



Developments in Digital Storage For Consumer Electronics

**—Mutual stimulus vs. direct
competition in digital storage for
Consumer Electronics—**

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Coughlin Associates

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Abstract

- ***Digital storage in the home will grow enormously. Digital storage hierarchies are developing for static and mobile consumer applications. Many factors lead to the integration of consumer applications in digital storage devices. Proliferating storage devices need virtualized home storage and home storage management.***

Thomas M. Coughlin

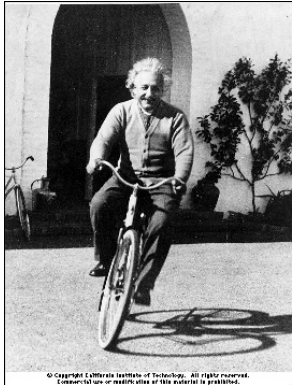
President, Coughlin Associates



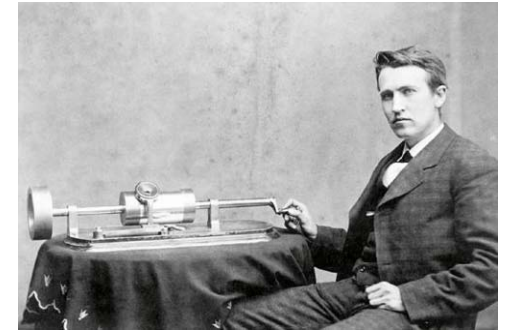
Tom has been working for over 25 years in the data storage industry at numerous companies such as Ampex, Polaroid, Seagate, Maxtor, Micropolis, Syquest, and 3M. He has over 70 publications and six patents to his credit. Tom is active with IDEMA, the IEEE, and other professional organizations. Tom is Vice-Chairman of the 2006 Santa Clara Valley IEEE Section and Chairman of the Santa Clara Valley IEEE Consumer Electronics Society. He is the founder and organizer of the Annual Storage Visions Conference, a partner to the annual Consumer Electronics Show. Coughlin Associates provides market and technology analysis as well as Data Storage Technical Consulting services. For more information go to www.tomcoughlin.com

2005-2006 Publications:

- [2006 Hard Disk Drive Capital Equipment Market and Technology Report](#)
- [2006 Tape and Disk--A User's Perspective](#)
- [2006 Backup and Archive--A User's Perspective](#)
- [2006 Continuous Data Protection--A User's Perspective](#)
- [2006 Tiered Storage--A User's Perspective](#)
- [2005 NAS and NAS Virtualization- A User's Perspective](#)
- [2005 Digital Storage in Entertainment Creation and Distribution](#)
- [2005 Integration of Digital Storage in Consumer Electronics](#)



Outline



- 2007 International CES Storage Products
- Unlimited demand for digital storage
- Storage hierarchies and uses of digital storage
- Hard Disk Drive Technology Projections
- Choosing the right digital storage for applications
- Developments of storage integration in consumer electronics
- Connecting everything at home
- Conclusions
- Sources



2007 CES & SV07 Storage Products



LG



Holographic
Storage
(InPhase)



Seagate



HGST



Samsung

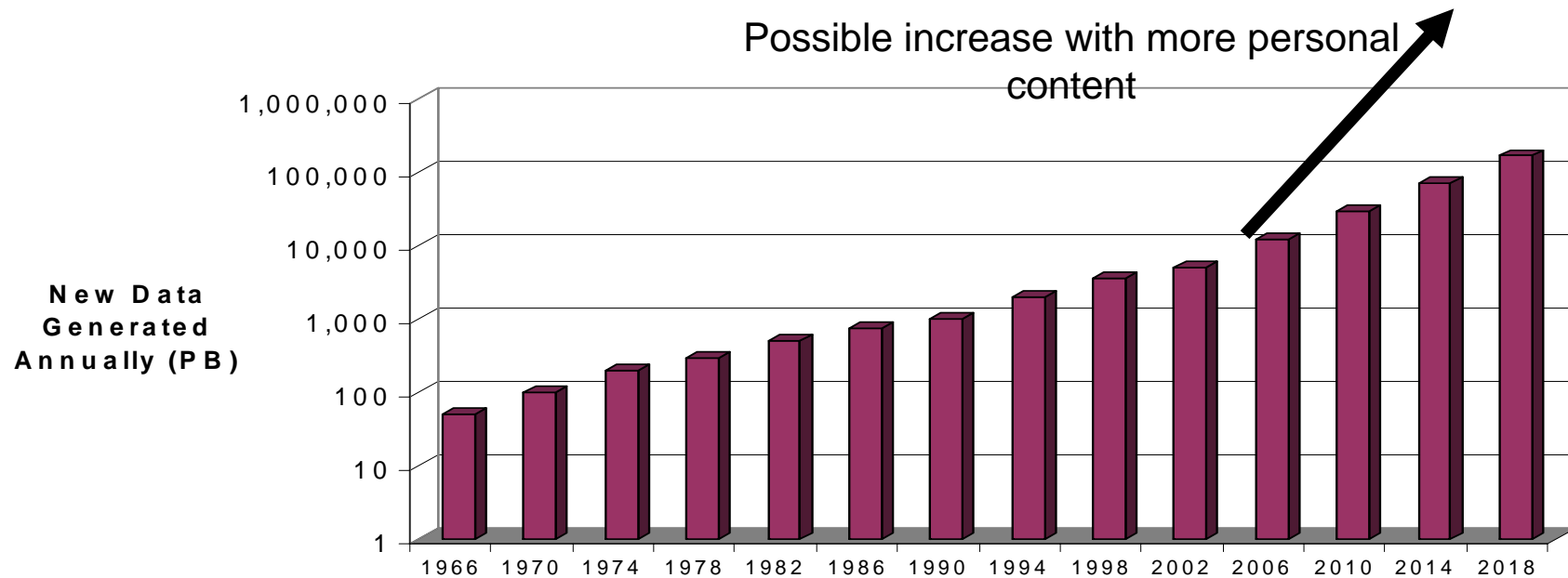


Sandisk



Digital Storage Everywhere

Projections for Annual New Data Production in Petabytes (10^{15} Bytes)

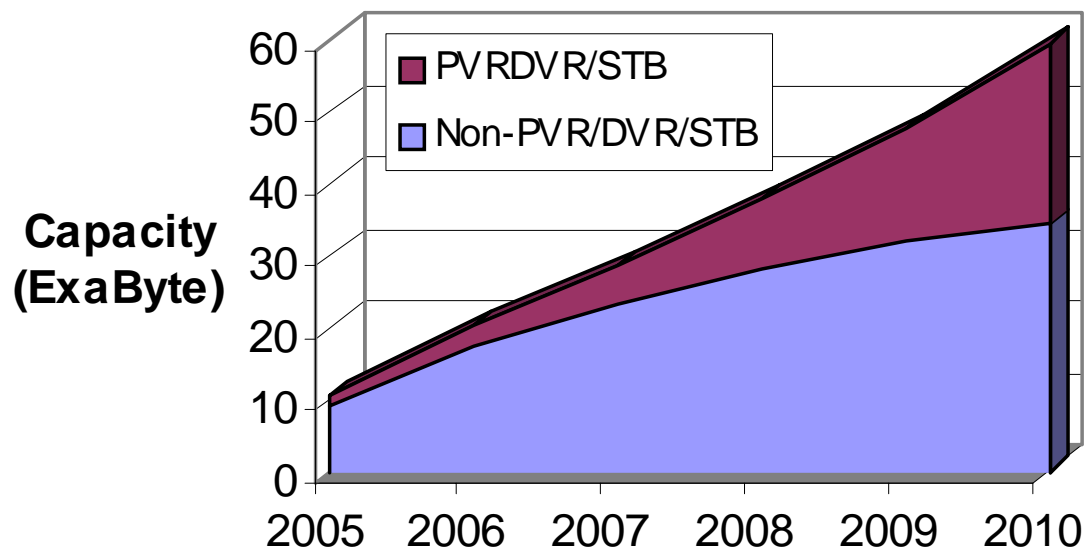


Extension of Univ. of California, Berkeley Hass School of Business Study, **How much Information**, 2003.

Changes in electronics and the market

- Customers don't buy anymore just because a product has a faster processor
- New trends driving CE market
 - Mass customization (low cost products meeting individual needs)
 - More niche products, loss of mainstream
 - More and more products and content will have to access individual preferences and experiences
 - Development of new levels of personal storage could drive entirely new markets for commercial products that utilize this information to the benefit of individuals
- More data now shipped for personal use (including personal computers) than commercial (e.g. IT) use

Comparative Total Storage Capacity Growth (Exabytes) for PVR/DVR/STB vs. Desktop Computers (3.5-inch HDDs)



42% of Total 3.5" Capacity is PVR/DVR/STB by 2010

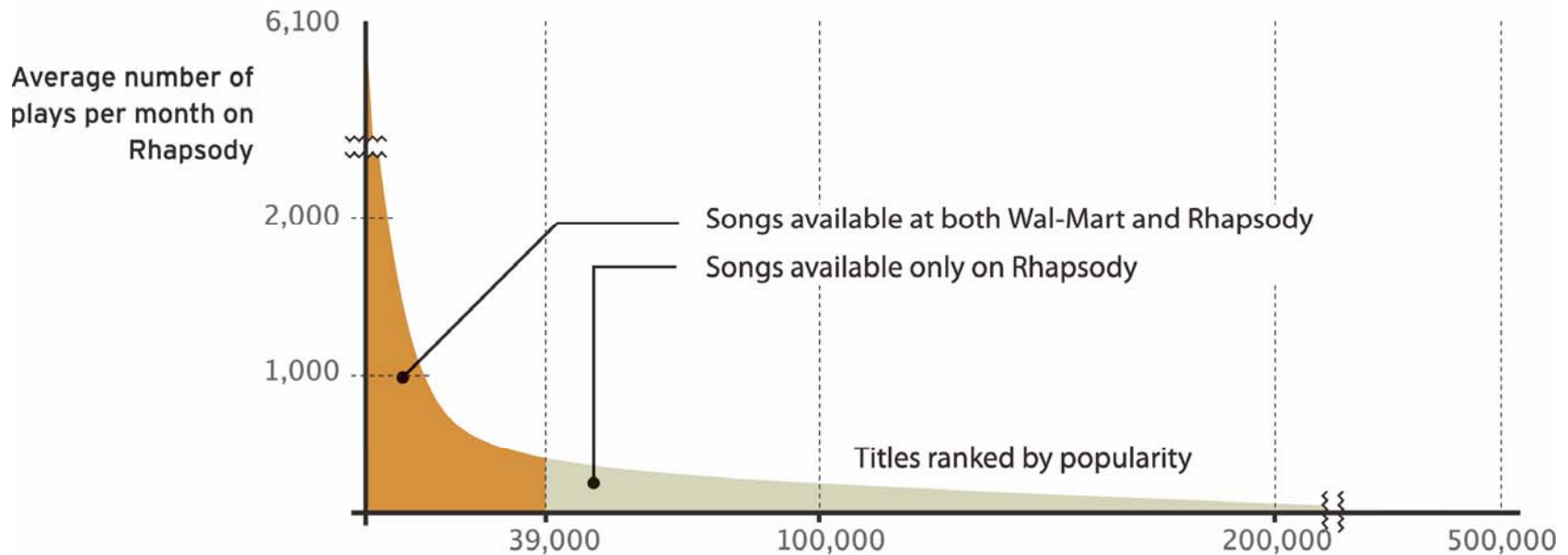
- **Entertainment Content growth**
Is even higher since fastest computer growth in home media center computers
- **After 2010 digital content for entertainment and personal content will dominate all other storage**

Growth and Expansion of Metadata

- Currently metadata (data about data) only focuses on what is within the data
- Metadata must expand to include data about how the data is used and its context and associations with other data
- Ultimately metadata should grow with time and exceed the size of the original data—like a raindrop surrounding a tiny dust particle

THANKS TO TECHNOLOGY

Consumers have many more choices
Likewise, more people can make and
distribute content



*Source: *The Long Tail: Chris Anderson, WIRED Magazine*

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Growth in personalized...maybe even personal content....

- New technology allows ever finer market segmentation—the ultimate segmentation is the individual
- Could we see demand for Life Logs or personal memory assistants (PMA)
 - access our own histories or friends and relatives' histories, or even just to find things we lost?
- To handle the required storage these devices would need new capabilities:
 - Indexing, organizing and management
 - Handle and facilitate the growth in metadata in personal content
 - Allow access to proxies or other ways to retain connection with the original data
 - Not only large storage capacities needed but much more intelligent storage systems required.

