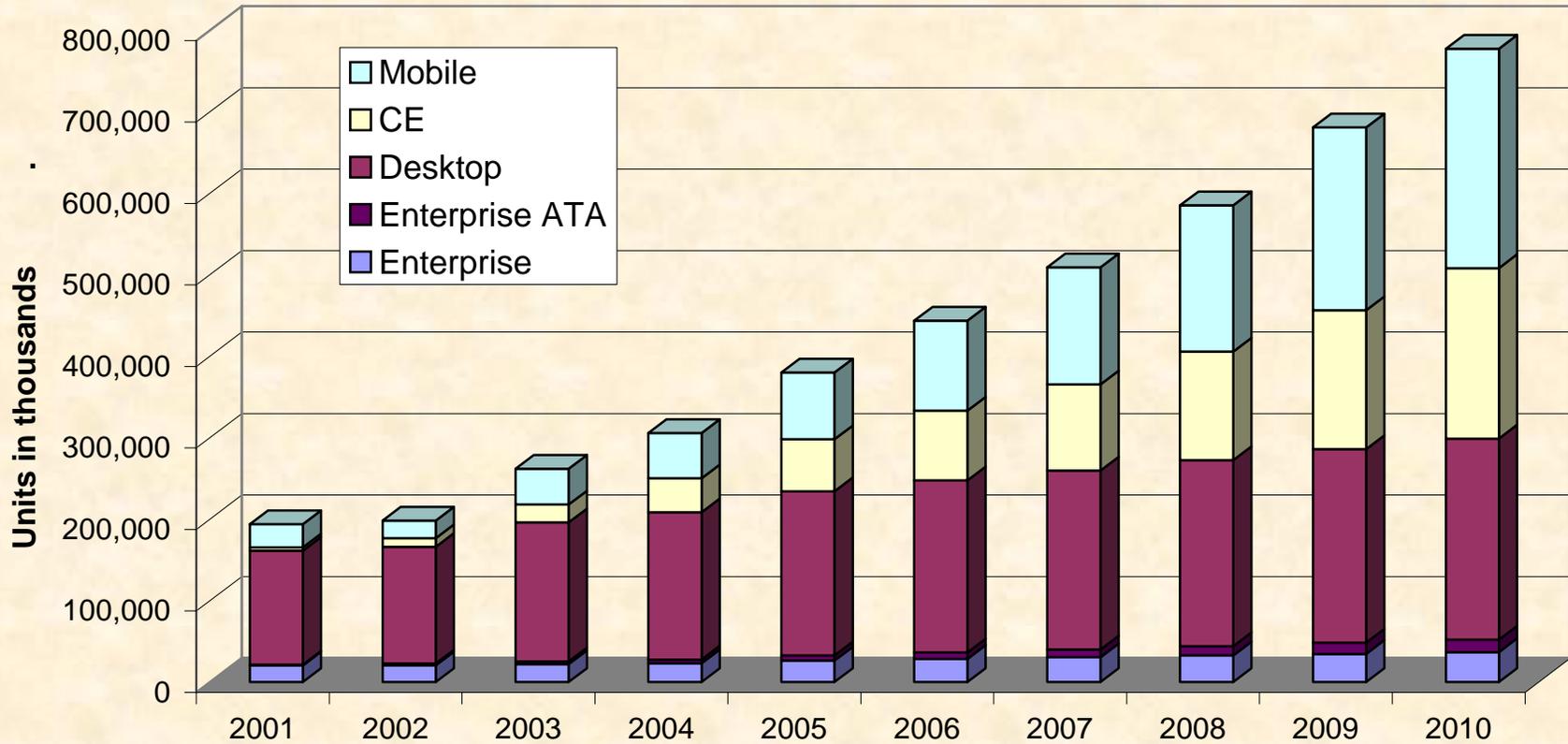Others 1%

Fujitsu 6%

Toshiba 9%

Hitachi 9%

Samsung 14%

Maxtor 15%

Seagate 29%

Western Digital 17%

Banded Hard Drive Volume Projections
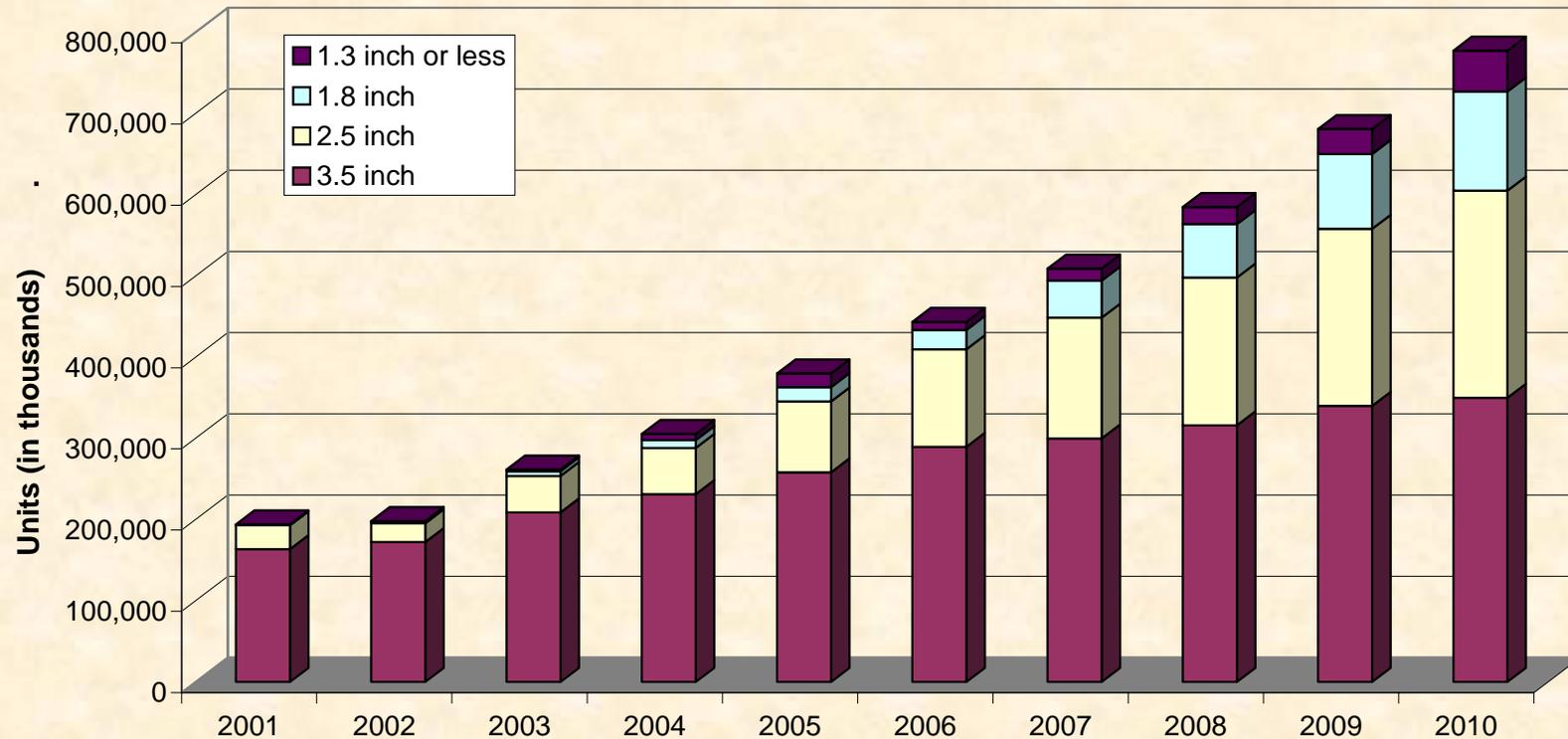
HDD Market Niche Projections

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

	2004	2005	2006	2007	2008	2009	2010
HDD	305,603	379,900	442,537	513,002	587,232	666,991	753,157
Heads	837,800	1,139,020	1,371,863	1,564,656	1,761,697	1,967,624	2,184,155
Disks	488,200	604,300	690,357	790,023	892,593	1,000,487	1,114,672
SPM	323,939	400,869	469,089	543,782	622,466	707,011	798,346

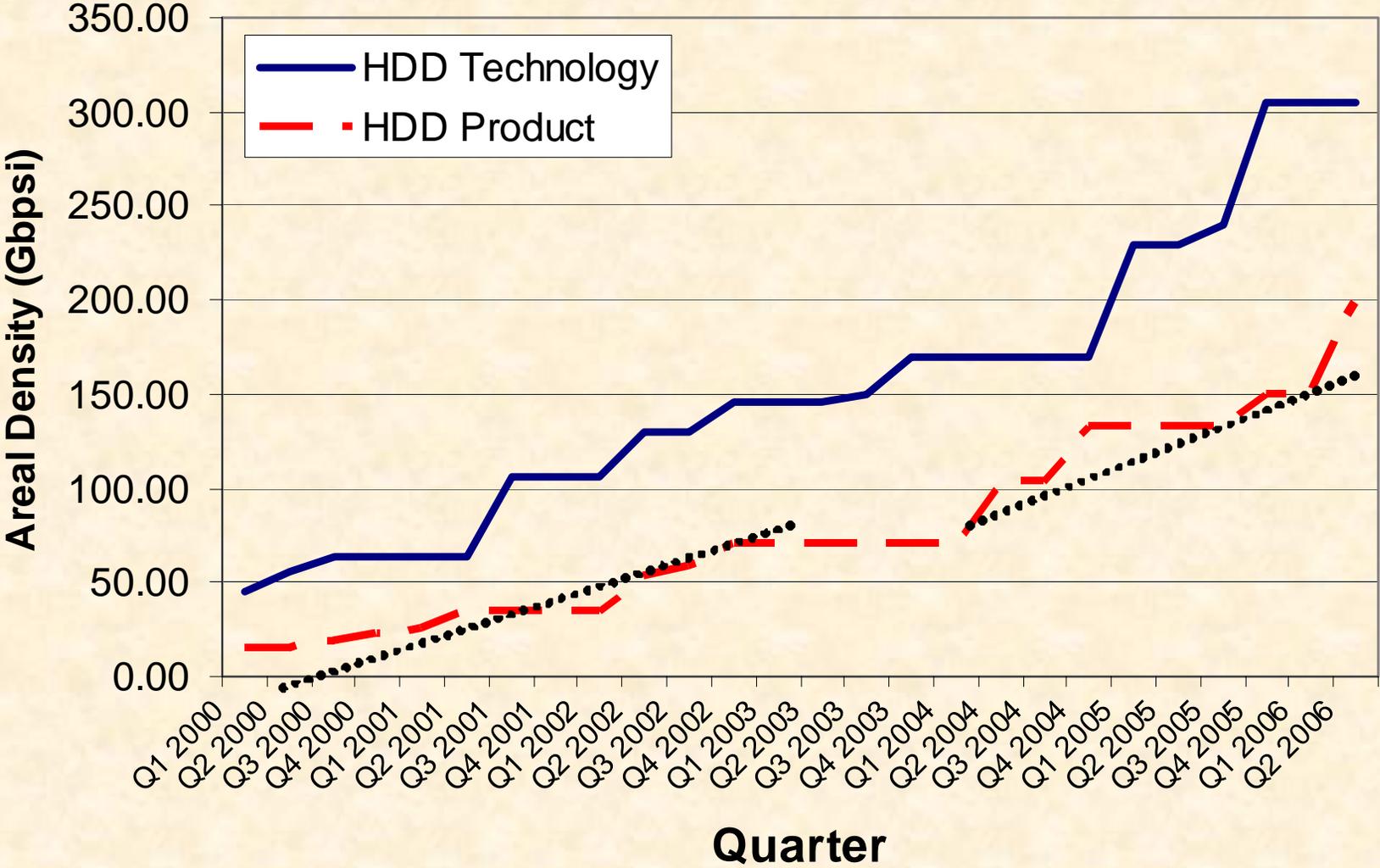| HEAD /HDD	2.74	3.01	3.10	3.05	3.00	2.95	2.90
DISK/HDD	1.60	1.58	1.56	1.54	1.52	1.50	1.48
SPM	1.06	1.06	1.06	1.06	1.06	1.06	1.06
Head/Media	1.72	1.90	1.99	1.98	1.97	1.97	1.96

