Matching Data Storage to Consumer Applications

Thomas M. Coughlin
Coughlin Associates

408-978-8184
Tom@tomcoughlin.com

Outline

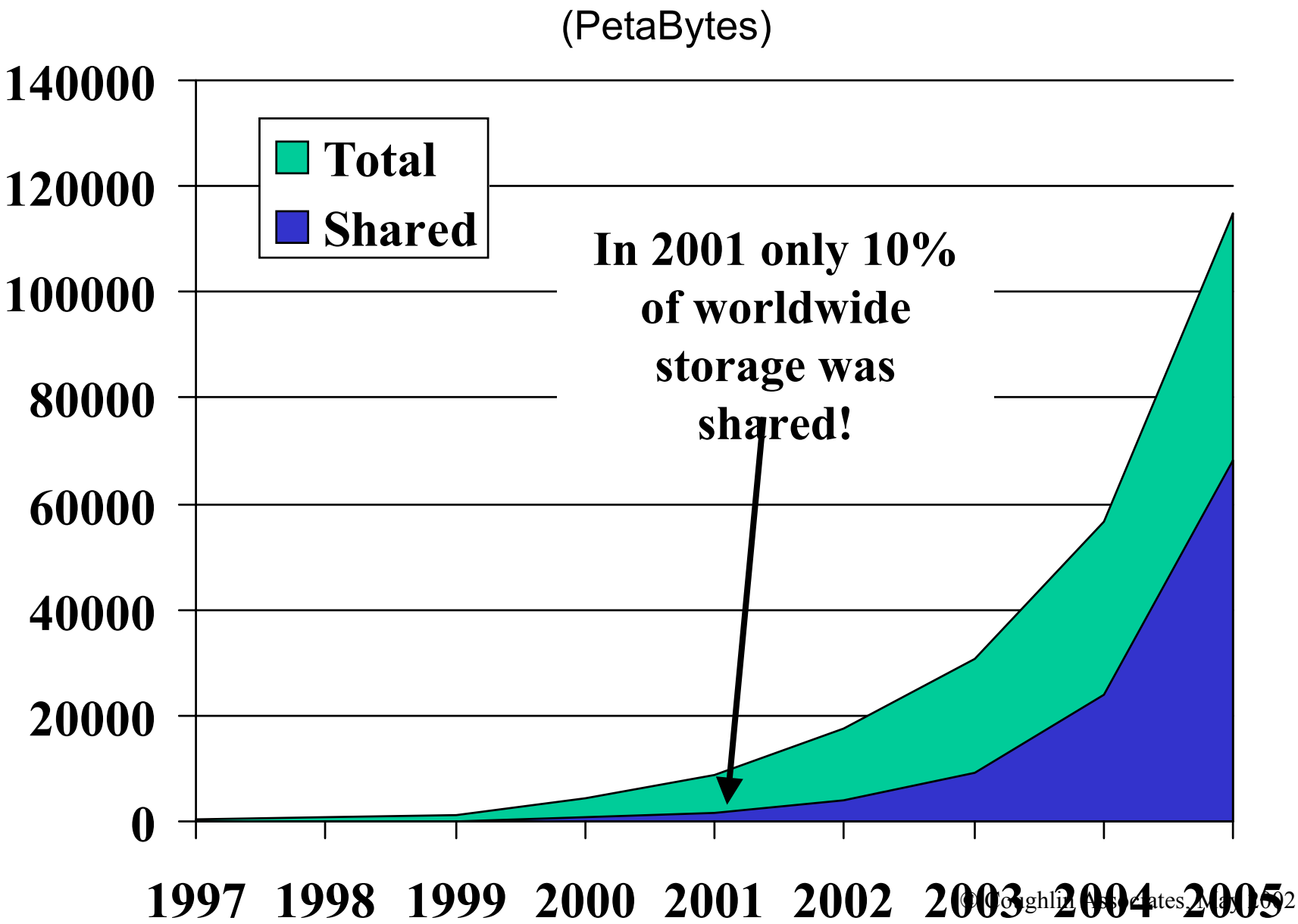
- Data Storage Market and Technology
- Important Data Storage Characteristics for Consumer Applications
  - Price
  - Storage Capacity
  - Performance and New Application Features
  - Ruggedness, Acoustics, and Vibration
  - Power Consumption
  - Size
- Conclusions

Data Storage Market and Technology

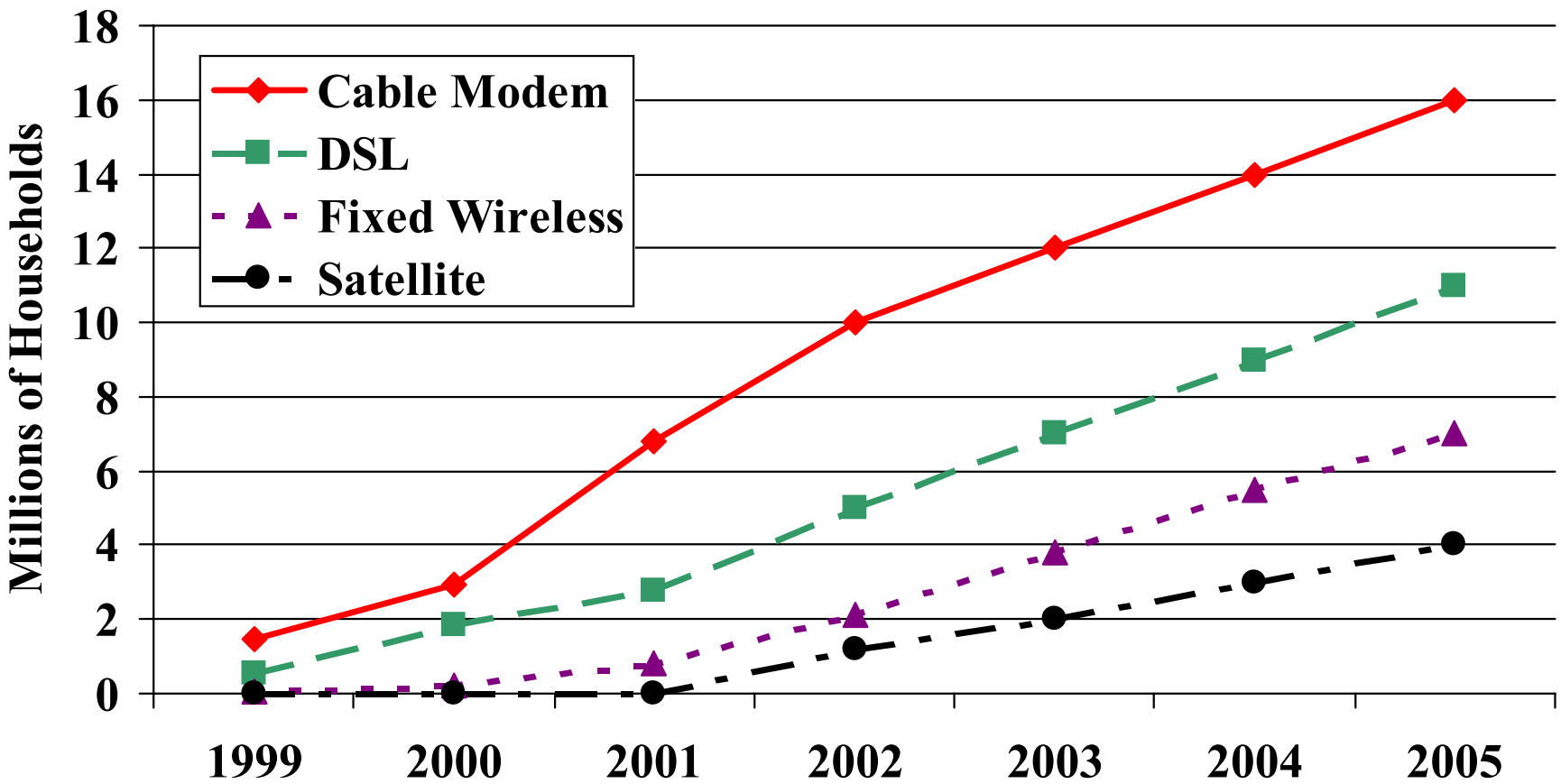
Drivers for Storage Growth

- Growth in digital information from faster processors and the digitization of human content (from literature, audio, and video to our genes)
- Ever lower cost of digital data storage
- Increasing availability of high data rate access
- New applications inspired by low cost that generate even more digital information

Cumulative Storage Capacity of Disk Memory



Household Broadband Access Growth

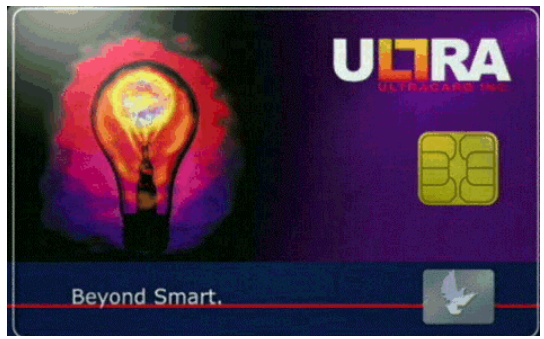


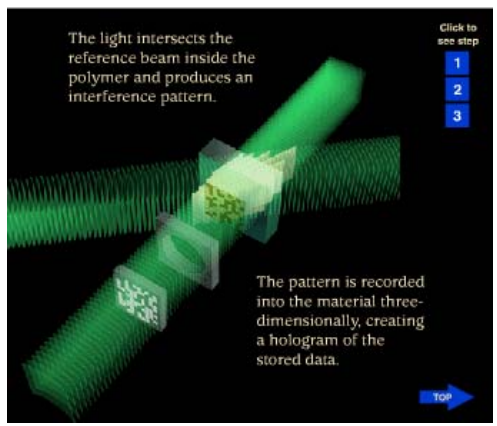
emarketeers 2000, Yankee Group Oct. 2001