Personal Life Recorder (Life Log)

History of the Concept

- **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 Facial 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

Impact of new modes of sharing information

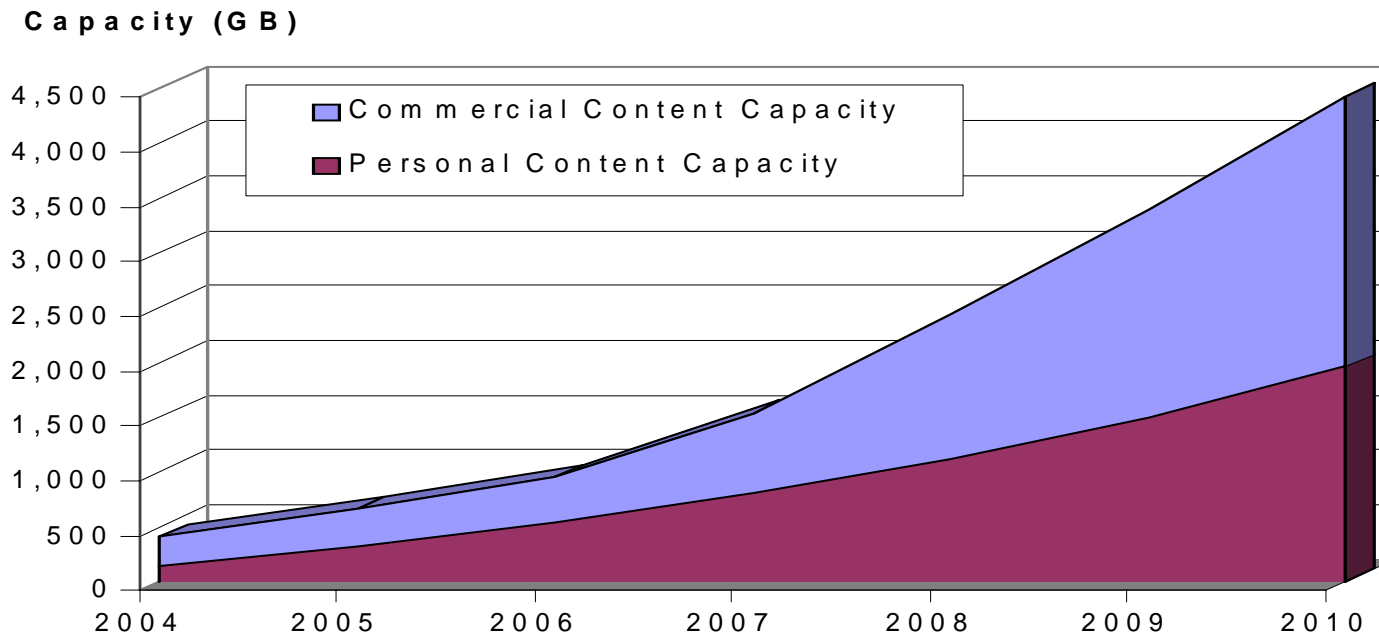
Content Creation and Distribution for Everyone!

- Social networking
- Second life
 - New virtual economic models with real world returns
- Youtube and similar content sharing technologies
- Peer to peer
- Could we see new modes of bringing people and ideas together
 - A common interest engine
 - New driver for economic growth

Growing importance of personal content

- By the next decade there will be more personal than commercial digital content stored
- This will create new markets and opportunities to serve this diverse and dispersed market
- Increasingly consumer electronics will be driving new technologies. CE could displace IT in the generation of technology solutions
- Storage demand is infinite—we can't keep enough information—as long as we can afford it, find it, keep it and preserve it
- Storage must help in organizing and finding data—object storage in CE devices

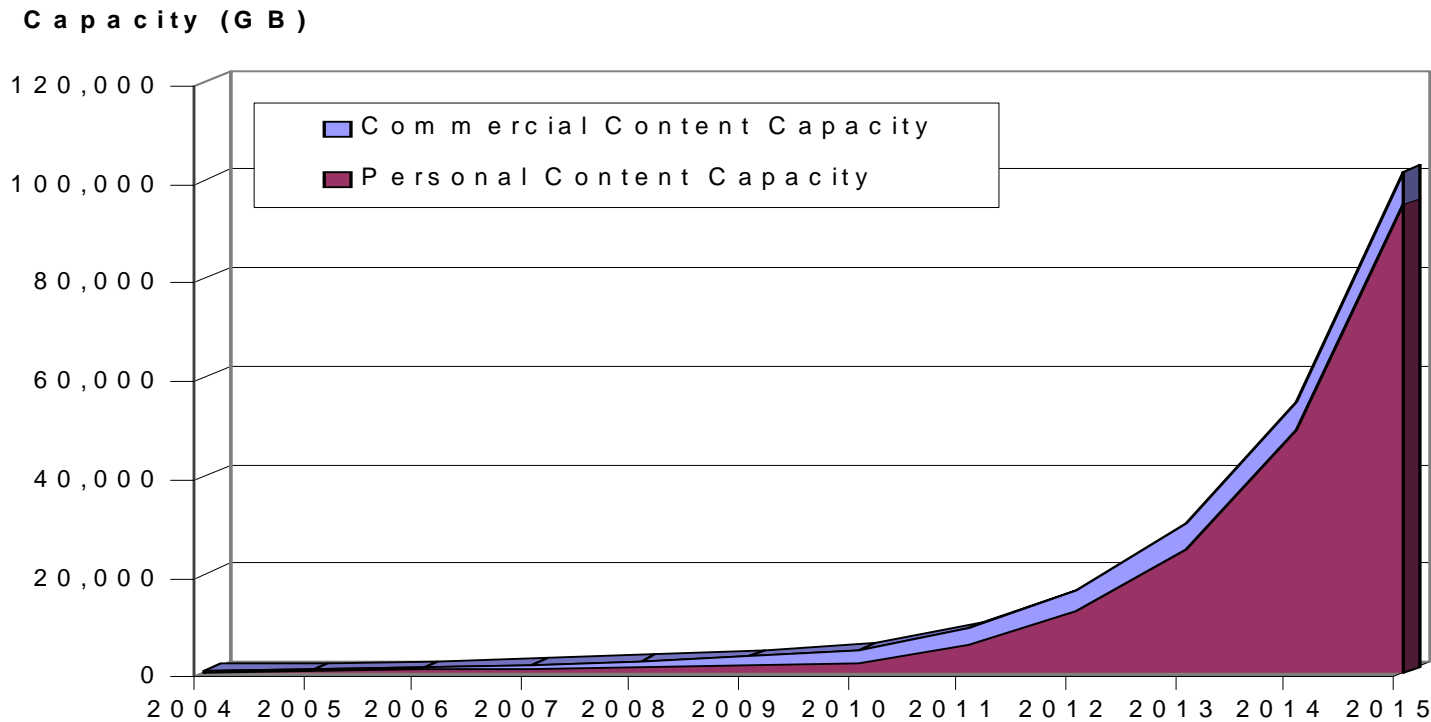
Cumulative Home Storage Capacity (at SV06)



**Almost 2 TB of personal reference data and
2.5 TB of home commercial content by 2010**

Extended Projection Showing the Impact of Life-Logs on Personal Content Generation in a Technology Savvy Home

--100's of TBs in Next Decade--



@SV07

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By 2015

- A terabyte in your pocket
- A petabyte in your home
- Exabytes in datacenters
- Zetabytes in the world

Digital storage demand is
very elastic

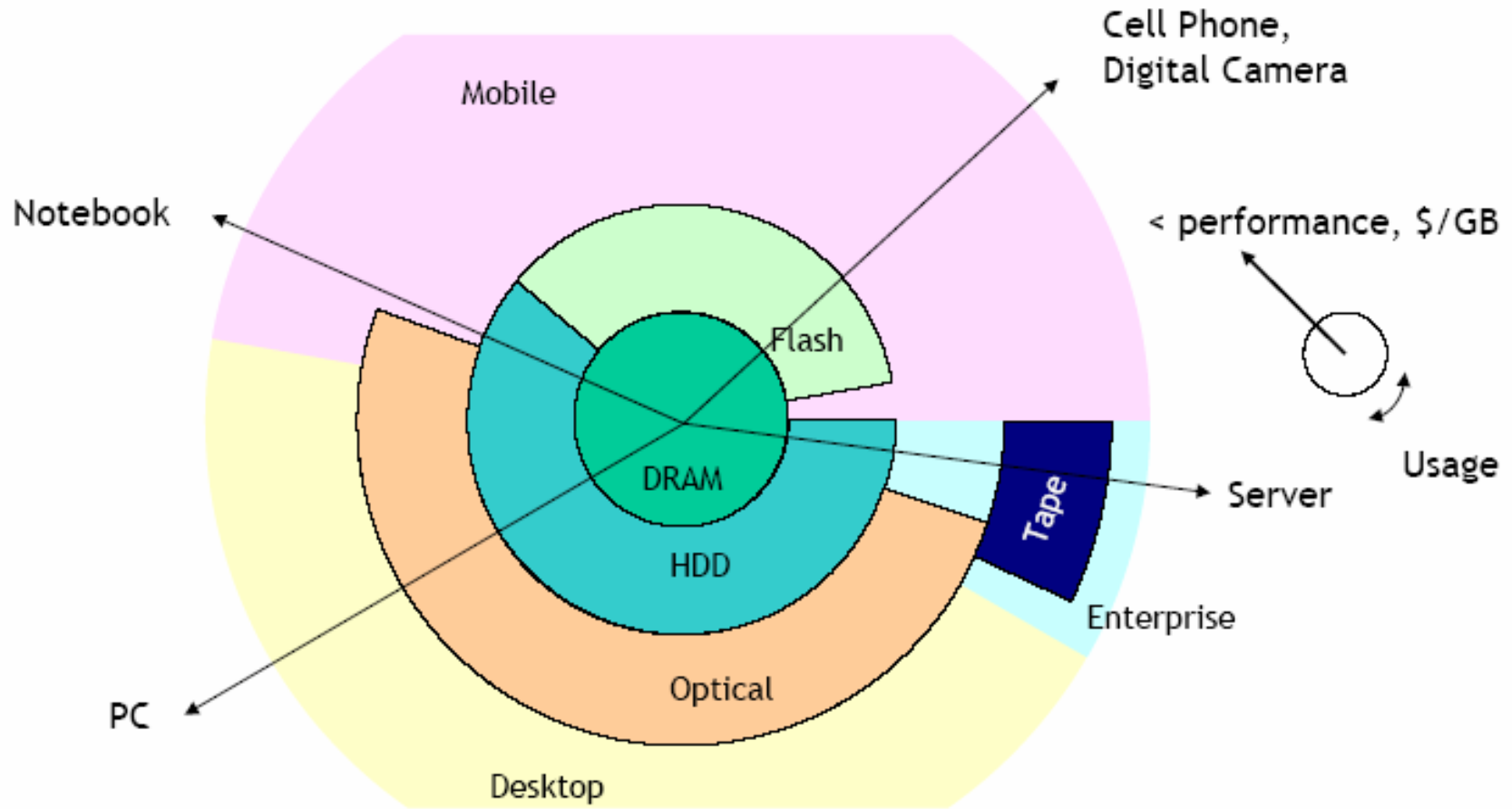
A collection of various coins and tokens in different colors (blue, gold, silver, brown) scattered on a white background. The coins are of various denominations and designs, some featuring intricate patterns and others with simple text. The text "Storage Hierarchies Lead to Multiple Paths for Development" is overlaid in the center of the image.