AVERAGE DRIVE PRICE TREND FOR SEAGATE, WESTERN DIGITAL AND MAXTOR (Q4 '98 to Q1 '06)
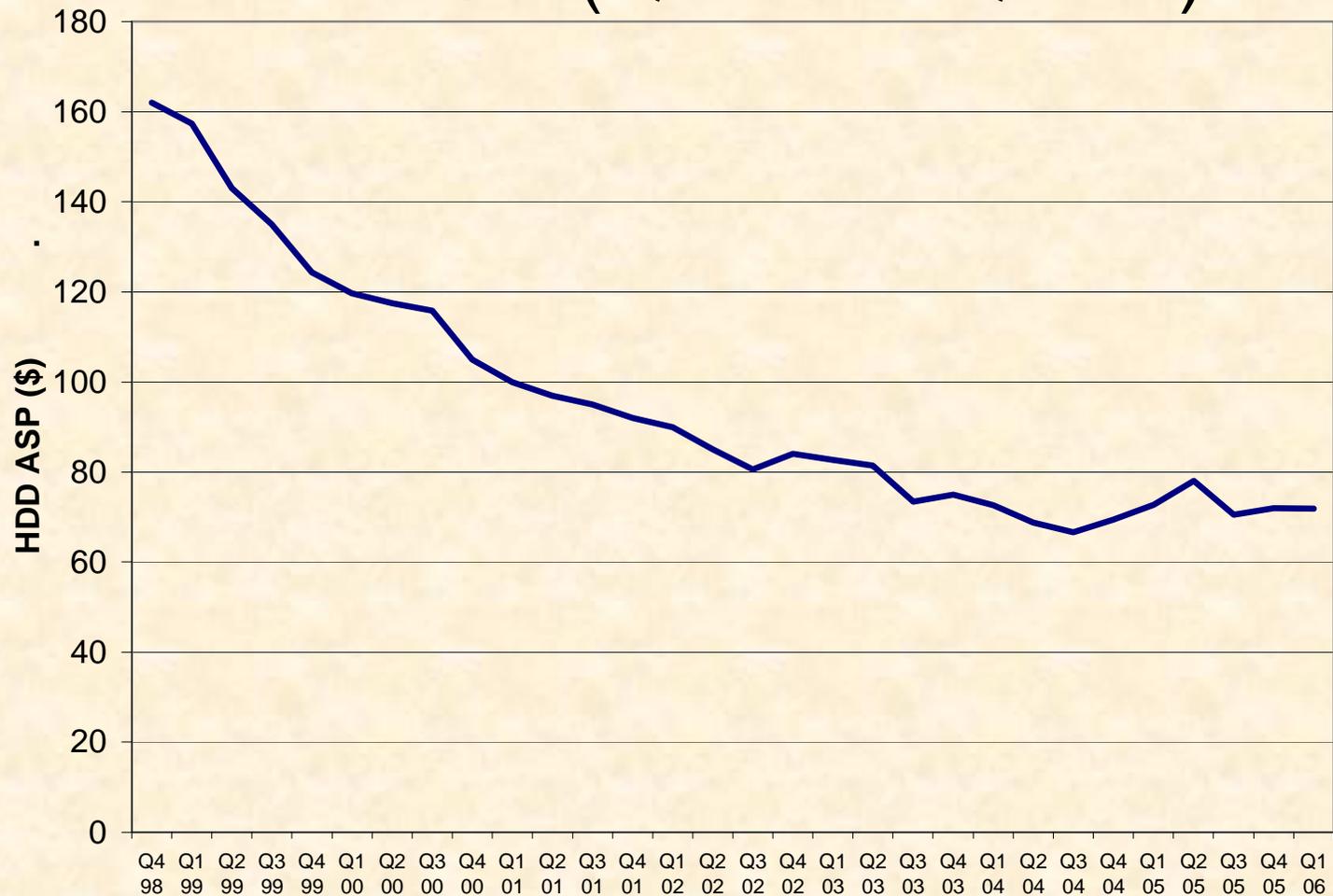
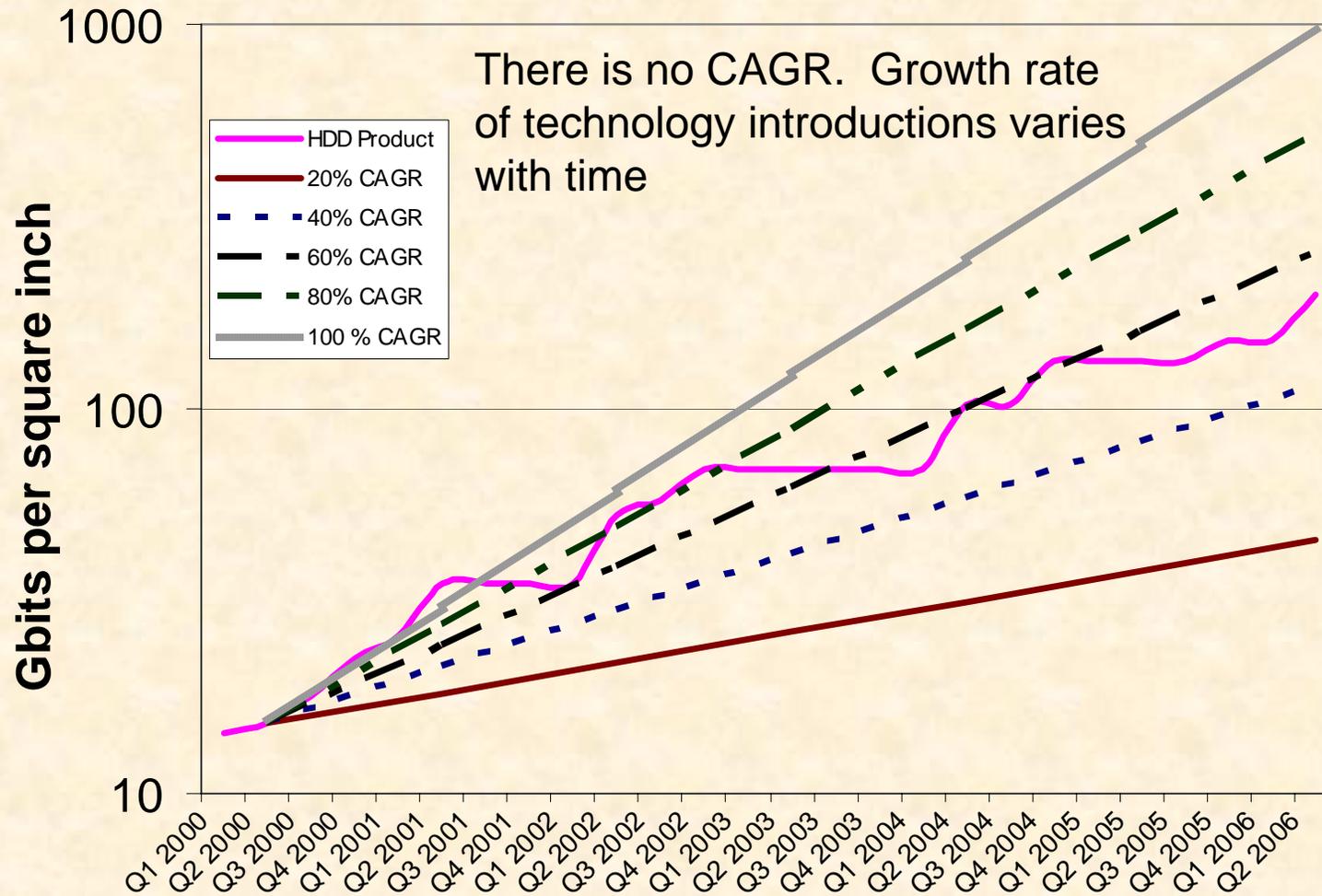© 2005 Coughlin Associates

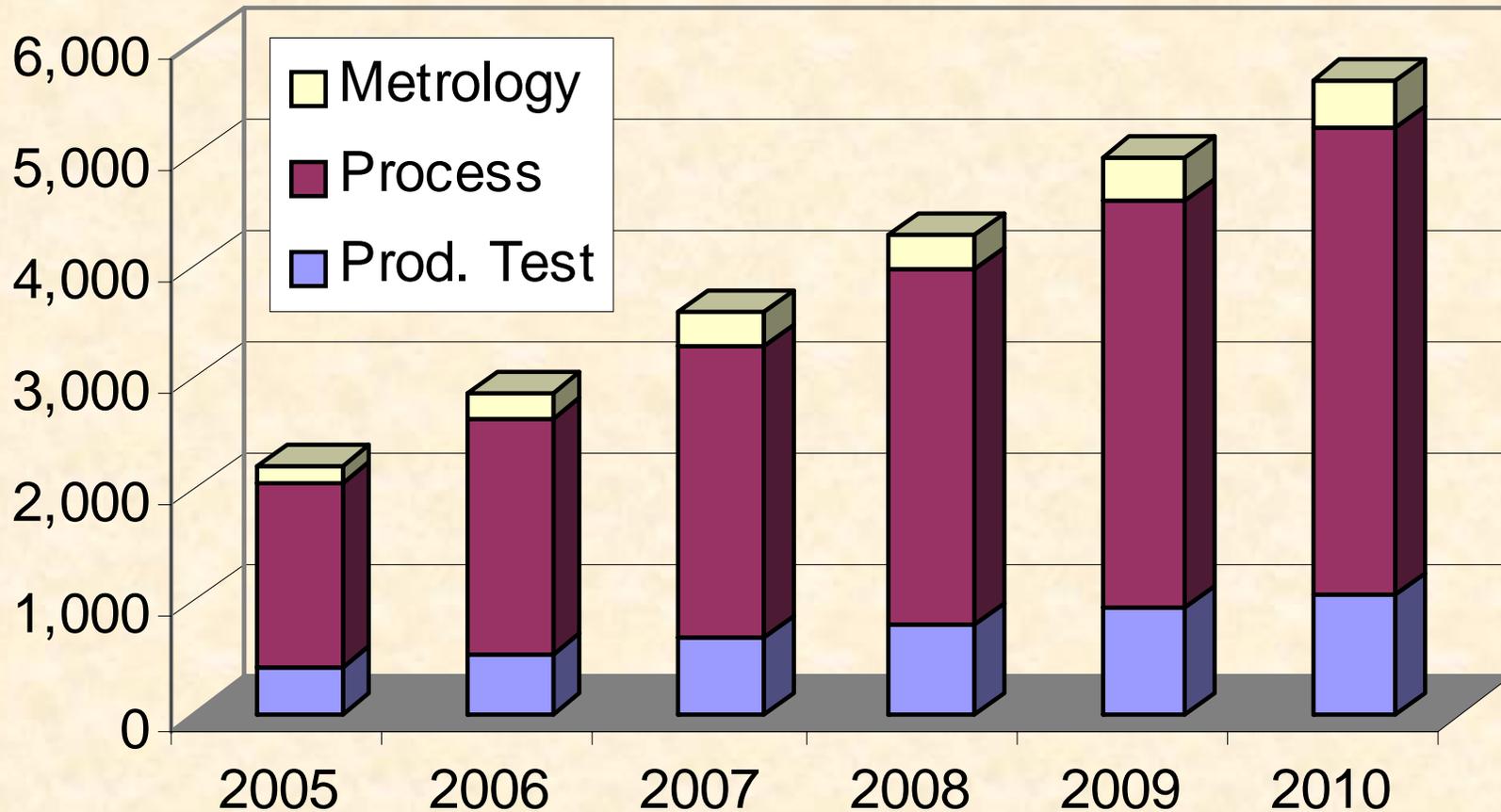# HDD Quarter by Quarter Public Technology Demonstrations and Product Announcements
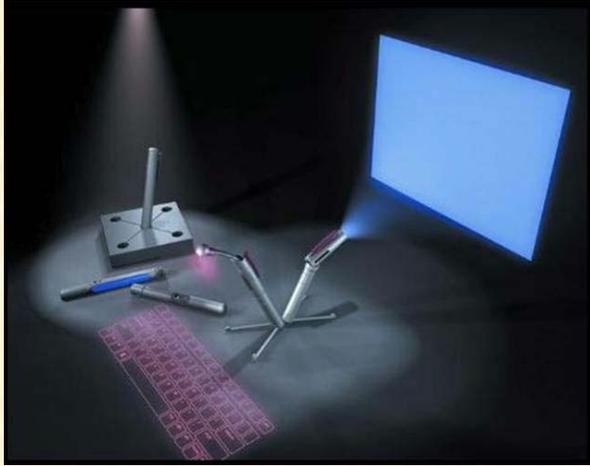

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Comparison of Product Announcement Trends vs. Areal Density Rates

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

Legend:
- HDD Product
- 20% CAGR
- 40% CAGR
- 60% CAGR
- 80% CAGR
- 100 % CAGR

Y-axis: Gbits per square inch (10, 100, 1000)

X-axis: Q1 2000, Q2 2000, Q3 2000, Q4 2000, Q1 2001, Q2 2001, Q3 2001, Q4 2001, Q1 2002, Q2 2002, Q3 2002, Q4 2002, Q1 2003, Q2 2003, Q3 2003, Q4 2003, Q1 2004, Q2 2004, Q3 2004, Q4 2004, Q1 2005, Q2 2005, Q3 2005, Q4 2005, Q1 2006, Q2 2006

# Capital Equipment Spending Projection Breakdown

What will your life be like in 2010?

- 5 TB of first-instance content digital capacity in a tech savvy home
- As much as double this amount of digital storage including copies of content
- 100+ GB mobile devices (using fuel cells to remove many power limitations?)
- Higher definition content available boasting storage requirements
- Consumer applications integrated in storage devices to reduce costs and resulting prices
- Beginning of integrated home storage pool with in-home data analysis and metadata tagging