Emerging storage consuming products

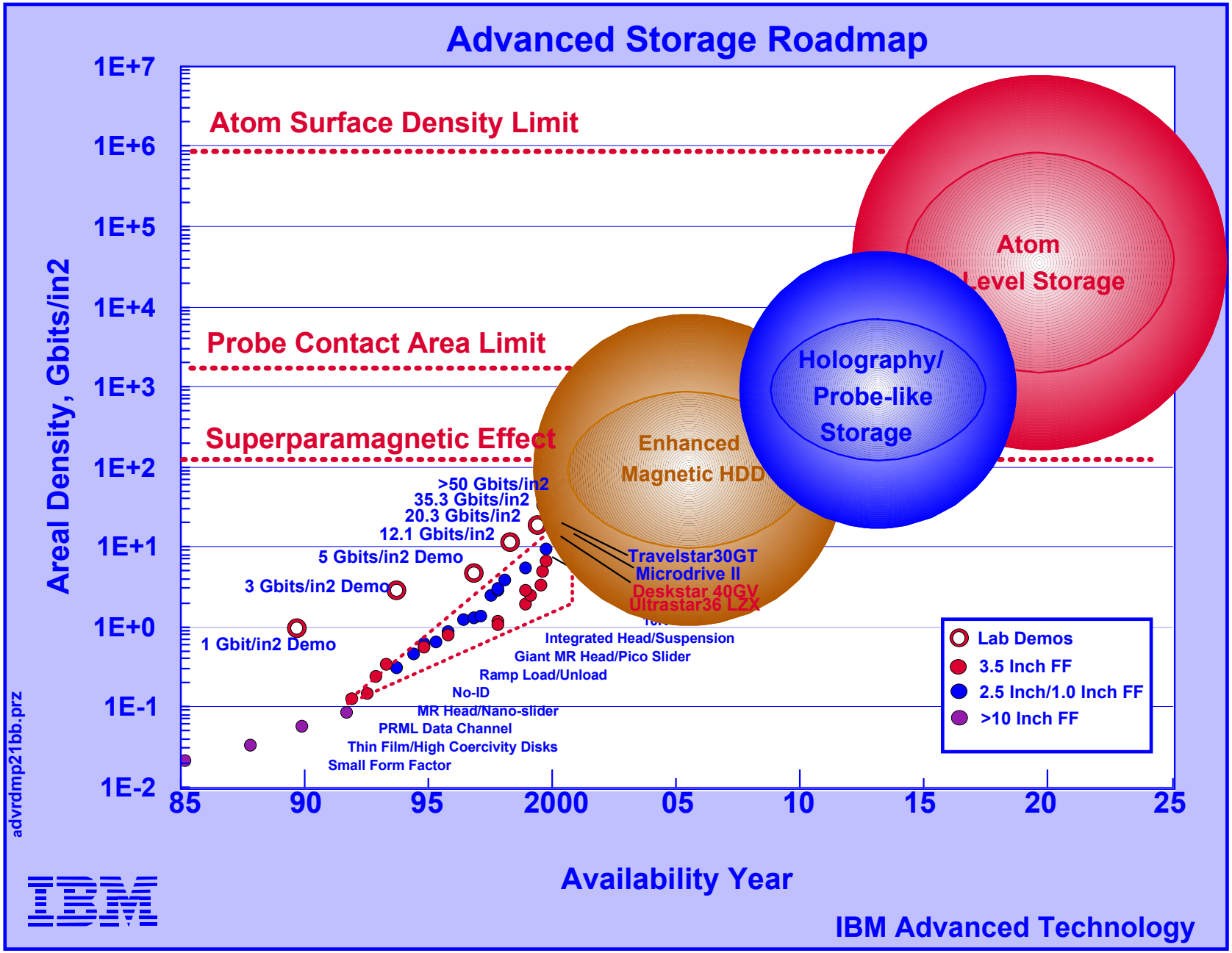
Your product here

Data Storage Technologies

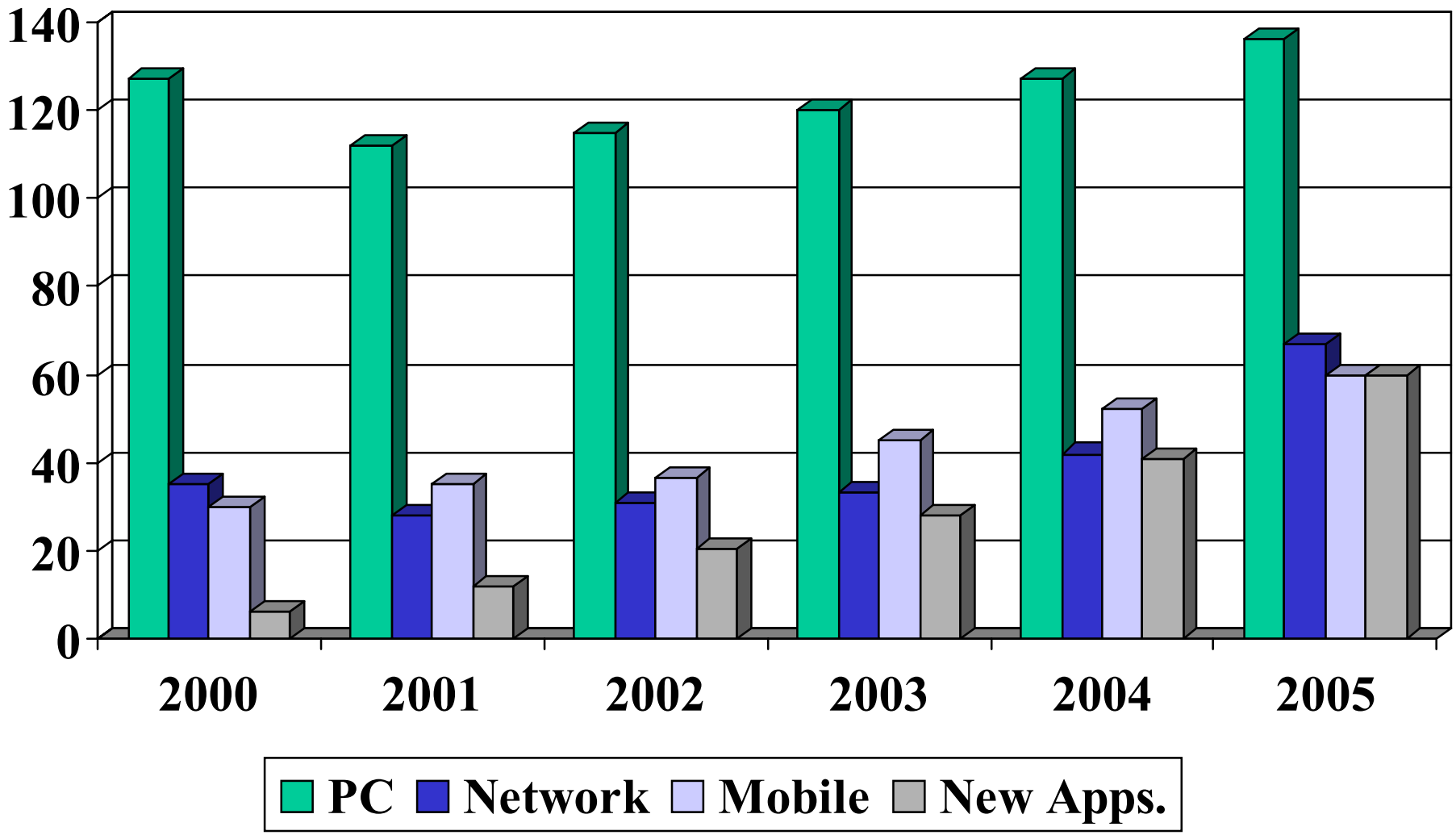




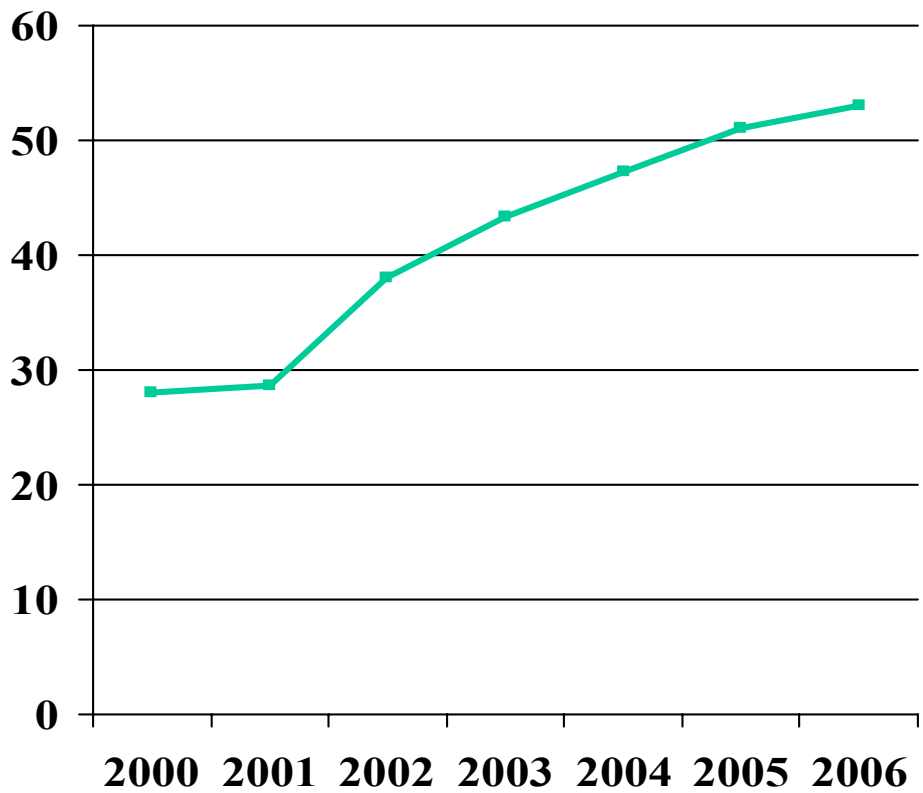
Holography


Advanced Storage Roadmap
Atom Surface Density Limit
Probe Contact Area Limit
Superparamagnetic Effect
Atom Level Storage
Holography/ Probe-like Storage
Enhanced Magnetic HDD
>50 Gbits/in2
35.3 Gbits/in2
20.3 Gbits/in2
12.1 Gbits/in2
5 Gbits/in2 Demo
3 Gbits/in2 Demo
1 Gbit/in2 Demo
Travelstar30GT
Microdrive II
Deskstar 40GV
Ultrastar36 LZX
Integrated Head/Suspension
Giant MR Head/Pico Slider
Ramp Load/Unload
No-ID
MR Head/Nano-slider
PRML Data Channel
Thin Film/High Coercivity Disks
Small Form Factor
Lab Demos
3.5 Inch FF
2.5 Inch/1.0 Inch FF
>10 Inch FF
Areal Density, Gbits/in2
1E+7
1E+6
1E+5
1E+4
1E+3
1E+2
1E+1
1E+0
1E-1
1E-2
85
90
95
2000
05
10
15
20
25
Availability Year
advrdmp21bb.prz
IBM
IBM Advanced Technology

Disk Drive Growth Trends
(Millions of Drives)



Worldwide Video Game Device Forecast (M)



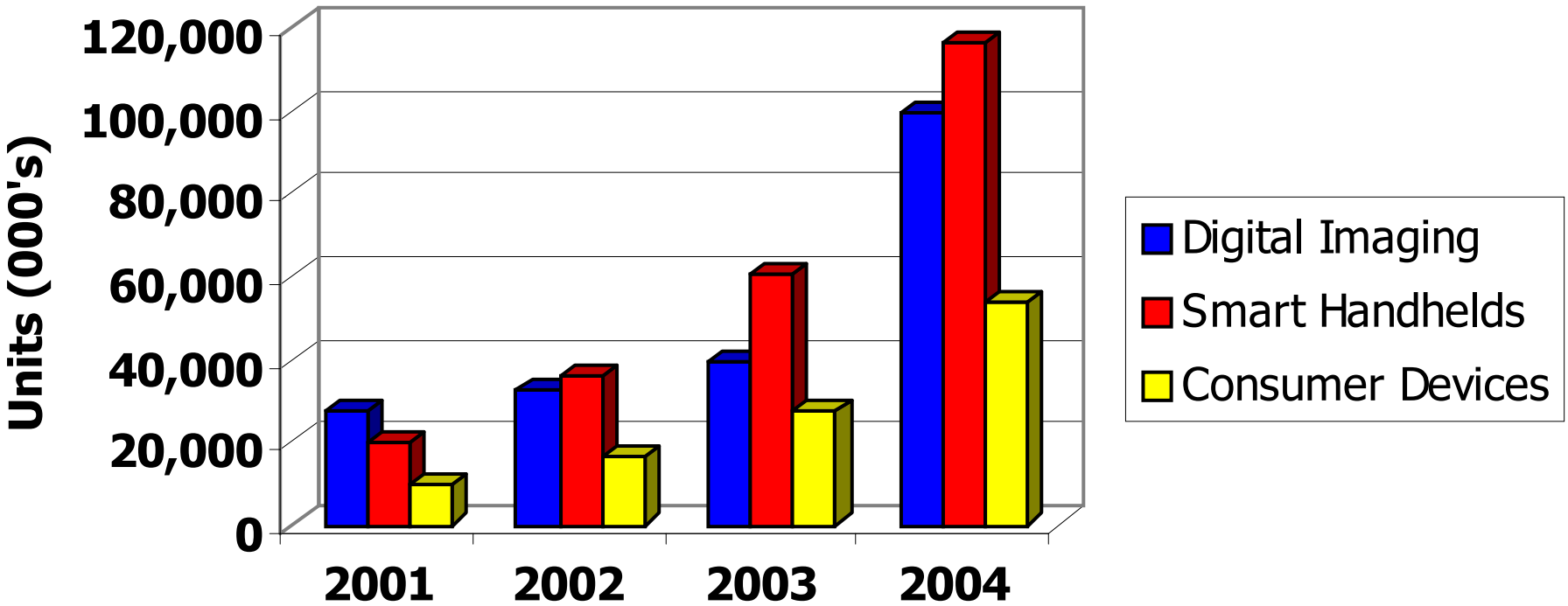
Regardless of exact forecast numbers, cumulative GC sales will provide for large volume of HDDs.

Opportunity grows only larger if Xbox competitors adopt internal HDD strategy in next products.

Source: Gartner Dataquest
WD, Storage Visions 2002

Market Size – Mobile Devices

- Worldwide Unit Forecast
  - Major segments where high density data storage is required
    - Smart Handhelds include new category of "Convergence Cell Phone"



