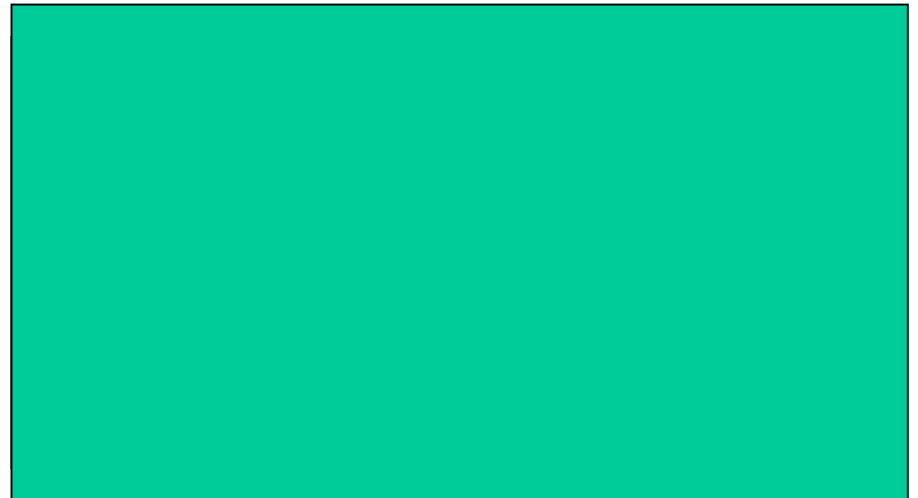
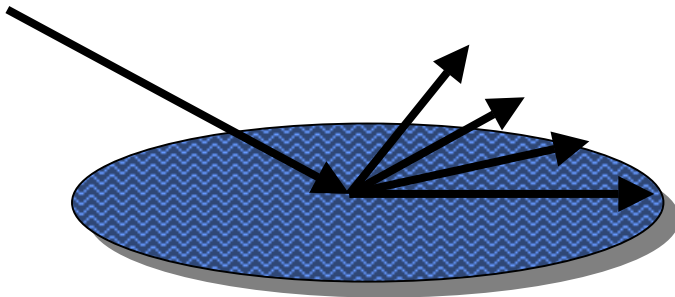


# DATA STORAGE INDUSTRY OVERVIEW & DIRECTIONS

“Reflections on a Aberrant Mirror”

Tom Coughlin  
Coughlin Associates,  
Peripheral Research Corp.



# Overview

- **The Aberrant Mirror**
- **Trends and Growth Opportunities**
- **New Applications for Storage Products**
- **Storage Industry and Components Status  
/ Directions / Forecast**

# The Aberrant Mirror

- An aberrant mirror gives a distorted view of the world, we draw an analogy to our always inaccurate view of the future.
- Correction of this aberration occurs over time as possibilities become certainties

“Time is nature’s way of preventing everything from happening at once.” Graffito

# Titanic Technology, Sinking Margins



Key Employees

Component Suppliers

SS Areal Density

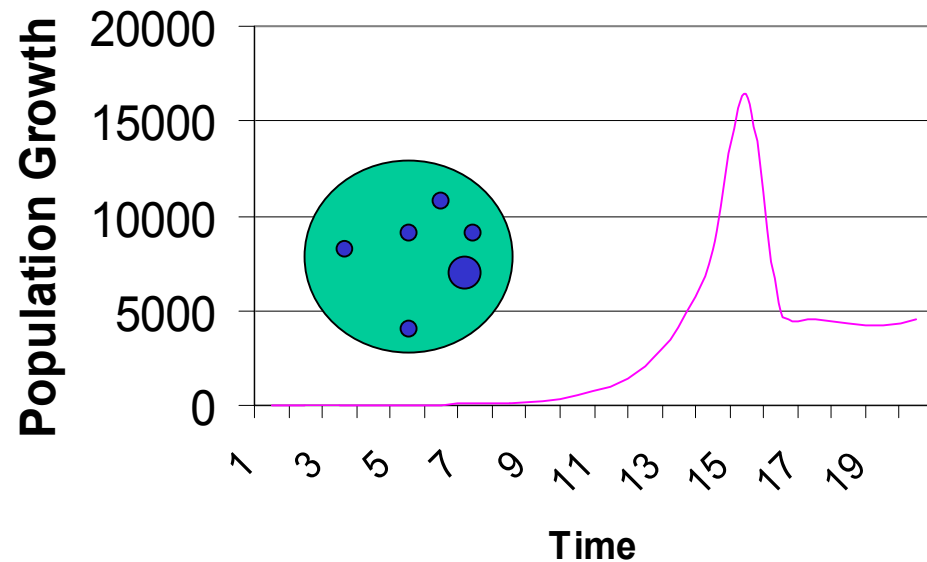
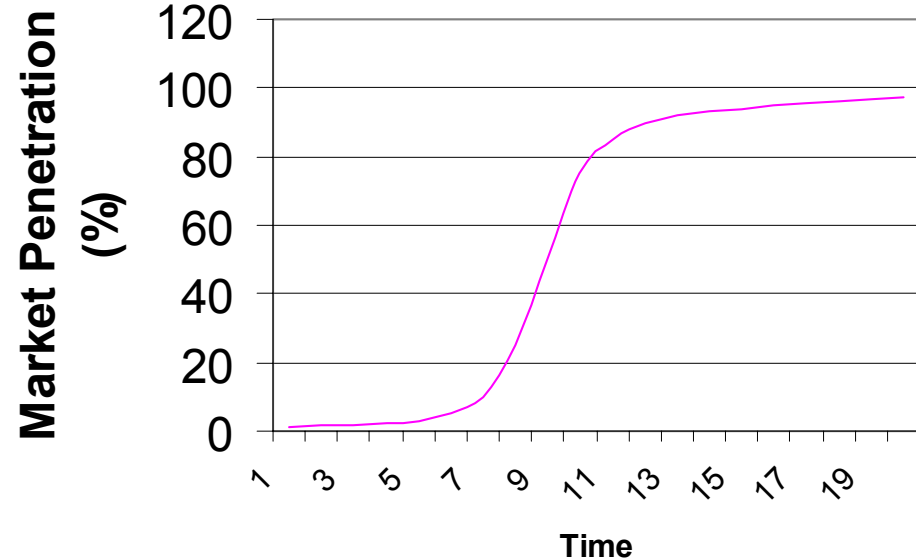
Investors

# Technology Growth Areas

- Data coding and compression:
  - How to deal with reducing SNR
  - Variations for niche markets--e.g. video storage
  - Implications of perpendicular recording
- Servo
  - Time for servo writing
  - Higher TPI requirements
- Areal density growth
  - Capital investments needed, particularly for head development
  - Flight of talent to more lucrative fields may limit creativity available to industry
  - Changes from longitudinal to perpendicular recording

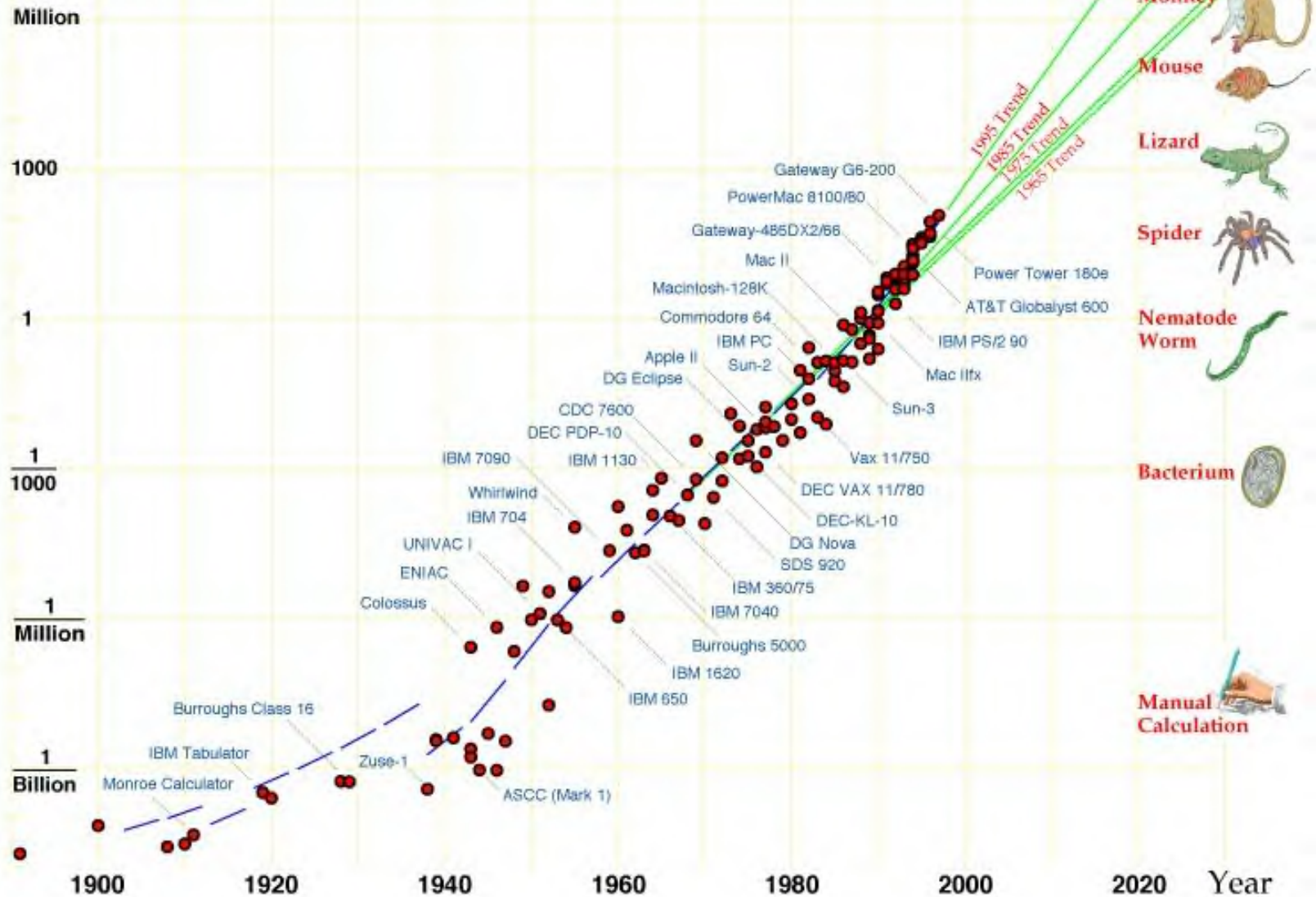
# Growth Models for Technology

- Is there a finite technology pool or limited resources in technology growth?
- Or could technology growth be ever exponential?



# Evolution of Computer Power/Cost

MIPS per \$1000 (1997 Dollars)