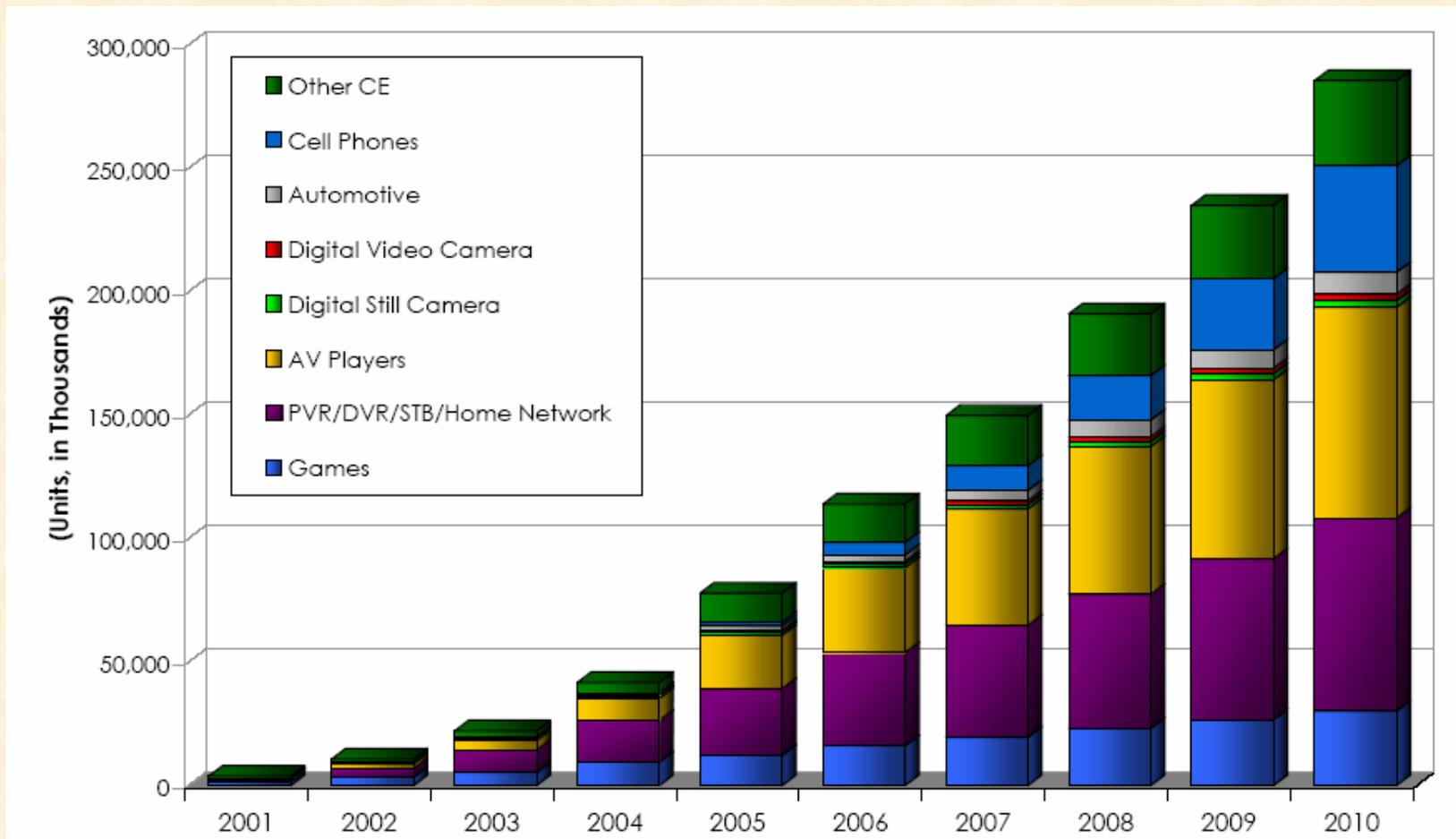# Cumulative Original-Instance Home Storage Capacity
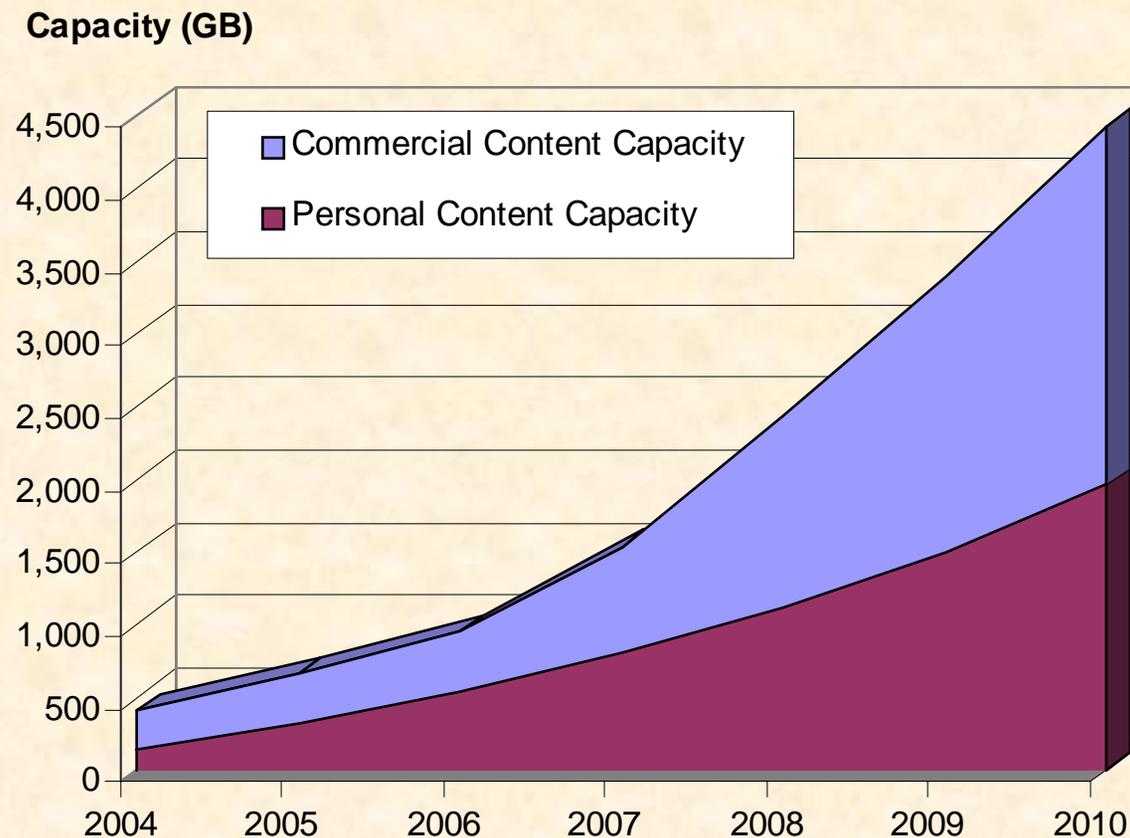
Almost 5 TB of combined personal reference data and home commercial content by 2010

Consumer Products Using HDDs

HDDs for Consumer Applications, Units Shipments

Consumer Electronics Storage Hierarchies

Storage Hierarchy

- Ordering storage options by some criteria important to the application
- The important characteristics become clear as the application matures
- Sometimes advantages for overall system performance comes from combining multiple memory options in a device: e.g. DRAM and HDD mass storage in a computer or flash memory in a hybrid HDD
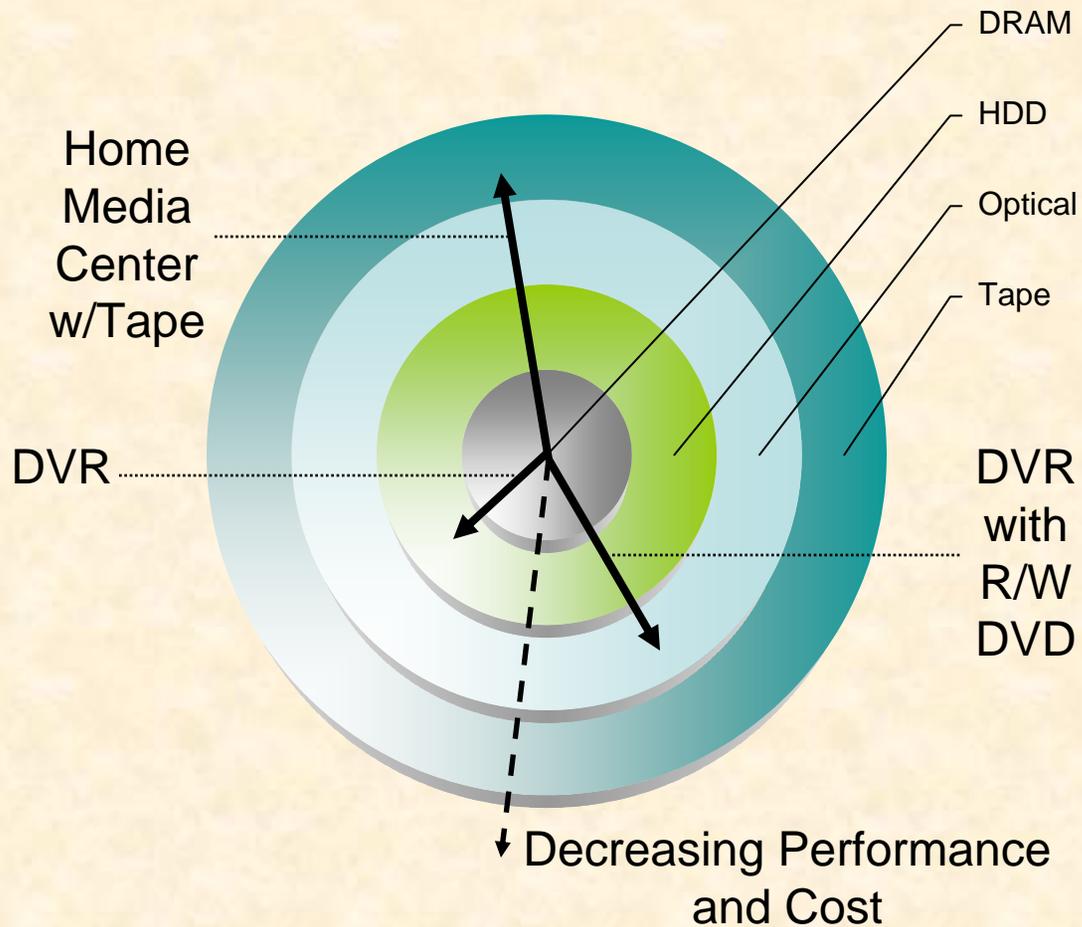
System View - Designs
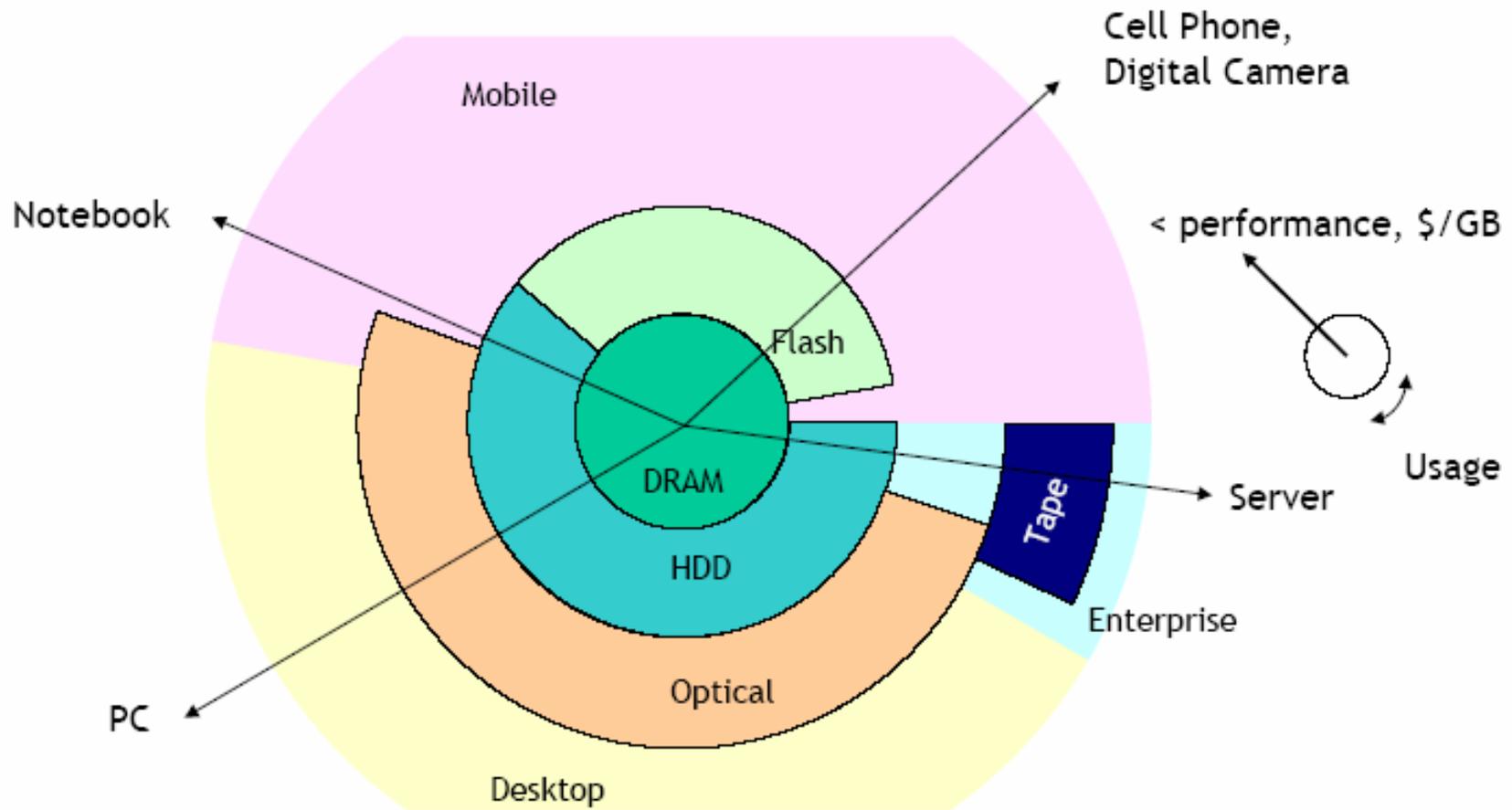
- Radial line is a system design

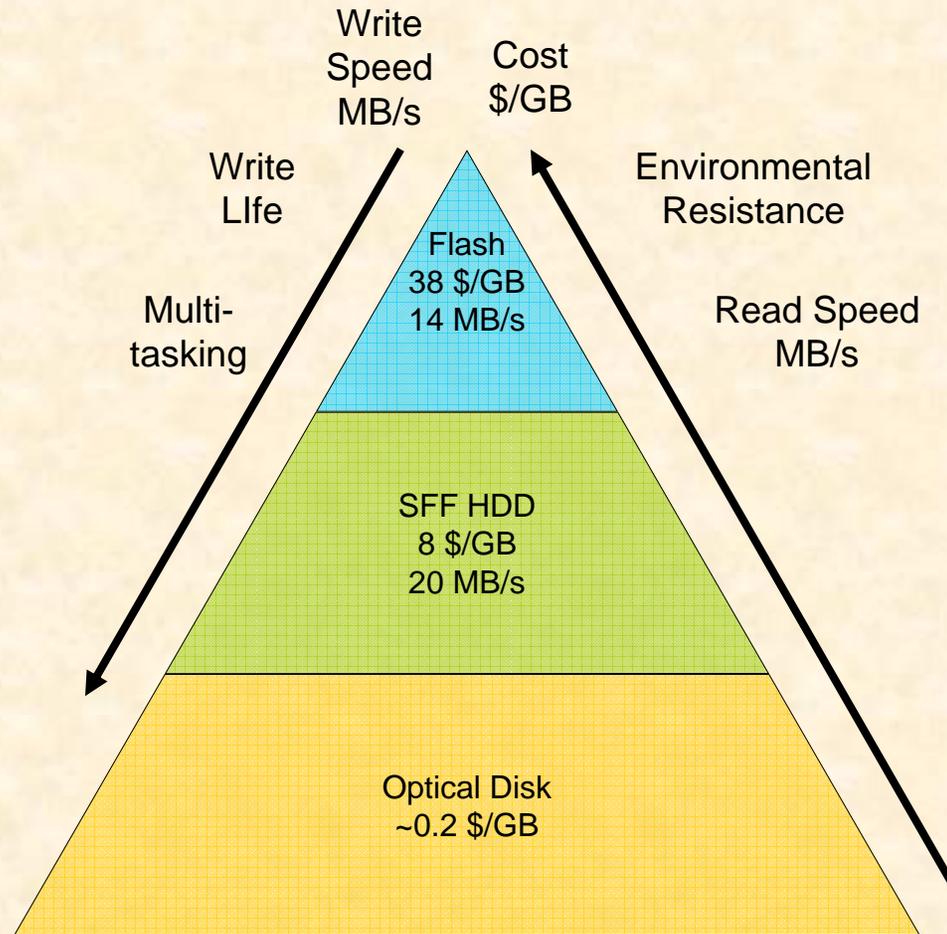# DVR/PVR Storage Hierarchy
(Static CE Application)