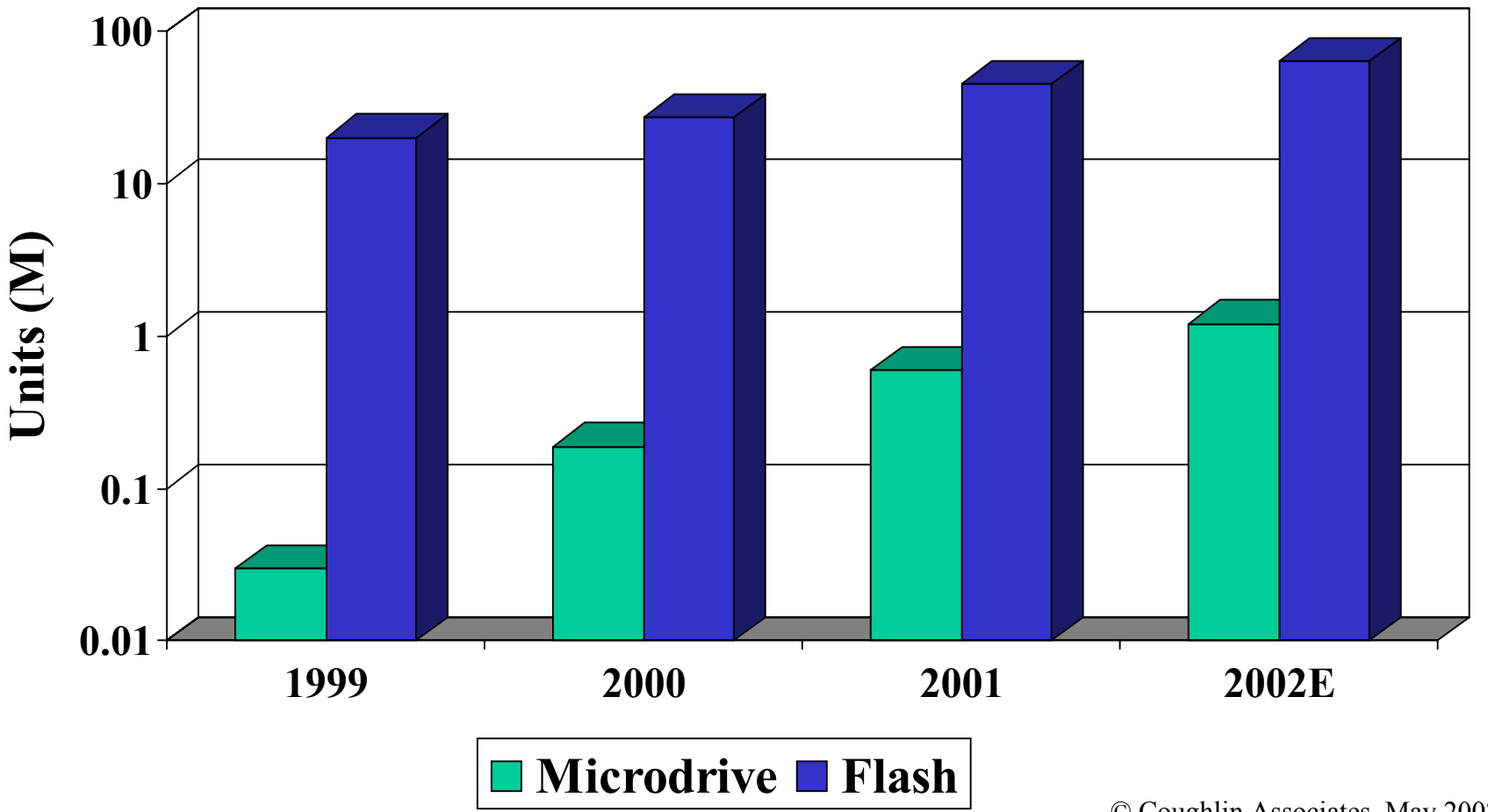
Source: IDC/WebFeet/SanDisk 2001

SanDisk, Storage Visions 2002

Shipments of Mobile Storage Devices

(note log scale)

Avg. Flash Price: <$50, Microdrive Price (end of 2001): ~$150



Important Data Storage Characteristics for Consumer Applications

- Price
- Storage Capacity
- Performance
- New Application Features
- Ruggedness
- Acoustics and Vibration
- Power Consumption
- Size

Prices

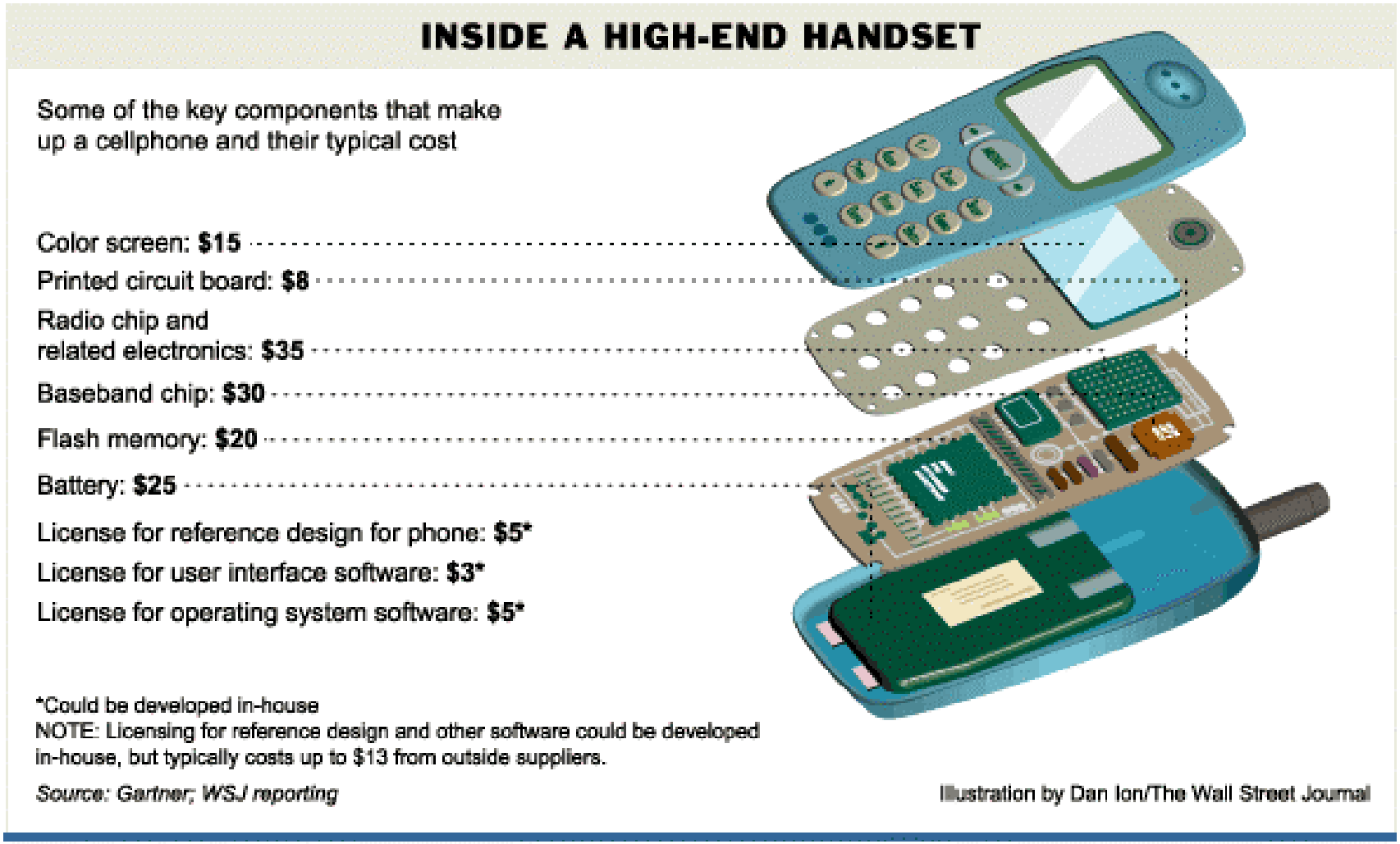
X-Box Estimated Cost vs. Price

Estimated Cost

Integrated circuits	$92
Discretes	38
Modules	5
Connectors	10
Pc-board cards	29
SMT assembly	18
Test	5
DVD+ hard disk	90
Enclosures/mechanical	31
Final assembly	1
Accessories	4
Total	$323