# Computer power available to AI and Robot programs

MIPS

Million

1000

1

1  
1000

1  
Million

Brain Power Equivalent  
Human



Monkey



Mouse



Lizard



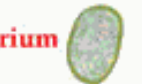
Spider



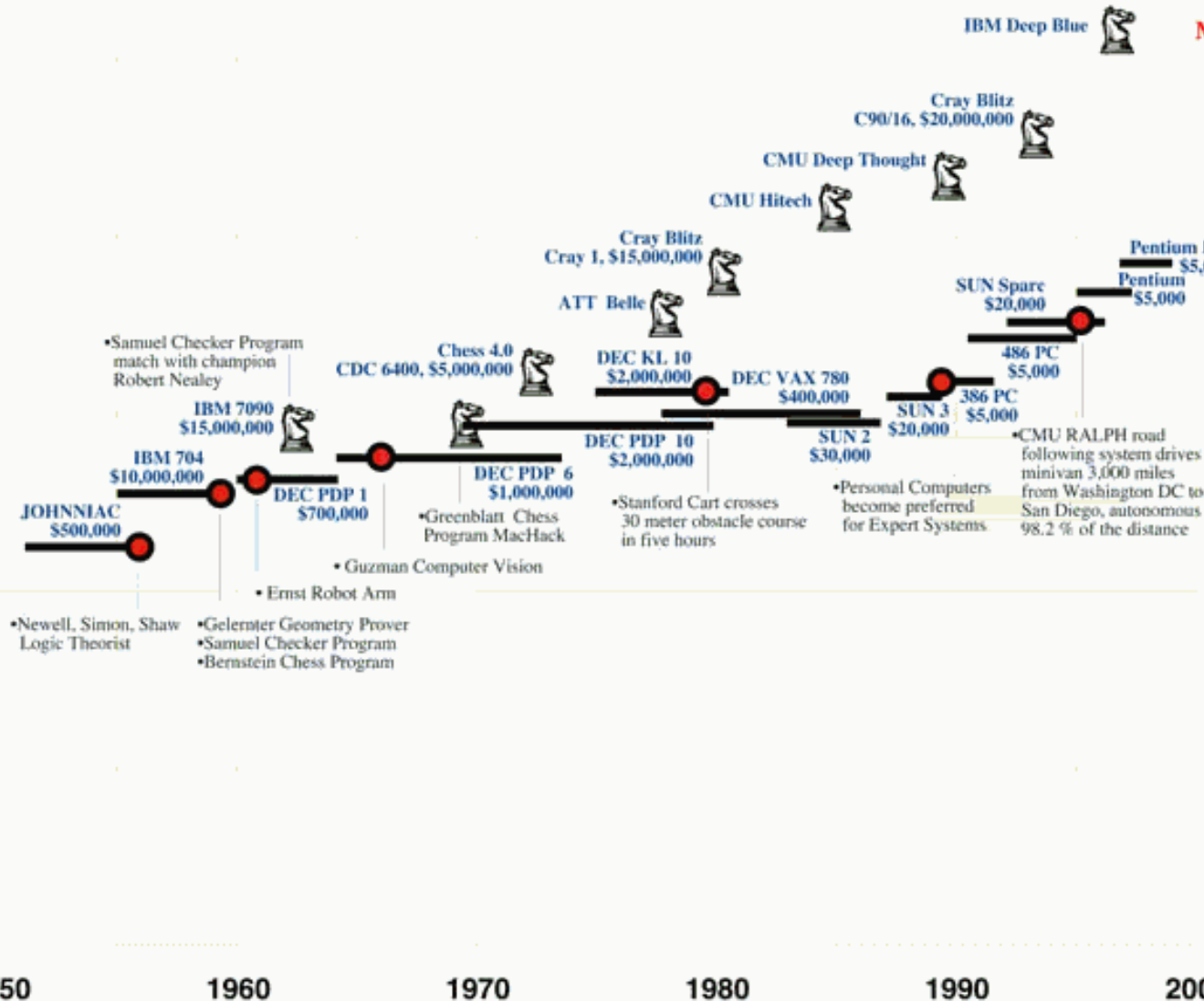
Nematode  
Worm



Bacterium

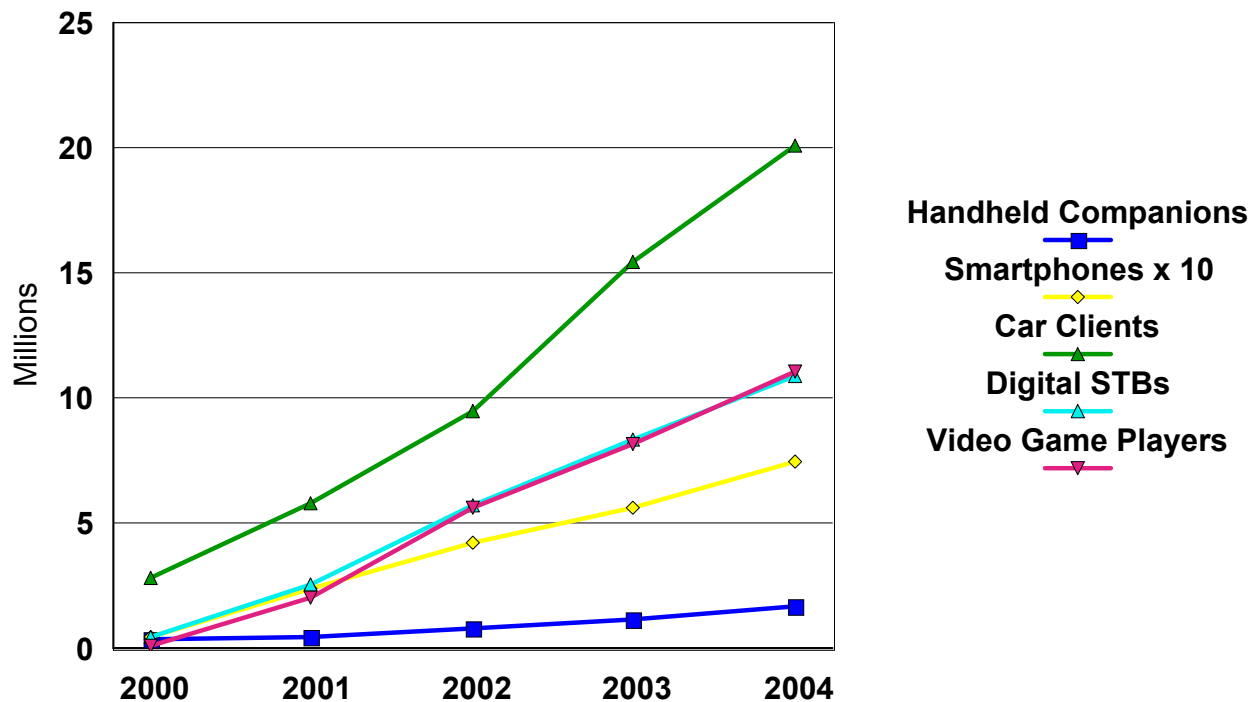


Manual  
Calculation



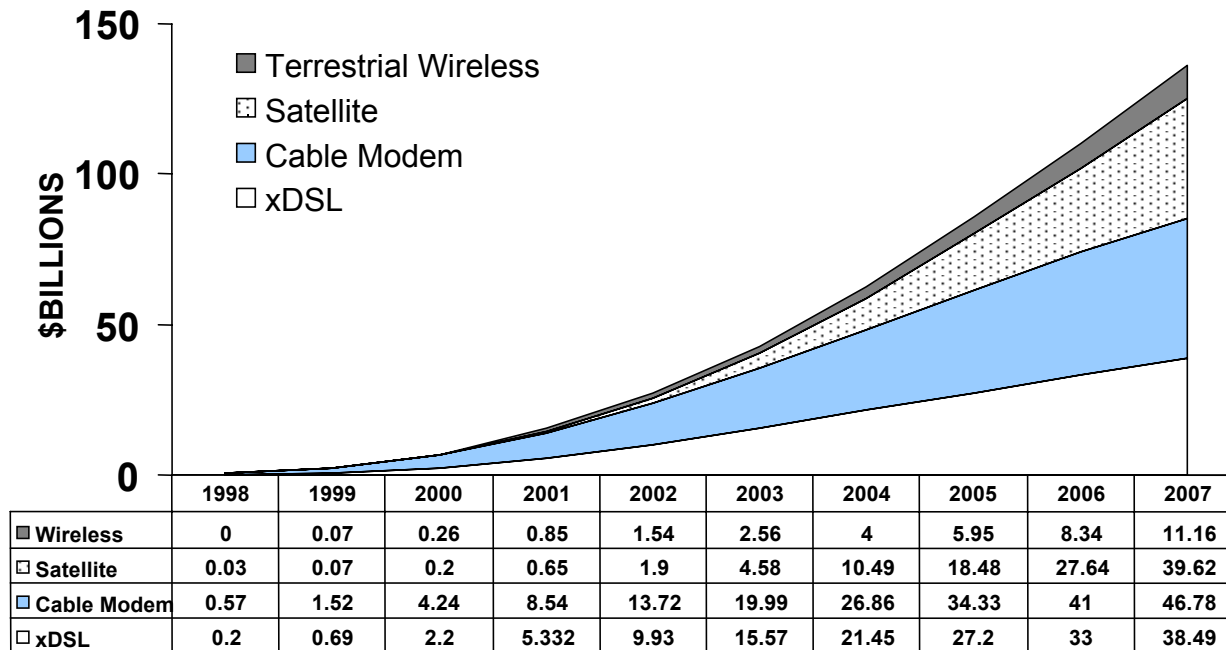


# GROWTH OF MOBILE INTERNET DEVICES TO 2004



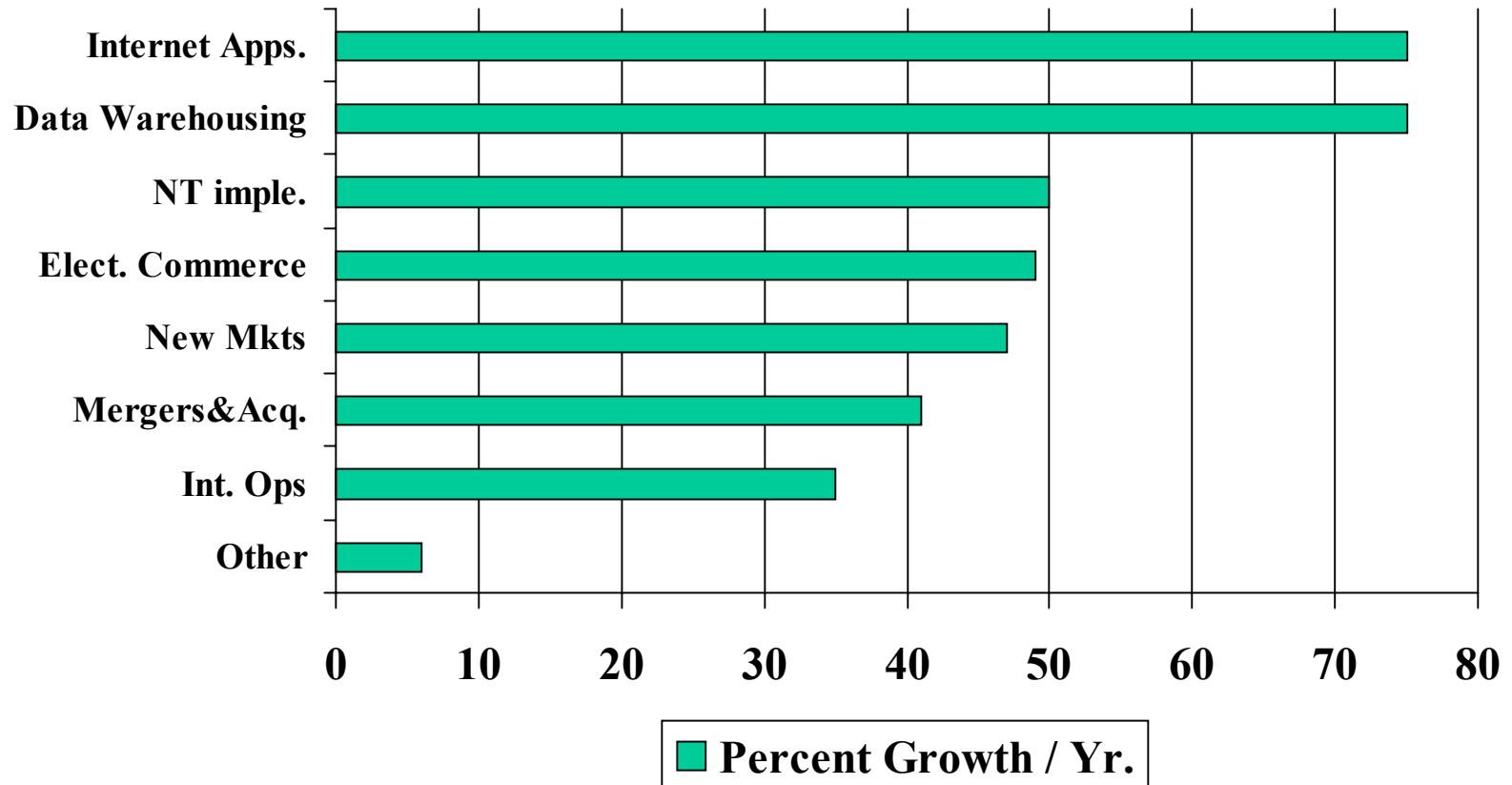
Source: IDC

# Residential Broadband Projections

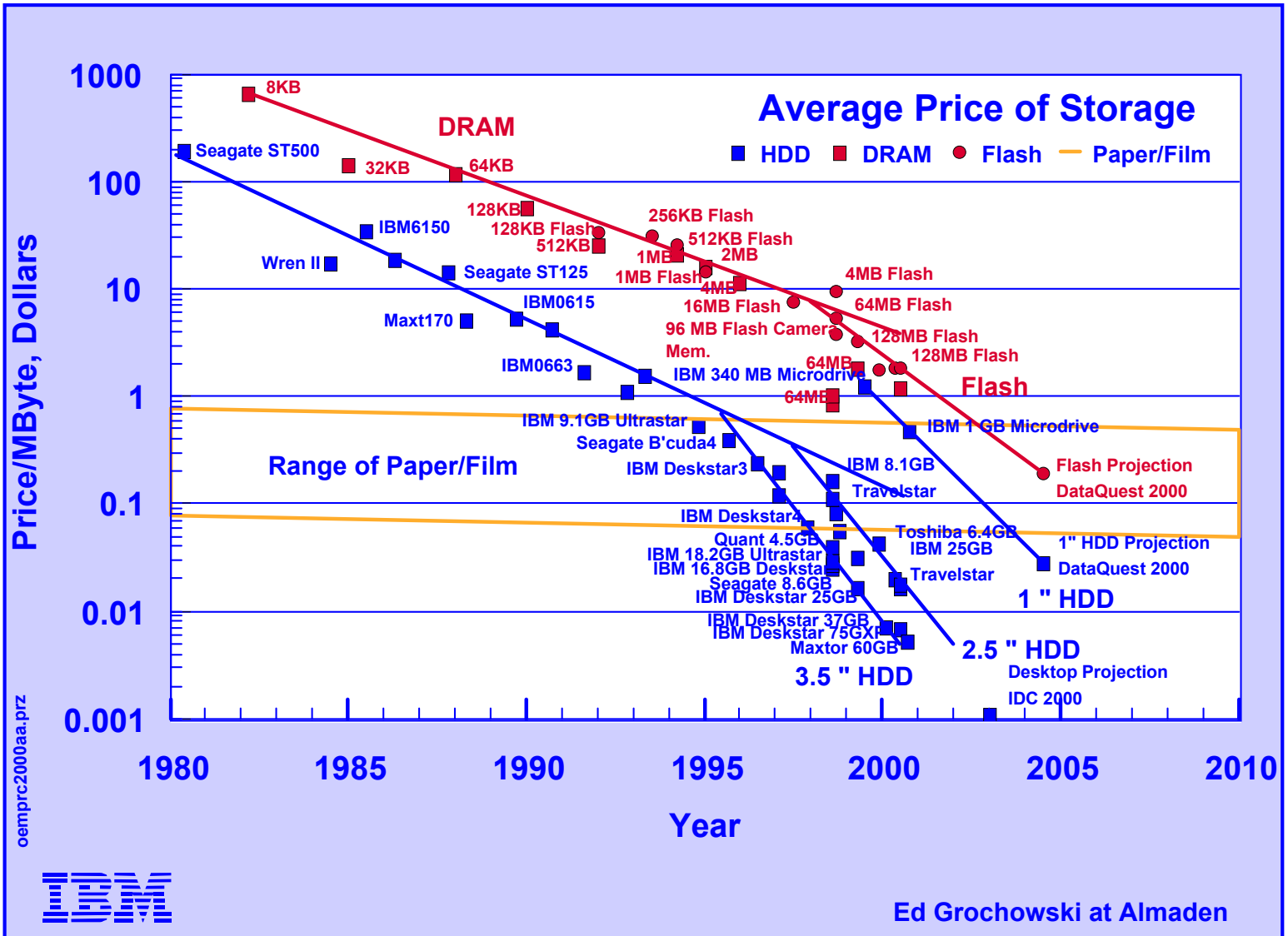


Source: Pioneer Consulting, "Global Broadband Access Markets: xDSL, Cable Modems and the Threat from Broadband Satellite, Wireless and All-Optical Solutions," Executive Summary, October 1998; Centennial Investments