Mobile Storage Hierarchy

Write
Speed
MB/s

Cost
$/GB

Write
LIfe

Environmental
Resistance

Flash
38 $/GB
14 MB/s

Multi-
tasking

Read Speed
MB/s

SFF HDD
8 $/GB
20 MB/s

Optical Disk
~0.2 $/GB
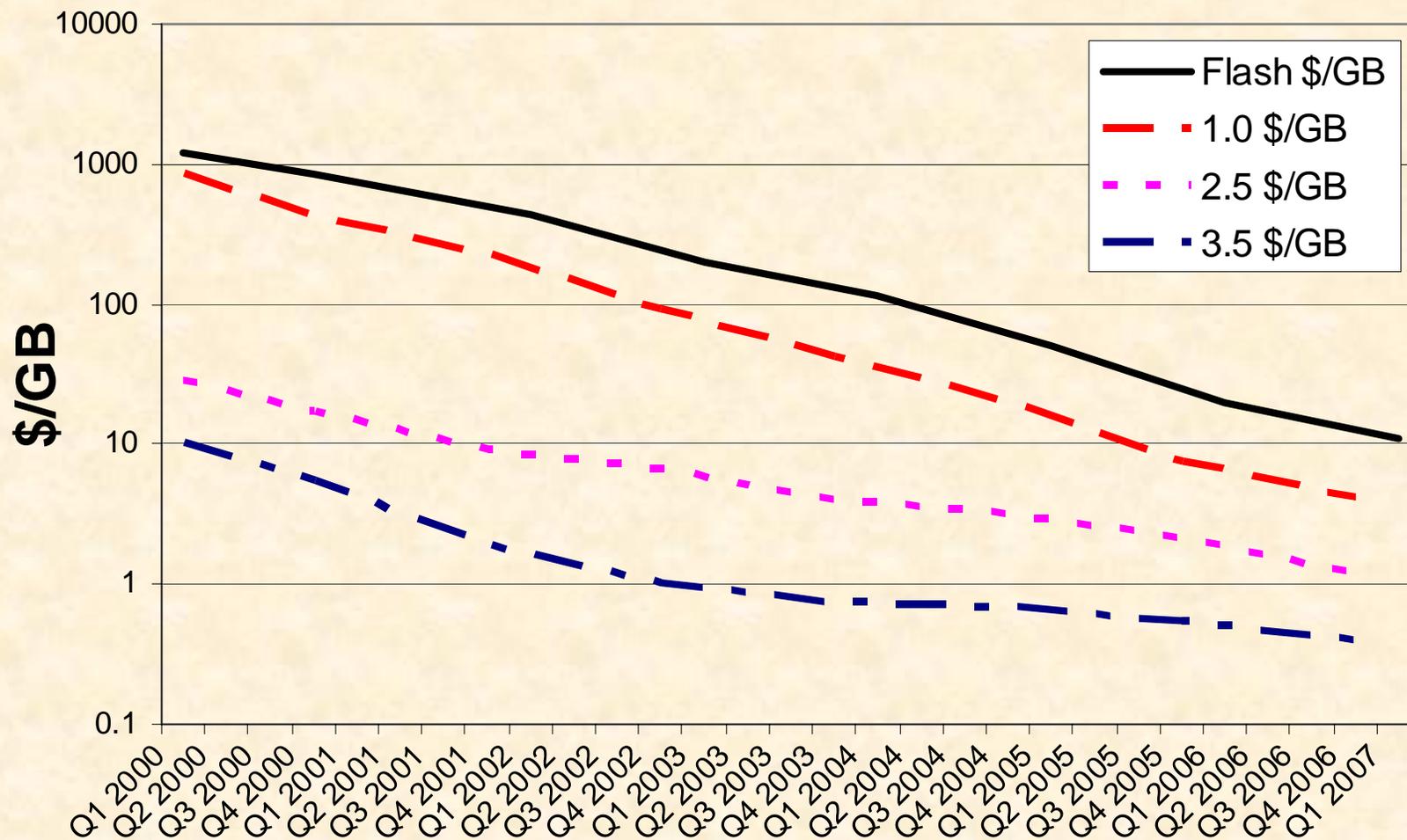
Comparative Prices Flash and Various Form Factor HDDs

[Sources: E. Grochowski (HDD to 2003), Coughlin Associates (HDD 2003+) and Semico for Flash]

© 2005 Coughlin Associates

Comparison of Price vs. Capacity of HDDs and Flash in 2005
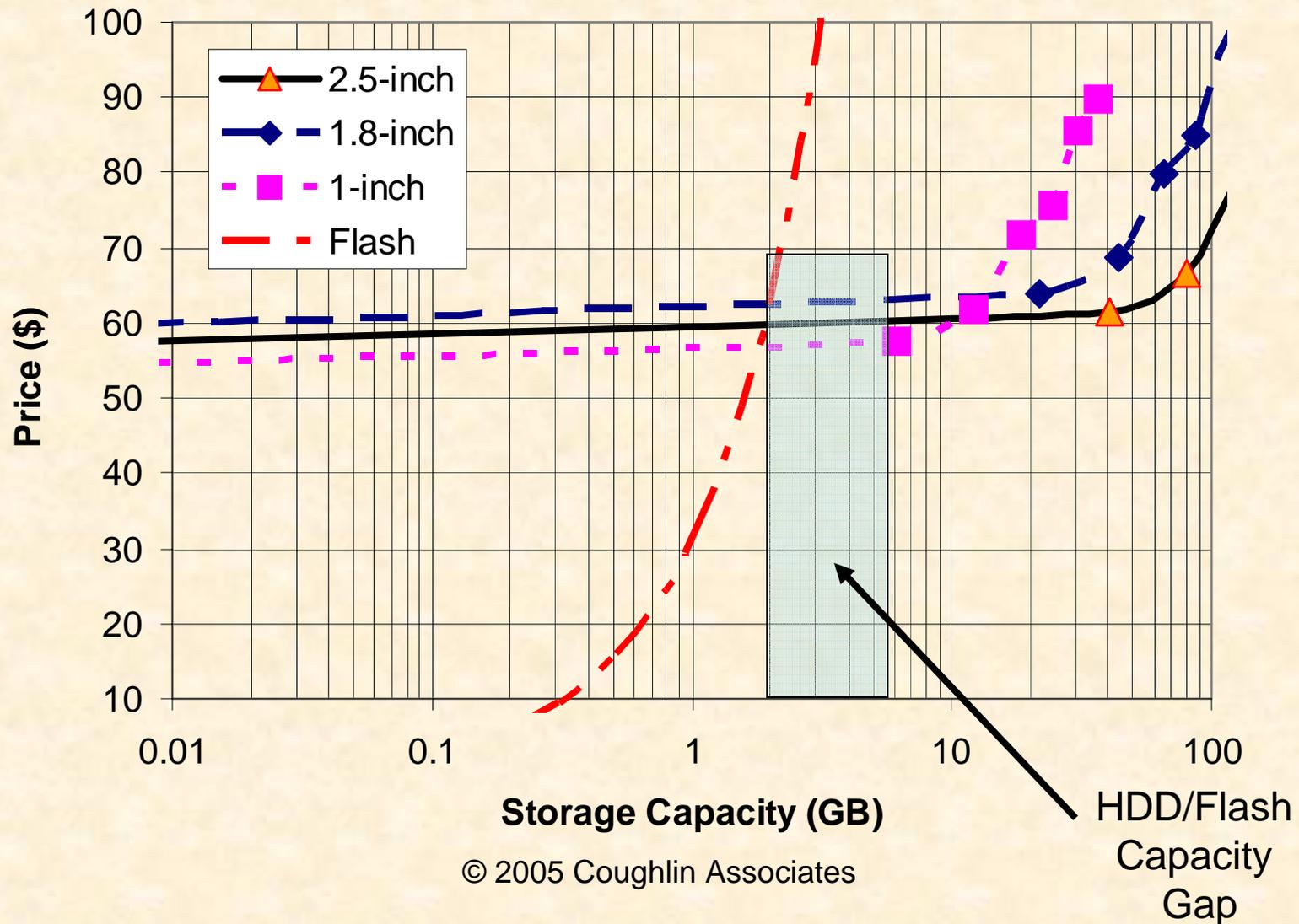
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Minimum 1-Inch Drive Capacity (one head) and Flash vs. HDD Cross-Over Price Point vs. Time

Legend:
- Minimum 1-inch Capacity
- Cross-over Capacity

Y-axis: Cross-over Capacity (GB) — 0, 5, 10, 15, 20, 25, 30

X-axis: 2006, 2007, 2008, 2009, 2010

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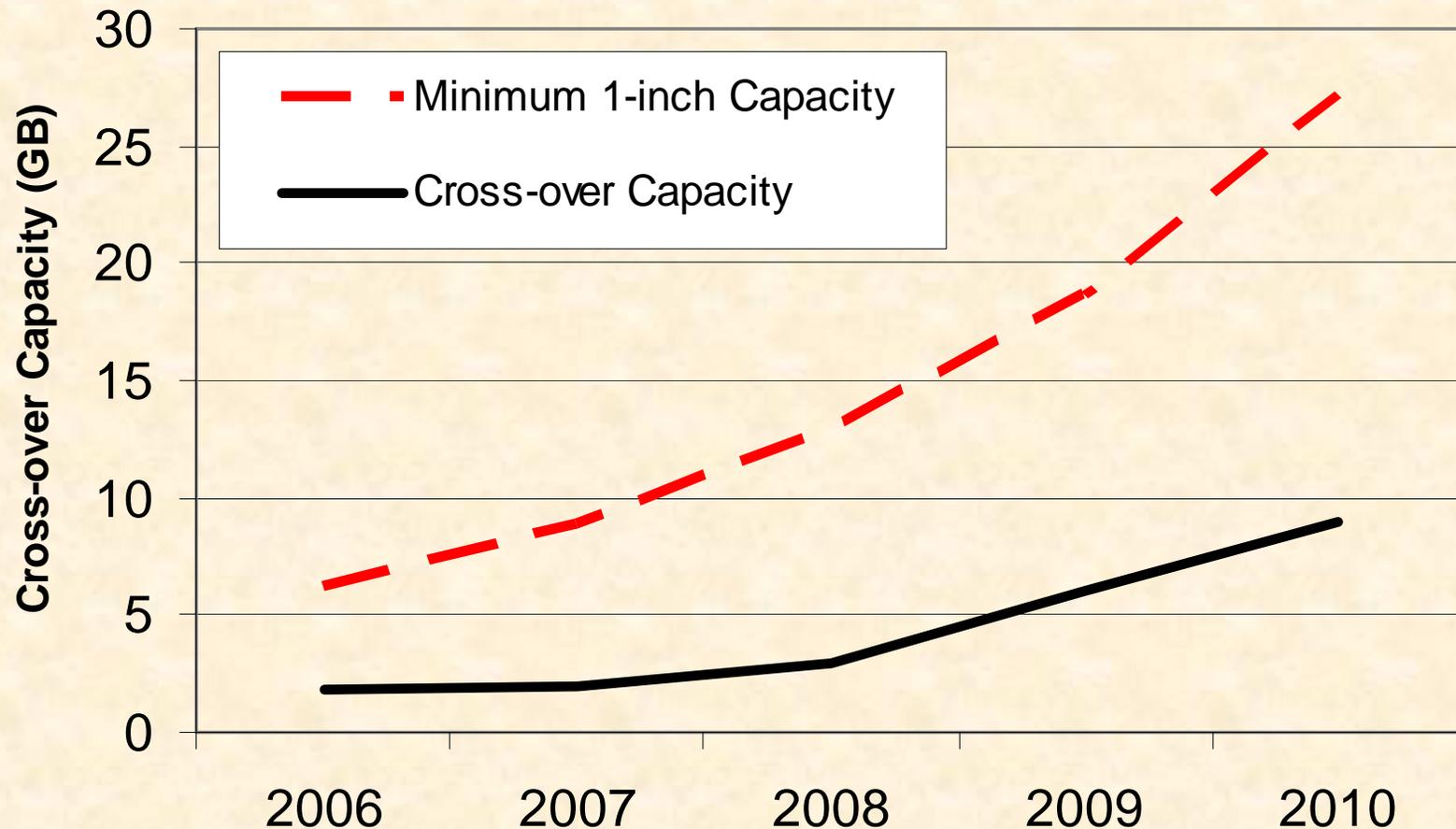
Weight Comparisons of SD Flash & SFF HDDs
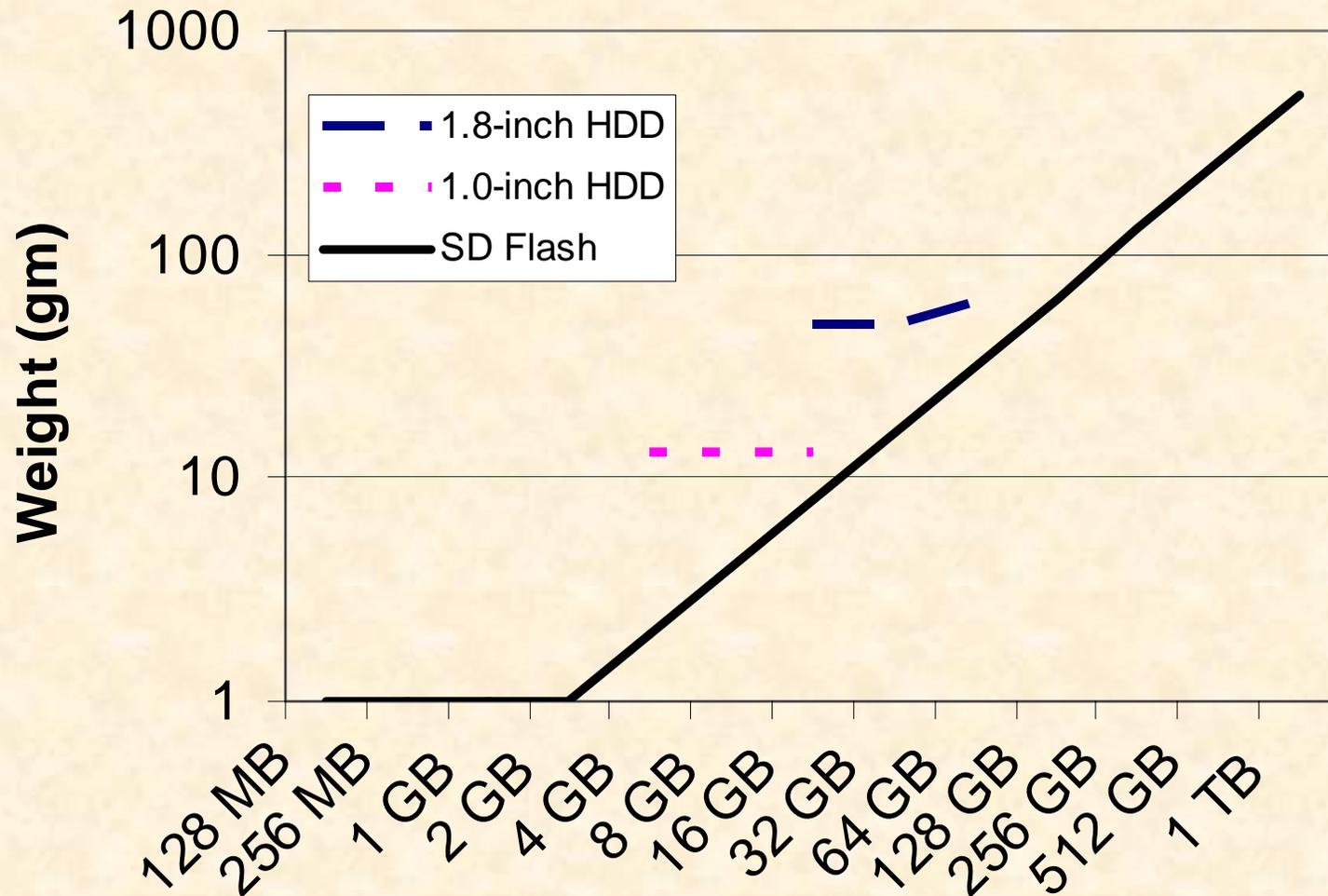
Volumetric Comparisons of SD Flash & SFF HDDs