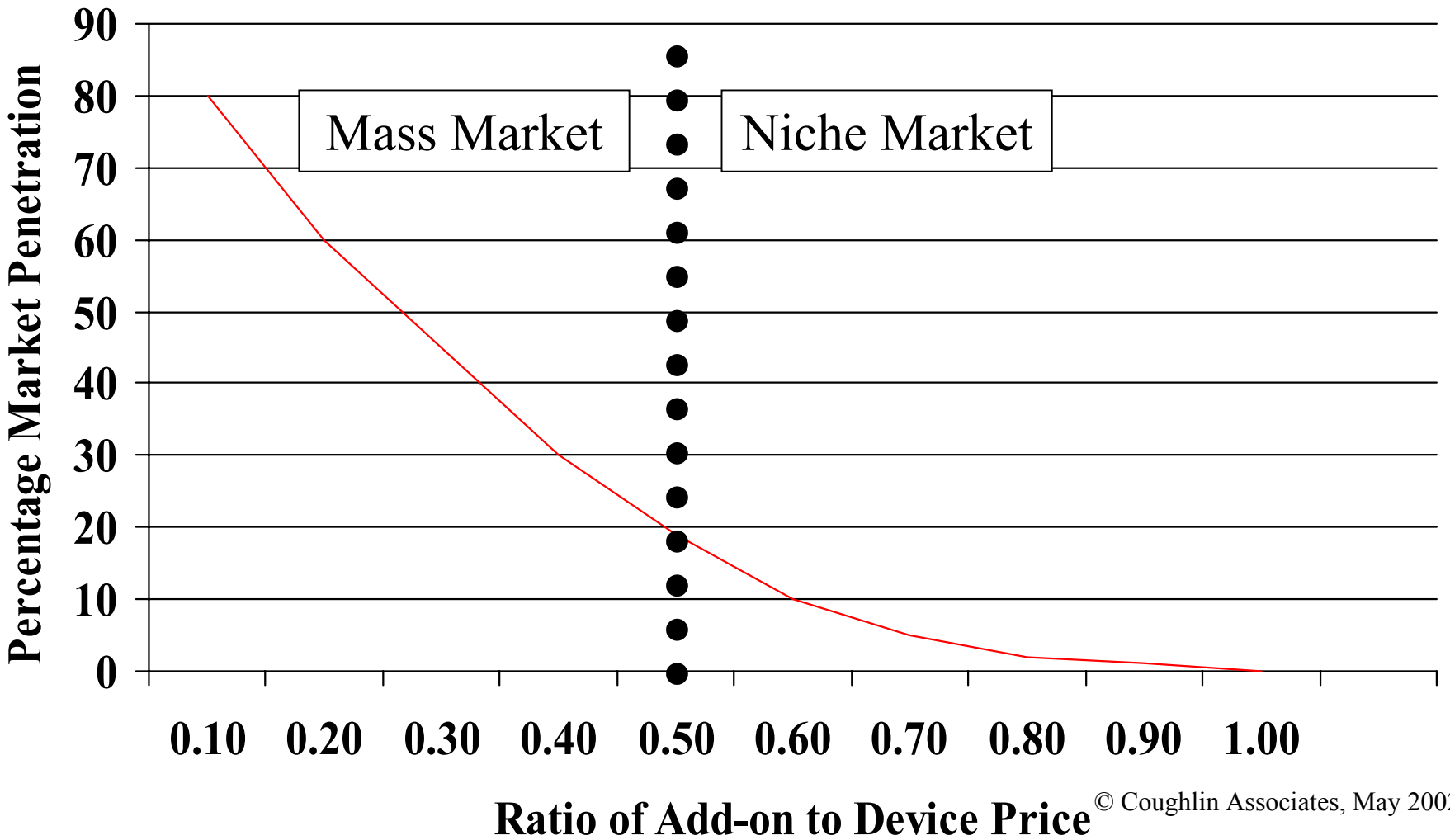
List Price $299

EE Times, Feb. 18, 2002

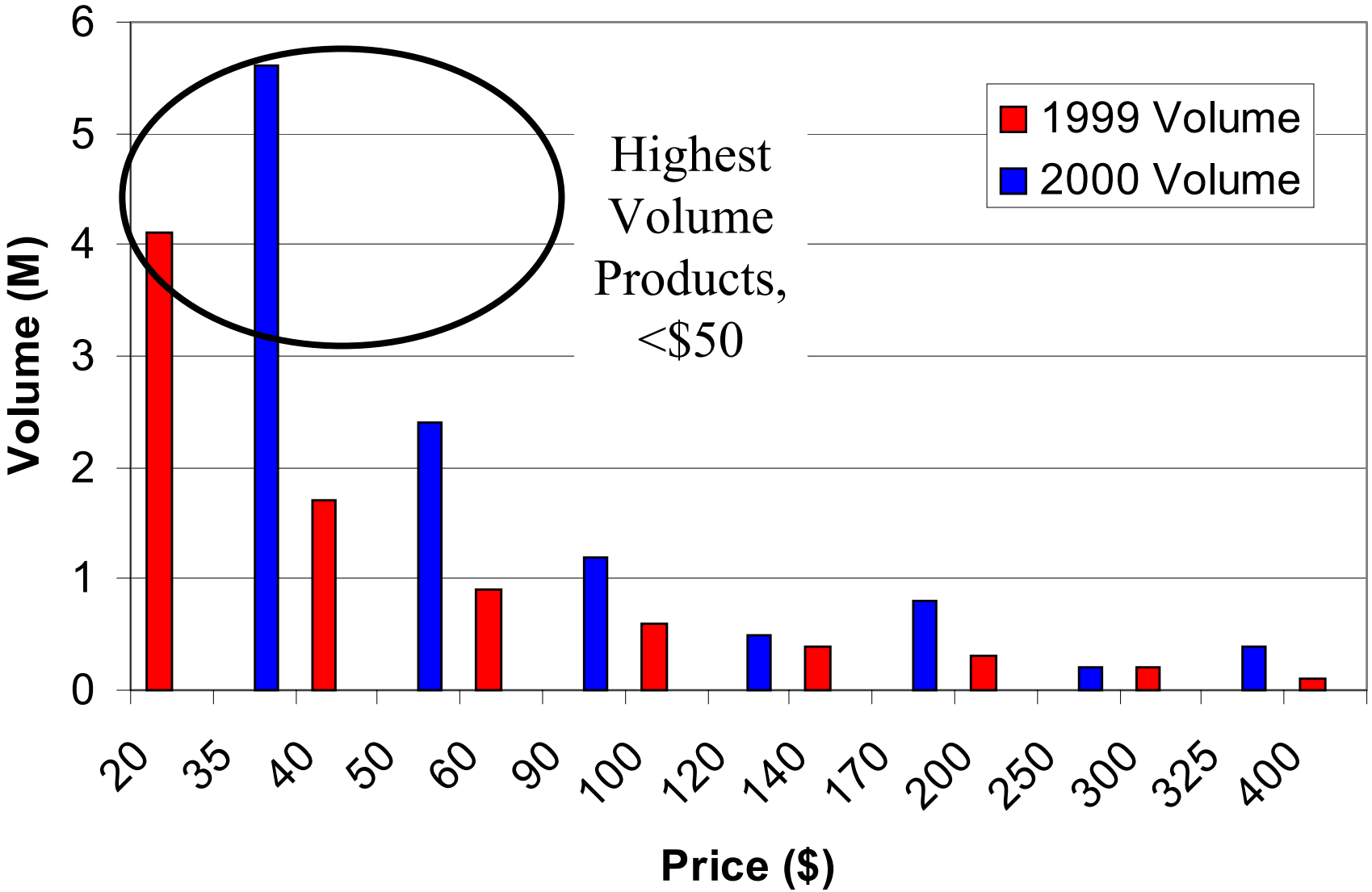


Complete Handset $200

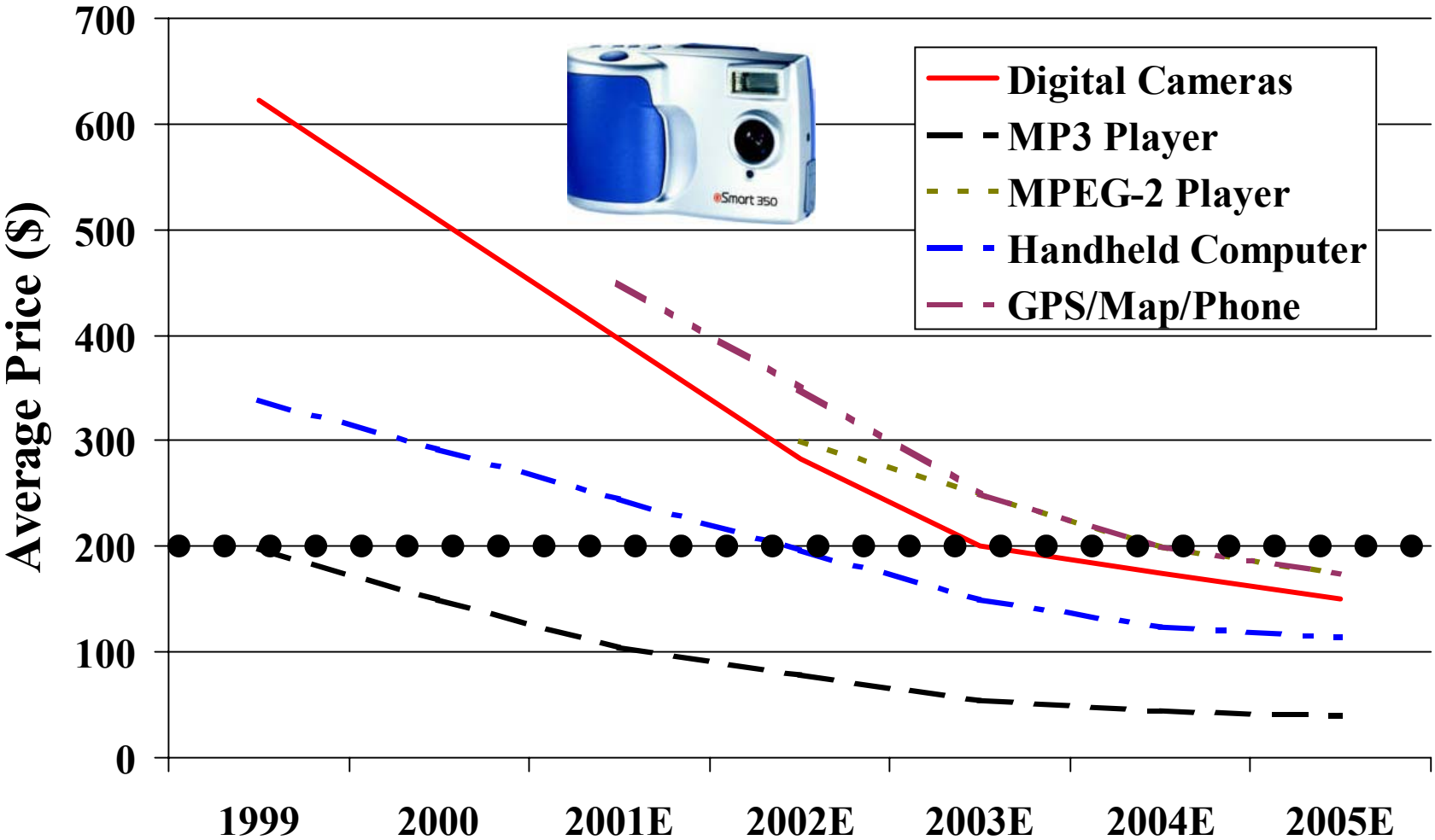
Add-on Product Market Penetration vs. Add-on Price/Device Price Ratio (assuming added value, no negatives with price)



Flash Volume vs. Price

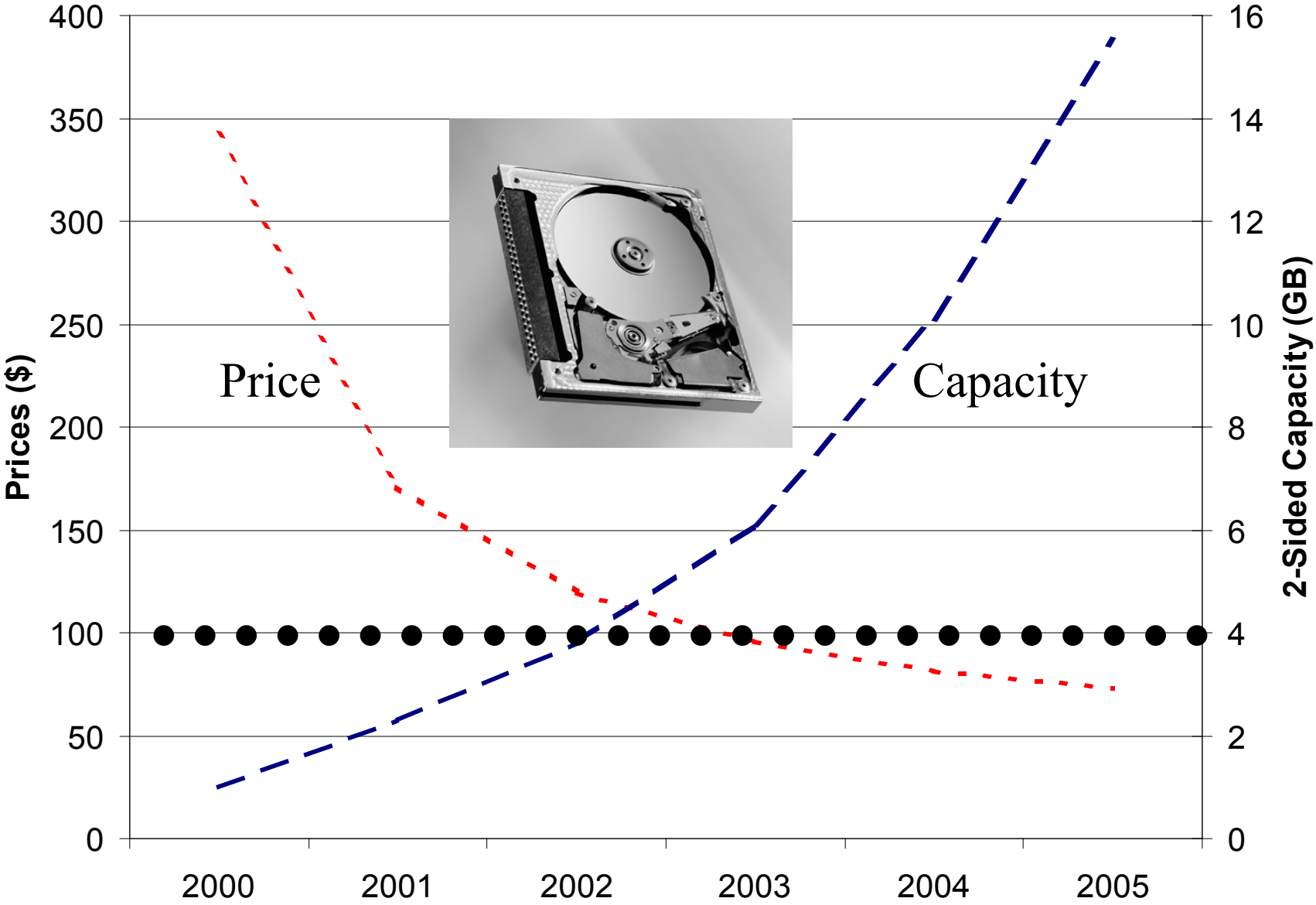


Average Mobile Electronic Product Price Projections



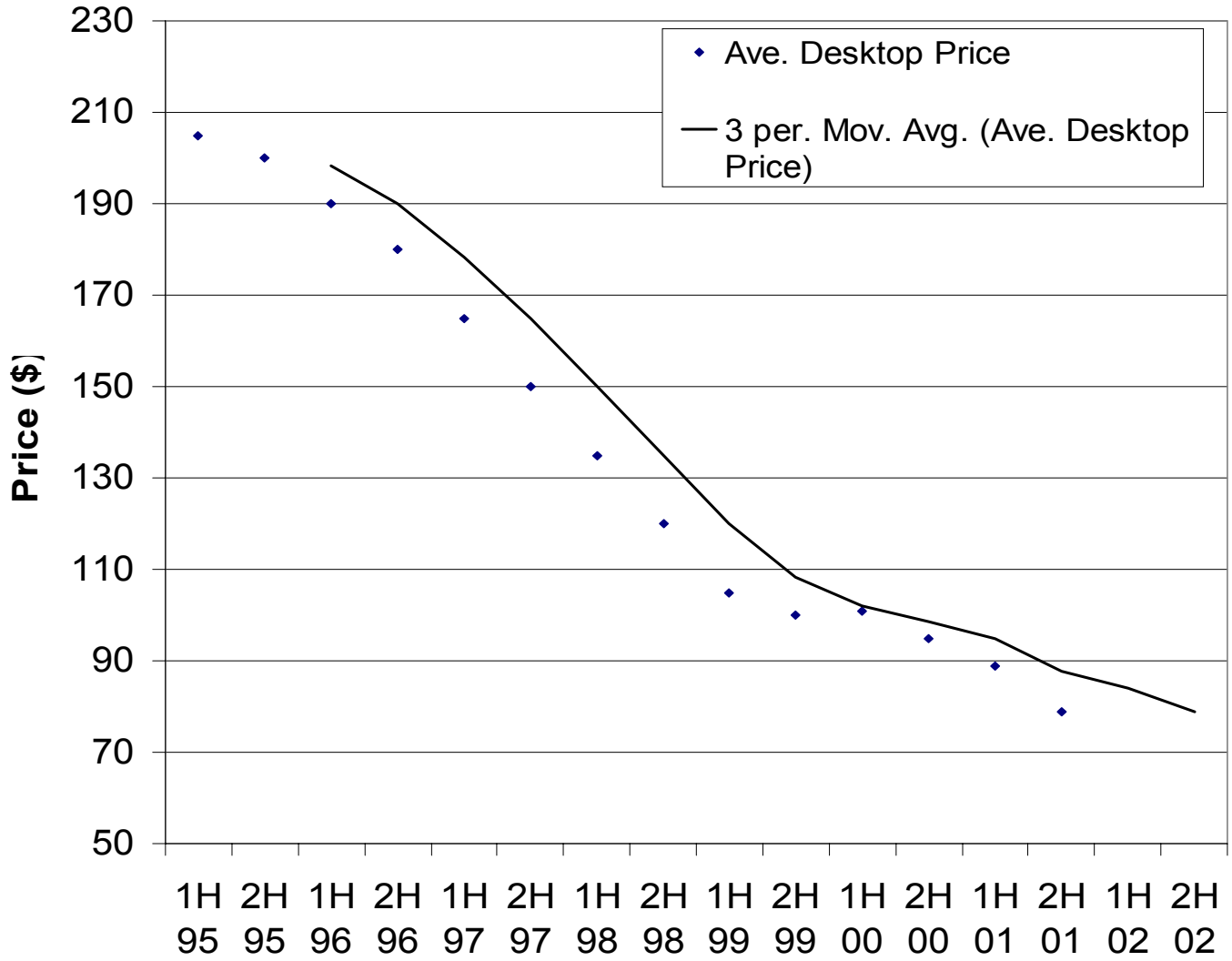
Projections based on Intelect Market Tracking for Digital Cameras and PDAs, 2000

Microdrive Price and Capacity Projections



Average Desktop Drive Prices vs. Time

(Sources: Disktrend 1999 and PRC 2002)