# FORECASTED YEARLY NETWORK STORAGE GROWTH SOURCES 2000 (Source: Find/SNP)



# Trends in Price of Storage/MB



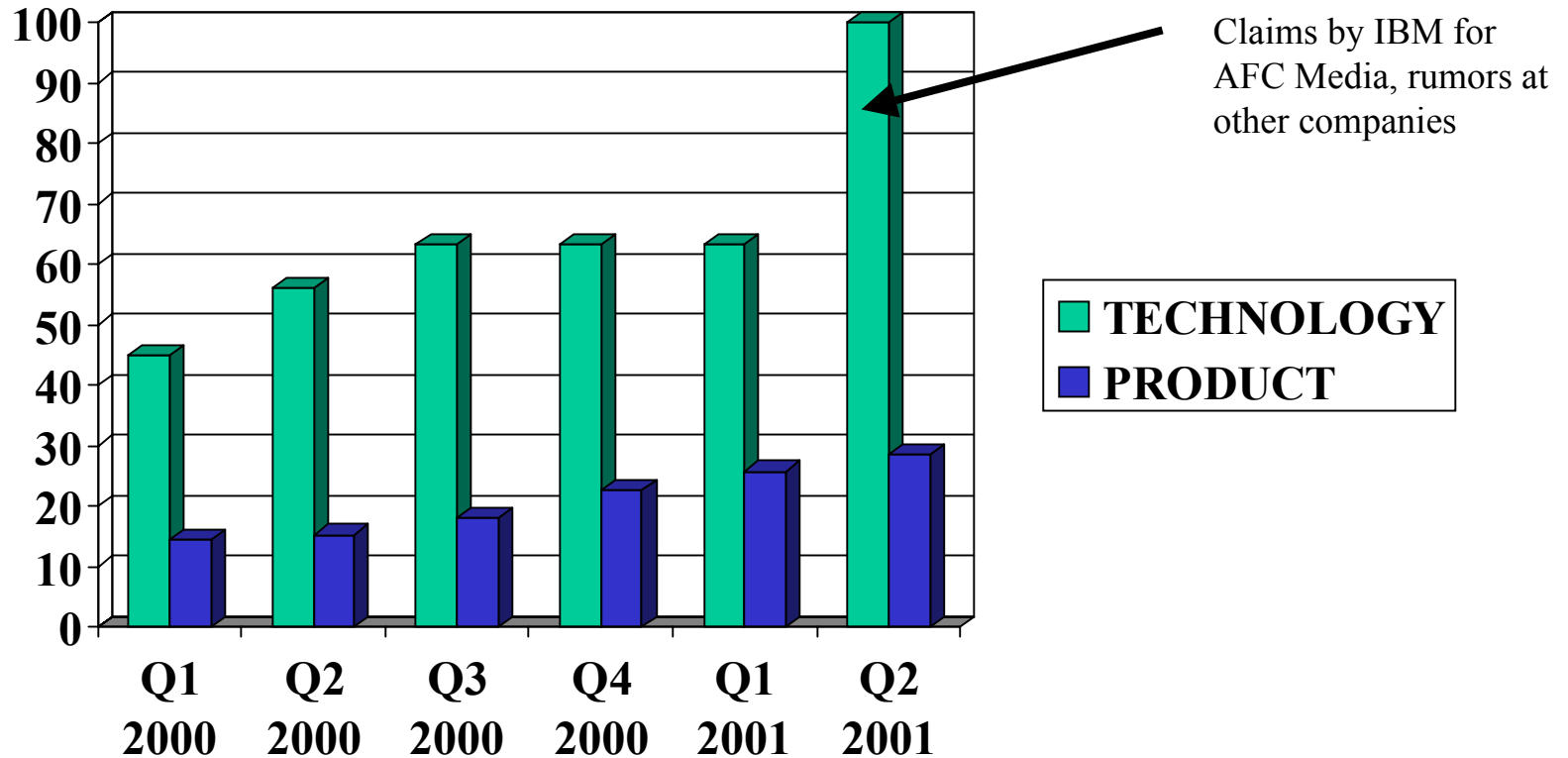
# AREAL DENSITY RACE, JUNE 2001

COMPANY	SIZE	CAPACITY (GB)	AREAL DENSITY Gb/in <sup>2</sup>	TPI	BPI	Time
<b>PRODUCT</b>						
MXTR 96147U8	3.5	61.4	11.3	27.3	412	3/00
IBM 40GV	3.5	40.0	14.3	35.0	415	3/00
IBM	1.0	1.0	15.2	35.0	435	6/00
MXTR DM80	3.5	81.0	14.7	34.0	402	7/00
QTM FBAS	3.5	80.0	14.7	35.4	417	7/00
QTM ATLASIII	3.5	73.4	179	40.0	448	10/00
MXTR 531DX	3.5	15.0	22.5	46.0	489	2/01
TOSHIBA MK1002	2.5	10.0	22.4			3/01
IBM	2.5	30.0	25.7			3/01
MXTR	3.5	20.0	28.3	54.0	524	6/01

## DEMONSTRATION

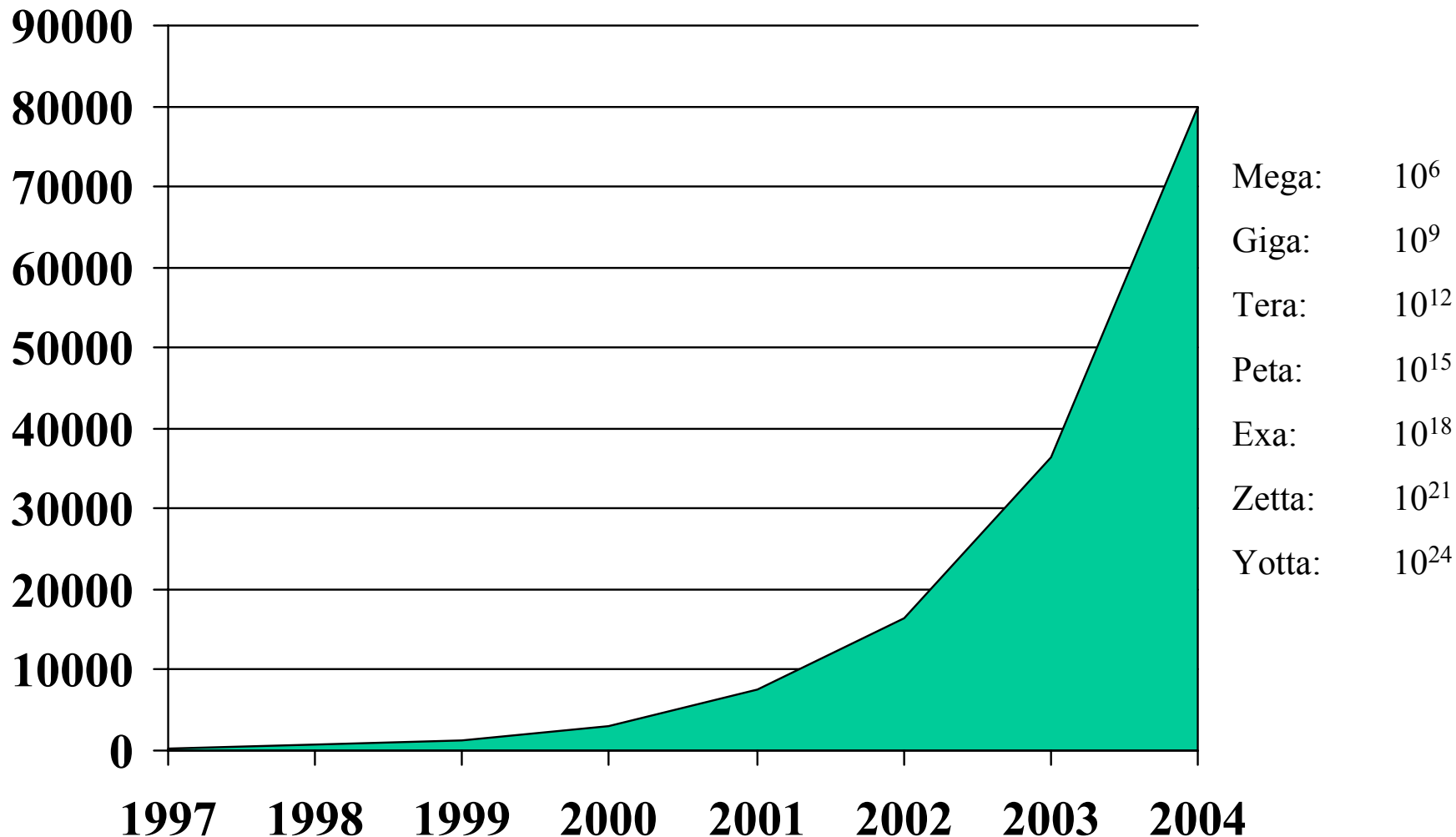
SEAGATE			45.0	70.0	640	3/00
R-R/KOMAG			50.0	90.0	552	3/00
FUJITSU			56.0	82.7	678	6/00
R-R/KOMAG/HTCH/GUZI			63.2	105	600	10/00

# AREAL DENSITY PROGRESSION TECHNOLOGY DEMONSTRATIONS / PRODUCTS



# World Wide Storage Capacity of Disk Memory

(In PetaBytes, Source: Disk/Trend plus projection to 2004)