Storage Hierarchies Lead to Multiple Paths for Development

The 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

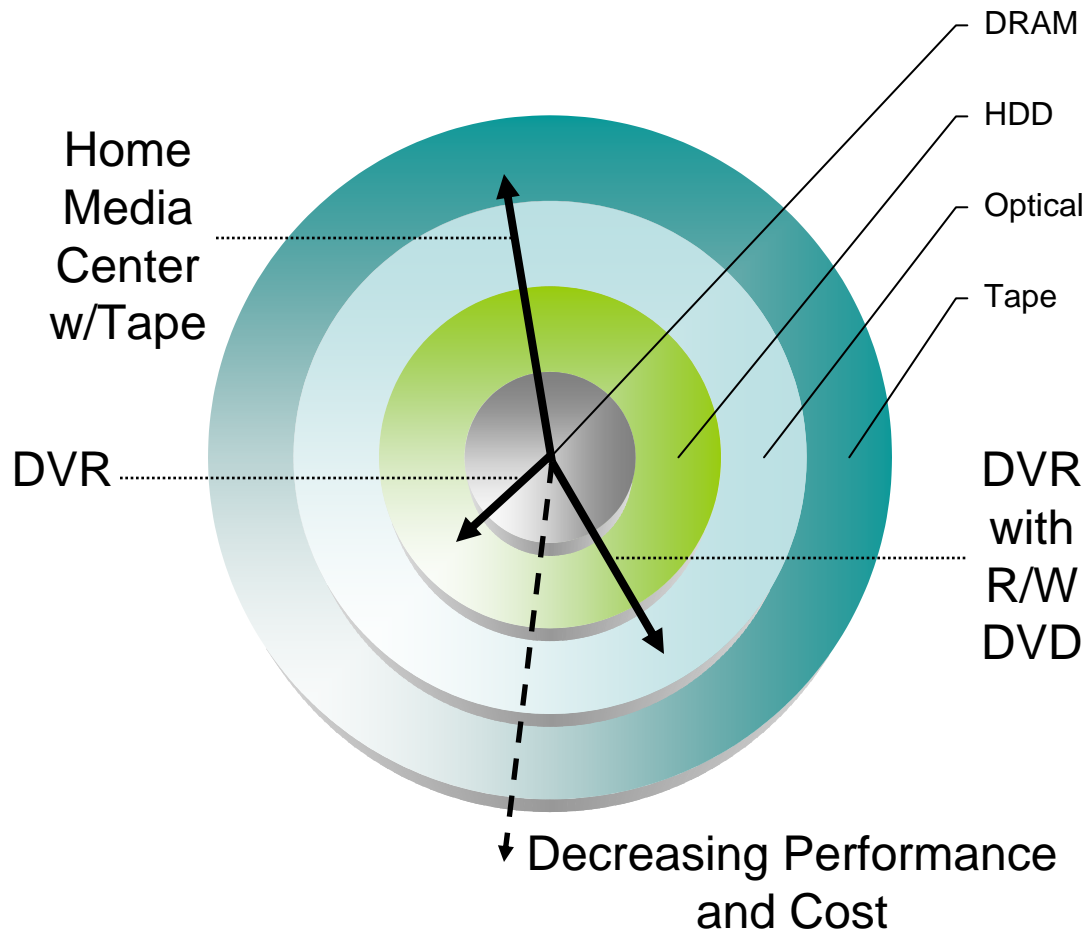


– Radial line is a system design

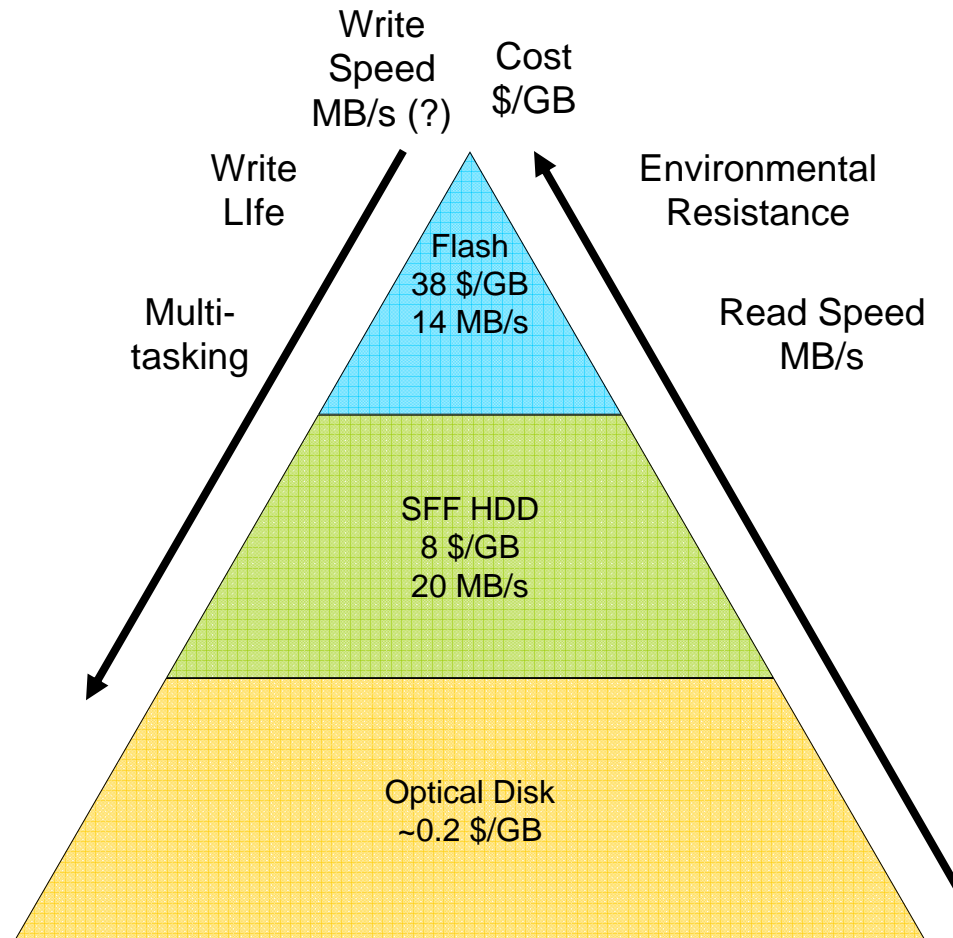
July 2005 iNSIC Conference, S. R. Hetzler: The Evolving Storage Hierarchy

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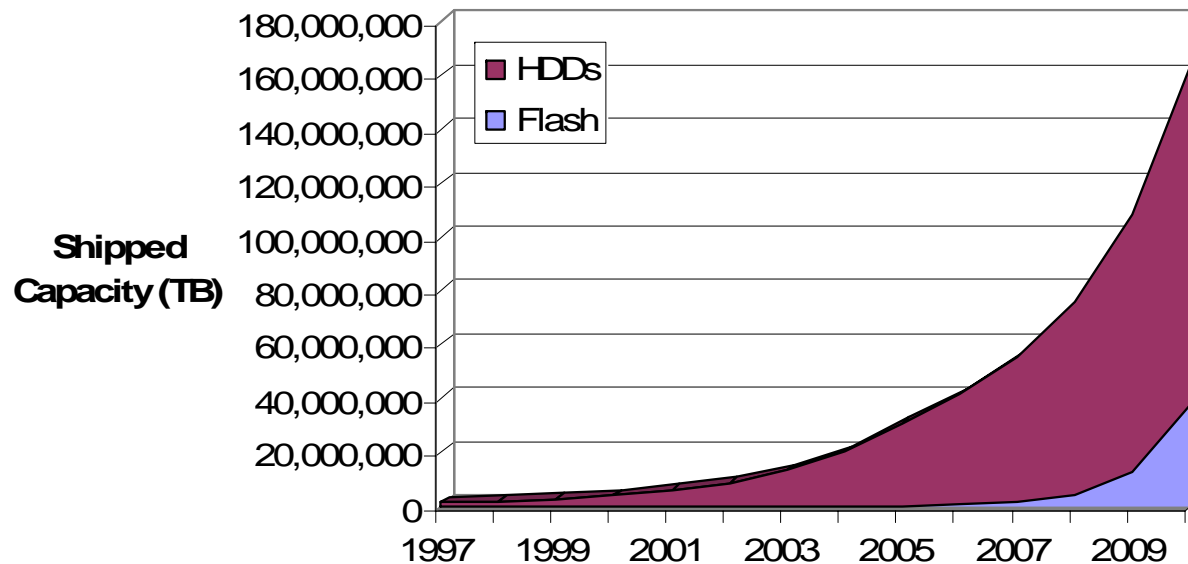
Consumer Devices Using Various Elements of Available Storage Hierarchy



Mobile Storage Hierarchy



Room for all!

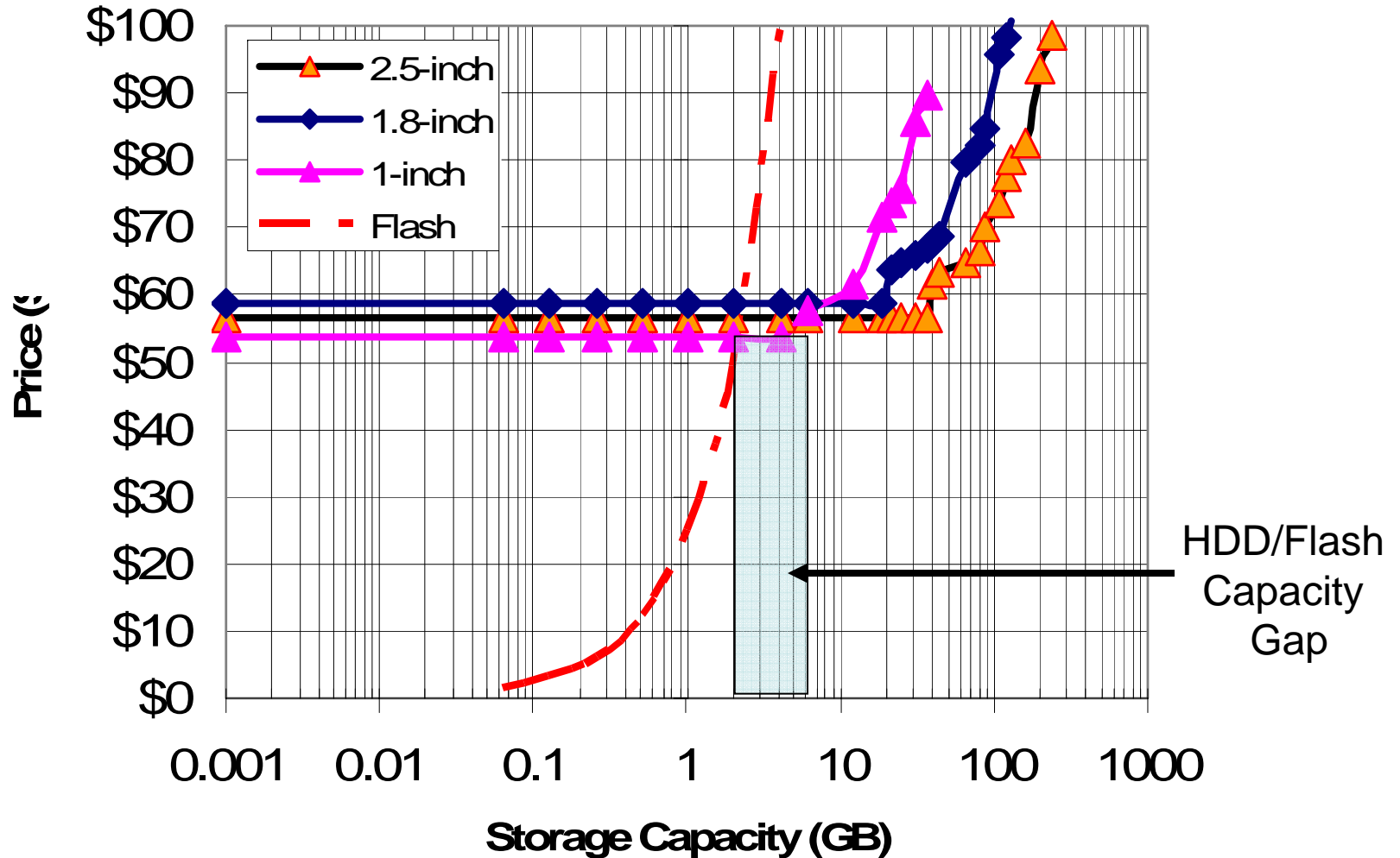


By the next decade over 1 Billion disk drives will be shipped per year.

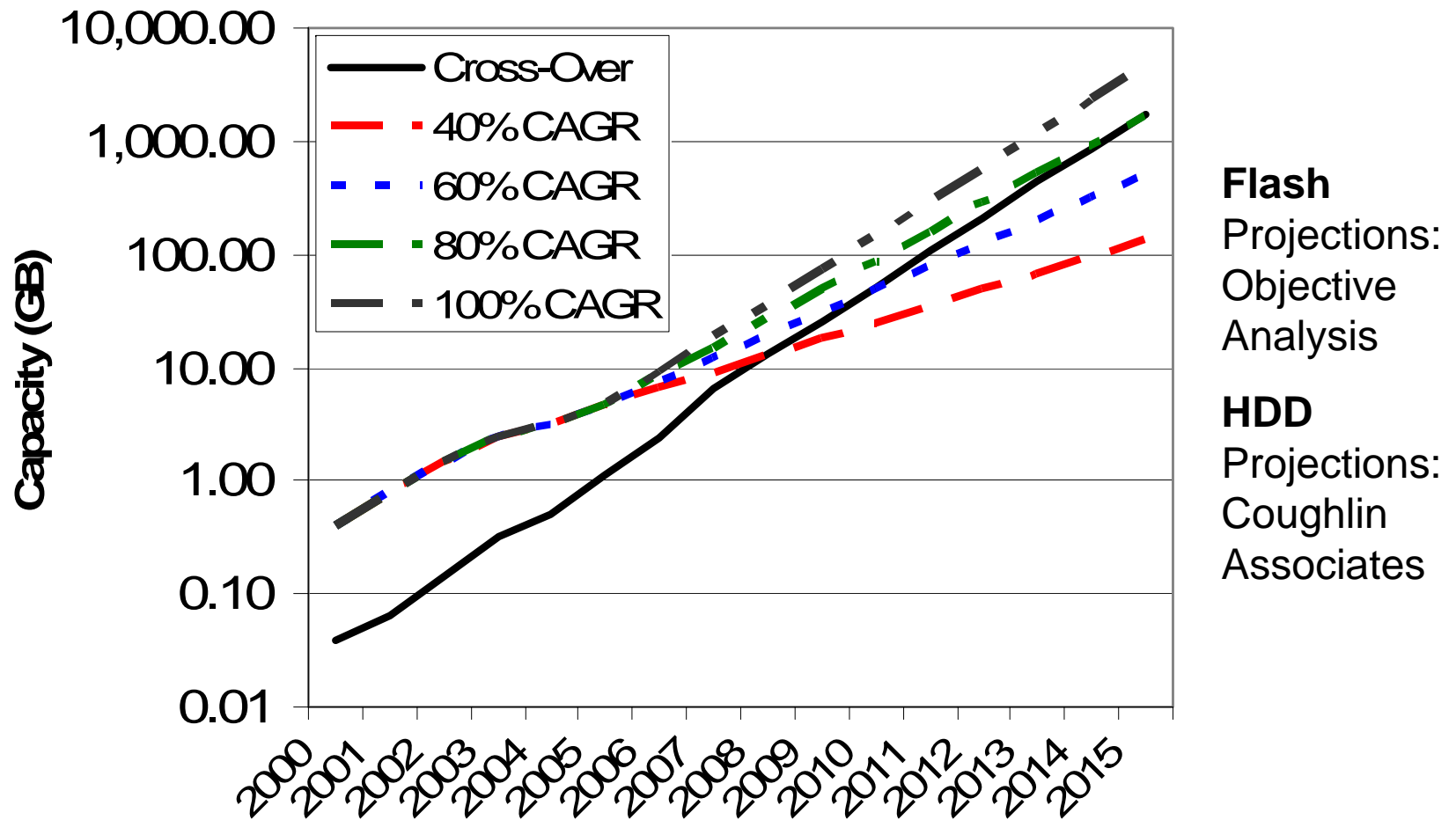
(Drive Data: Coughlin Associates, Flash Data: Objective Analysis)