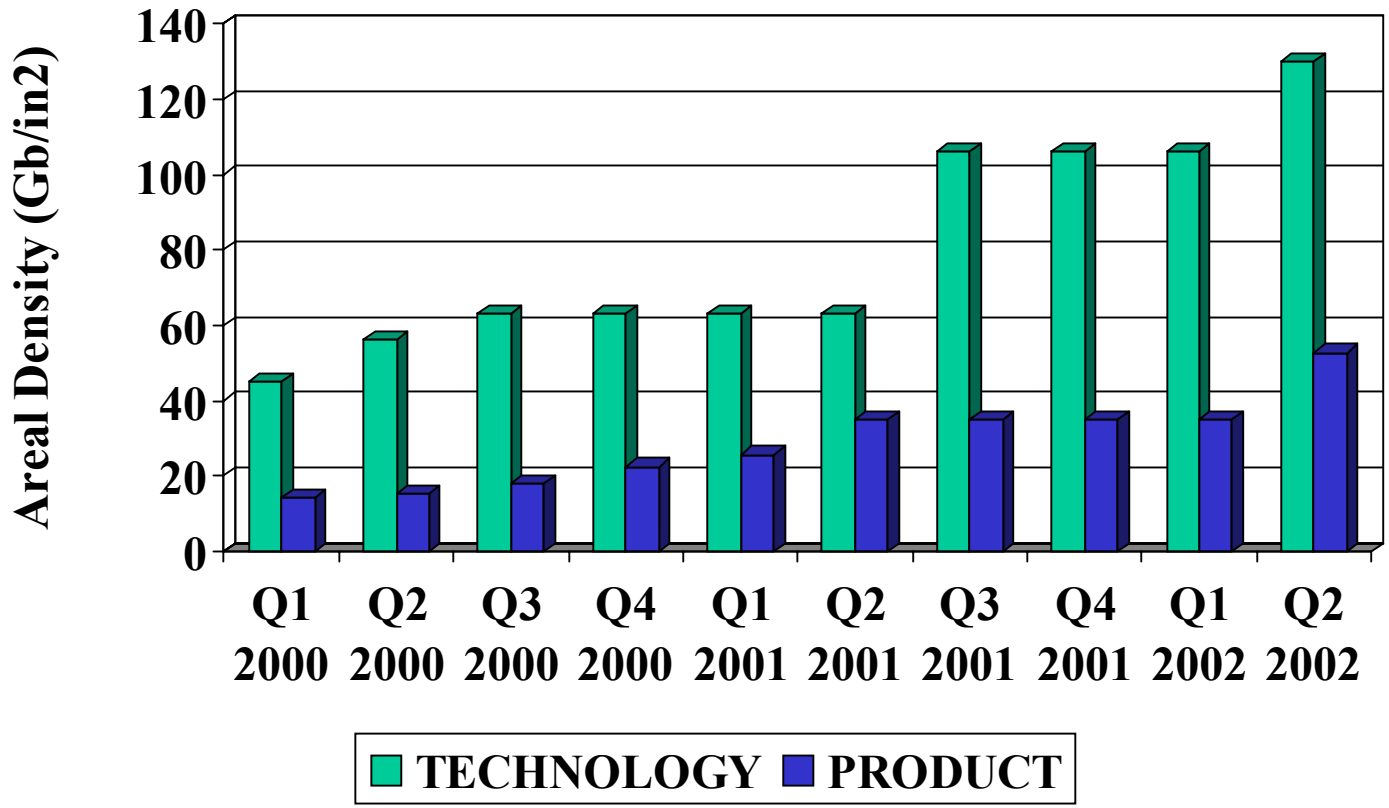


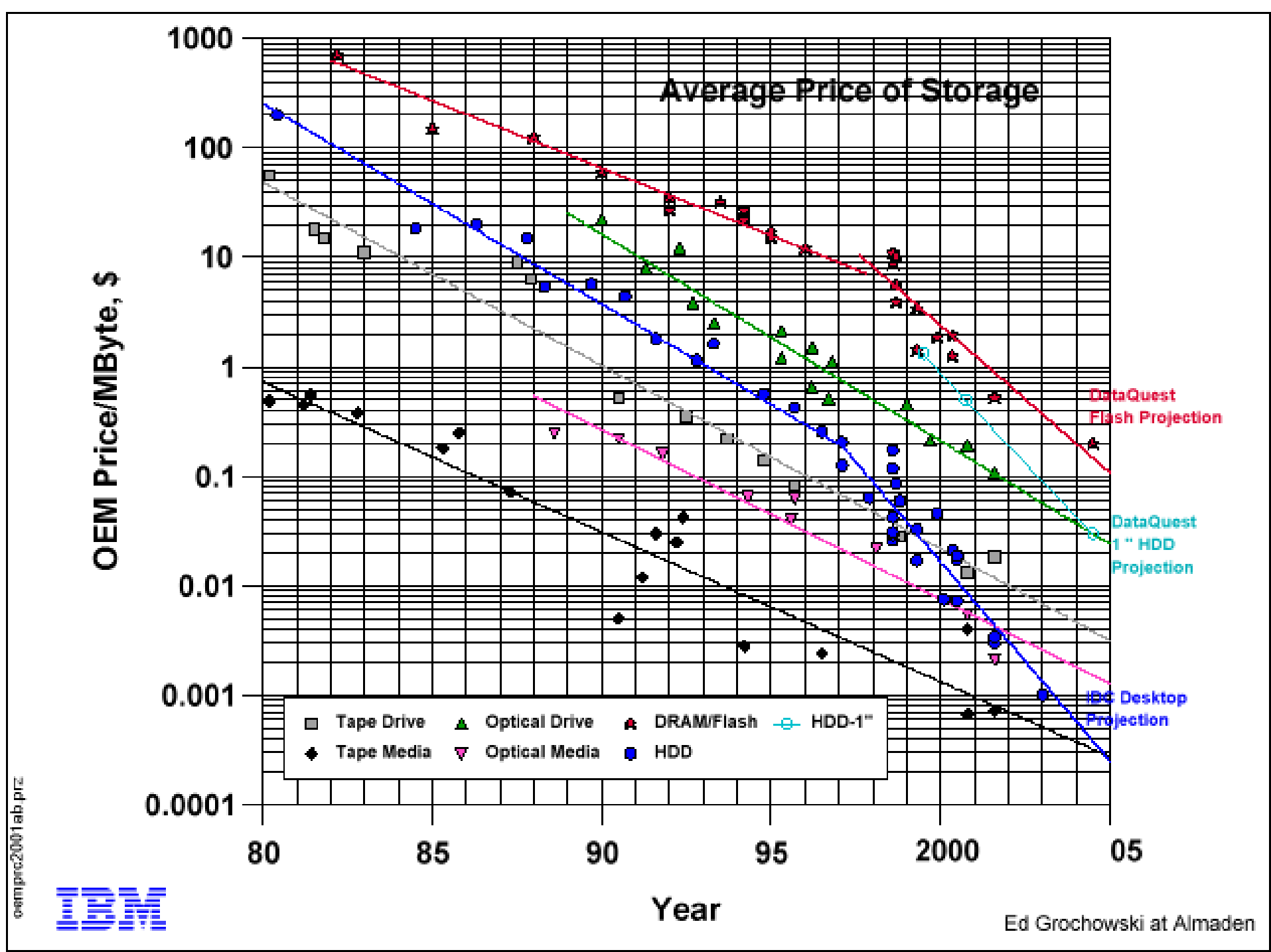
The $30 Cost Consumer Products Disk Drive

- Single Head, high volume, simplified manufacturing.
- Acceptable acoustics, shock resistance
- ***Sells for less than $45*** for games, PVRs.
- Reduced Parts Count, high electronic integration
  - electronics ~$10.50
  - head and media ~$9.50
  - mechanics ~$10.00
  - **total cost** **~$30.00**

AREAL DENSITY PROGRESSION

(Source: PRC, 2002)




Average Price of Storage
OEM Price/MByte, $
1000
100
10
1
0.1
0.01
0.001
0.0001
80
85
90
95
2000
05
Year
Tape Drive
Optical Drive
DRAM/Flash
HDD-1"
Tape Media
Optical Media
HDD
DataQuest
Flash Projection
DataQuest
1 " HDD
Projection
IDC Desktop
Projection
Ed Grochowski at Almaden
oemprc2001ab.prz

Storage Capacity

Content Based Storage Requirements

Commercial Video

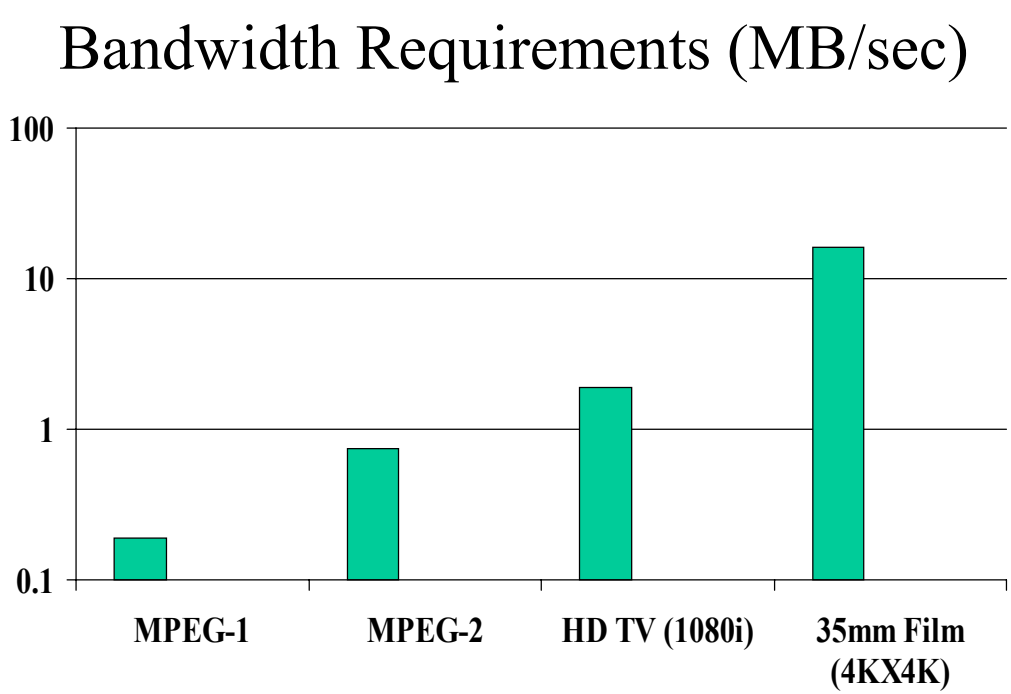
- ~1 TB is required for a digital theater complex
- ~800 TB may be required for single movie production
- Including TV, movie, commercial production, and video distribution the annual video production storage market may be **740 PB by 2006**

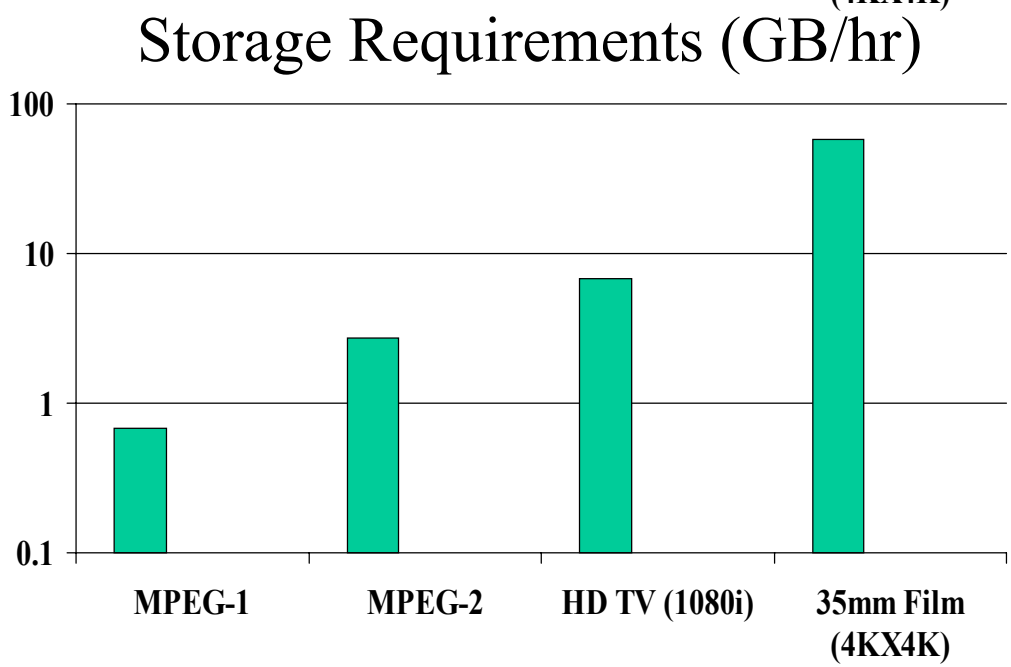
Personal Video

- 50 years of MPEG-2 quality digitized television content is estimated to require 912 PB by 2006
- With 10% utilization this would result in about **91 PB downloaded/year**
- With mirroring this on-line content might require **3.6 EB by 2006**

High Resolution Images-A BIG Driver

- High End Customer are initial drivers
  - medical file transfer
  - movie distribution
  - interactive collaborations
  - physical and biological simulation