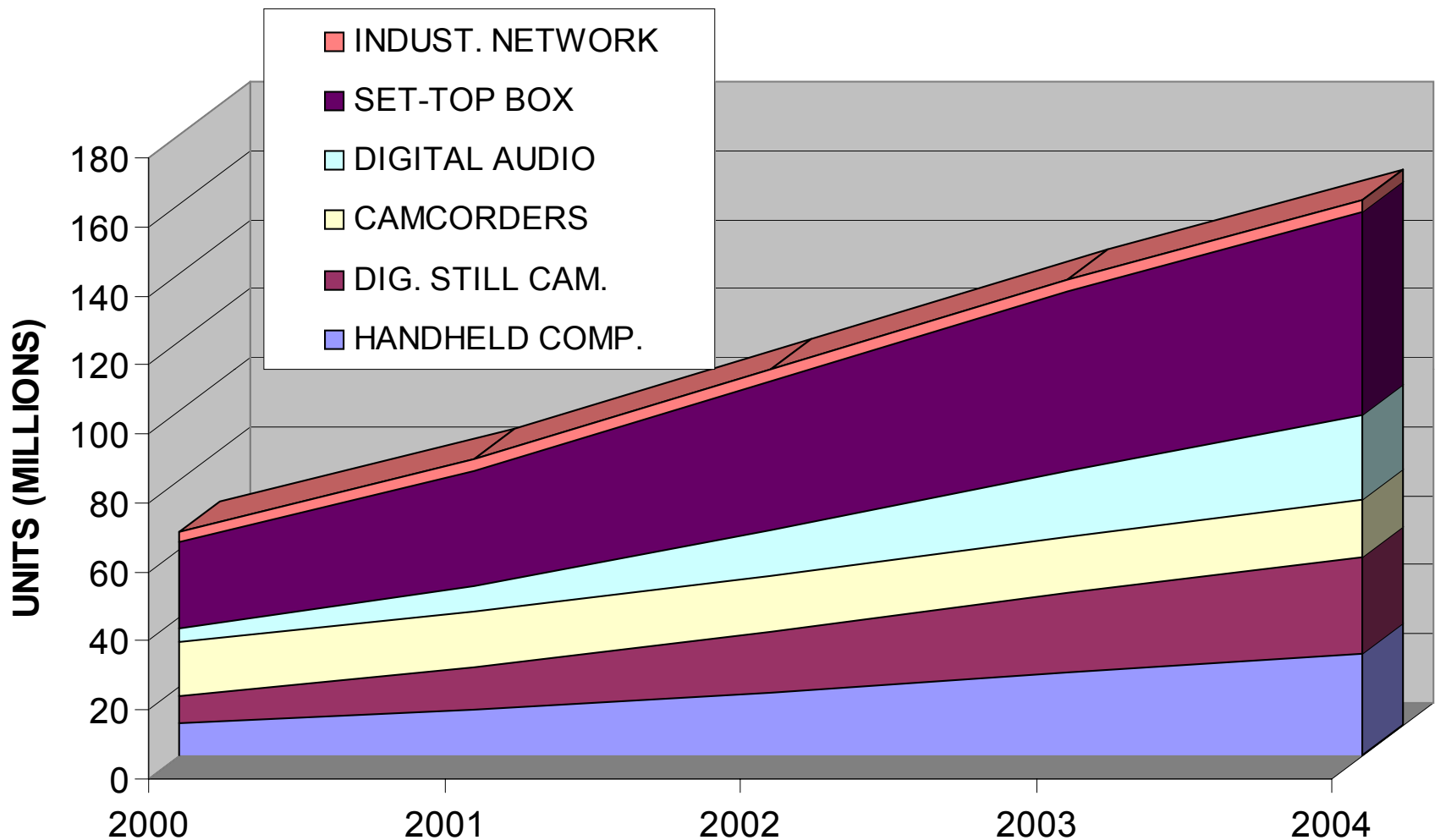


# NON-PC REMOVABLE STORAGE DEVICE OPPORTUNITY FORECAST (UNITS MILLIONS)

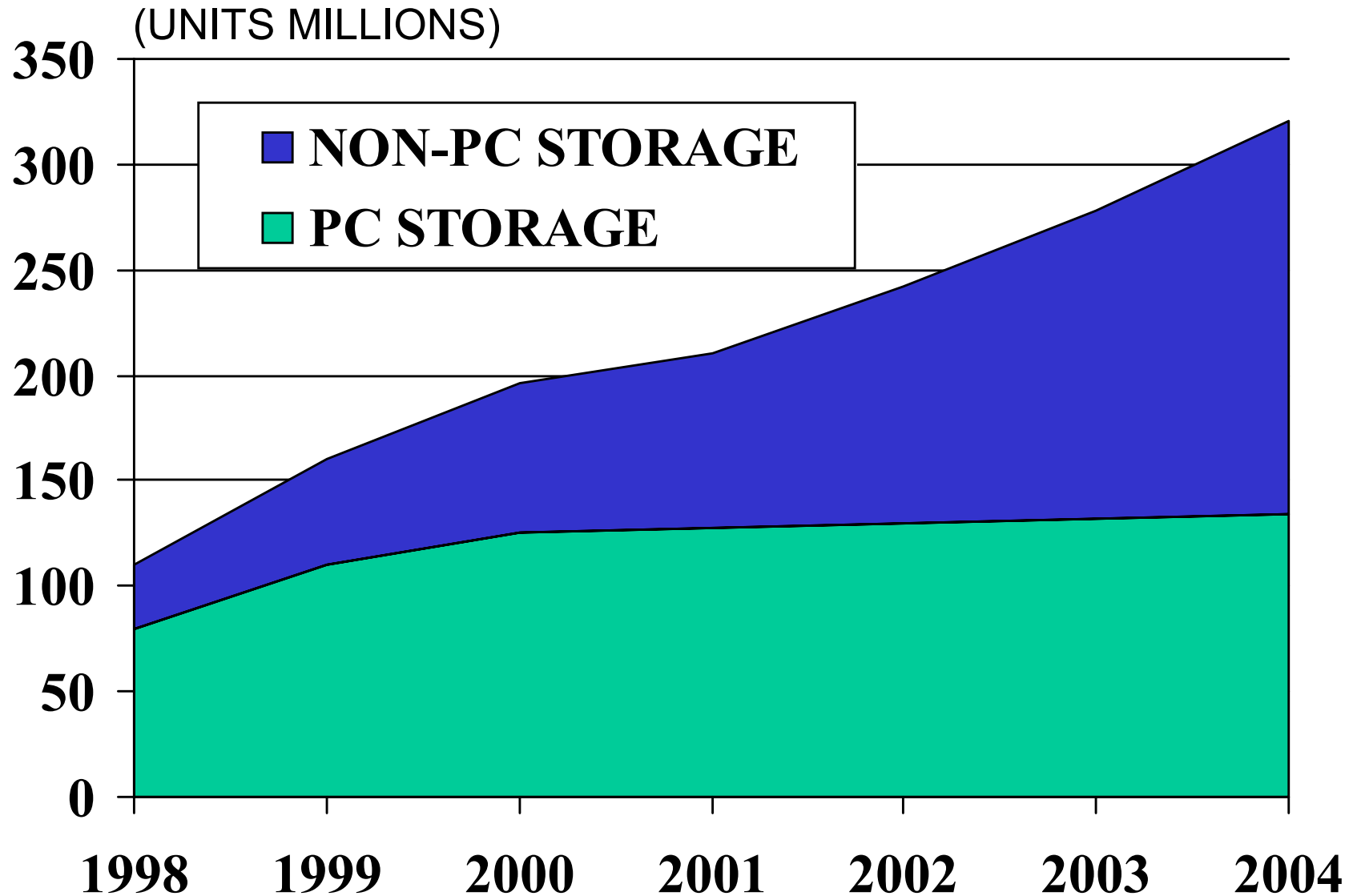
APPLICATION	2000	2001	2002	2003	2004
HANDHELD COMP.	9.6	13.3	18.1	24.3	29.8
DIGITAL STILL CAM.	7.9	12.3	17.9	22.8	27.9
CAMCORDERS	15.7	16.1	16.3	16.6	16.8
DIGITAL AUDIO	4.0	7.8	13.3	19.1	24.2
HAND HELD GPS	3.7	6.3	10.9	13.8	16.7
SET-TOP BOX	24.8	33.3	43.3	52.1	58.9
INDUST. NETWORK	3.0	3.1	3.2	3.3	3.4
SUB-TOTAL	68.7	92.2	123.0	152.0	177.7
DIGITAL CELL	326.1	421.1	532.5	585.0	622.0
TOTALS	394.8	513.3	655.5	737.0	799.7



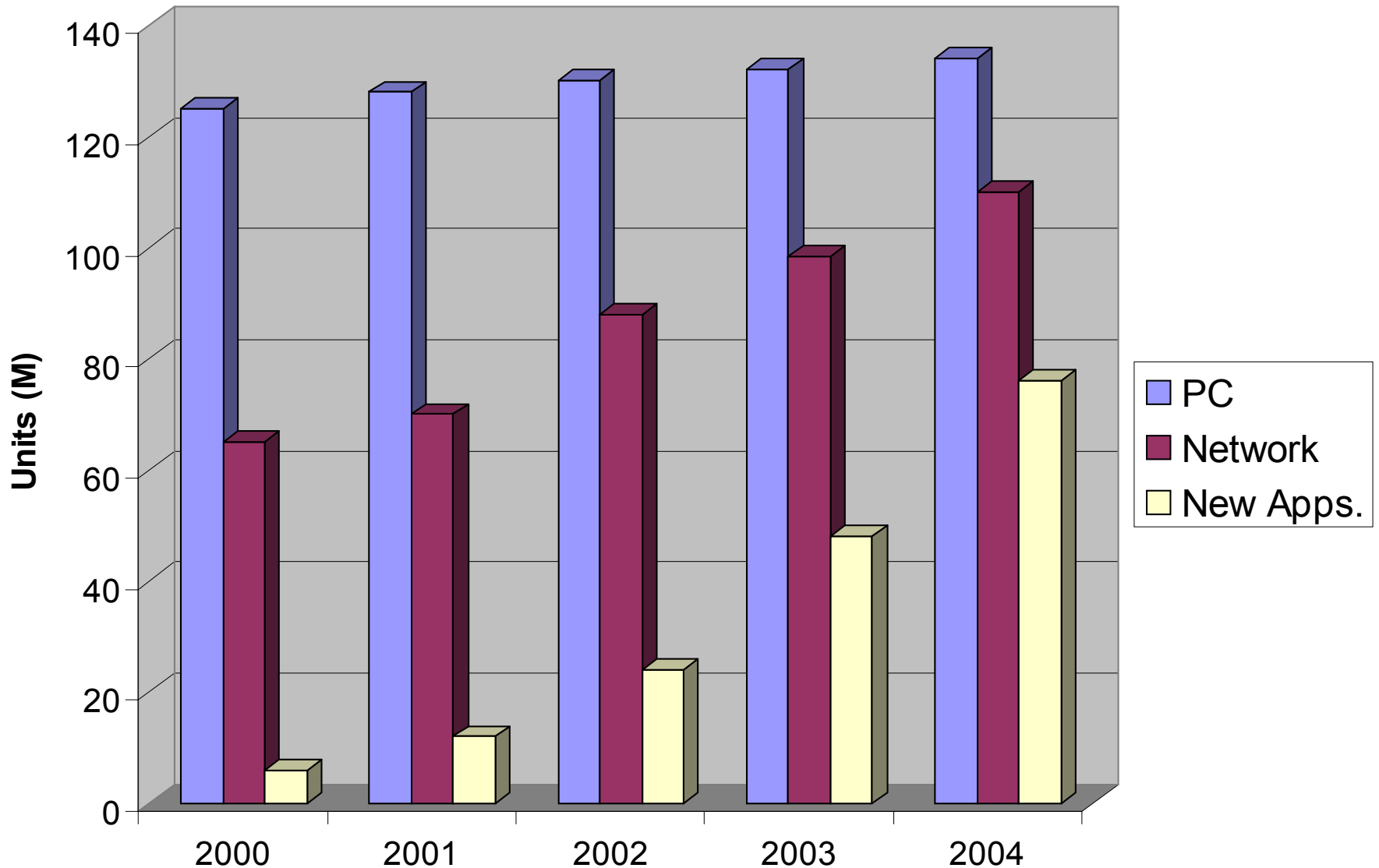
# Growth in New Storage Applications



# PC / NON PC HDD STORAGE MARKETS



# Breakdown in Disk Drive Useage



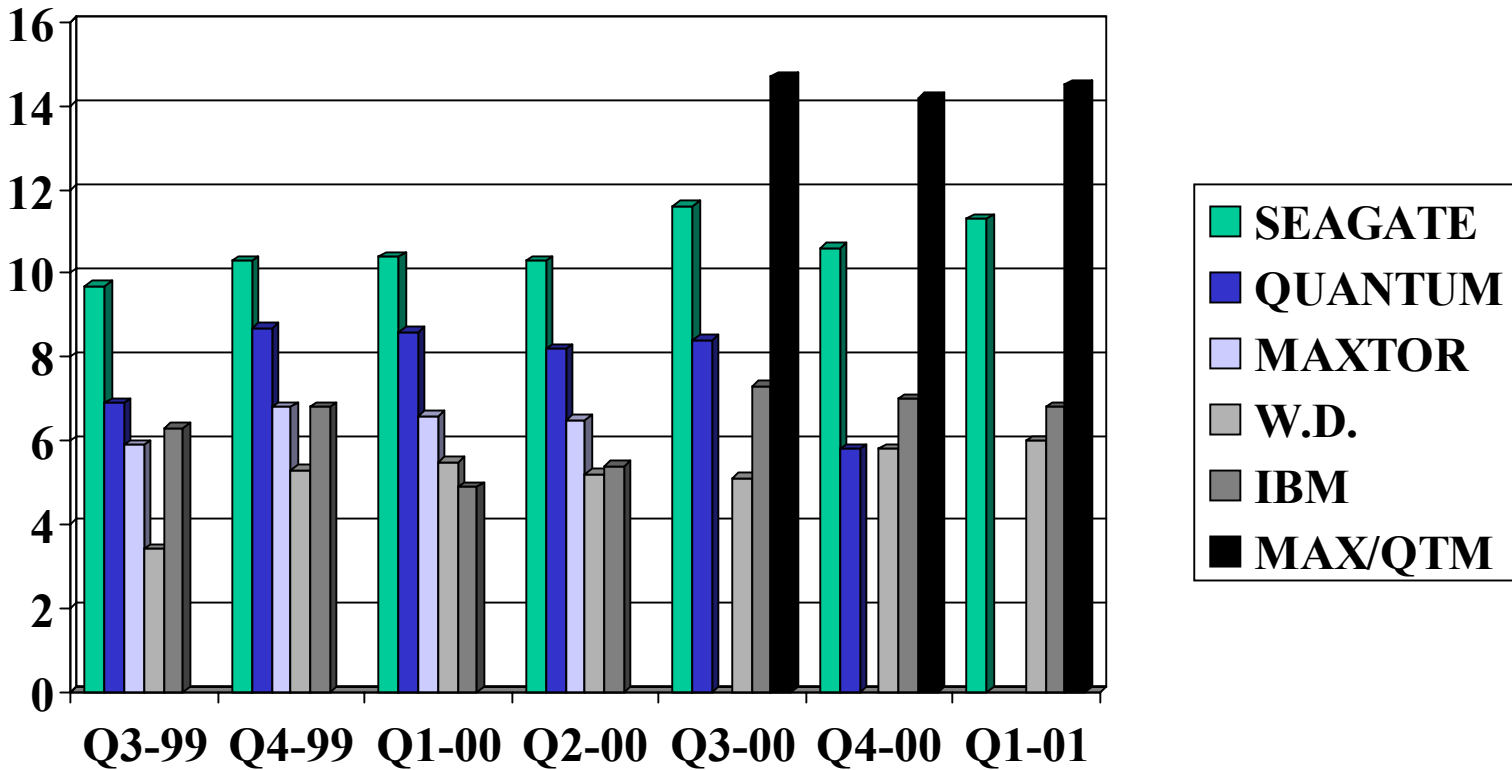
<p><b>ESTIMATED DISK DRIVE FORECAST BY FORM FACTOR FOR NEW APPLICATION STORAGE MARKETS (UNITS THOUSANDS)</b></p>
--

<b>DISK DRIVE SIZE</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>
<b>&lt;=1.8 INCH</b>	856.0	1,452.0	2,468.0	4,196.0	7,134.0
<b>2.5 INCH</b>	2,785.0	3,850.0	5,390.0	7,546.0	10,564.0
<b>3.5 INCH</b>	5,395.0	15,780.0	25,800.0	38,700.0	58,050.0
<b>TOTALS</b>	<b>9,036.0</b>	<b>21,082.0</b>	<b>33,658.0</b>	<b>50,442.0</b>	<b>75,748.0</b>