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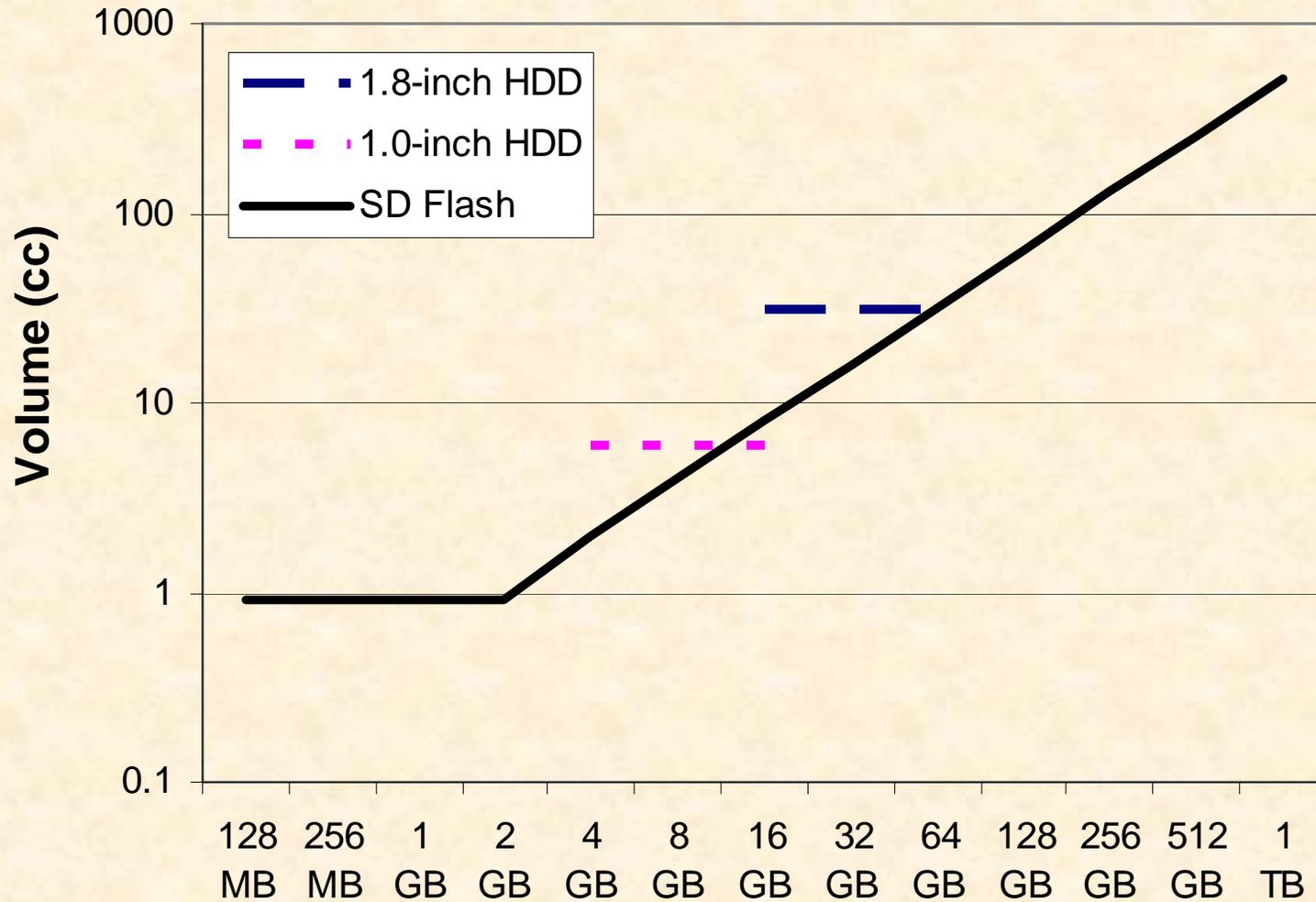
Mobile Storage Hierarchy

- MP3 is a lossy format meant to allow OK audio on small capacity storage if used in a noisy environment with lower quality headphones, if storage capacity increases then we could go to richer music formats
- Video storage and playback or higher resolution audio could really generate larger files
- Larger files favor small form factor HDDs that can deliver higher storage capacity for lower prices than flash at any given point in time
- MusicGiants launched first loss-less compressed music download service—thus more storage for a portable music player
- Hybrid devices with a mass storage device such as a HDD and removable storage such as flash and/or optical could create a higher end differentiated product for mobile devices just as they are doing for fixed CE devices
- Could optical media eventually stake a larger role for richer media distribution to avoid BW bottlenecks?

Higher Resolution Mobile Device Storage Needs
(HDD's Still Have a Role)

- A pure 4-MPixel photo viewer with 20,000 maximum images has 20 GB
- A combination camera and photo viewer with 8 MPixel Resolution and 20,000 images has 40 GB
- A 10,000 song MP3 player has 40 GB
- A 10,000 song loss-less compression player has 140 GB
- A 10,000 CD quality song player has 280 GB
- A 100 movie player at VGA resolution has 70 GB
- A 100 movie player at DVD resolution has 417 GB

- A combination 20k 4-Mpixel photo, 10k MP3 song, 100 VGA movie player has 130 GB

- A combination 20k 8-Mpixel photo, 10k loss-less compressed song, 100 DVD movie player has 597 GB

i-Pod Portability vs. Song Capacity
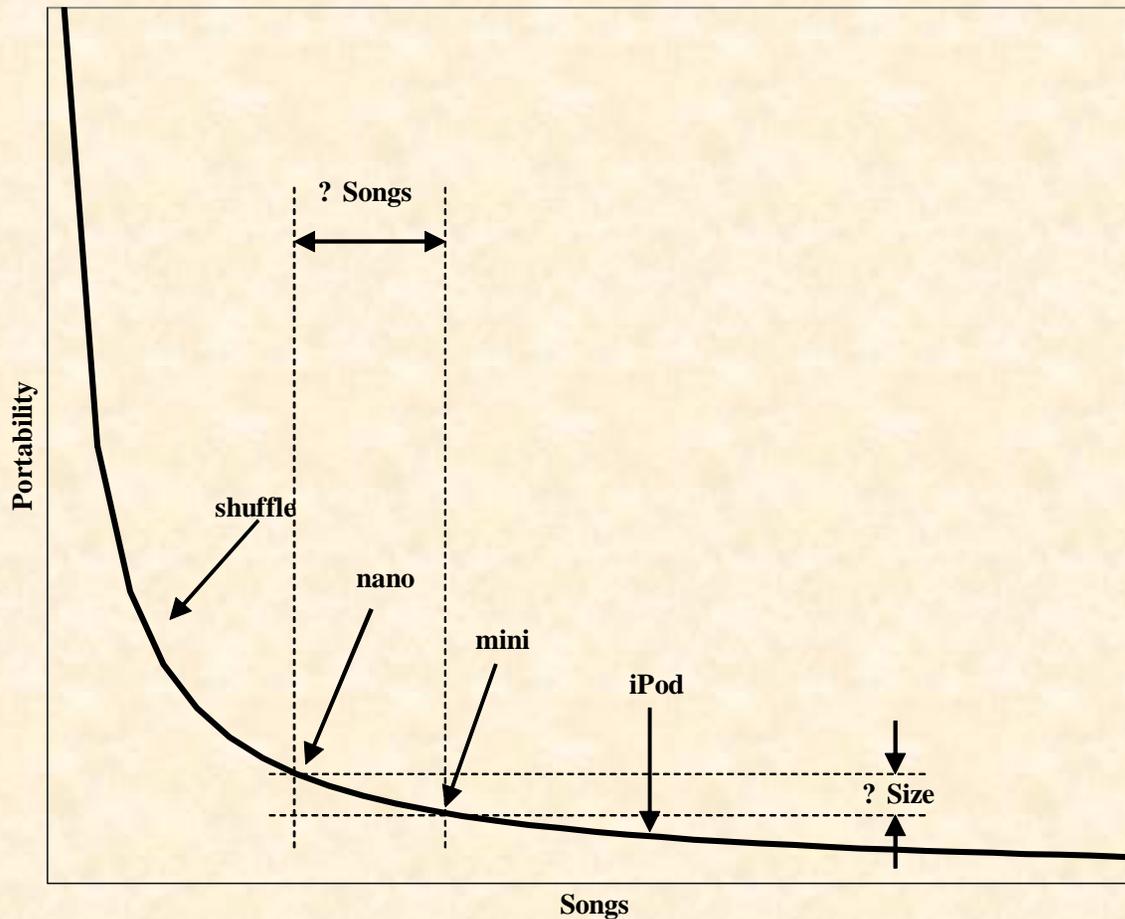
Portability is inversely proportional to the physical size, volume or weight

Source: Semico Research Corp., June 2006

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1 Disk/2 Head Capacity vs. HDD Form Factor (50% A.D. CAGR) and Flash Memory for ~$55 OEM

© 2005 Coughlin Associates
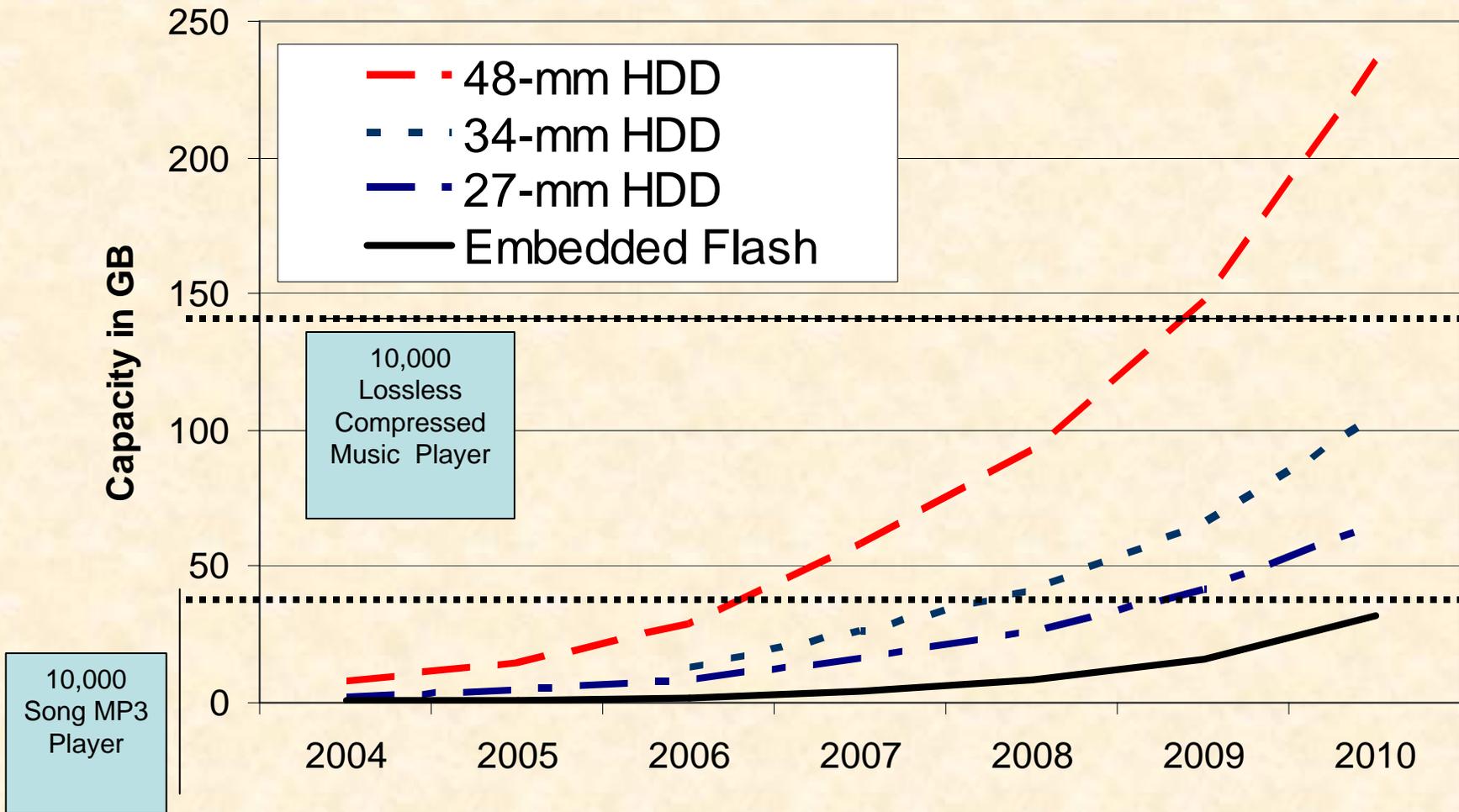
Capacity, Price and Requirement for 2010 Personal Media Players