Home Entertainment Data Storage Requirements

- Digital Audio Jukebox
  - Today – 40GB – 100GB
  - Future (2003-2005) – 250GB
- PVR/Set-Tops
  - Today – 40GB – 180GB
  - Future – 100GB – 250GB (Network gateway will probably be in place.
- Media Gateway
  - Today – 100GB – 500GB
  - Future (2003-2005) – 1TB – 20TB

Top Mobile Product Requirements - 2004

- Smart Handheld Devices – **116M Units**
  - **128MBytes – 512MBytes** primary demand
  - Primarily consists of PDA's and Convergence Phones
  - Store everything from PIM data to emails to Audio to Video (future)
  - Requires very small memory device – cell phones, PDA's, VAD's.
  - Memory Card slot in Devices allows capacity and price to scale with application need

- Digital Cameras – **99M Units**
  - **64MBytes – 512MBytes** primary demand
  - Primarily consists of Digital Still and Video Still cameras
  - Store 1.3M to 4.2Mpixel Images
  - Requires very small memory device – palm-size DSC's and DVC's
  - Memory Card slot in Devices allows capacity and price to scale with application need

- Consumer Devices – **54M Units**
  - **64MBytes – 256MBytes** primary demand
  - Primarily consists of Portable Compressed Audio Players and Handheld GPS
  - Store Music and Maps
  - Requires very small memory device – belt-clip and wristwatch players
  - Memory Card slot in Devices allows capacity and price to scale with application need

Source: IDC/WebFeet/SanDisk 2001

Smartphones and Web Tablets

- Features, Present & Future
  - All the features in high-end phones, plus…
  - Integration of phone and PDA, more than the sum of the parts
  - Wireless communications and PDA functions each have a dedicated processor
  - Bulk storage integrated with PDA function
  - Larger wireless PDAs and Web Tablets have an expansion slot for a micro-drive
- Bulk storage applications in a smartphone
  - Interactive maps, music or video, still images
  - Games
  - Barcode scanning data

Kyocera-Wireless QCP-6035

Samsung Smartphone

Cyberbank PC-EPhone

AirPrime SB3000 in a Handspring Visor

Storage Sharing in Wireless PAN

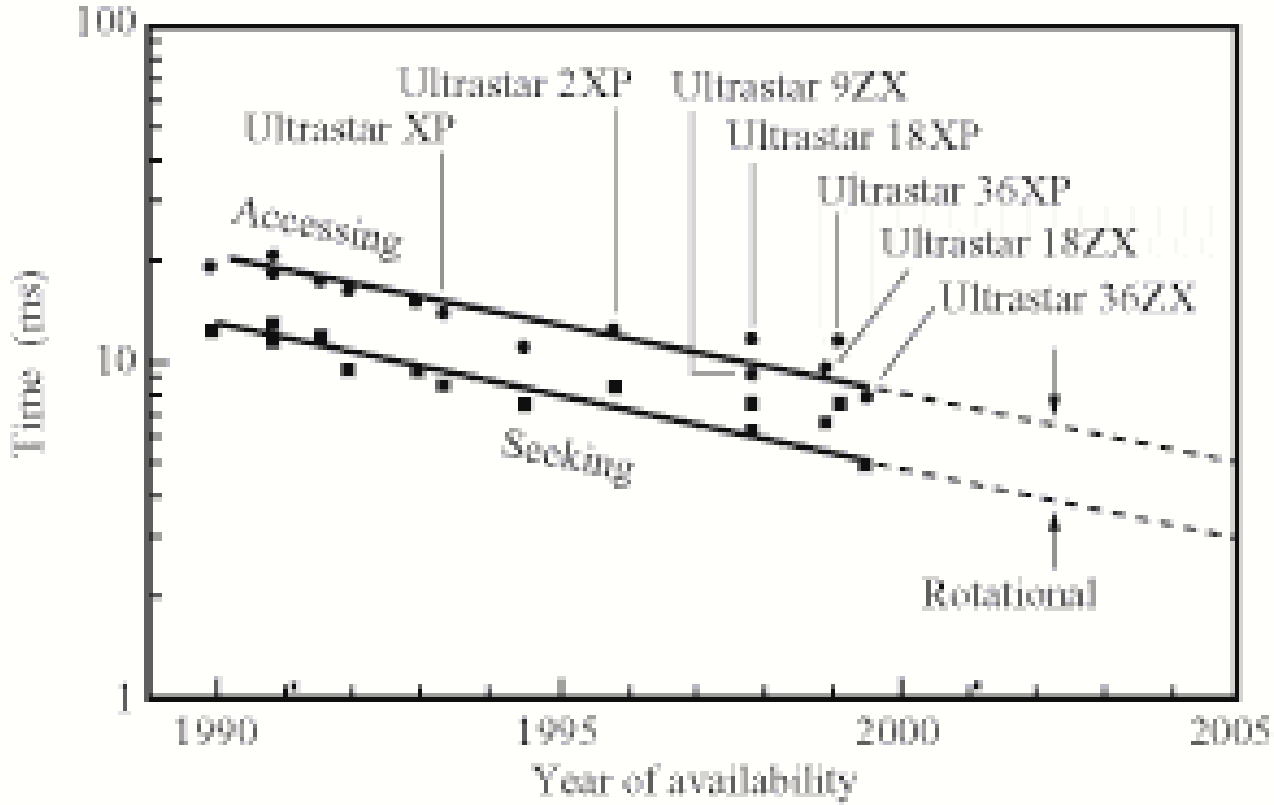
- Wireless Personal Area Network (PAN) allows sharing of bulk storage between devices.
  - Phone has access to your address book and MP3 files stored in PDA.
  - PDA actively synchronizes database with wireless enabled laptop
- Potential networks are Bluetooth or 802.15.3 TG3

HMD plugs into any of the wireless devices

Wireless keyboard

Performance and New Application Features

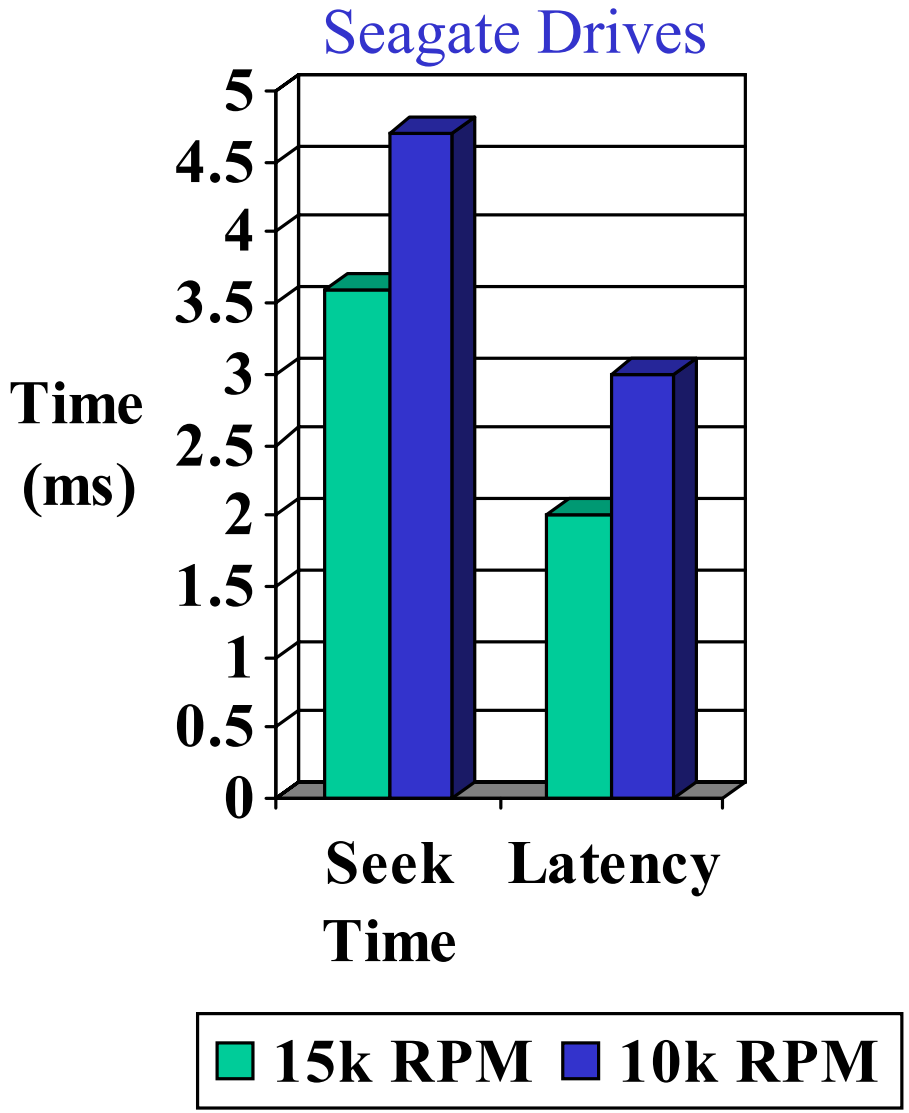
Access, Rotational and Seek Time Trends (Source: IBM)



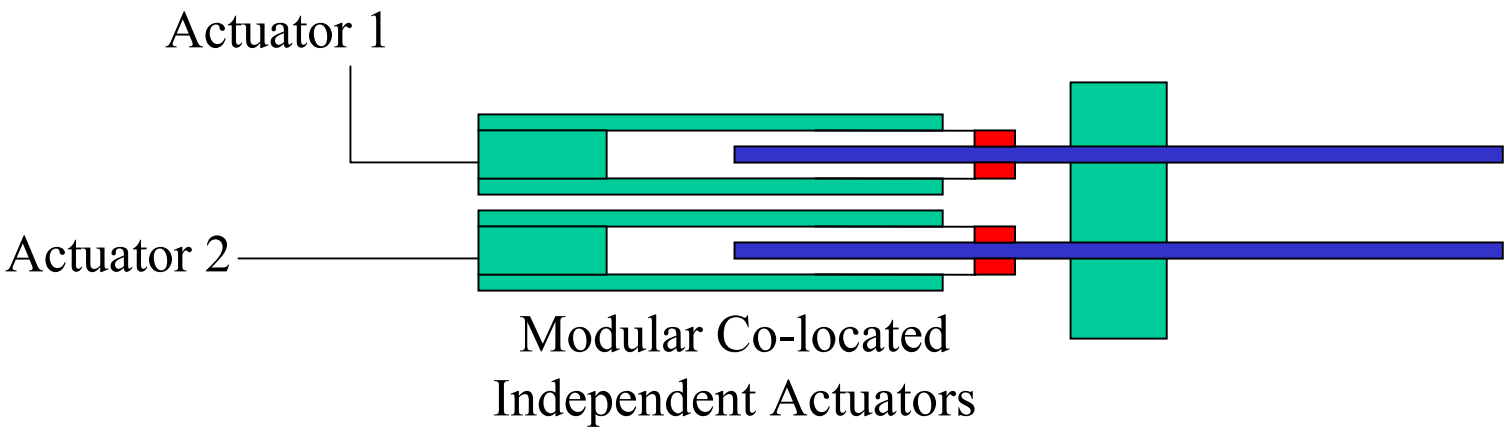
	1987	1999	Increase
CPU	1 MIPS	700 MIPS	700X
Memory	100 microsec	100 nanosec	1,000X
Drives	60 msec	6 msec	10X

Trends in Data Access

- While areal densities have been increasing by about 2X per year the access time to data has only been increasing about 2.5X every 10 years.
- Thus for a given disk form factor and RPM the time to get to a particular data item is increasing by about 80% annually.
- This may cause a change in form factor (3.5 inch to 2.5 inch), disk RPM, or a change in disk architecture to improve data access performance.



Dual Actuator Disk Drive



- Allows recovering data independently from multiple surfaces.
- This allow faster time to data
- Extra actuator has a significant increase in drive cost
- One could also see using the surfaces for interesting internal drive architectures, such within drive mirroring

Home Gateways and PVRs

- Personal Video Recorders record television signals on a hard disk drive for time-shifted viewing.
- Home Gateways provide a home entertainment and computer network that can distribute video, music, and data.
- A home network may also include a small disk drive array or NAS system.
- Home based data storage tends to use IDE interface disk drives.

PVRs - Evolution from the Broadcaster to the Viewer

TV Station

- 1956 Time Shifting (Ampex VTR/$250k)
- 1963 “Instant Replay” (CBS/Army-Navy Football/$250k VTR)
- 1967 Slow Motion/Instant Access/Trick Play (Ampex/$250k HDR)
- 1969 Live Time Delay (NBC/2-Ampex VTRs)
- 1995 Video Server (Tektronix Profile/$100k)
- 1995 Downloadable Content (TV Spot Recorder/$50k)

Home

- 1998 Personal Video Recorder (TiVo & ReplayTV/<$500)
  - Record and playback concurrently
  - Pause playback while continuing to record
  - Automatically record selected and/or suggested programs for later viewing

Embedding Additional Functions into Disk Drives for Fun and Profit

- Modern disk drives have a sophisticated microprocessor used for motor control and data transfer. The capability of these processors is not fully utilized.
- Furthermore electronics integration leaves lots of potential board space unused on a disk drive.
- Could disk drive microprocessors be used for additional functions?
- One example is to incorporate other devices into the disk drive, such as a PVR built on the drive.
- An added benefit is utilizing the low cost manufacturing expertise of disk drive manufacturers to make consumer electronics products

Different Strokes for Different Folks

- There may develop different types of storage services in the future
  - High performance drives with multiple actuators, higher RPM, short stroking, higher data rates, faster servo systems, etc. for use in fast cache applications (>$$$).
  - Slower, higher capacity drives for use in "data tub" applications. Such products are now being introduced by NetApp and Quantum to replace or augment tape backup (<$$$'s).
- Price to performance trade-offs determine choices (e.g. vs. solid-state drives).