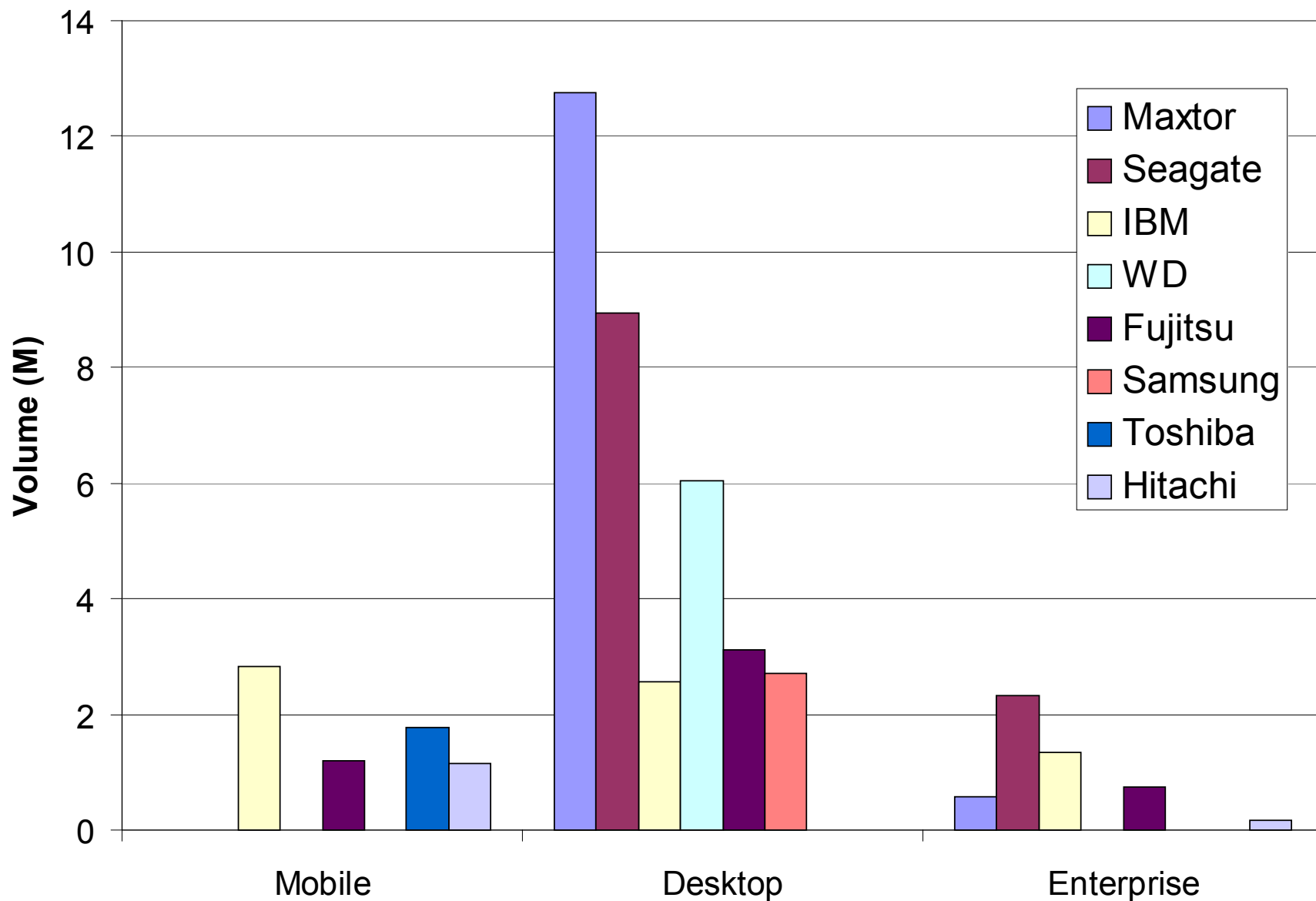
# RIGID DISK DRIVE MARKET FORECAST BY SIZE (UNITS 000)

<b>DISK DRIVE SIZE</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>
<b>&lt;=1.8 INCH</b>	250.0	475.0	800.0	1,600.0	3,600.0
<b>2.5 INCH</b>	24,090.0	28,740.0	31,850.0	43,229.9	75,258.0
<b>3.5/3.0 INCH</b>	173,016.1	179,136.0	190,406.0	195,254.2	200,225.0
<b>5.25 INCH</b>	1,095.0	400.0			
<b>TOTALS</b>	<b>198,451.1</b>	<b>208,751.0</b>	<b>223,056.0</b>	<b>240,084.1</b>	<b>279,083.0</b>

# DISK DRIVE SHIPMENTS BY SUPPLIER (UNITS MILLIONS)



# Drive Company Market Share vs Market Sector (Q1 2001)



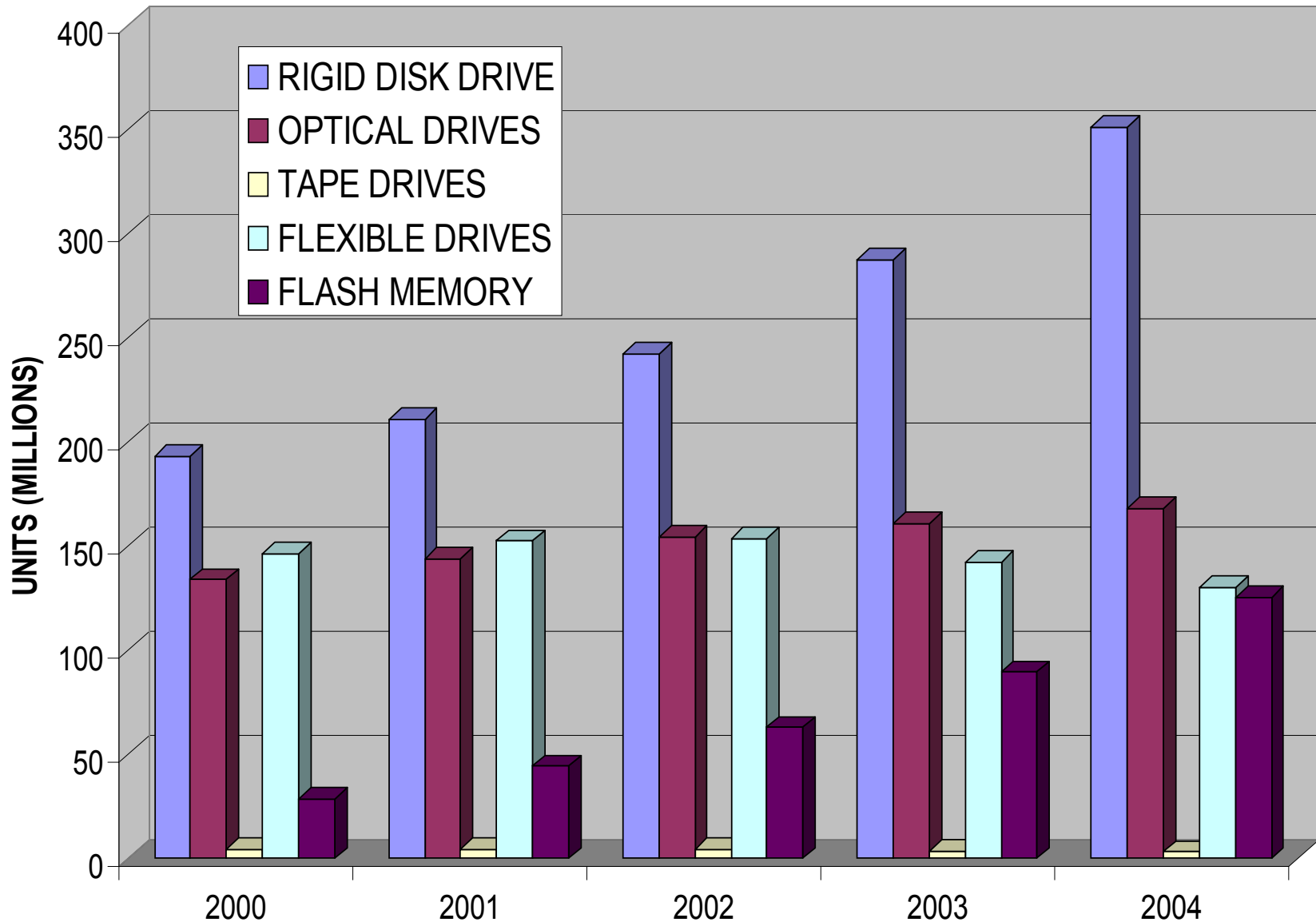
# DISK DRIVE AVERAGE SALES PRICES ( \$ASP) 1999-2001

MFG.	Q-3 99 UNIT/\$	Q-4 99* UNIT/\$	Q-1 00* UNIT/\$	Q-2 00* UNIT/\$	Q-3 00 UNIT/\$	Q-4 00 UNIT/\$	Q-1 01 UNIT/\$
MAXTOR	5.8/\$100	6.8/\$102	6.6/\$105	6.5/\$102	6.5/\$95	7.4/\$98	6.6/\$94
QUANTUM	6.9/\$111	8.7/\$102	8.6/\$105	8.2/\$105	9.0/\$92	6.8/\$104	7.9
SEAGATE	9.7/\$161	10.3/\$149	10.5/\$140	10.3/\$140	11.6/\$141	10.6	10.0
WEST. DIG.	3.4/\$121	5.3/\$106	5.5/\$98	5.2/\$91	5.1/\$86	5.8/\$92	6.0/\$88.9

UNITS IN MILLIONS



# Storage Product Projections


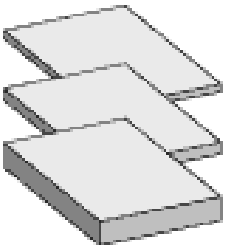
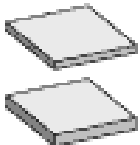






## **WORLDWIDE STORAGE DEVICE REVENUE SUMMARY (\$BILLIONS)**

<b>CATEGORY</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>
<b>RIGID DISK DRIVES</b>	<b>37.2</b>	<b>38.9</b>	<b>41.3</b>	<b>42.5</b>	<b>43.7</b>
<b>OPTICAL DRIVES</b>	<b>7.7</b>	<b>8.9</b>	<b>9.3</b>	<b>9.5</b>	<b>9.7</b>
<b>TAPE DRIVES</b>	<b>4.8</b>	<b>4.7</b>	<b>4.6</b>	<b>4.1</b>	<b>3.6</b>
<b>FLEXIBLE DRIVES</b>	<b>2.4</b>	<b>2.4</b>	<b>2.3</b>	<b>1.9</b>	<b>1.5</b>
<b>FLASH MEMORY</b>	<b>1.2</b>	<b>2.1</b>	<b>2.9</b>	<b>3.9</b>	<b>5.2</b>
<b>TOTALS</b>	<b>53.3</b>	<b>57.0</b>	<b>60.4</b>	<b>61.9</b>	<b>63.7</b>

# MOBILE ELECTRONIC DATA STORAGE

# Mobile Memory Form Factors

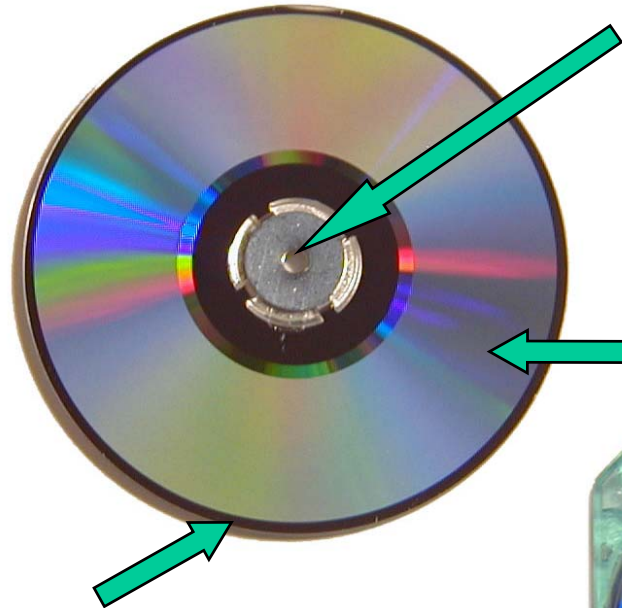
Storage Device	Size	Typical Capacity <sup>1</sup>	Optional Adapter
 <b>Microdrive</b>	42.8 x 36.4 x 5.0 mm	170 MB and 340 MB	PC Card adapter
 <b>PC Card (PCMCIA)</b> - Type I - Type II - Type III	85.6 x 54.0 x 3.3 mm 85.6 x 54.0 x 5.0 mm 85.6 x 54.0 x 10.5 mm	Type II Memory= 4 MB-128 MB	External Reader/Writer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

**FIGURE 4-28.**  
**Compact Flash capacity vs. Prices (1999, 2000)**

<b>Capacity (MB)</b>	<b>MSRP 1999 (\$)</b>	<b>MSRP 2000 (\$)</b>	<b>Street Price 1/17/01 (\$)</b>	<b>Est. Volumes 1999</b>	<b>Est. Volumes 2000</b>
4	20			4.1	
8	40	35	12	1.7	5.6
16	60	50	25	0.9	2.4
32	100	90	54	0.6	1.2
48	140	120		0.4	0.5
64	200	170	95	0.3	0.8
96	300	250		0.2	0.2
128	400	325	172	0.1	0.4
160	500*	425			0.2
192		500	325		0.1
256		700*	436		0.1
300		800*			
<b>Total</b>				<b>8.3</b>	<b>11.5</b>