- Storage in flash-based devices is usually ancillary to storage on a HDD, e.g. a computer downloads content that is then loaded on an MP3 player
- Long term accessible storage will remain on hard disk drives and hard disk drive enabled storage networks
- Having many storage choices will create multiple market niches serving multiple clients

Comparison of Price vs. Capacity of HDDs and Flash in mid-2006



Projected Minimum 1-Inch Drive Capacity as a Function of Areal Density CAGR and Flash vs. HDD Cross-Over Price Point vs. Time

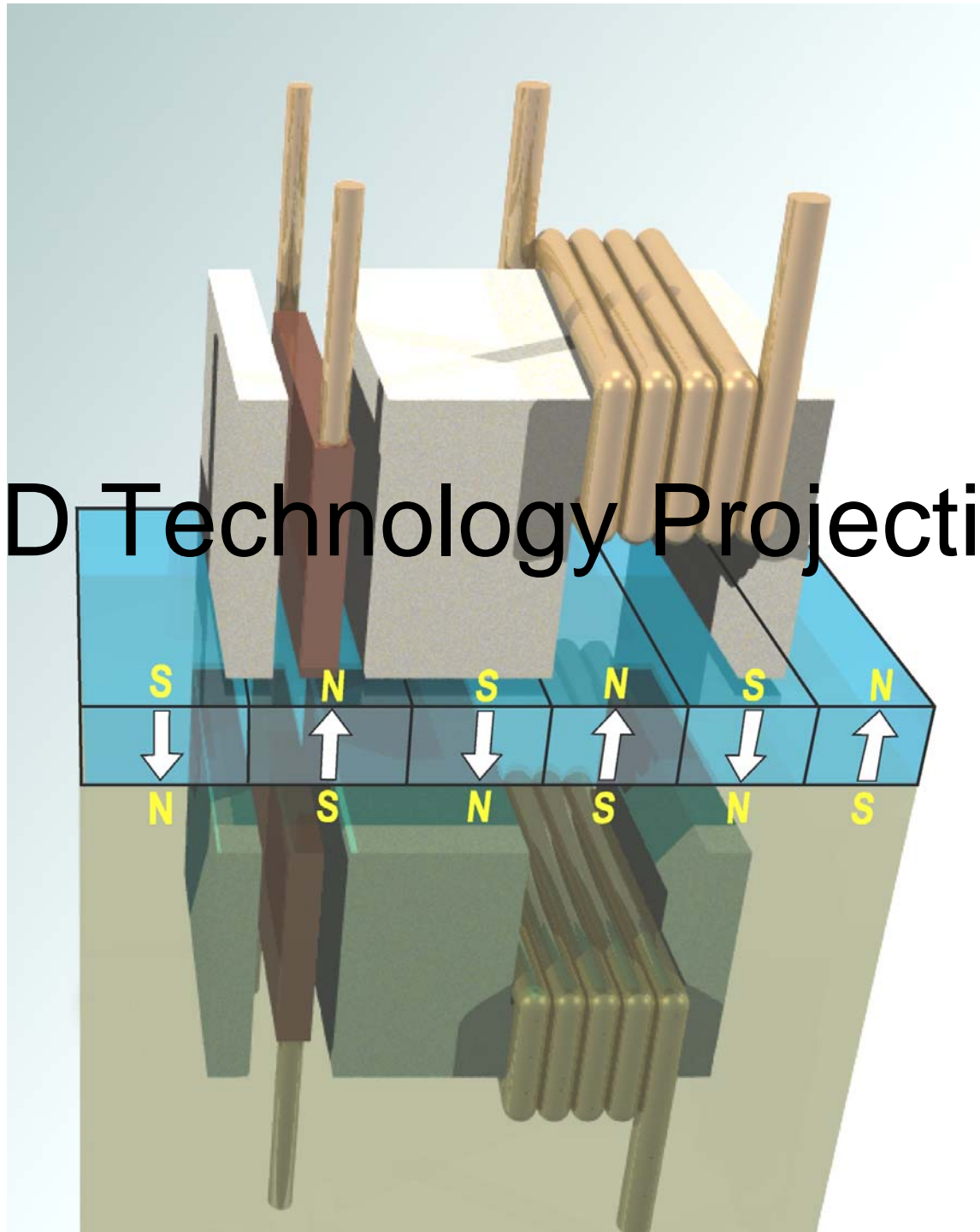


Consumer Products using or Enabled by Digital Storage



**E-SATA 3 Gbps!
Ethernet (IP and Cable)**

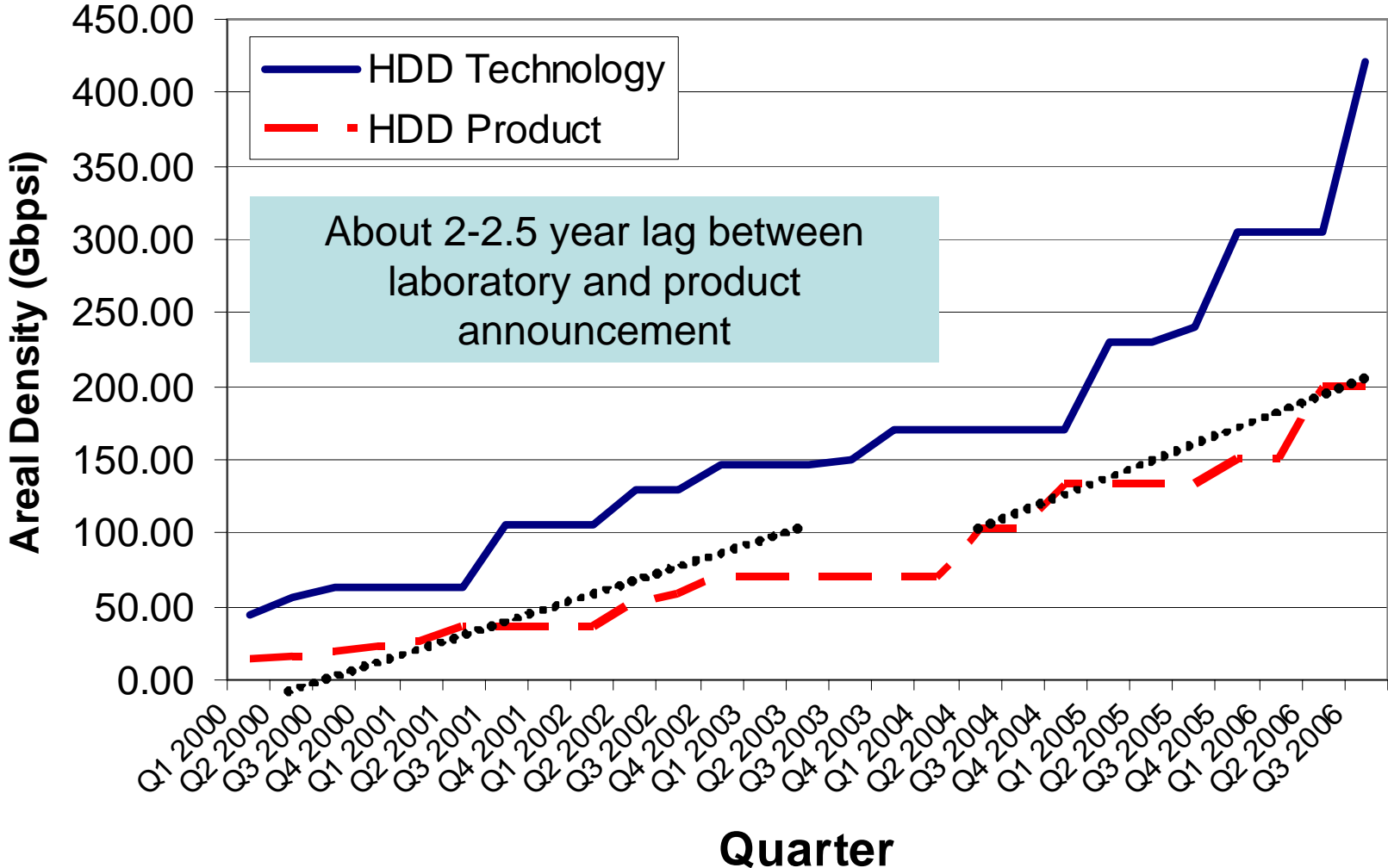
HDD Technology Projections



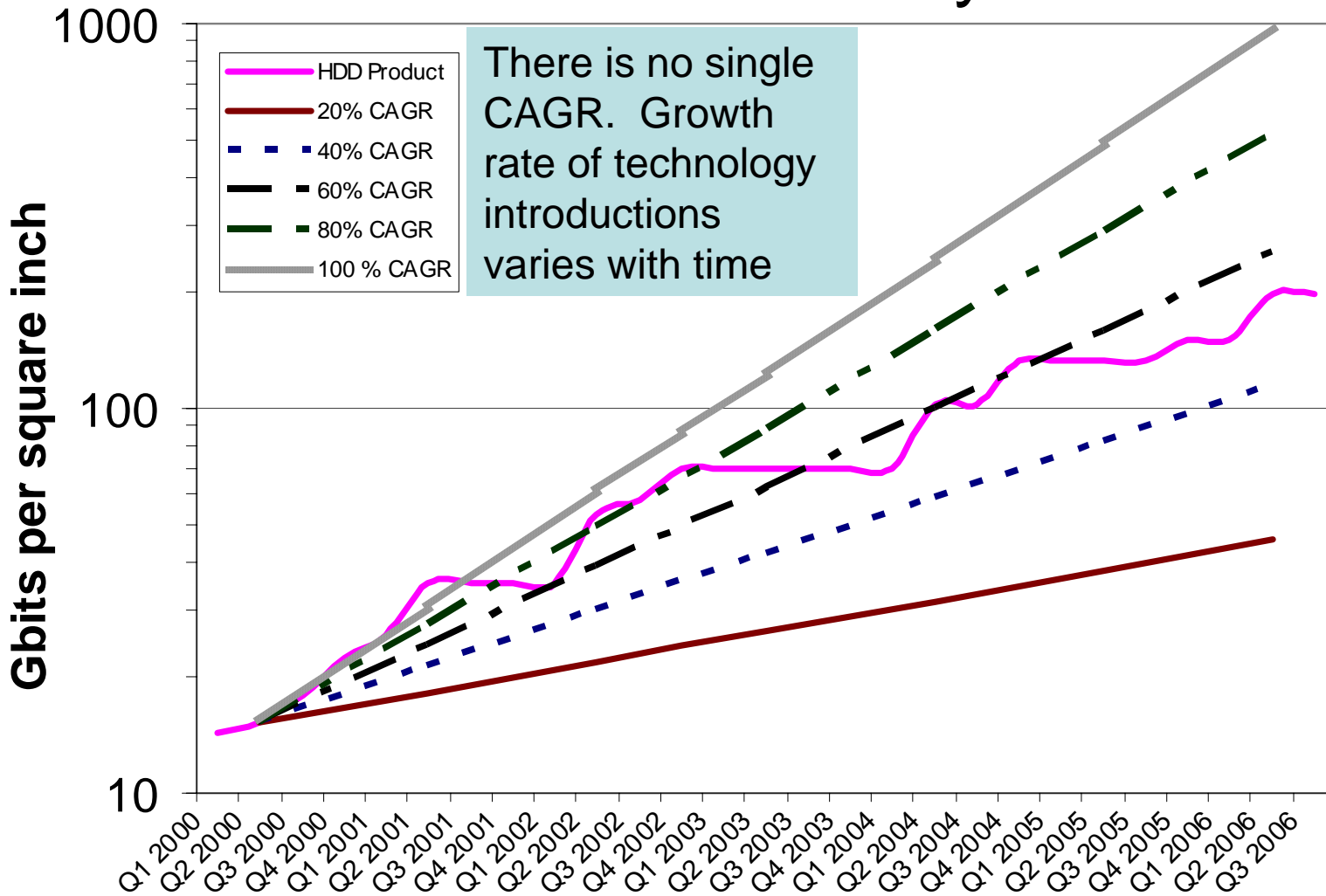
Observations regarding Technology Introductions