Ruggedness, Acoustics, and Vibration

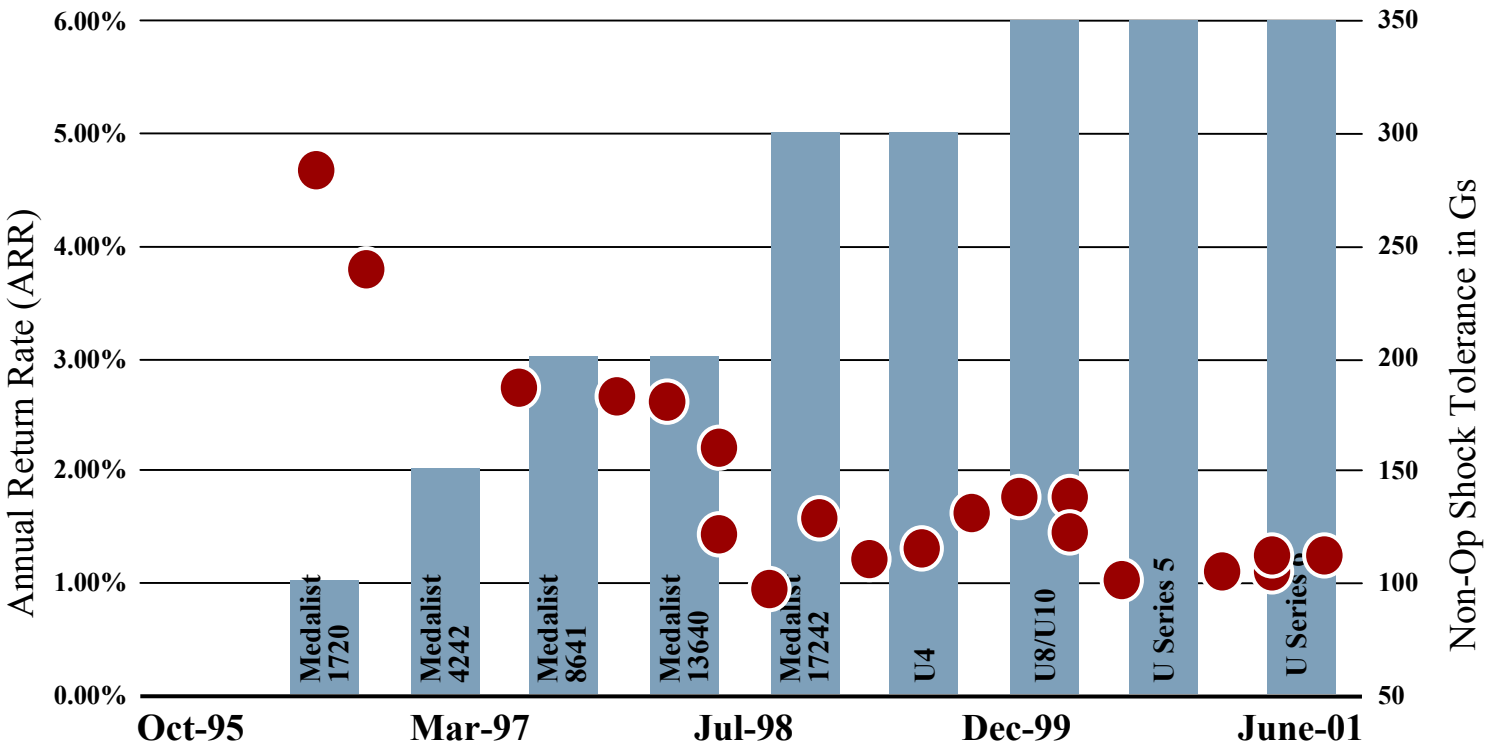
Specifications of Microdrive vs Compact Flash Memory (2001)

	Non-Op Shock (G)	Op Shock (G)	Max. Power (W)	Write Access Time (ms)	Read Access Time (ms)	Data Rate (MB/s)
Compact Flash	2000	2000	0.450 (5V) 0.198 (3.3V)	2.5	2.0	4.0
Microdrive	1500-2000	175-250	1.3 (5V) 0.775 (3.3V)	15	15	4.2

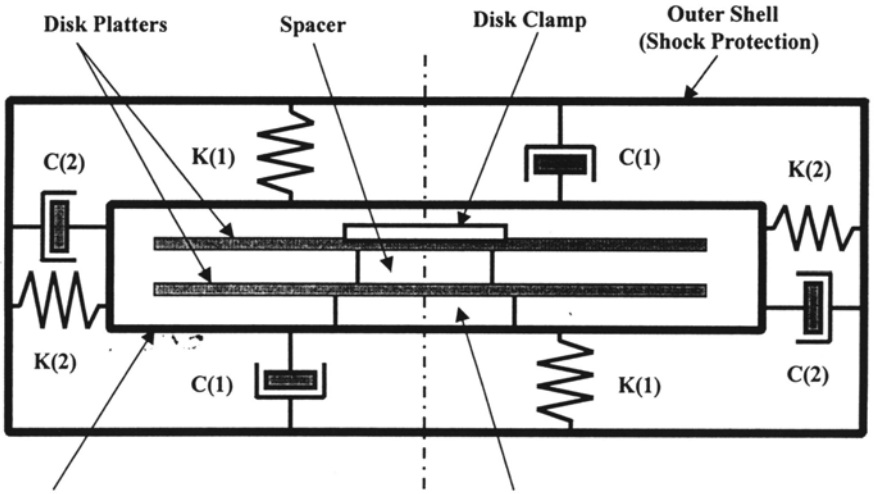
Figure 4H-5

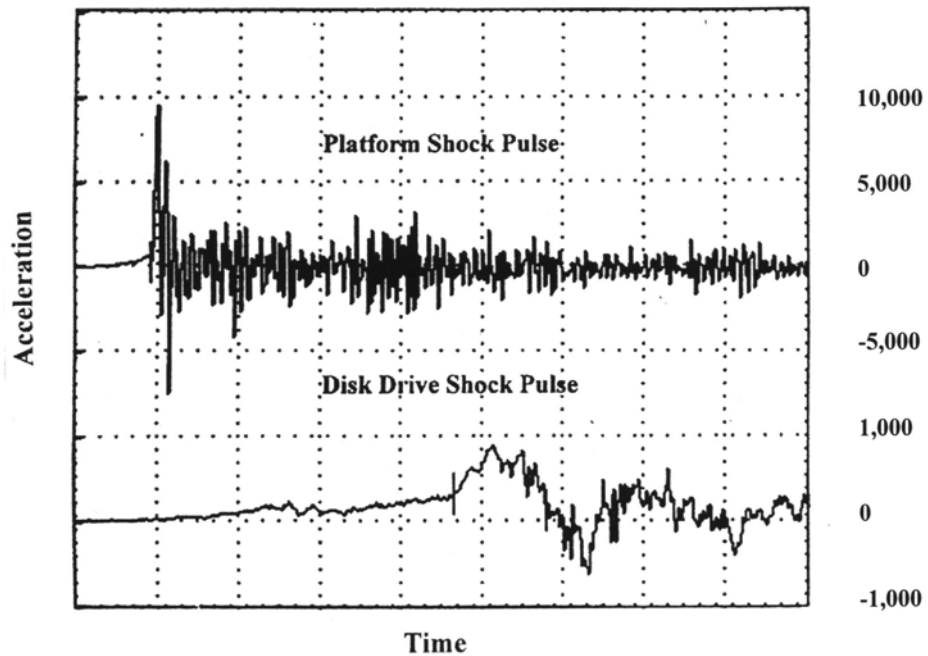
System-Level Shock Events

- A new environment for hard drives
- Non-operating shock



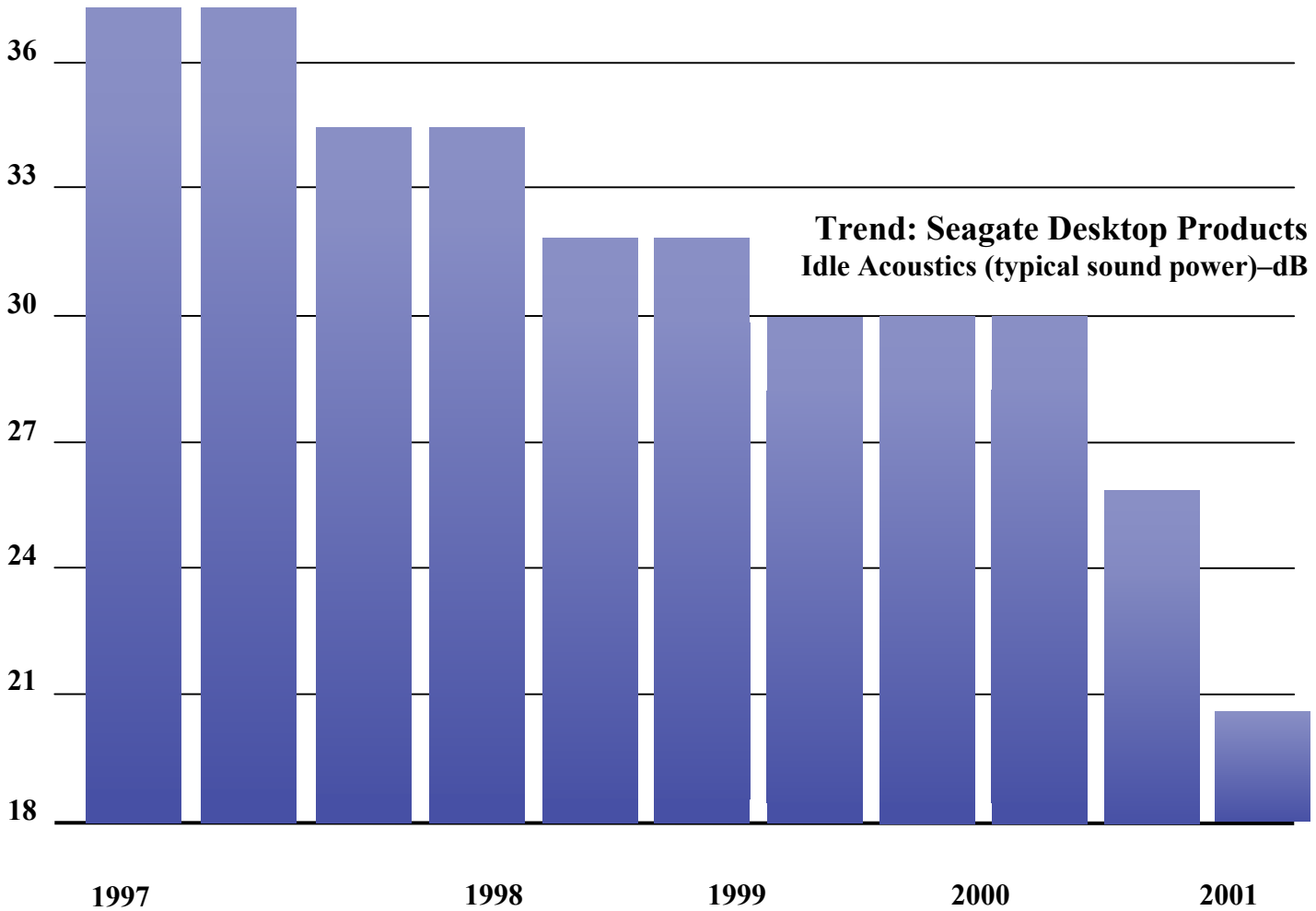
High Shock Resistant Drive Packaging





- Non-operating shock specifications as high as 10,000 G's are available by surrounding a disk drive with a shock adsorbing foam.
- Shock resistance is very important for many consumer electronics and mobile storage applications.