# DataPlay Digital Media

Magnetic clamping hub



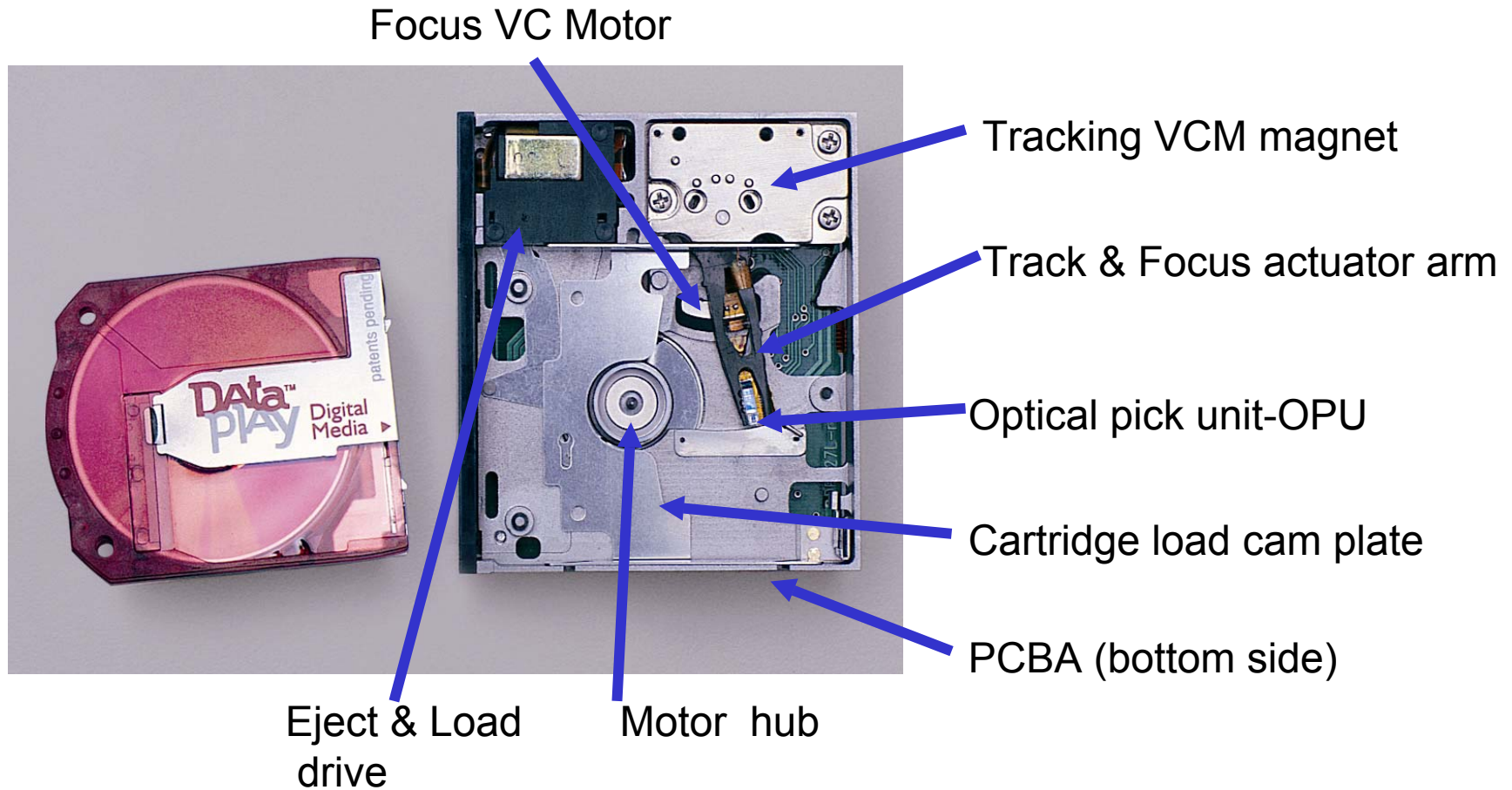
Alloy coating  
With dielectric



Molded double sided  
Polycarbonate disc  
- single piece  
- 32mm diameter

- 500 MB Capacity (250 MB/side)
- 3+ Hours CD-Quality Music
- User Recordable and Pre-Masterable (On Same Disc)
- Archival – 100-year life
- Universal – all data types
- Content enabling technology
- Encryption at cartridge level
- Ultra low write power
- Low manufacturing and mastering cost
- Retail price: ~\$10-12 (500 MB)
  - \$.02/MB!!!

# DataPlay Micro-Optical Engine Subassemblies



# IOMEGA HipZip

- STORES MP3 FILES ON POCKETZIP (AKA CLIK) DISKS.
- DISKS <\$10 COMPARED TO ~\$60 FOR 32 MB AND ~\$104 FOR 64 MB COMPACT FLASH.
- A COMMERCIAL CD WORTH OF MP3 COMPRESSED MUSIC IS ~40 MB.
- AMOUNG TOP 5 SELLER OF MP3 PLAYERS ACCORDING TO CNET. MSRP ~\$150





## IBM Microdrive



# **IBM MICRODRIVE MARKETS**

<b>SHIPMENT EST.</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>
<b>(UNITS 000)</b>	<b>30.0</b>	<b>188.0</b>	<b>600.0</b>

## **APPLICATIONS:**

**40% THINK-PAD, LAPTOP, P.C. APPLICATIONS**  
**60% DIGITAL CAMERA**

## **CAMERA MODELS: 19 TOTAL**

<b>CANON-4</b>	<b>CASIO- 3</b>	<b>KODAK-2</b>
<b>FUJI- 3</b>	<b>HITACHI- 2</b>	
<b>MINOLTA-3</b>	<b>SANGYO-2</b>	

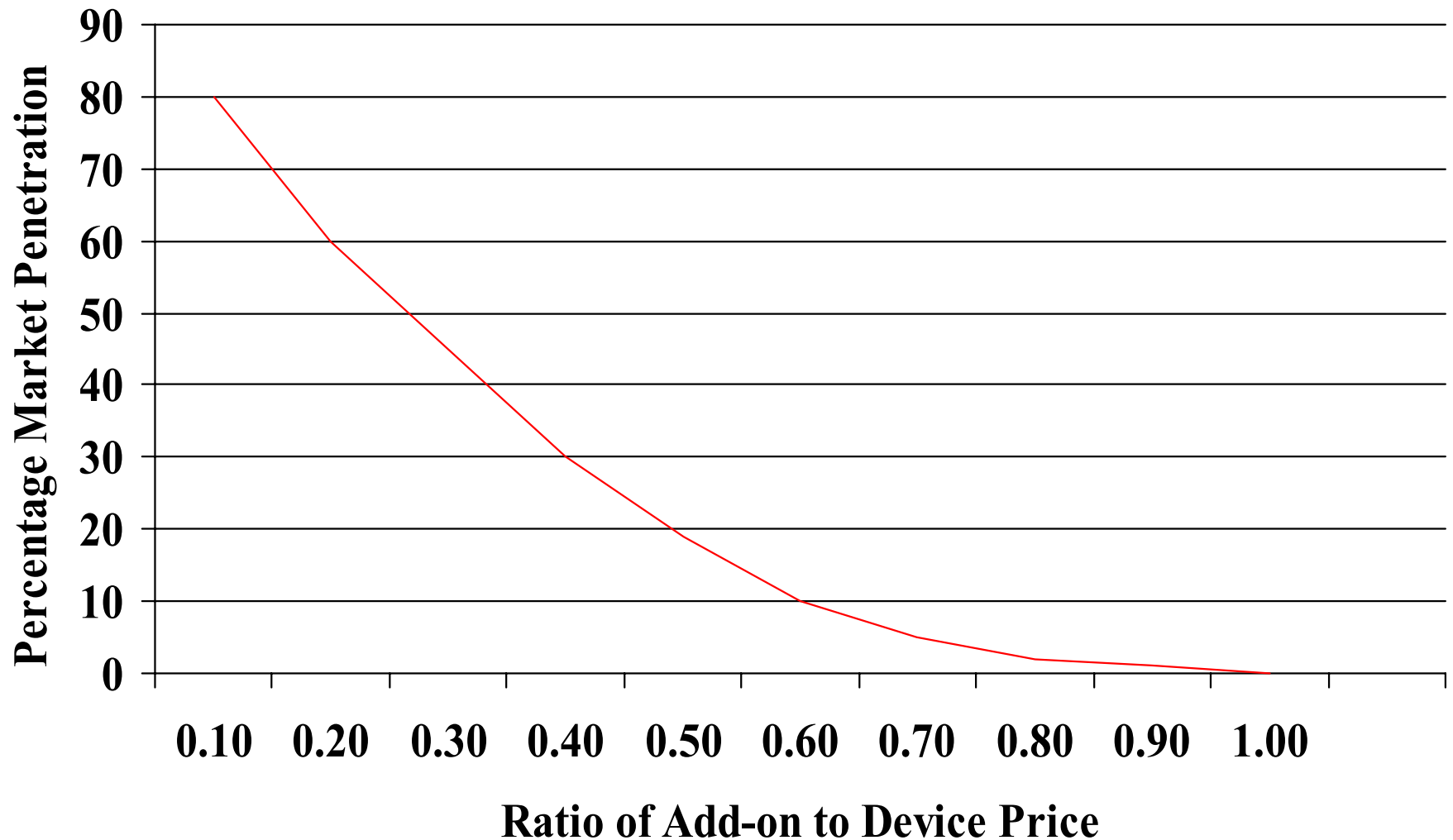
**\* OTHER POTENTIAL “1” INCH DRIVE SUPPLIERS: HALO, MARQLIN, QUANTUM,  
TOSHIBA,SEAGATE, OTHERS**

## FIGURE 4-38.

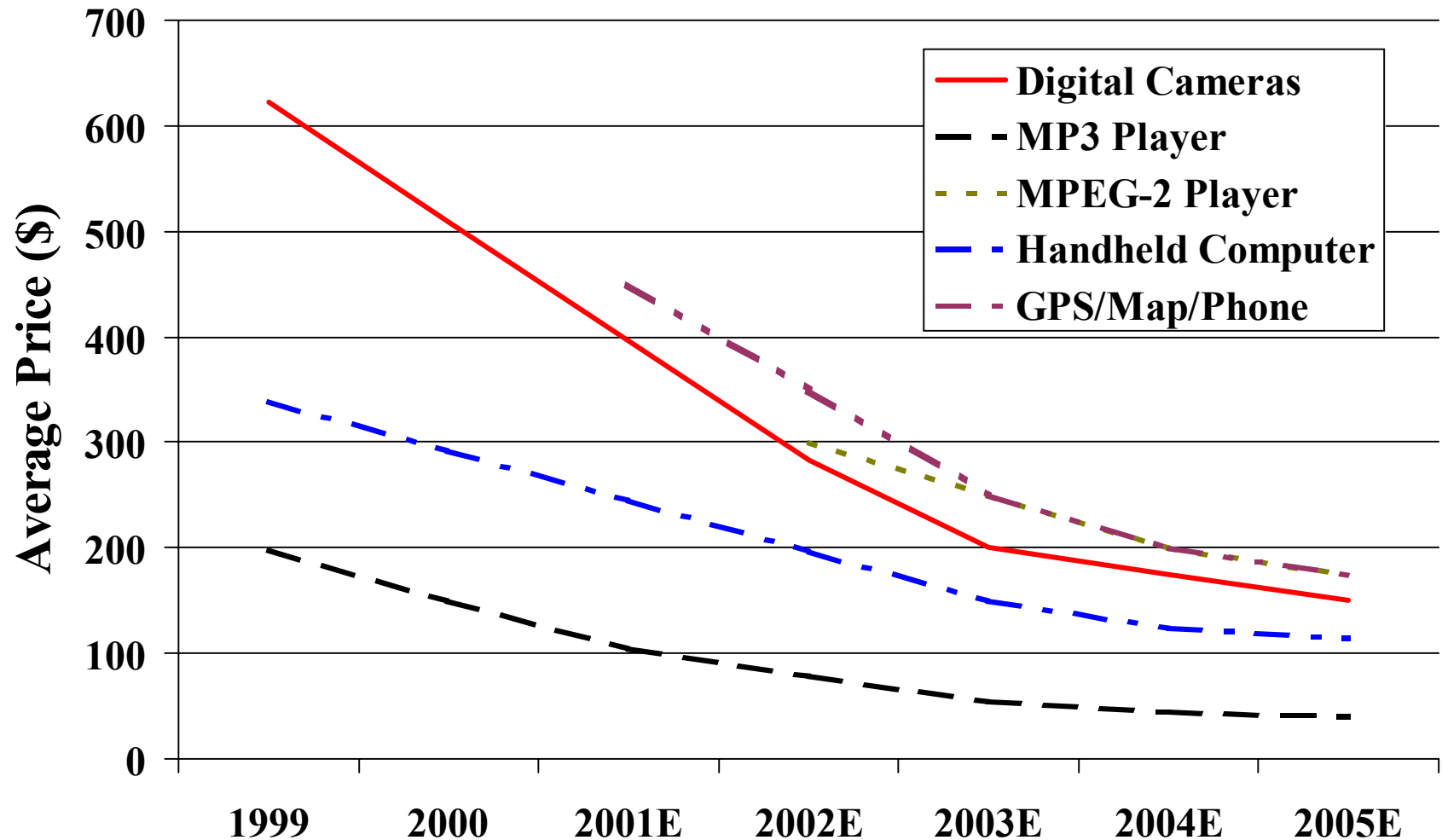
### Storage Requirements for Various Applications

<b>Application</b>	<b>Min. MB</b>	<b>Max. MB?</b>
Mapping/Directions	500	2,000
Face Recognition	500	2,000
Camera	100	1000
Phone Book, Dialer	2	10
Calendar	1	1
Email	1	500
Fax	1	200
To Do List	1	5
Memo	1	1
Speech Recognition/Output	200	500
News	1	10
Market Quotes	1	1
Entertainment: Games/Video/Spoken Books	2	5,000
<b>TOTALS</b>	<b>1,311</b>	<b>11,528</b>