- 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

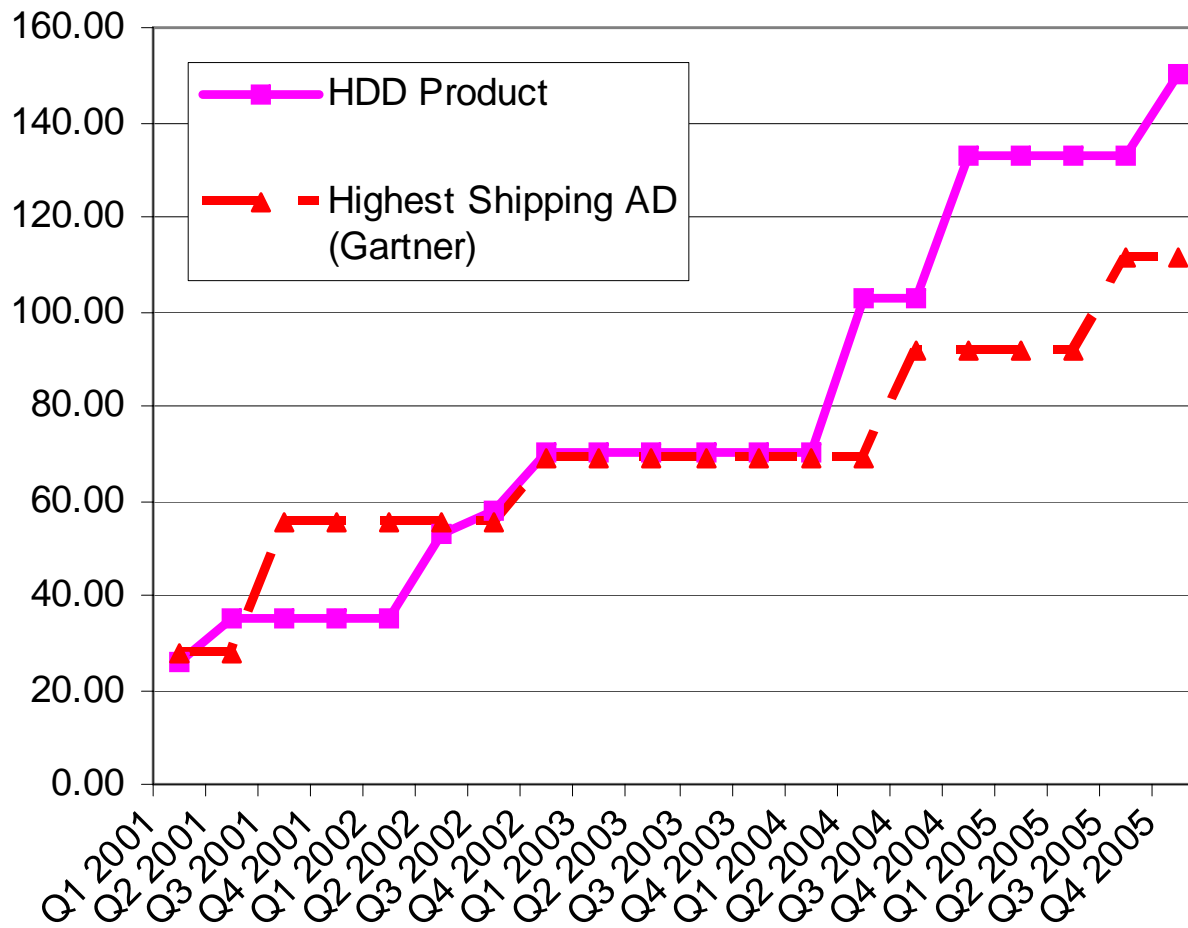
HDD Quarter by Quarter Public Technology Demonstrations and Product Announcements



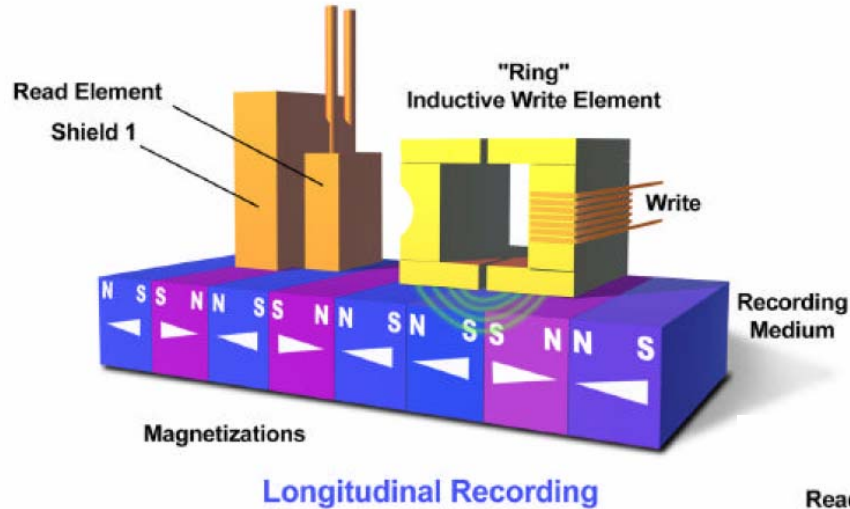
Comparison of Product Announcement Trends vs. Areal Density Rates



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

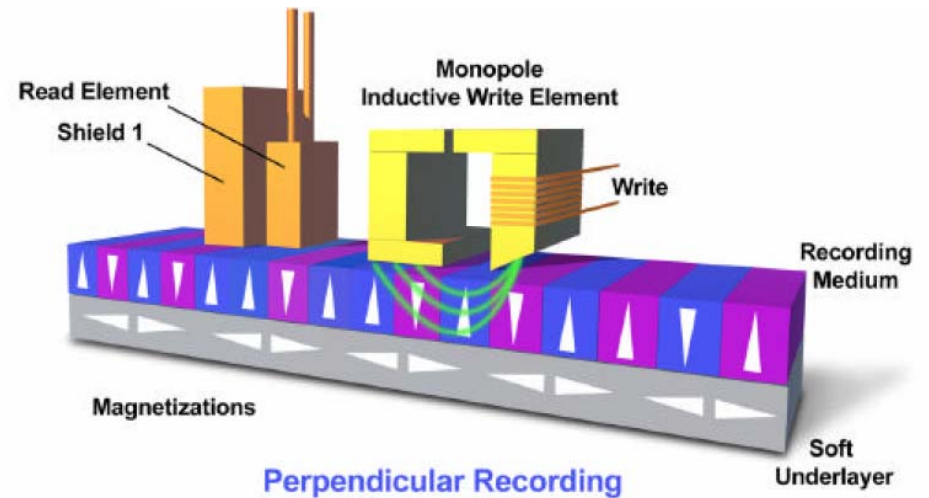


Transition from LMR to PMR

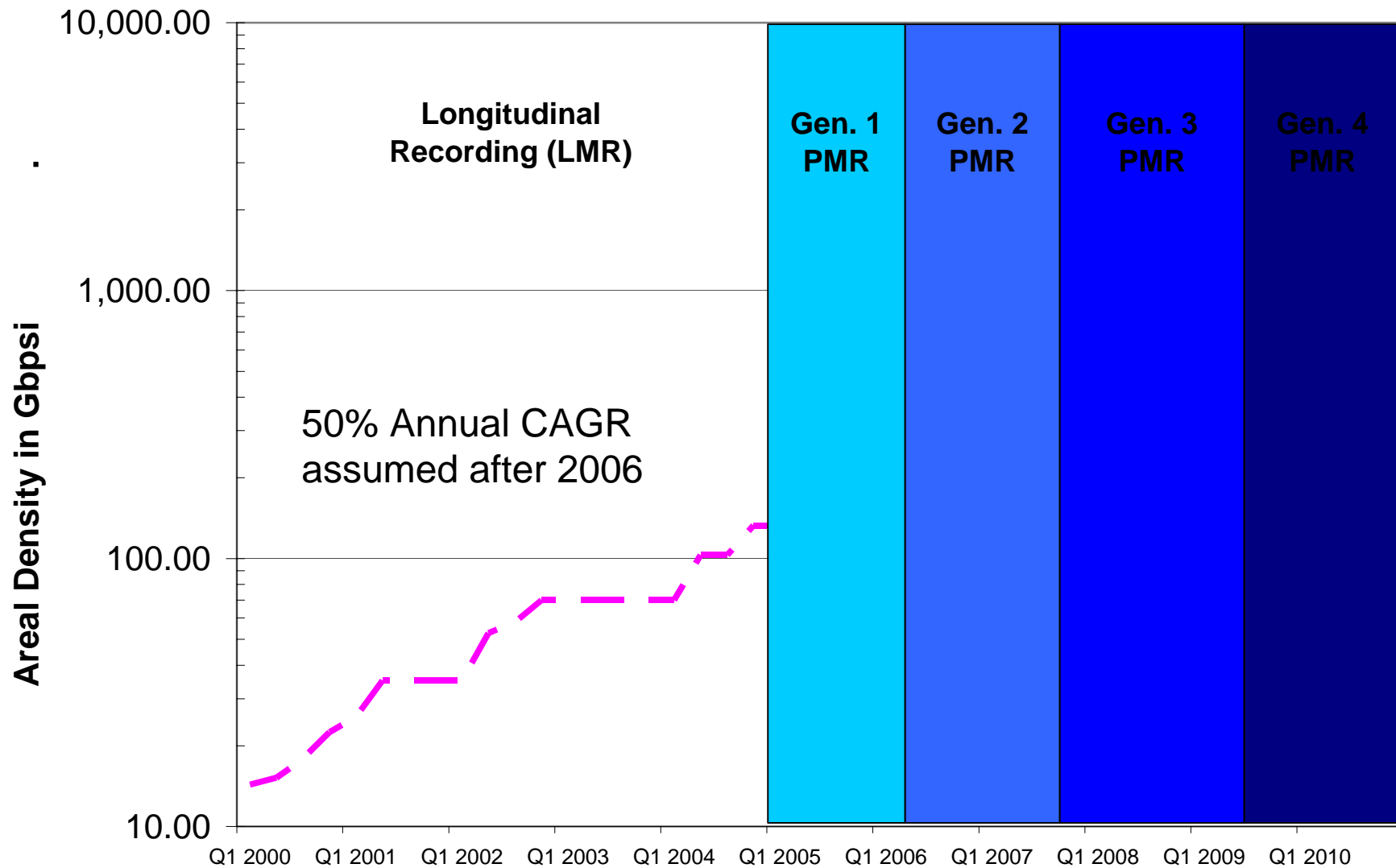


Longitudinal Recording

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 (products by all drive manufacturers)
- Generation 3: Further improvements including discrete tracks and/or dual-stage actuator
- Generation 4: TAR/HAMR or Patterned Media with more advanced read sensors, dual-stage actuators

A Terabyte in the Pocket and a Petabyte in the Home

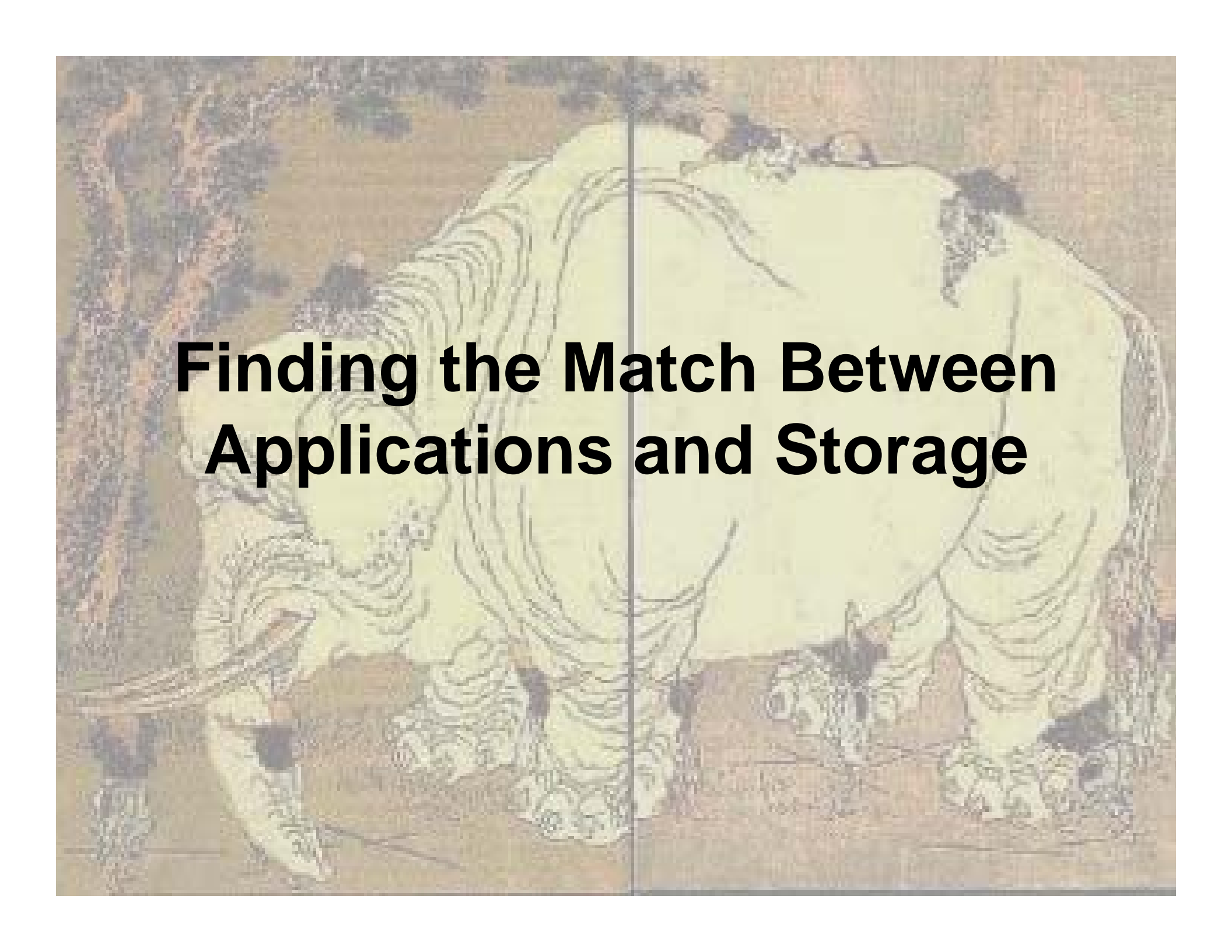
- Estimated Areal density required for 1-TB 2-sided disk vs. FF (Gpbsi)

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

- With 19.4 Tbps/area 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.