Personal Media Players

HDDs Cheaper than Flash

48mm HDD
Flash Memory

Price

$120
$100
$80
$60
$40
$20
$0

0 GB   100. GB   200. GB   300. GB   400. GB   500. GB   600. GB   700. GB

Capacity (GB)

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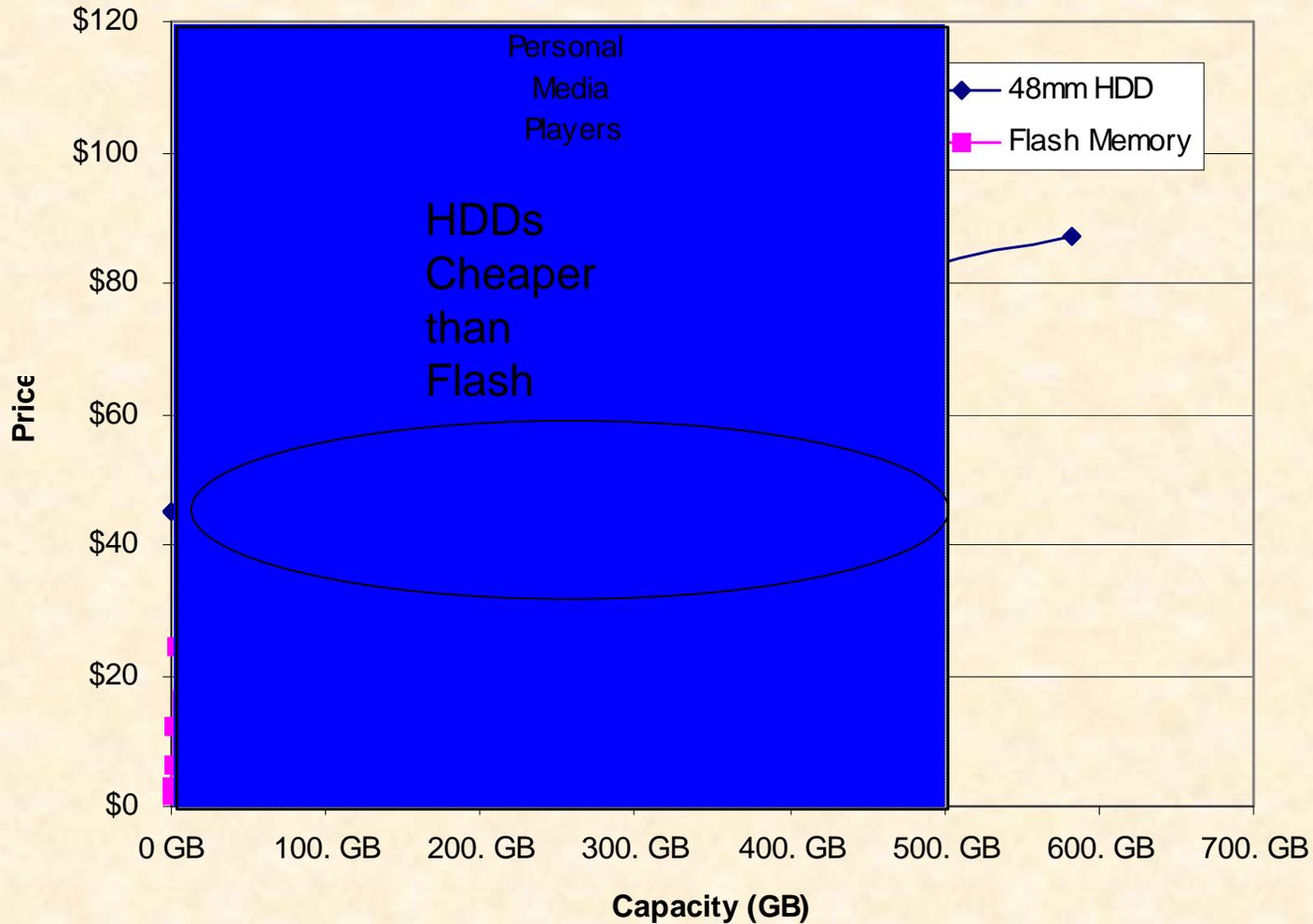
Hours of MPEG-2 Video for ~$60 of Storage Capacity
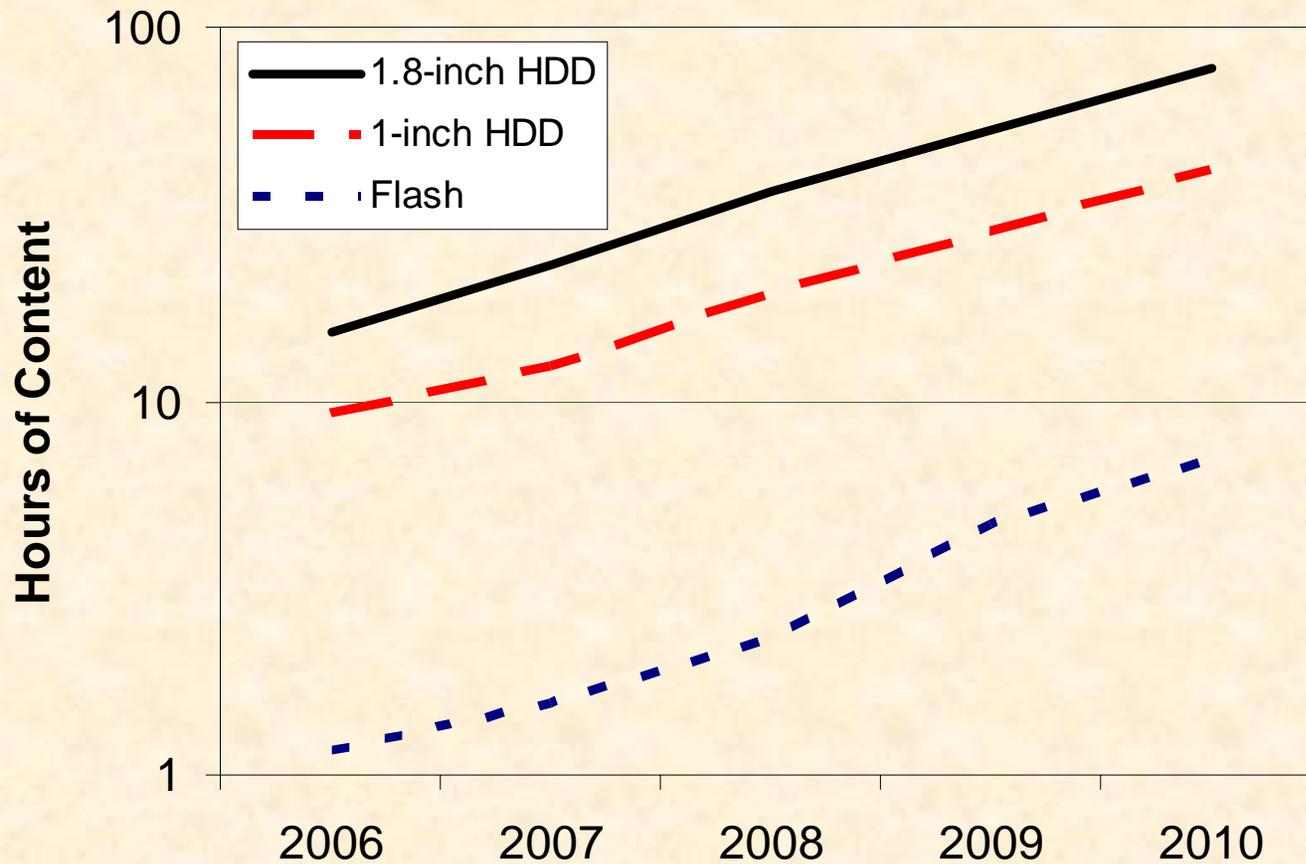
CE Storage Demand vs. Available Technology Capacity—Cell Phones

Price vs. Capacity, 27mm HDD vs Flash Memory, Year 2005
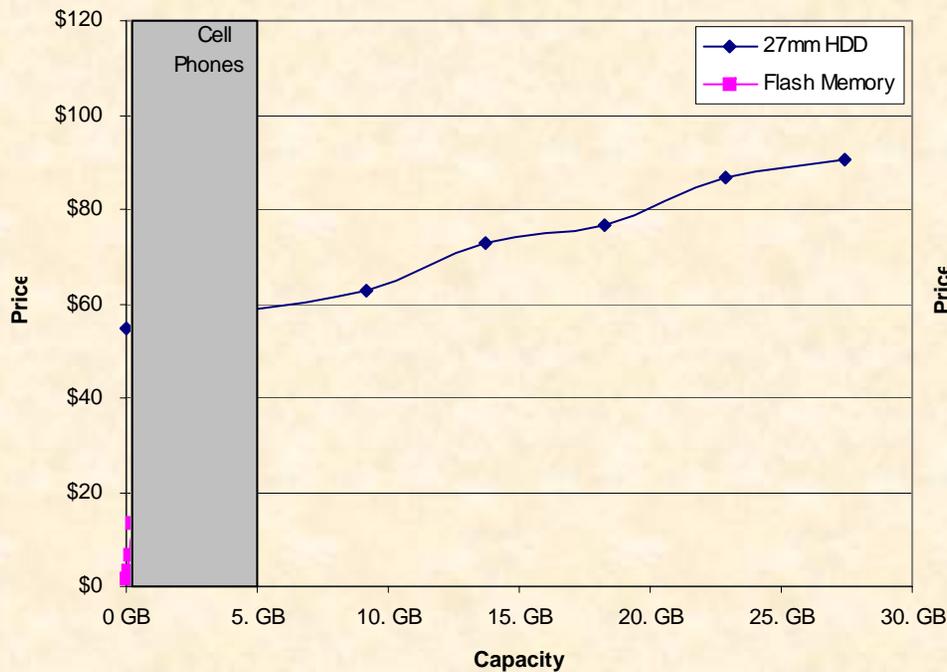
Price vs. Capacity, 27mm HDD vs Flash Memory, Year 2010
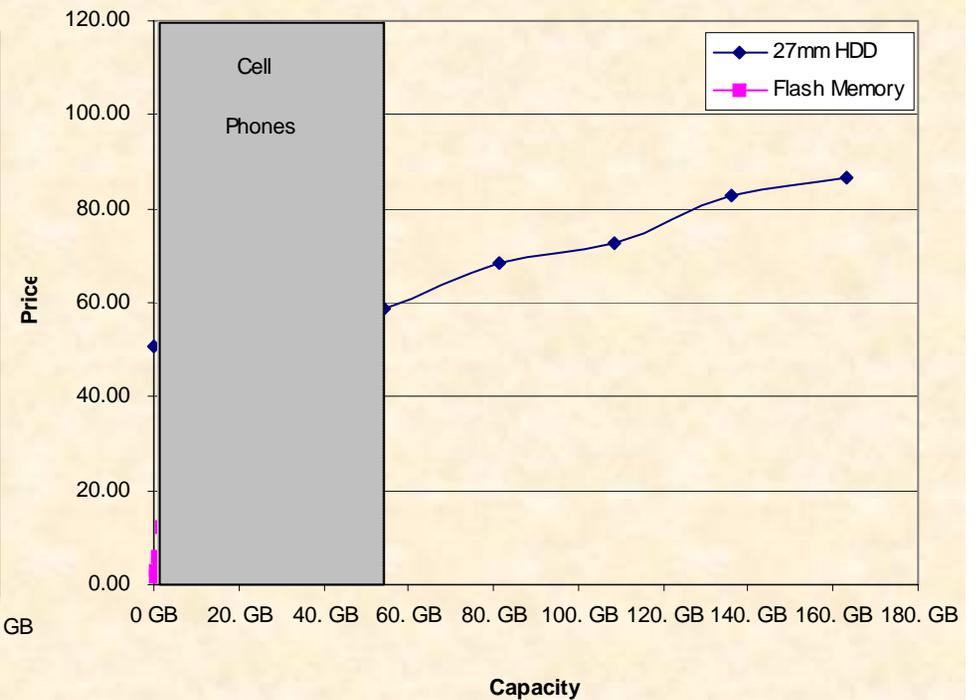
Cell Phone Market Niches

Market Volume

Flash or HDD
•Moderate storage needs
•Features and environmental factor trade-offs