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

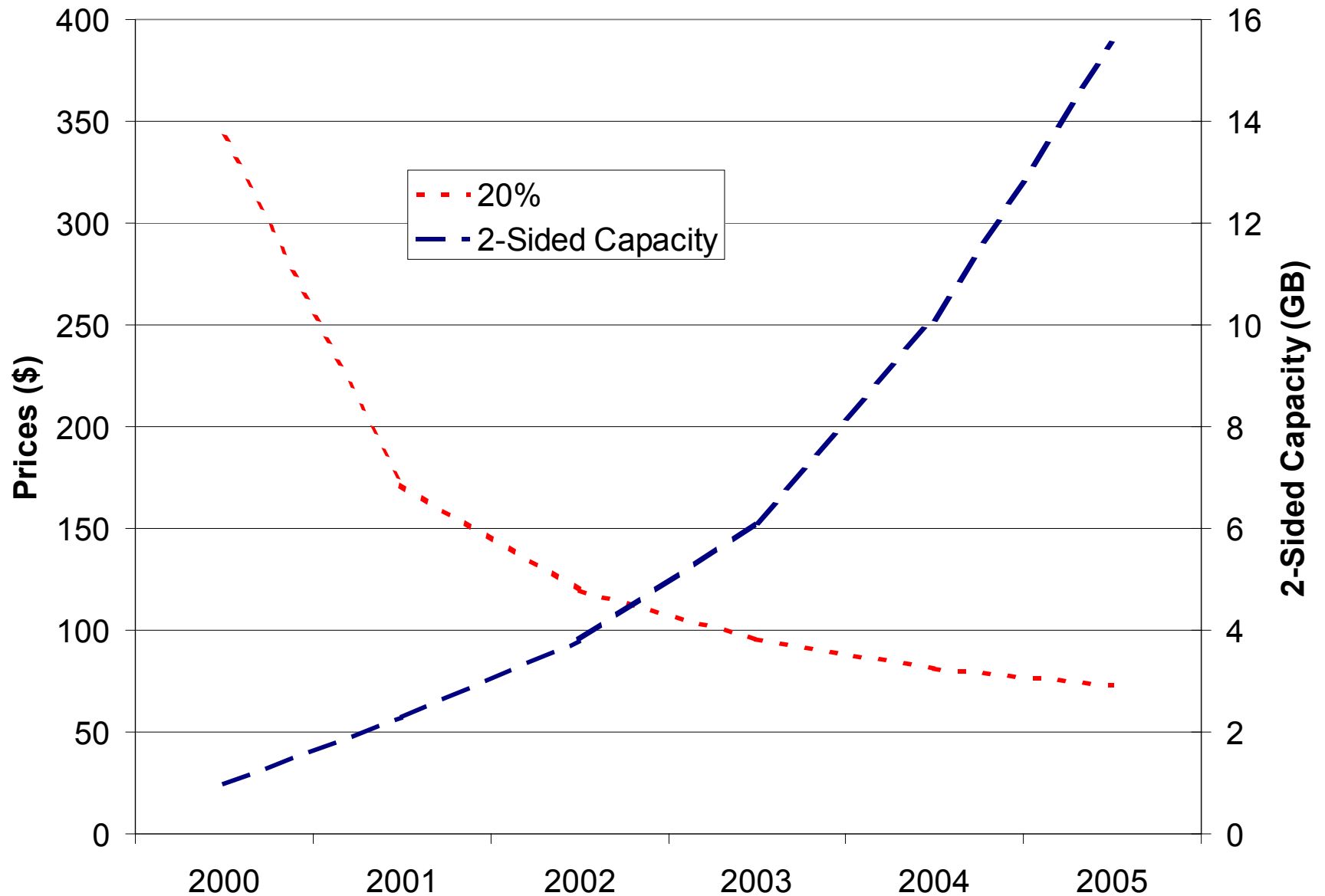


# Average Mobile Electronic Product Price Projections



Source: Projections based on Intellect Market Tracking for Digital Cameras and PDAs , 2000

# Microdrive Price Projections at 20% Gross Margin and 2-Sided Capacity



## Specifications of Microdrive vs Compact Flash Memory (2001)

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

Figure 4H-5

## 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, a video MPEG-2 player, or a GPS/Map system proper memory buffering with the microdrive can reduce the power requirements to be similar to compact flash.

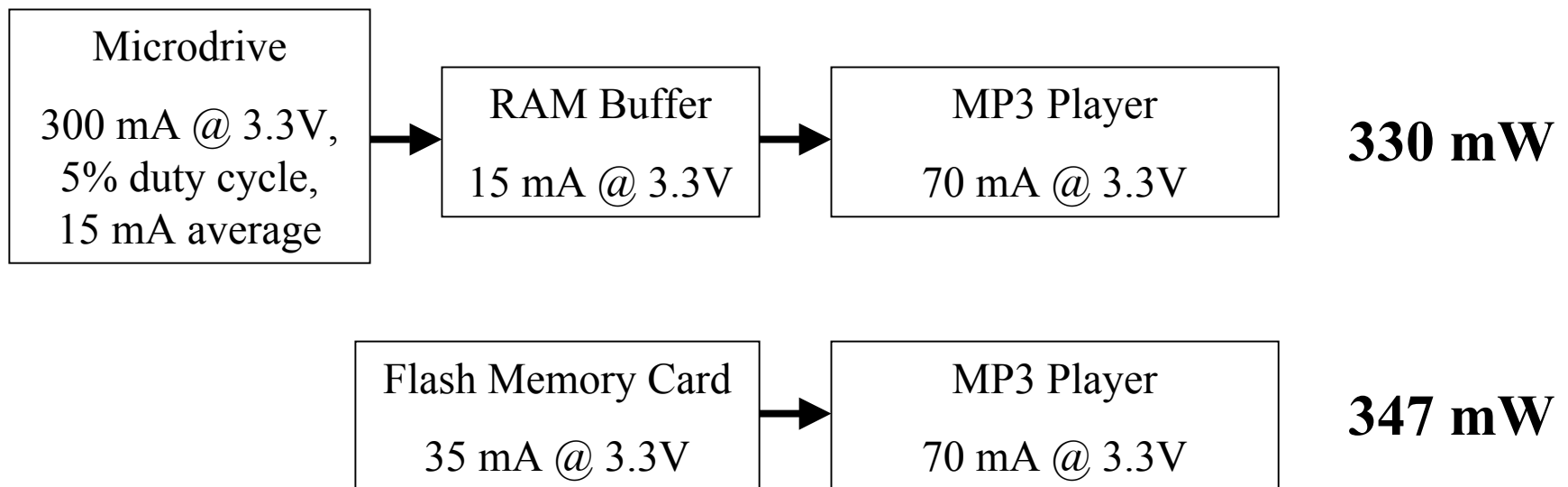
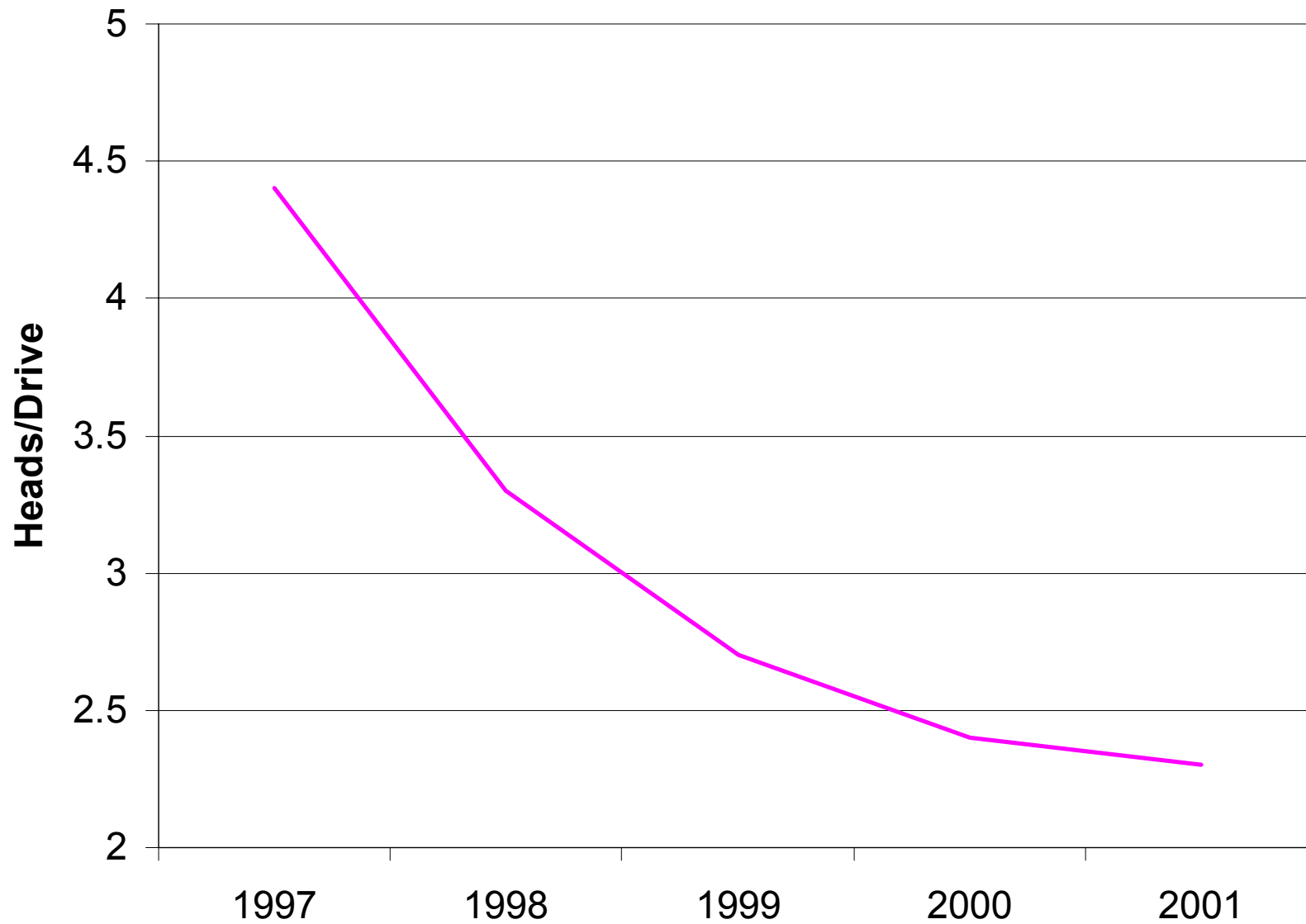