Other Hard Disk Drive Developments

- In-Drive Encryption
 - Allows protection of contents in a form that drive keys cannot be obtained using simple hacking.
 - Allows effective “secure erase” by throwing away the drive key—takes ms vs. minutes to hours for overwrite SE of large hard disk drives
 - Pushed by Trusted Computing Group (members include Seagate and Hitachi)
- Hybrid Hard Disk Drives
 - Allows write aggregation using part of flash cache saving power for mobile device
 - Allows putting some boot information in a locked portion of the flash memory to speed up computer booting
 - New Hybrid Drive Association announced at 2007 Storage Visions Conference

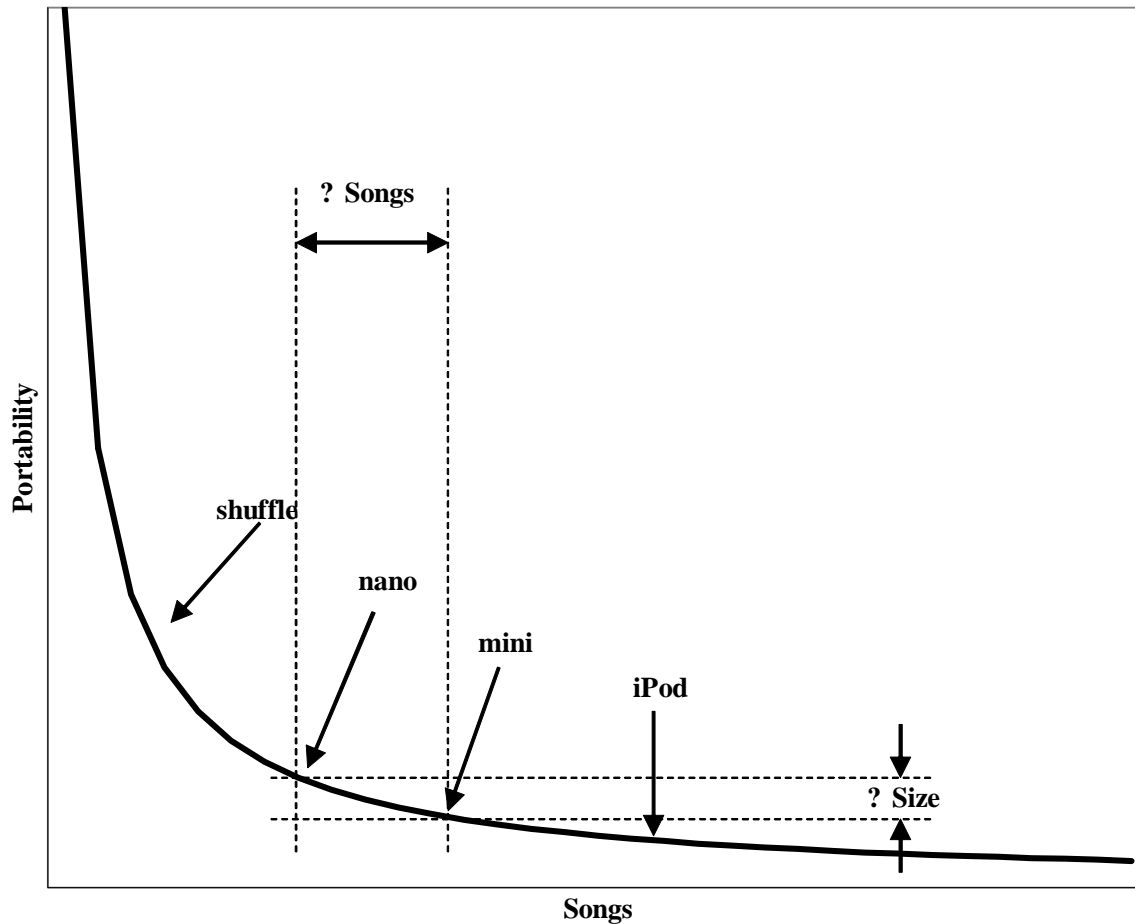


Finding the Match Between Applications and Storage

Rules for Storage Design

- Use the most cost effective storage component(s) that provide enough capacity for the application
- Never design a product where you intentionally limit the available storage capacity to the customer—always allow a means of storage capacity expansion
- Make it easy to back up and copy data (storage is cheap, time is not!)
- Make management and organization automatic (storage utility)
- Design to provide lowest total product cost (storage integration concepts)

i-Pod Portability vs. Song Capacity

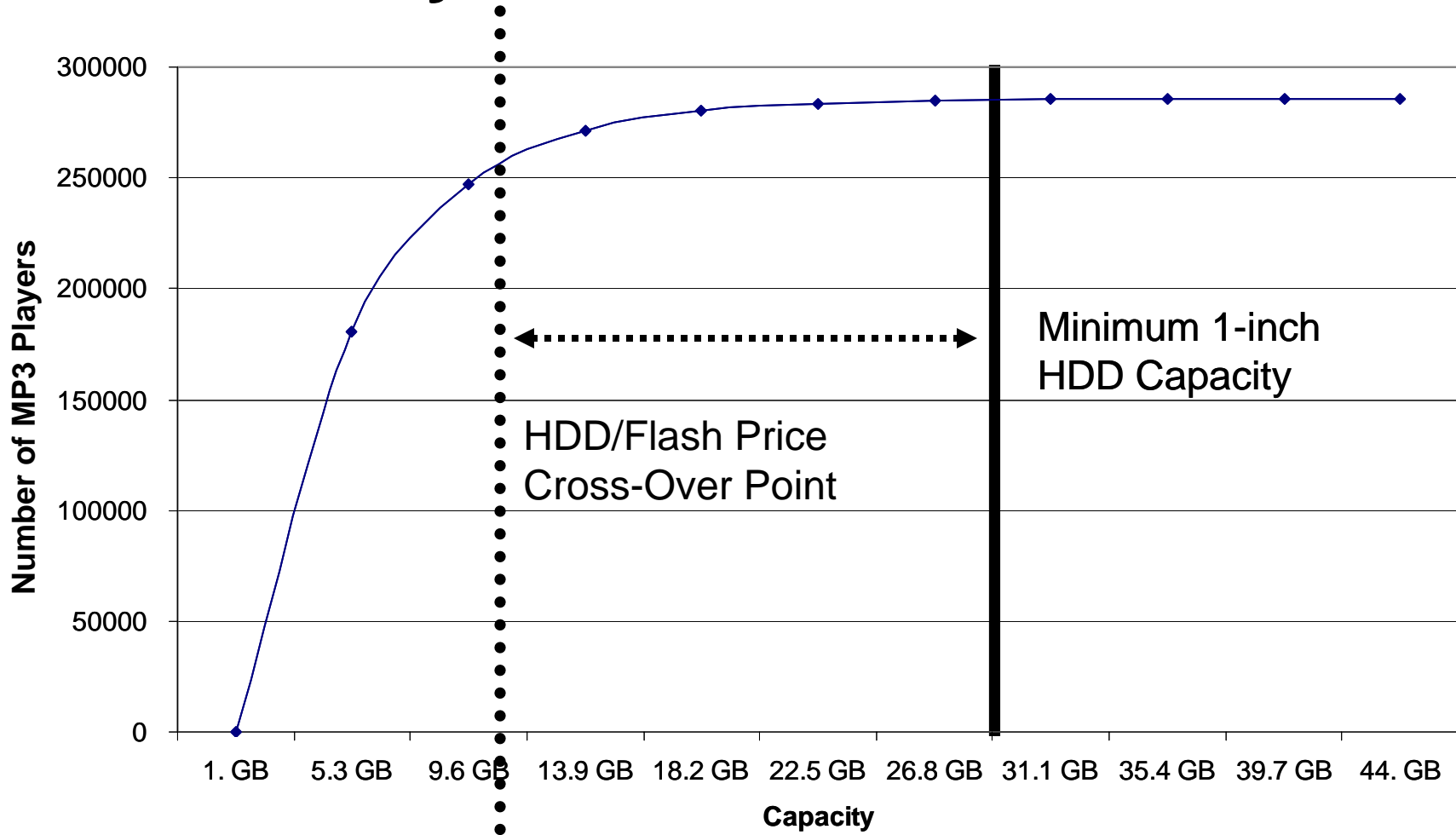


Portability is inversely proportional to the physical size, volume or weight

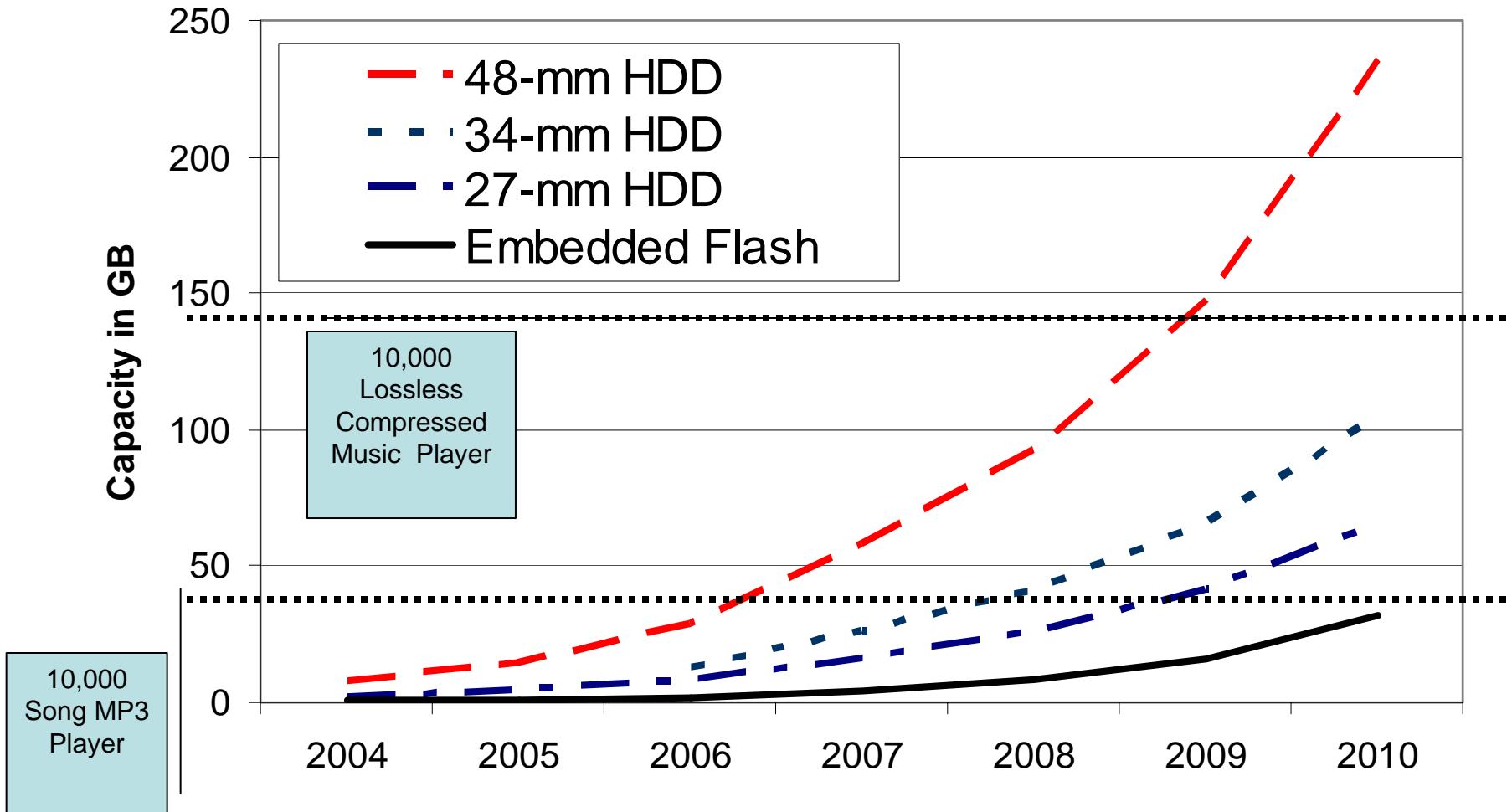
Source: Semico Research Corp., June 2006

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2010 Accumulated Market Volume Model for MP3 Players (MP3 typically uses 90% lossy compression)