HDD Only
•Rich media
•Convergence device
•High storage needs
•Highest margins

Flash Only
•Lower storage needs

Price/Features
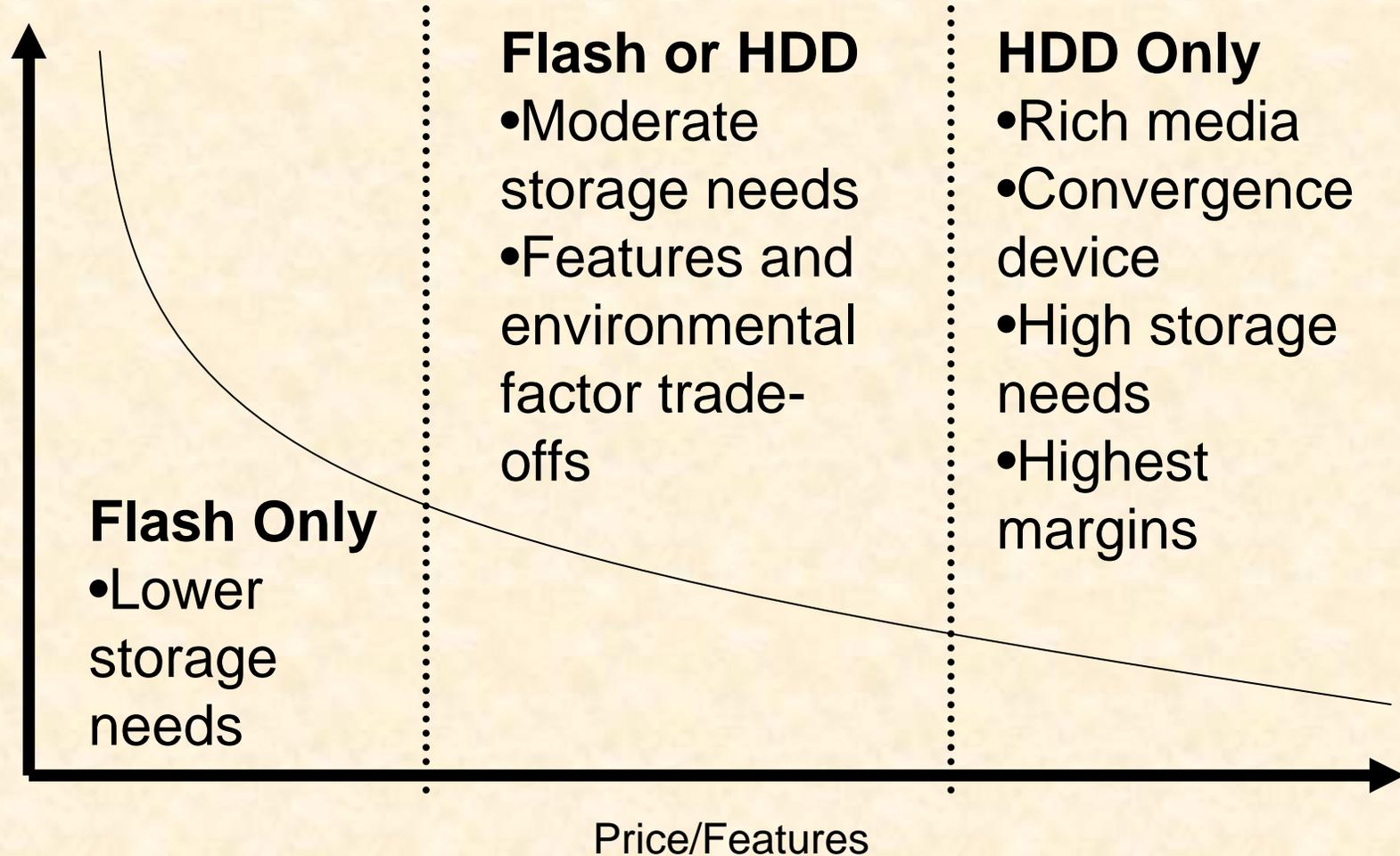
Small Form Factor HDD Projections vs. Mobile Storage TAM

Small form factor HDDs will provide mass storage for higher end portable devices

Personal Life Recorder
Storage Requirements on Hyperdrive

- Memex, As We May Think, Vannevar Bush, 1945

  "A memex is a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility"

- Don Norman speculated about a "Personal Life Recorder" (PLR) type of device in his 1992 book "Turn Signals Are The Fac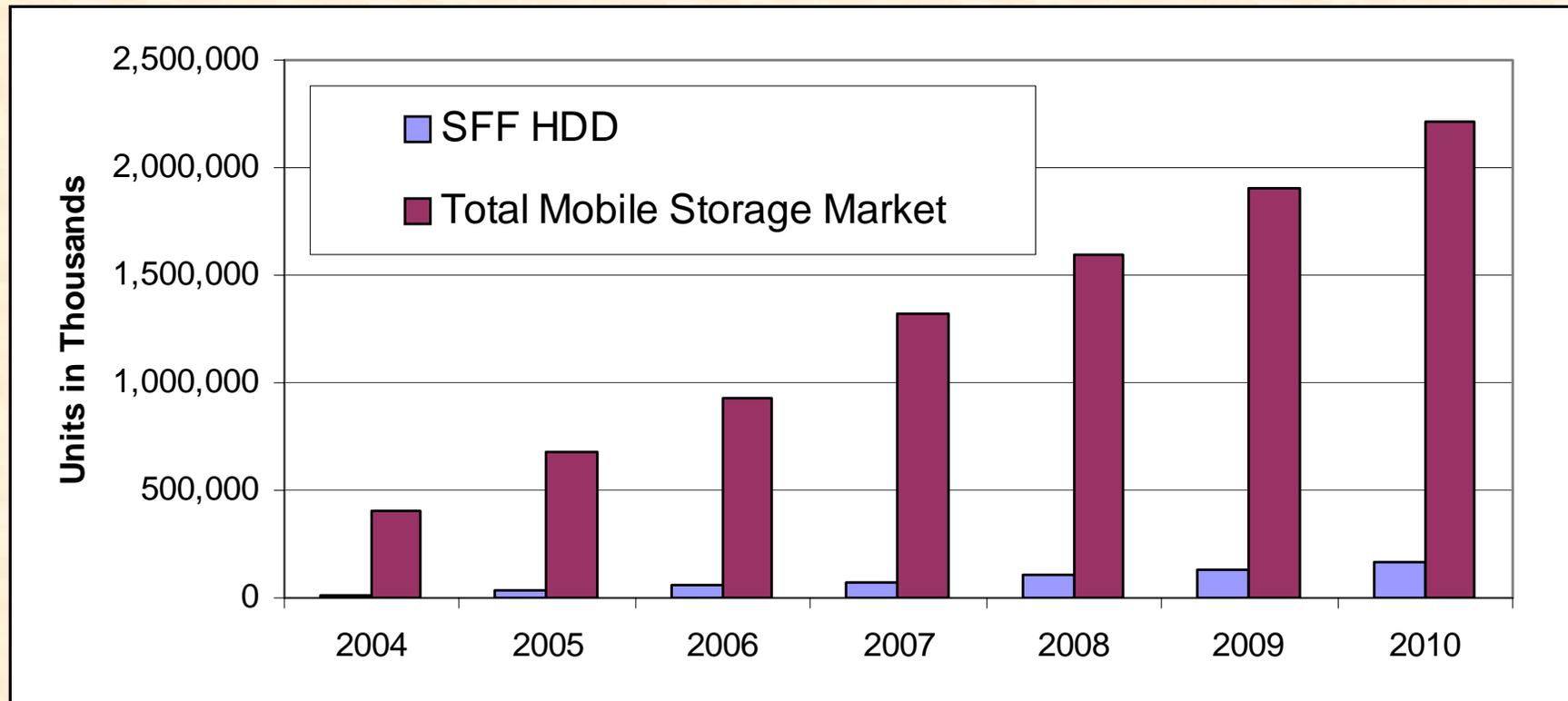ial Expression of Automobiles". He theorized that these PLR's would start out as a device given to young children, called the "Teddy." The "Teddy" would record all of your personal life moments, and as you mature, the data could be transferred to new devices that matched your maturity level.

- MyLifeBits, Gordon Bell at Microsoft is digitizing his life

- Memory Prosthesis, Presentations given by David Thompson in 2001 on how such a device could be used to improve our memories

Filling a terabyte in a year

Item	Items/TB	Items/day
300 KB JPEG	3 M	9,800
1 MB Doc	1 M	2,900
1 hour 256 kb/s MP3 audio	9 K	24
1 hour 1.411 Mbps CD audio	1.6K	5
1 hour 1.5 Mbp/s MPEG video	290	0.8

gbell wag: 67 yr, 25Kday life
a Personal Petabyte (~2003)

Lifetime Storage

1PB

© 2005 Coughlin Associates
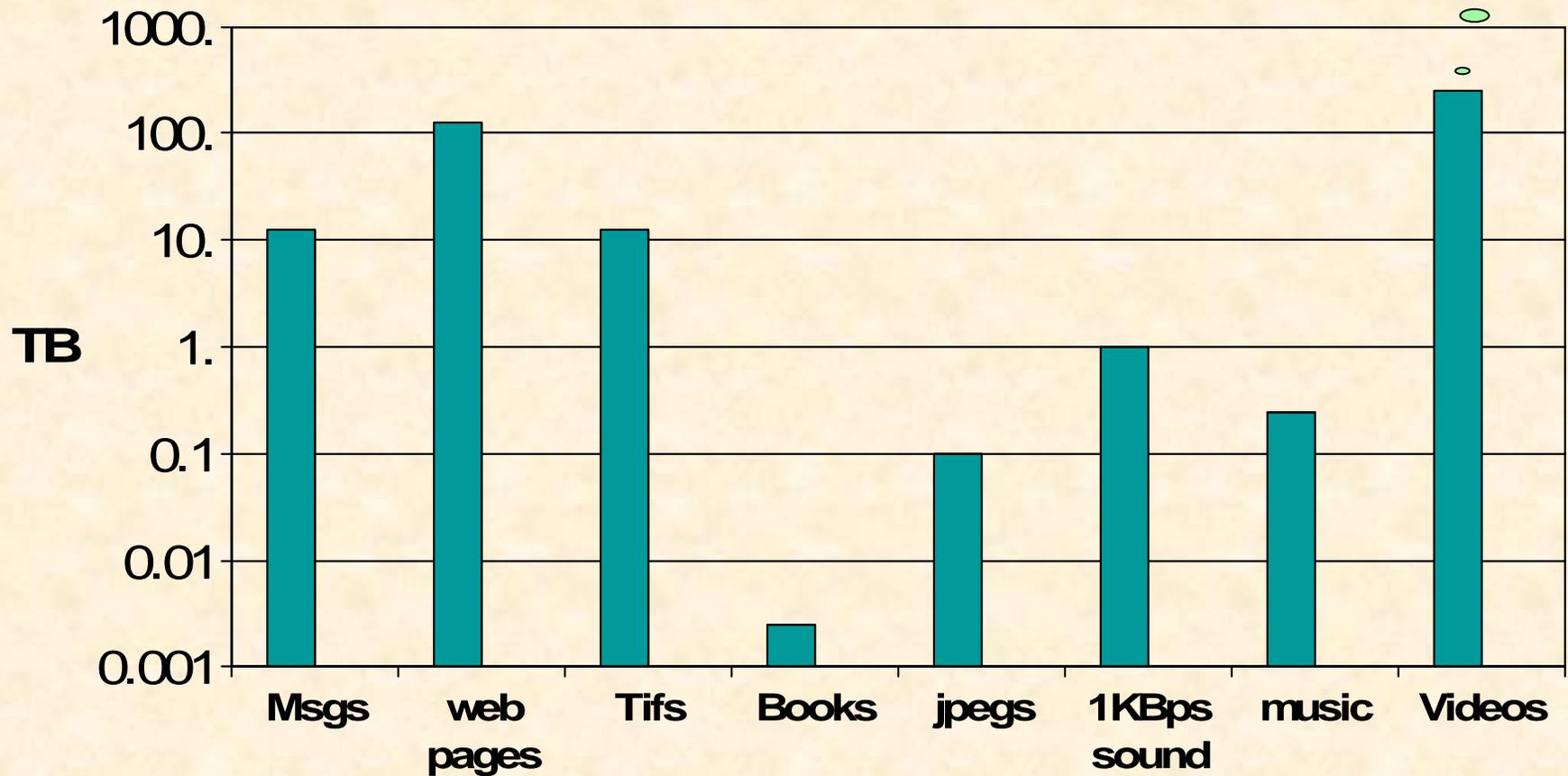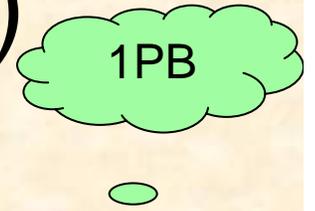
A Terabyte in the Pocket and a Petabyte in the Home

- Estimated Areal density required for 1-TB 2-sided disk vs. FF (Gpbsi)

1.8-inch	1.3-inch	1.0-inch	0.85-inch
3,160	7,100	11,300	19,400

- With 19.4 Tbpsi areal density we could have a ~25 TB 2-sided 3.5-inch disk so a 4-disk drive would be 100 TB.   A 10-drive array would be 1 PB.

Application Integration into HDDs

Comparison of Consumer Device and Component Storage Costs

| Product	Capacity (GB)	Avg. Prod. Price ($)	Est. Prod. Cost ($)	Est. Cost of Storage ($)	Ratio Storage & Prod. Cost	Type
DVR	250	$450	$200	$80	40%	HDD
Game System Ext. Storage	20	$90	$80	$65	89%	HDD
Personal Video Player	60	$390	$195	$130	67%	HDD
MP3 Player	4	$240	$190	$140	74%	Flash

The Next Level of Disk Drive Integration

- Requires high performance common interface standards (ATA)
- Requires common application command standards (UHAPI, others)
- Requires greater electronic integration so CE applications can be placed on the circuit board of the HDD (Moore's Law)
- Requires business agreements with CE companies to make HDD companies ODMs for the CE industry (Up to You!)