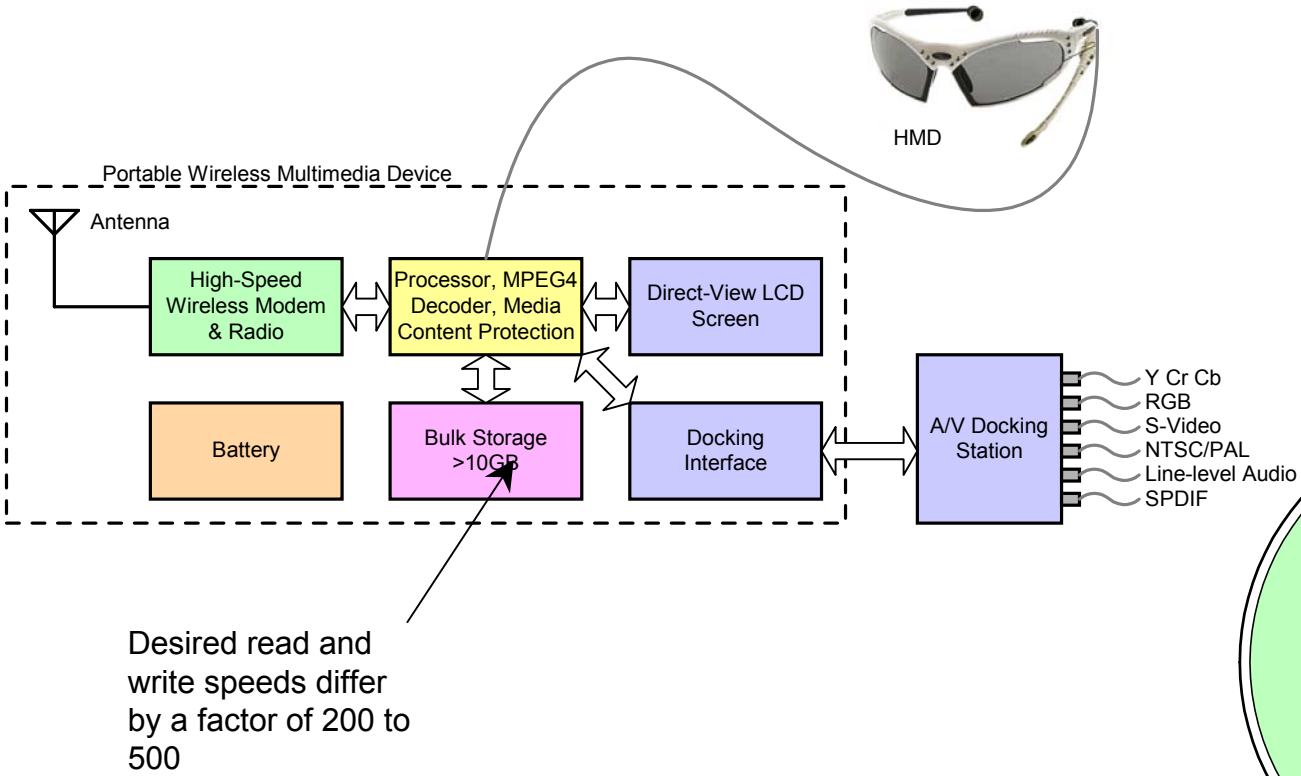
Improving System Acoustics



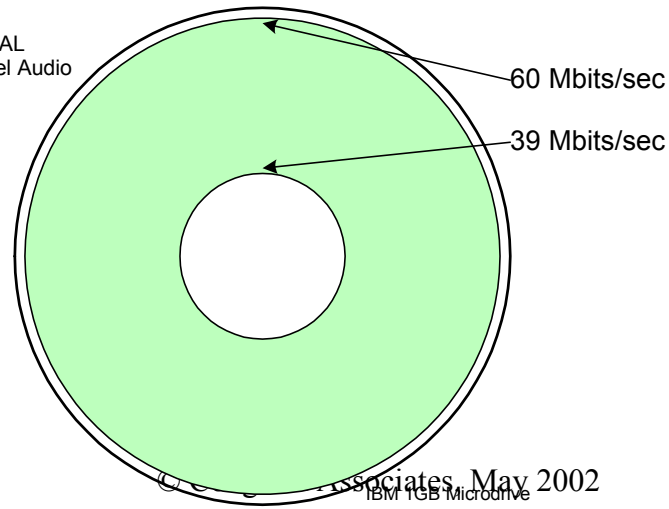
Power Consumption

Wireless Personal Multimedia Device

- Download media at video store or other shopping location.
- Digital media is much more flexible for improvements in compression and resolution (just download a new codec, upgrade to HDTV later)



Mbps	download time (seconds)	download time (minutes)
1000	16	0.3
500	32	0.5
200	80	1.3
100	160	2.7
50	320	5.3
20	800	13.3
10	1600	26.7
5	3200	53.3



Qualcomm, Storage Visions 2002

© Associates, May 2002

IBM 1GB Microdrive

Dealing with Microdrive vs. Compact Flash Power Consumption Differences

- For streaming applications where the required data rate is less than the microdrive data rate such as in an audio MP3 player or a video MPEG-2 player, proper memory buffering with the microdrive can reduce the power requirements to be similar to compact flash.

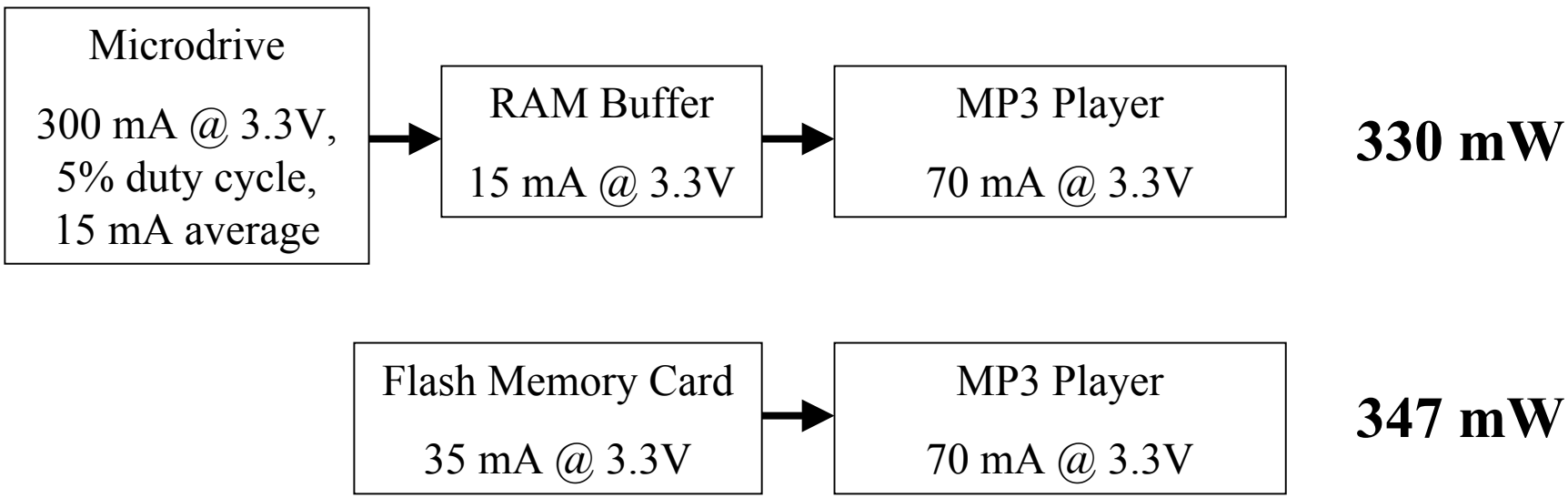


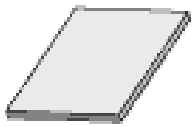
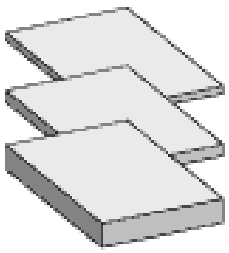
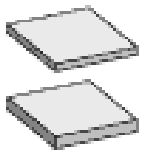
Figure 4H-6

Average Power Budget

- Monitor x
- Storage y
- Transceiver & electronics z
- Total $x + y + z = t$
- Battery Rating (Ah, ampere-hours), Voltage V
- Battery Life = (Ah)V/t

Size

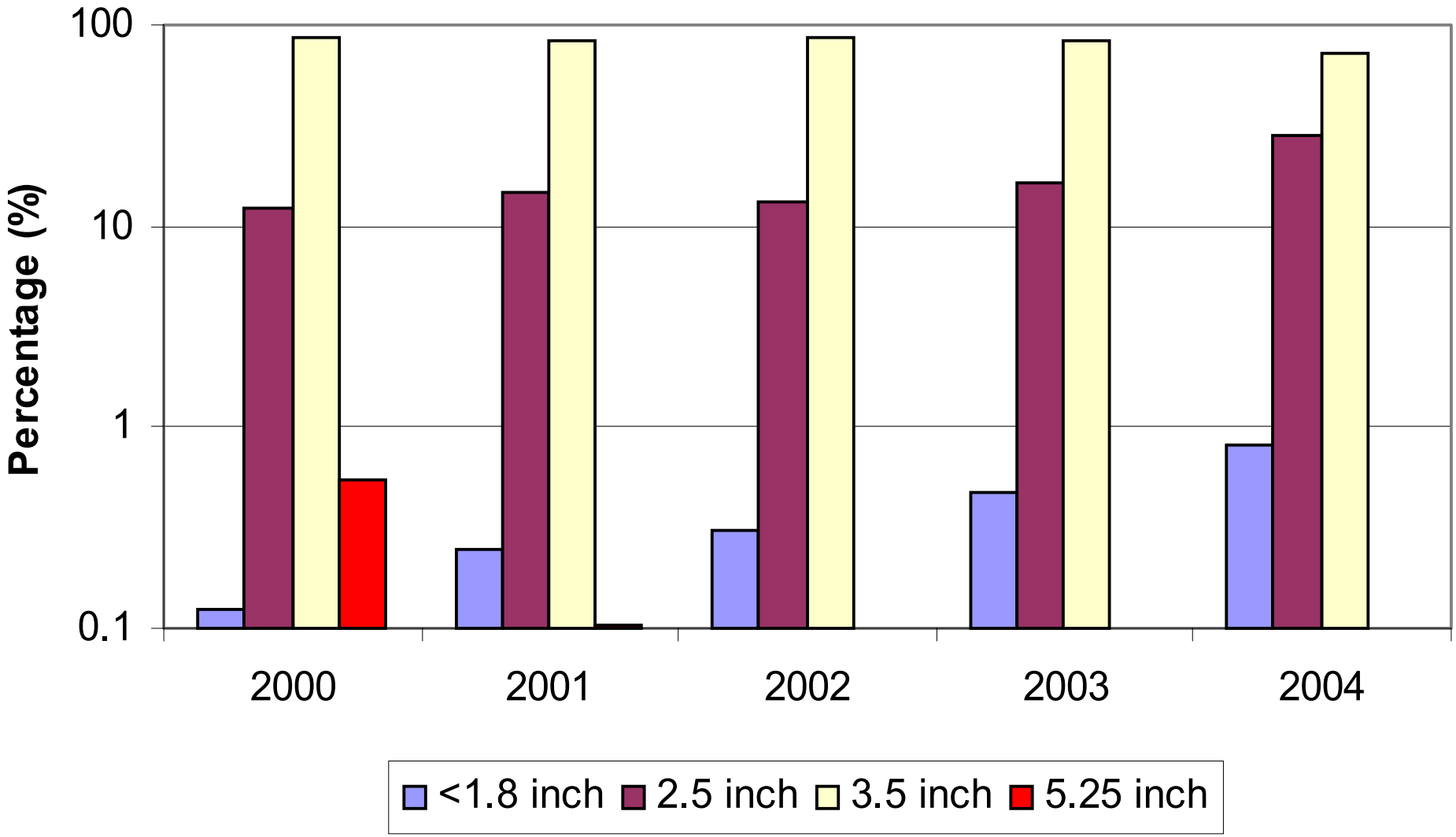
Mobile Memory Form Factors

	Storage Device	Size	Typical Capacity[1]	Optional Adapter
	**Microdrive**	42.8 x 36.4 x 5.0 mm	170 MB and 340 MB	PC Card adapter
	**PC Card (PCMCIA)** - Type I - Type II - Type III	85.6 x 54.0 x 3.3 mm 85.6 x 54.0 x 5.0 mm 85.6 x 54.0 x 10.5 mm	Type II Memory= 4 MB-128 MB	External Reader/Writer Notebook slot
	**CompactFlash cards** - Type I - Type II	42.8 x 36.4 x 3.3 mm 42.8 x 36.4 x 5.0 mm	4 MB-128 MB	External Reader/Writer PC Card adapter
	**SmartMedia Card**	45 x 37 x 0.76 mm	4 MB-32 MB	PC Card adapter Floppy adapter
	**MultiMedia Card**	32 x 24 x 1.4 mm	2 MB-16 MB	Available
	**Memory Stick**	21 x 50 x 2.8 mm	4 MB-32 MB	Available
	**Miniature Card**	38 x 33 x 3.5 mm	4 MB-32 MB	Available

Transition to 2.5 inch Form Factor

- 2.5 inch most popular mobile computer form factor.
- 65-mm disks used in 15k RPM enterprise disk drives (although not yet in 2.5 inch form factor box)
- For new consumer products size and volume will become important.
- Dense server and storage environments favor many more smaller drives. This also gives better performance since the time to data is faster for smaller form factors
- New consumer electronics initiatives using smaller form factor disk drives such as the Japaneses iVDR consortium.
- 2.5 inch drives should be as inexpensive or less expensive per box compared to 3.5 inch disk drives.

Disk Drive Form Factor Changes



Conclusions

- Data generation continues to grow, driving the need for more data storage.
- Disk drive areal density growth and lower unit costs have made them attractive for many applications from network storage through various consumer and even mobile applications.
- The choice of data storage for a particular application depends on the interplay of a number of important requirements.
- In the future expect even lower drive prices, smaller form factors, higher RPM.
- Could other products be embedded in a disk drive ?