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



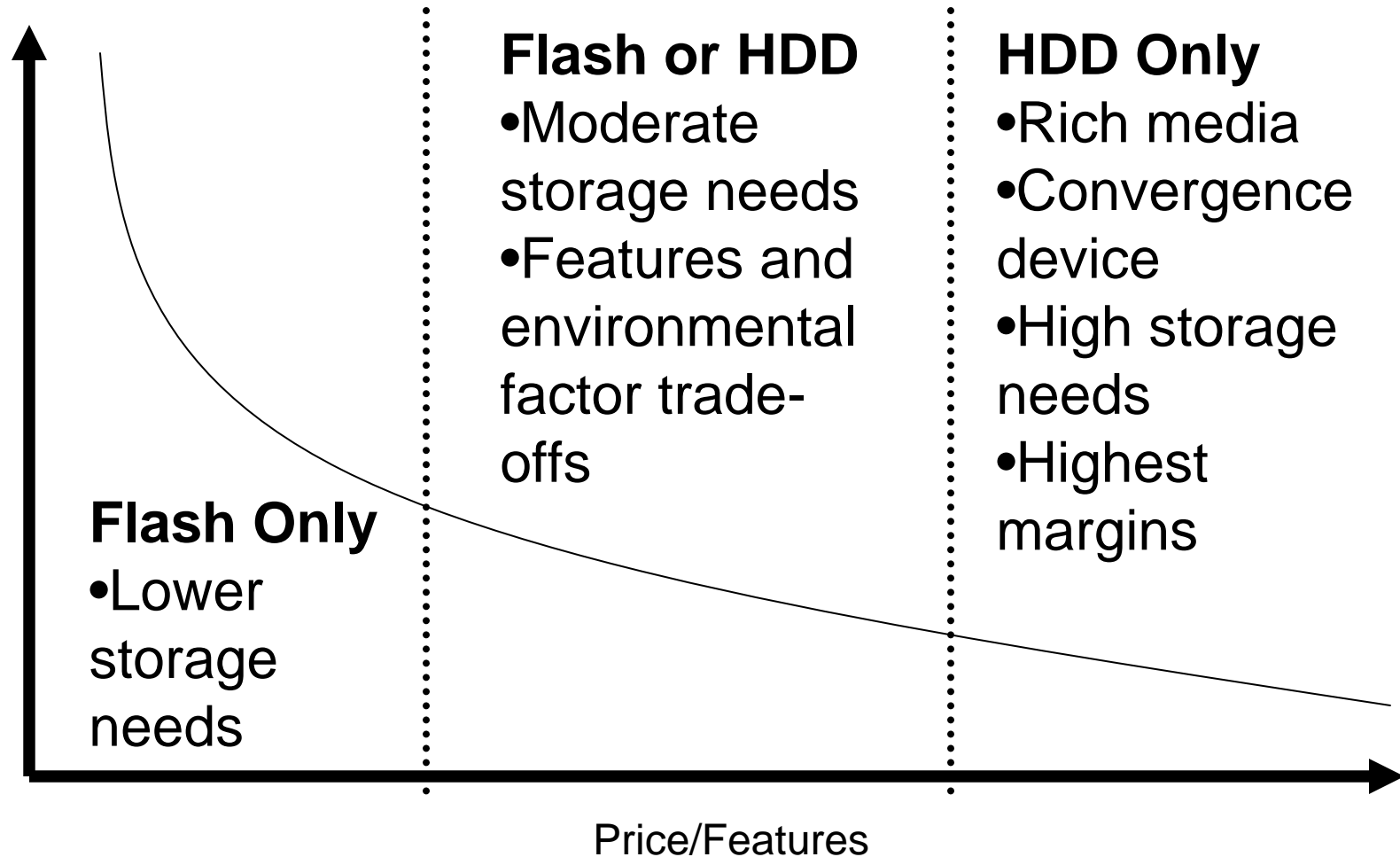
Higher Resolution Mobile Device Storage Needs (HDD's Still Have a Role)

- 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

Mobile CE Product Market Niches (e.g. cell phones)

Market Volume



Where will Flash Dominate?

Where will HDD's Dominate?

- Flash
 - Digital still cameras (HDDs still used for very highest resolution)
 - MP3 players (very compressed content fits into needed capacity point for lowest price)
- HDDs
 - Rich media players (Personal Video Players)
 - Rich media cell phones
 - All applications requiring high resolution content such as higher quality music and higher resolution video

The Future of SSD Laptops (1)

Today (<1% of market)



Inexpensive
Mass Market
Notebook
Concept

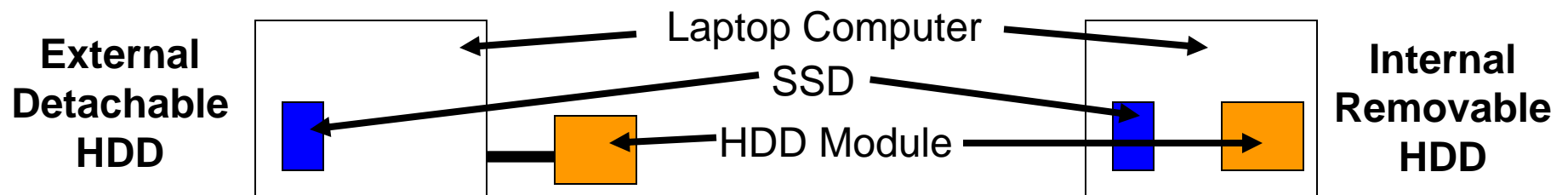


Expensive
Limited
Memory
Very Rugged
Notebook

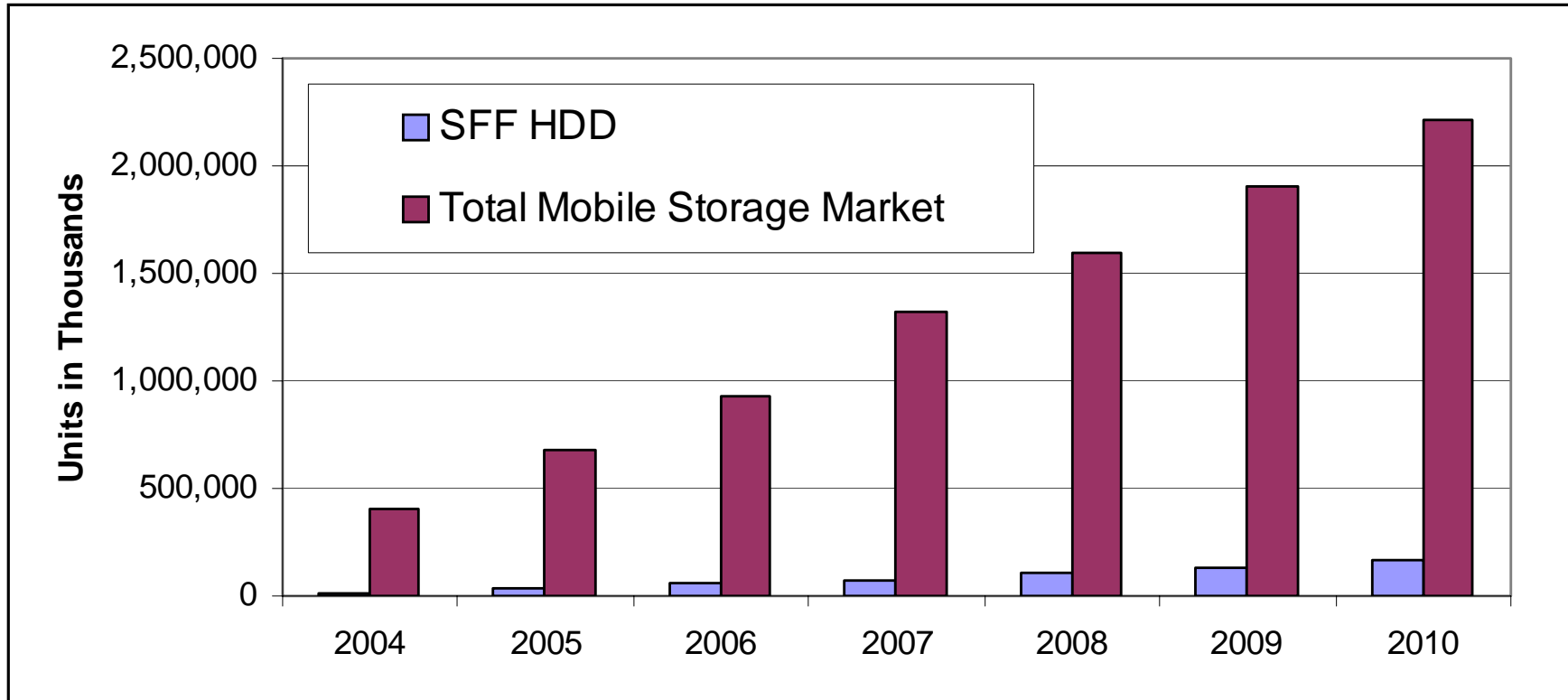
- Tomorrow (2011)
 - Higher capacity at lower prices (perhaps 100 GB at \$200 premium compared to 300-500 GB 1.8" HDD by 2011)
 - Better remote connectivity allowing access to corporate data when on the road
 - Even so, I expect the growth of rich content even for corporate uses to limit this market to <10% of total notebook market by 2011

The Future of SSD Laptops (2)

- How to make SSD laptops more popular
 - Don't limit the amount of local storage to the user
 - Enable choices in content access rather than restrict it
 - Use the storage hierarchy to your advantage!
 - This could increase market share to >15% by 2011
 - One concept—turn the laptop inside out (SSD fixed and HDD removable)
 - This gives users more options and if designed together could be very sleek and attractive



Small Form Factor HDD Projections vs. Mobile Storage TAM

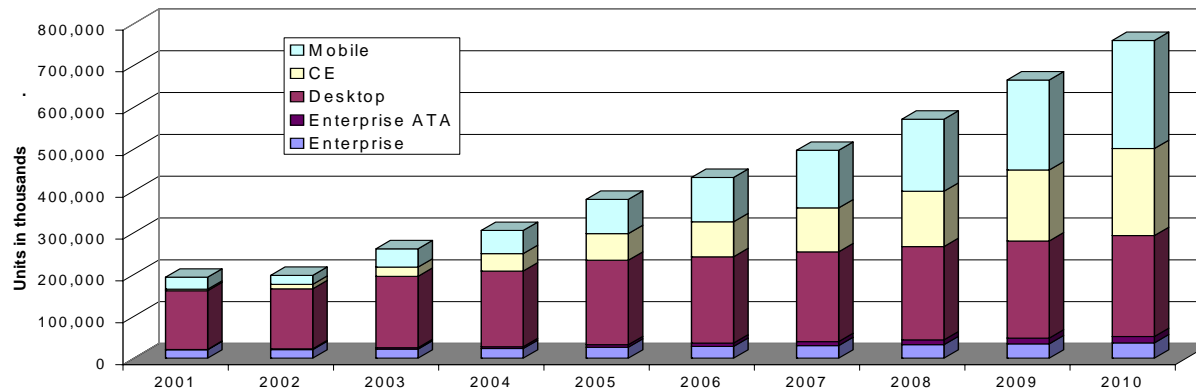


Small form factor HDDs will provide mass storage for higher end portable devices
Potential annual market for HDD in mobile devices in next decade is over 100 M.

HDD Projections

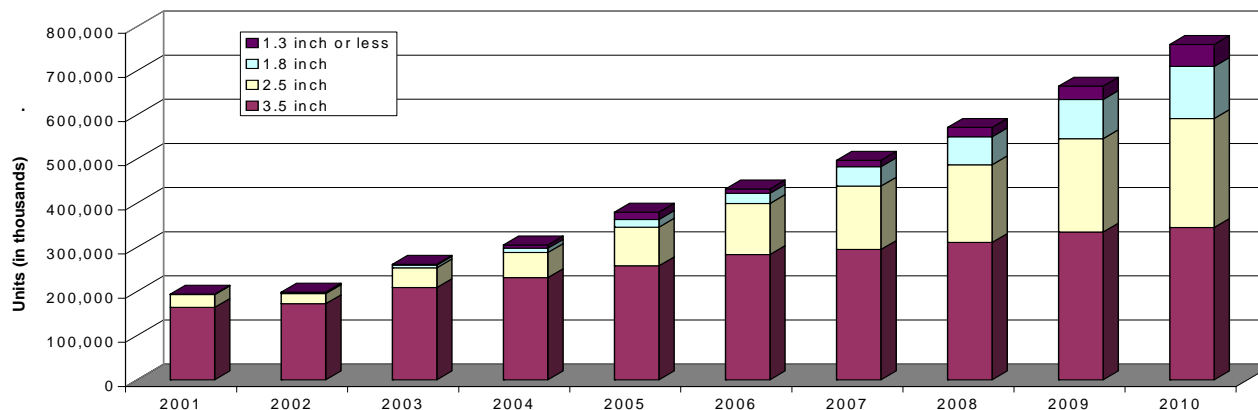
(Coughlin Associates, 2006)

Market Niches



Majority of HDDs in CE and mobile computers by 2010

Form Factor



Majority of HDDs in 2.5-inch or smaller by 2010



**The Next Steps in Electronic
Integration**

Drivers and Consequences for Applications on Storage Devices

- There is a drive to reduce number of devices and increase ease of use in entertainment networking
- For many applications the digital storage device is highest cost items in the BOM
- Decreasing semiconductor line-widths increases the complexity that can be implemented on a chip, allowing new functions and lower overall costs
- Reduced cost of CE products overall by eliminating second circuit board and integrating product test into storage device burn-in
- Tighter integration of applications and digital storage could result in lower power usage and higher performance
- Many CE applications are reaching a level of maturity that they could be implemented as a sequence of standard command calls in the storage device (e.g. hard drive) electronics