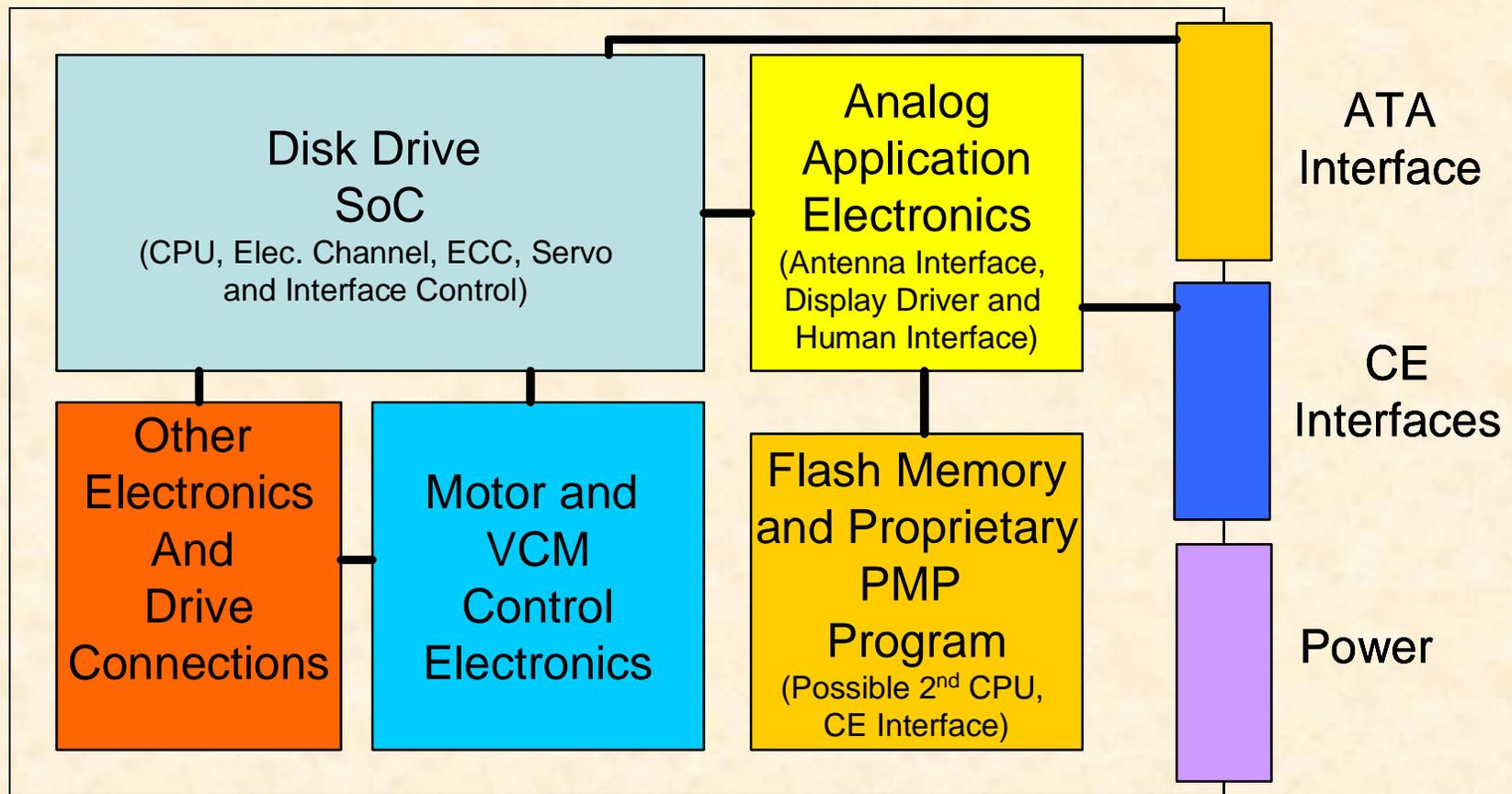# *Integration of Applications on Storage Device Circuit Board.*

Hard Disk SOC for CE Apps - Multi CPU & Custom CE Logic
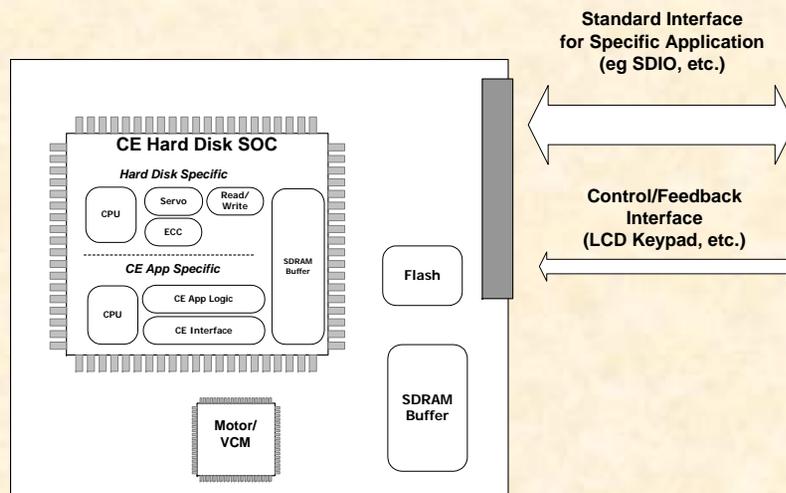
Hard disk SoC with separate CPU and custom logic for CE applications

- Digital storage is often the single most expensive component in a CE device, thus reducing this cost is key to reducing total cost

- Digital storage devices have their own circuitry and application circuitry could be integrated into it as these applications mature

- There are considerable savings in manufacturing, test, and inventory/distribution by having CE applications built into storage devices and activated by proprietary firmware by the CE company—I estimate at least 15% manufacturing cost savings to CE company

Example of a Personal Media Player (PMP) implemented on a Hard Disk Drive

Disk Drive SoC
(CPU, Elec. Channel, ECC, Servo and Interface Control)

Analog Application Electronics
(Antenna Interface, Display Driver and Human Interface)

ATA Interface

Other Electronics And Drive Connections

Motor and VCM Control Electronics

Flash Memory and Proprietary PMP Program
(Possible 2nd CPU, CE Interface)

CE Interfaces

Power

The Home Storage Utility

Pivotal Role for Home Storage Network (Where you store your PB)

Robust

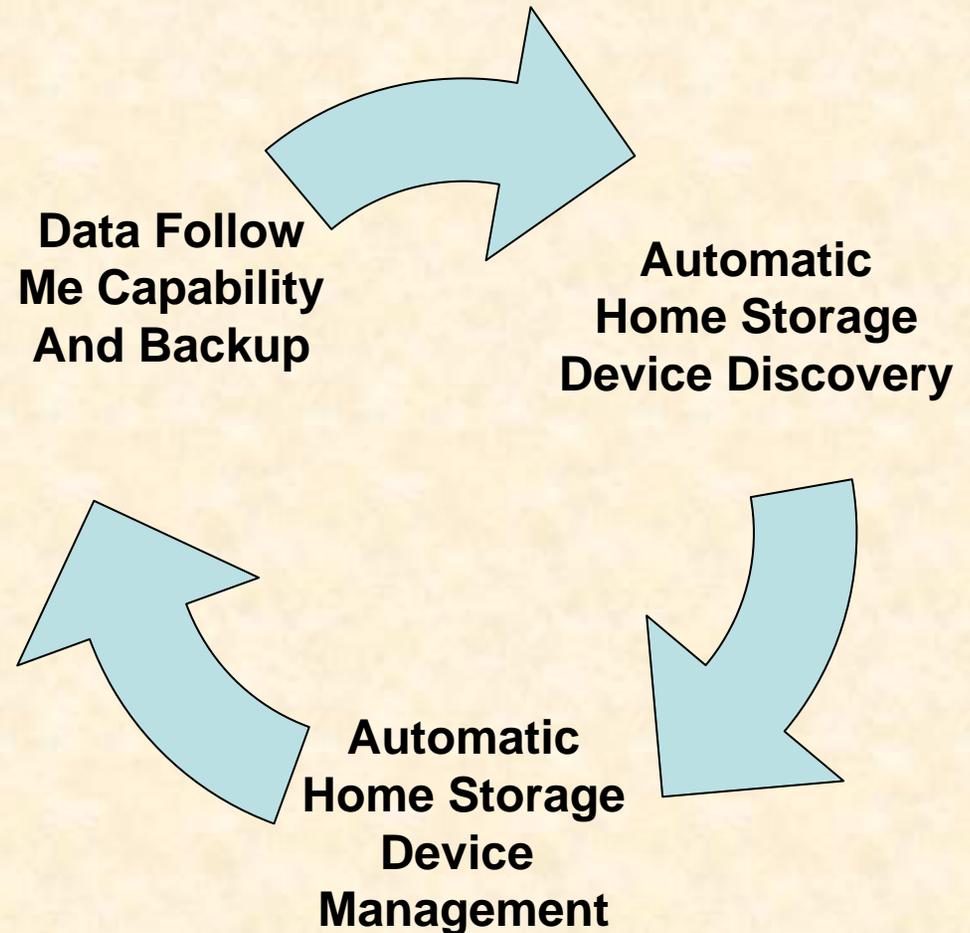**Easy to Use**   **Low Cost**
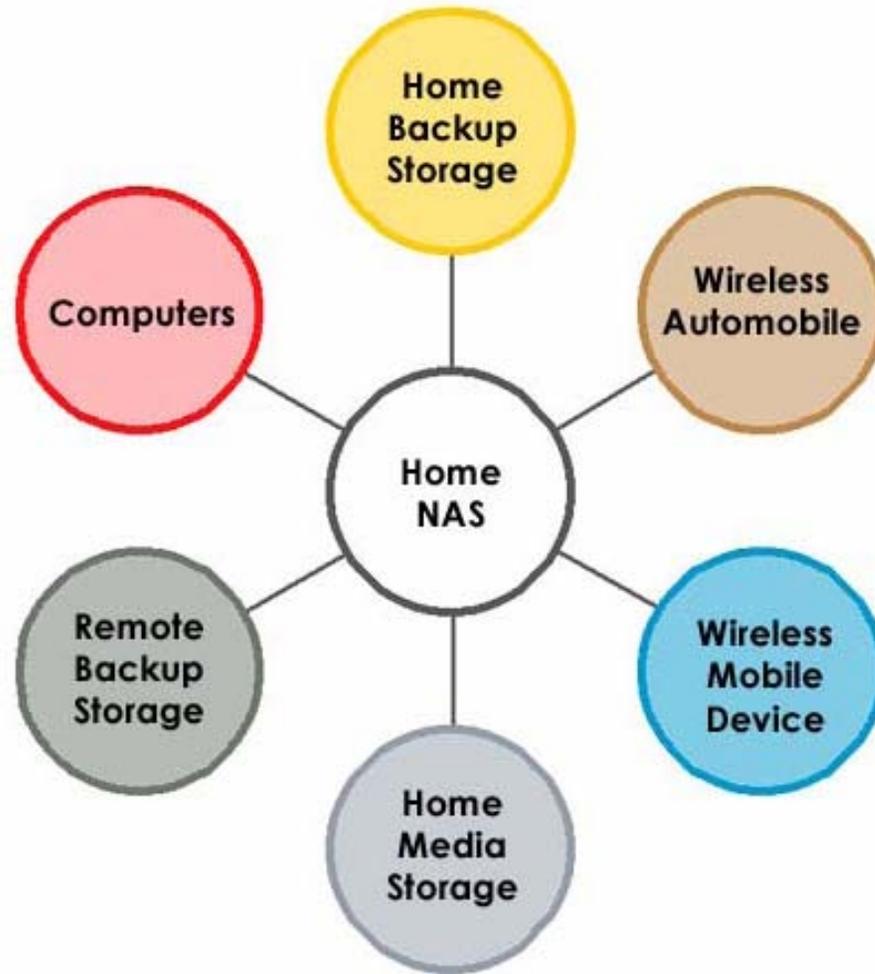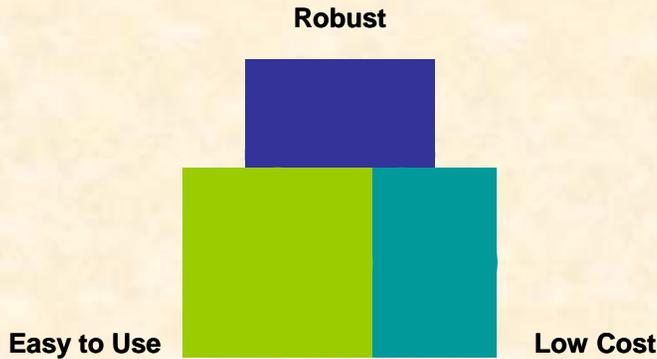
Drivers for Home Network Storage

- Growth in various networking technologies in the home
- Growth in home reference data (personal, non-commercial content) is growing and this needs backup—**easy 2 TB by 2010– 1 PB by 2020?**
- Increased need to back-up data in the home and perhaps outside the home for disaster recovery
- Greater use of PVR/DVR, MP3 and other content in the home leads to a greater desire to share this content within the home
- Need to centralize and organize home content

Home Storage Utility

- Discovers any digital storage device in the home that is on the network
- Once detected a storage device is made part of the home storage pool
- The storage pool managing functions such as backup, synchronization and content distribution as well as traffic control
- Organizes and tags all data in storage pool
- Watches your use of content anticipating your needs and prepositioning material for you.
- Protects itself from outsiders

Data Follow Me Capability And Backup

Automatic Home Storage Device Discovery

Automatic Home Storage Device Management

Source: 2005 Integration of Storage in Consumer Electronics
Coughlin Associates

Conclusions
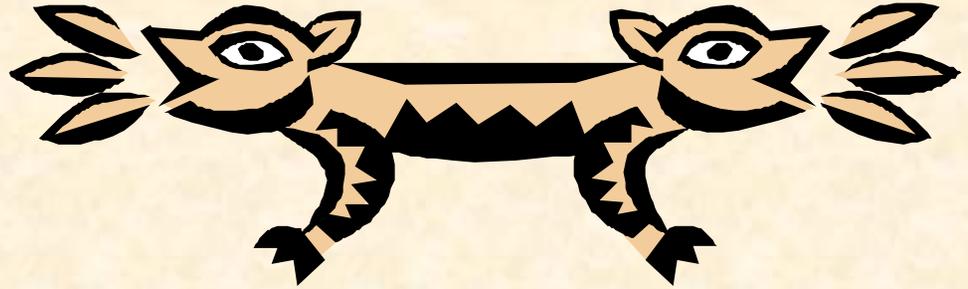
- Huge growth for all types of Storage for Mobile and fixed Consumer applications!
- As CE mobile (and fixed) applications mature they create digital storage hierarchies that help design in the appropriate storage based on capacity, price and environmental sensitivity.
- More than a single storage component may be used to create CE product differentiation
- Storage demand for CE applications is unlimited—1 TB in your pocket and 1 PB in your home by 2020!
- Economic forces will drive increased electronic integration of digital storage and CE applications
- The need for ease of use, low cost and reliability will lead to the creation of a home storage utility linking all storage devices in the home into a single digital storage entity

Sources

- **2005 & 2006 Entertainment Creation and Distribution Digital Storage Report**, Coughlin Associates, www.tomcoughlin.com
- **2005 Integration of Digital Storage Into Consumer Electronics Report,** Coughlin Associates, www.tomcoughlin.com
- **Trends in Digital Home Storage: Defining the Opportunities for Network-Attached Storage ,** Tom Coughlin, Coughlin Associates, TDG Report
- **2006 HDD Capital Spending Report**, Tom Coughlin, Coughlin Associates (to be released in July 2006)
- Presentations at **2006 Storage Visions Conference**, www.storagevisions.com

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

Thank
You!