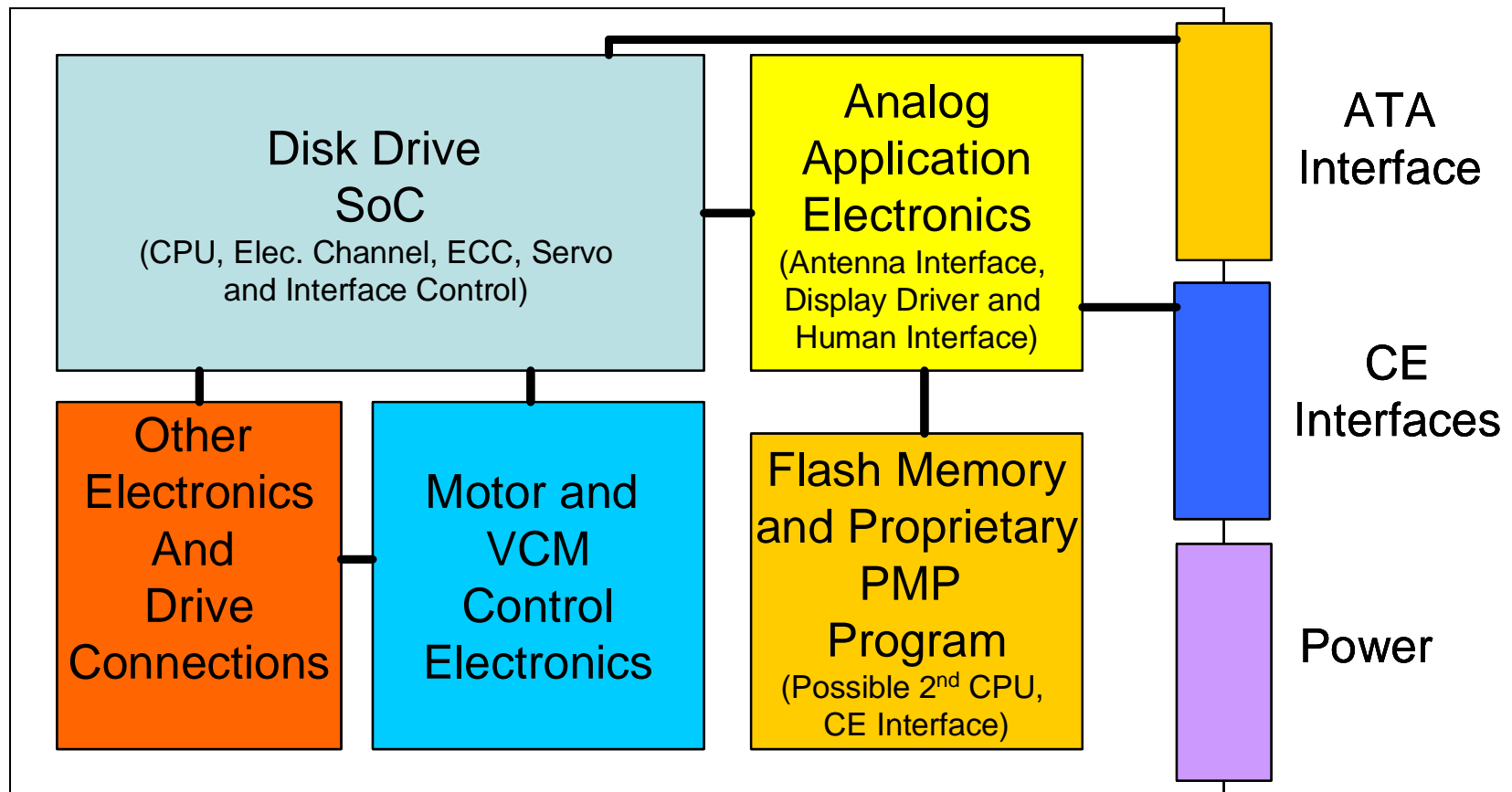
Comparison of Consumer Device and Component Storage Costs

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

Additional Features in Application HDDs

- Other features can be built into HDDs such as Bluetooth, WiFi, UWB, LCD drivers, Audio Amp drivers, GPRS/GSM, UMTS/3G and video as well as audio codecs—this could be a path to universal home storage networking using wireless networking
- Built-in interfaces can save money over bridge solutions for volume applications, e.g. eSATA bridge chip cost is about \$1.00 while embedded native implementation could be \$0.10 to \$0.20 (examples could include USB, IEEE 1394 as well).
- Move from simple block downloads to true file sharing using e.g. UPNP or DNLA
- Net savings in CE application implementation can be passed on to consumer or give better product margins
- Faster design cycles due to tighter product integration and programmable applications—the application becomes a firmware download and updates could even be made in the field

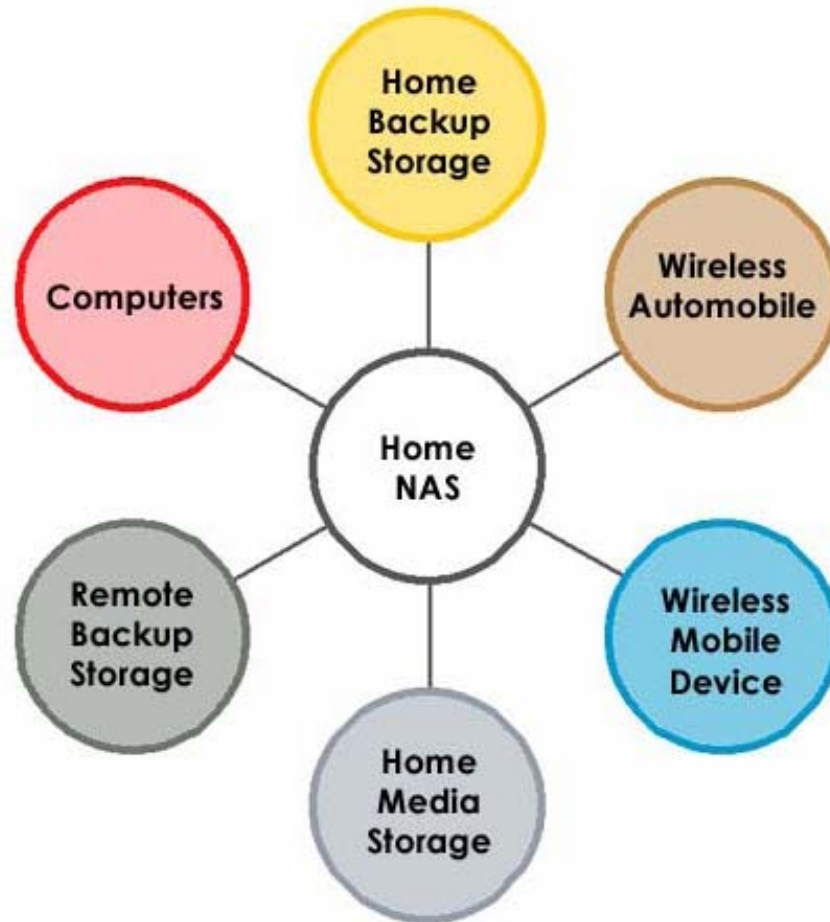
Example of a Personal Media Player (PMP) implemented on a Hard Disk Drive

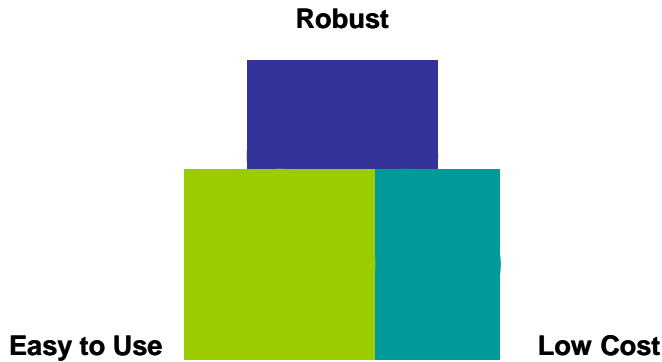




Connecting Everything at Home

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



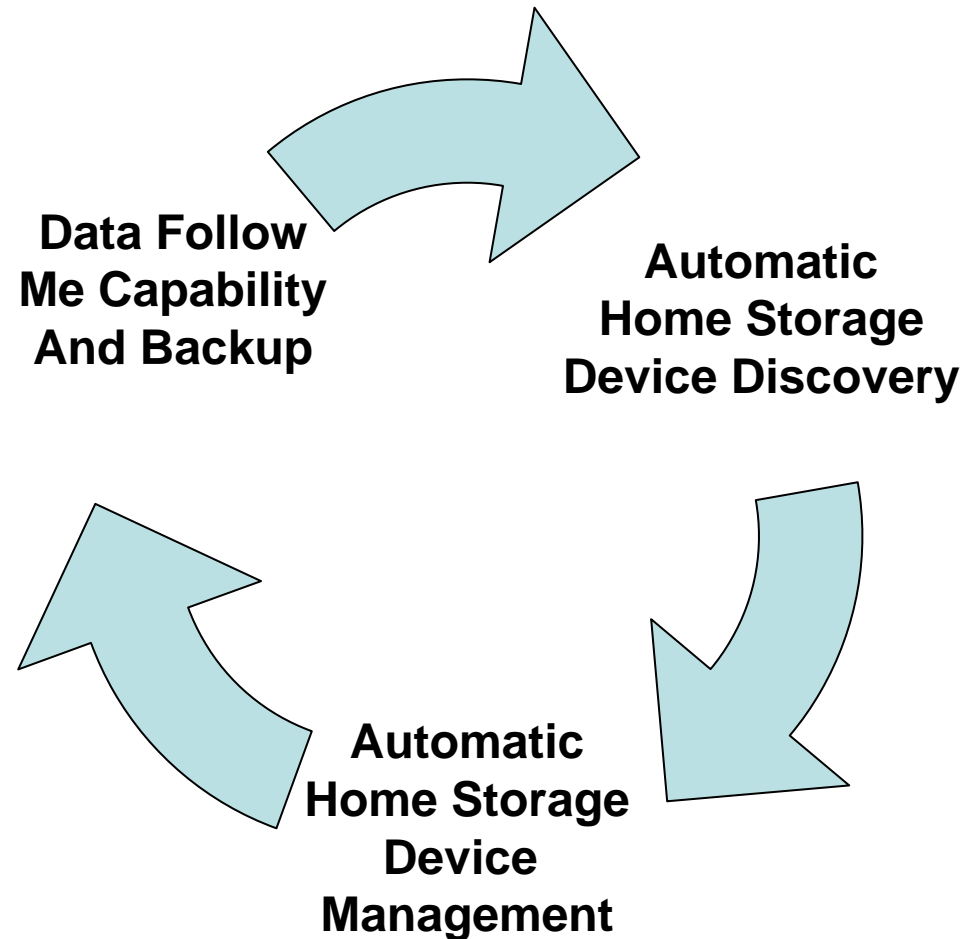


Drivers for Home Network Storage

- 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, close to 100 TB by 2015 (?)**
- 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
- Possible built-in storage networking through application integration into storage devices

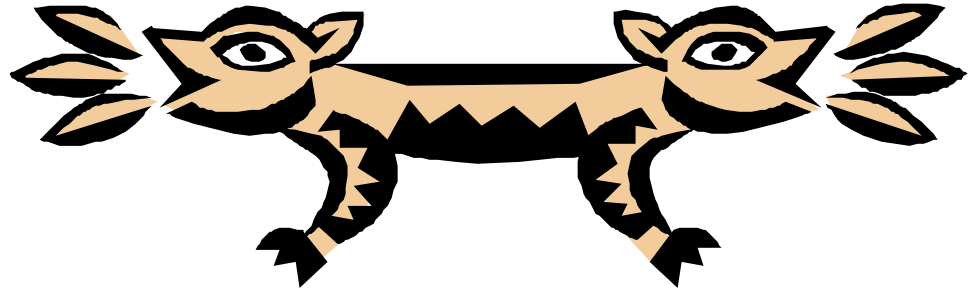
Home Storage Utility

- 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 indexes all data in storage pool
- Watches your use of content anticipating your needs and prepositioning material for you.
- Protects itself from outsiders



Source: 2005 Integration of Storage in Consumer Electronics
Coughlin Associates

Conclusions



- Consumer electronics will drive demand for storage devices for the foreseeable future.
- Personal content will be larger than commercial content in the future. Metadata could become larger than the original data
- The storage hierarchy should guide our choices of digital storage for CE devices
- The rate of technology development is irregular but the net result is significantly greater storage with time—probably true of all storage technology development
- Economic forces will drive increased electronic integration of digital storage and CE applications
- Integration of networking applications could speed the development of a universal home storage network

Sources

- **2007 Entertainment Creation and Distribution Digital Storage Report**, Coughlin Associates (December 2006)
- **Trends in Digital Home Storage: Defining the Opportunities for Network-Attached Storage**, Tom Coughlin, Coughlin Associates, TDG Report, 2005
- Presentations at **2007 Storage Visions Conference** (www.storagevisions.com)
- **The Development of Digital Storage for Consumer Electronics**, Presented at July 2006 ISCE Conference

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

A photograph of two children standing in a forest. They are both wearing bright yellow rain ponchos. The child on the left is leaning their head on the shoulder of the child on the right. The background is filled with green foliage and white flowers. The text "Welcome to our Future..." is overlaid at the top in white, and "Thank You!" is overlaid at the bottom in white, italicized font.

Welcome to our Future...

Thank You!