Figure 4H-6



# Head and Medium Market and Technology

## Desktop Drive Average Heads/Drive Ratios



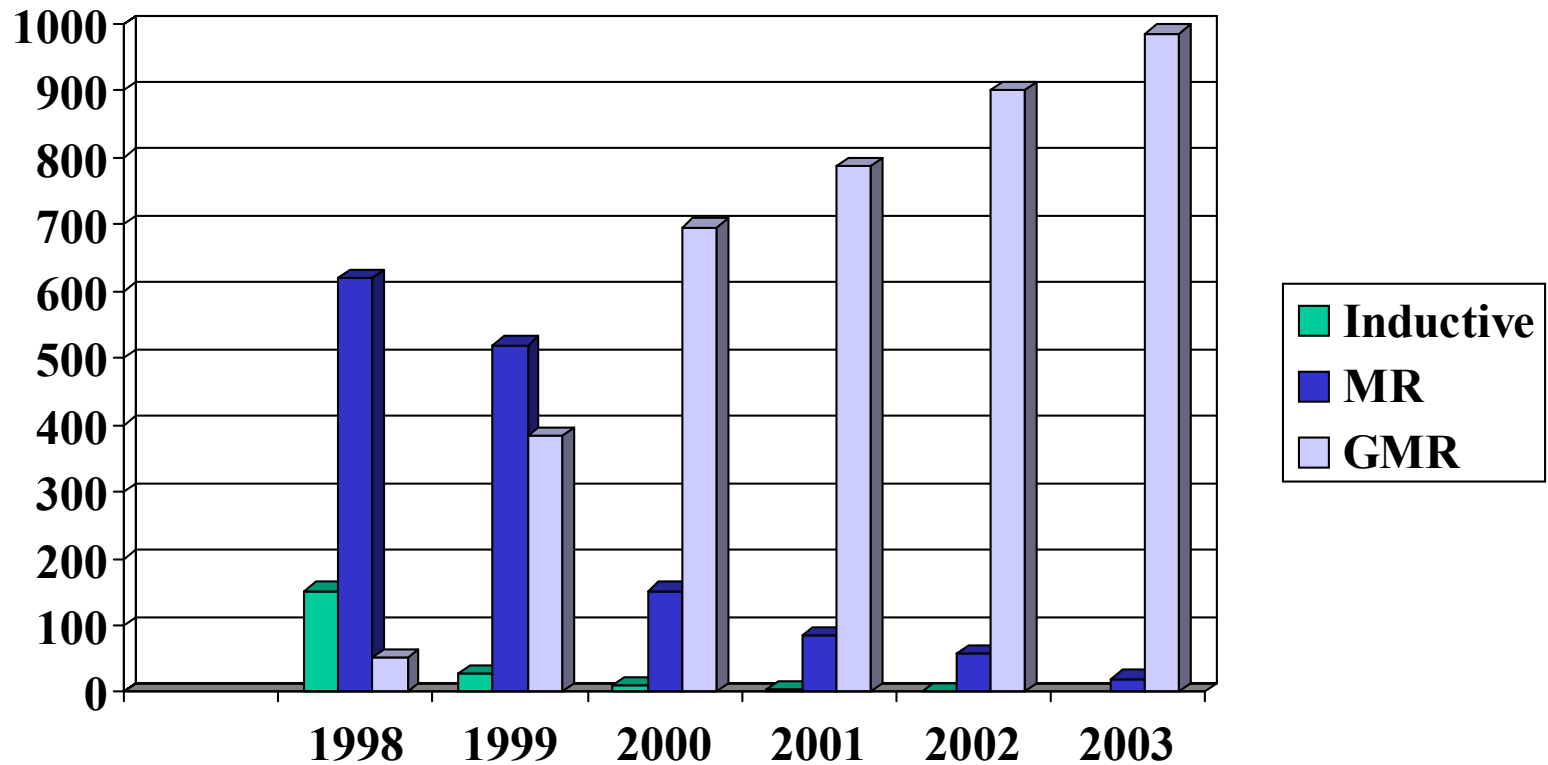
# MAGNETIC HEAD MARKET DEMAND SUMMARY

## MERCHANT / CAPTIVE (MILLIONS)

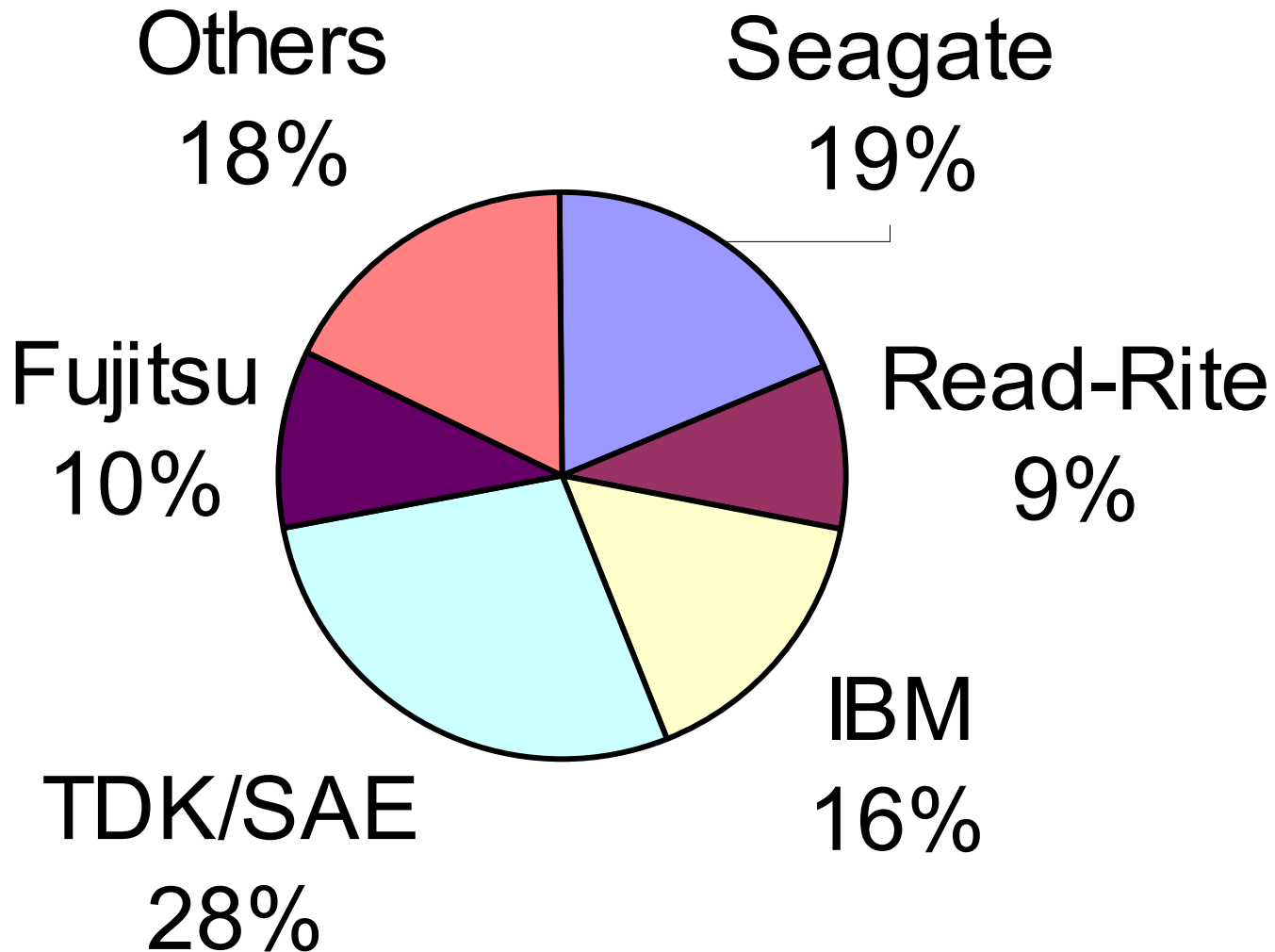
HEAD TYPE	1999	2000	2001	2002	2003	2004
INDUCTIVE	27.7	9.3	3.1	--		
M R	519.0	212.3	83.8	15.7	8.6	1.2
GMR	384.1	635.2	748.3	895.0	930.2	960.0
TOTALS	930.8	856.8	835.2	910.7*	938.8*	961.2*

\* Assumes head/disk reduction continues due to popularity of SSD drives

# MAGNETIC HEAD MARKET DEMAND SUMMARY (UNITS MILLIONS)



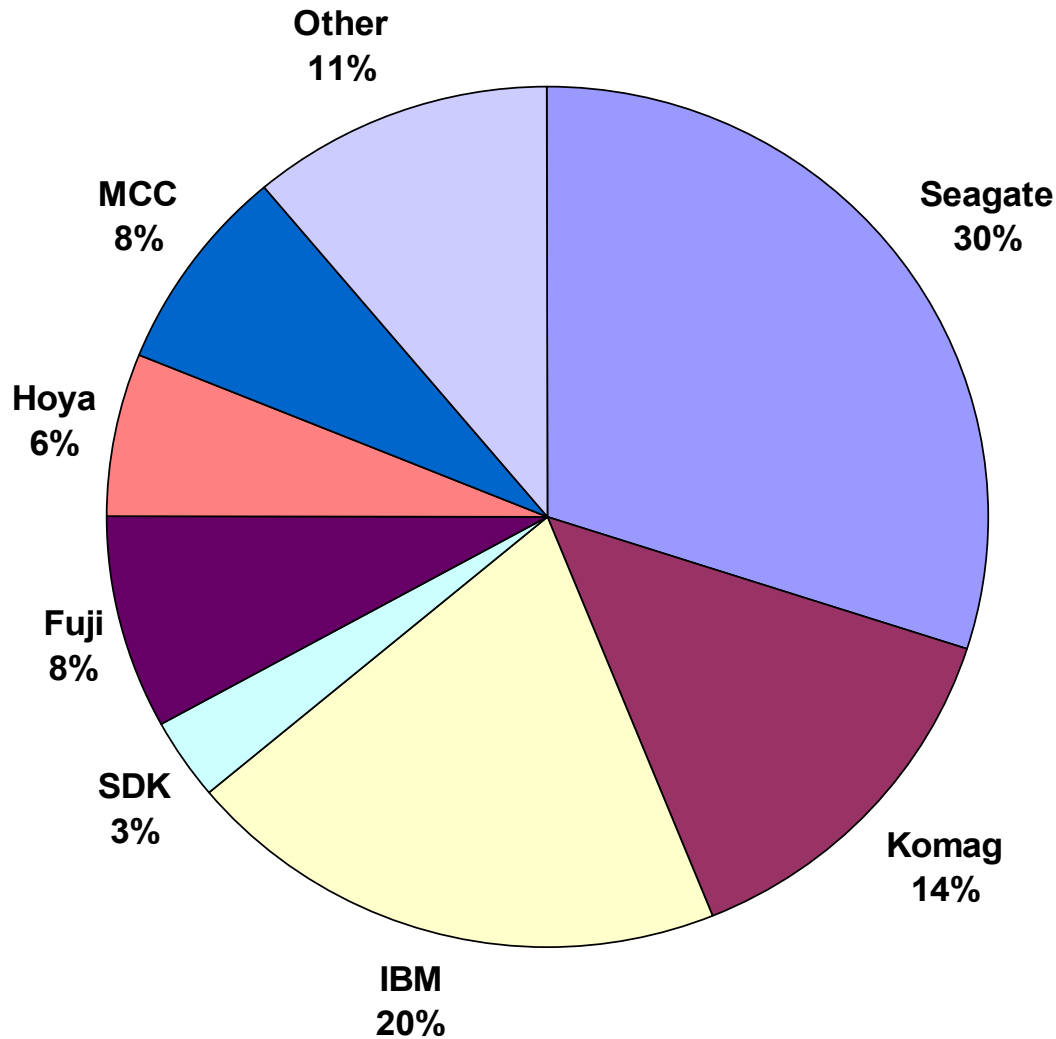
# 2000 Head Company Market Share



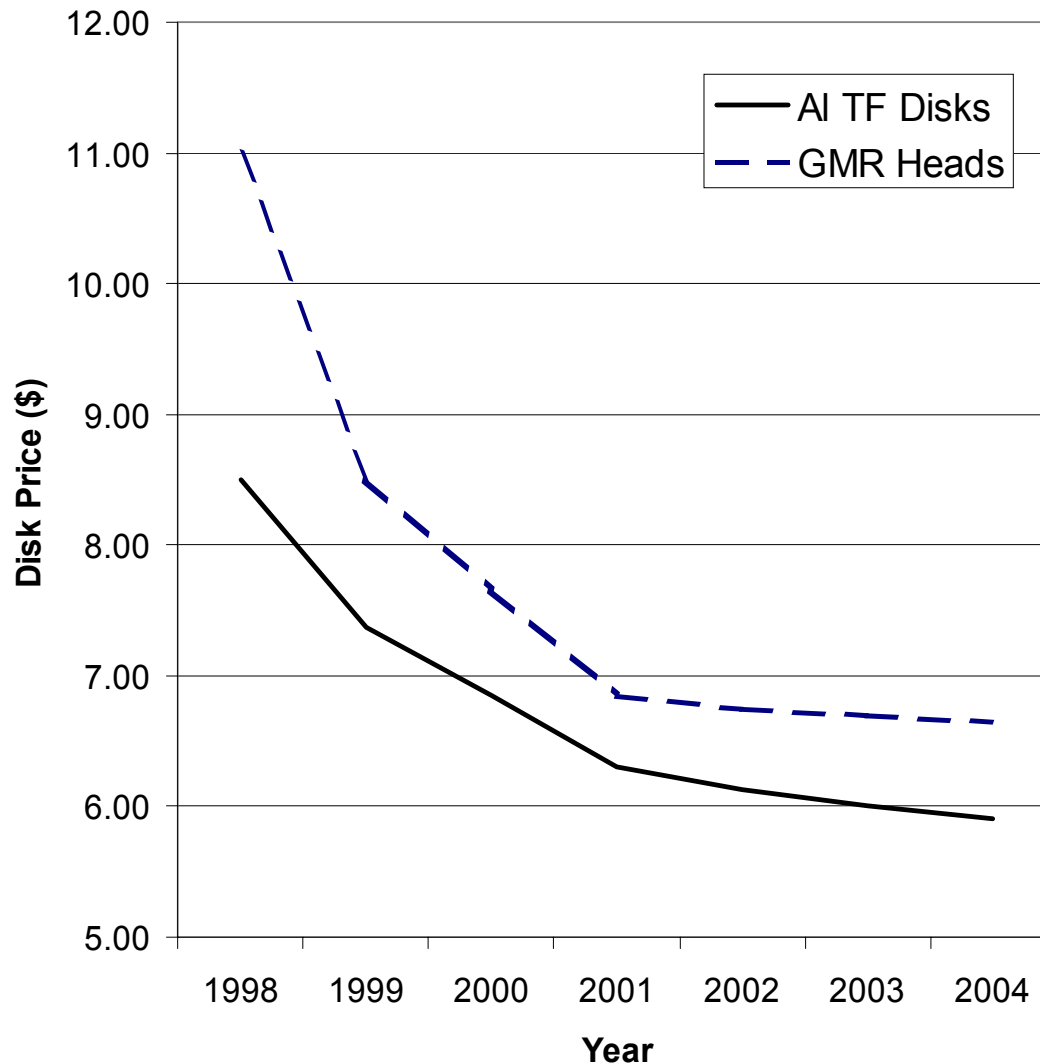
## **RIGID DISK MEDIA DEMAND SUMMARY BY TYPE (UNITS MILLIONS)**

<b>TECHNOLOGY</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>
<b>SPUTTERED (ALUM)</b>	<b>369.8</b>	<b>344.8</b>	<b>307.5</b>	<b>294.9</b>	<b>276.3</b>	<b>242.1</b>
<b>SPUTTERED (ALTER)</b>	<b>83.5</b>	<b>94.7</b>	<b>112.4</b>	<b>140.5</b>	<b>184.0</b>	<b>248.4</b>
<b>TOTALS</b>	<b>453.3</b>	<b>439.5</b>	<b>419.9</b>	<b>435.4</b>	<b>460.3</b>	<b>490.5</b>

# 2000 Media Company Market Share



# Projected Average Disk and Head Prices





# **INDUSTRY STATUS**

## **MARKET / TECHNOLOGY CHANGES**

- **NETWORK STORAGE MARKETS TEMPORARILY STAGNANT DUE TO IT RECESSION BUT GROWTH PRESSURE IS INTENSE (OPPORTUNITY FOR LOW COST NETWORK STORAGE)**
- **SLOWNESS IN P.C. MARKETS**
- **GMR / AGMR TECHNOLOGY DOMINATES HEADS**
- **DRIVE AND COMPONENT PRICING PRESSURES HAVE LESSENED**
- **CONSUMER ELECTRONICS AND MOBILE MARKETS GROWING**
- **UNIT FORECASTS THROUGH 2005 WILL INCREASE**
- **1.0 / 1.8 / 2.5 INCH MARKETS WILL INCREASE DRAMATICALLY**

## **FUTURE**

- **LESS TECHNOLOGY AND CAPITAL FUNDING**
- **SLOWING OF AREAL DENSITY GROWTH (120-100-90 % CAGR?)**
- **FEWER MANUFACTURERS (CONSOLIDATION)**
- **RETIRING EXCESS CAPACITY**
- **MORE AUTOMATION AND MOVE OF COMPONENT MANUFACTURING OVERSEAS**

# **SUMMARY**

- **STORAGE DEMANDS WILL CONTINUE TO INCREASE**
- **NEW APPLICATIONS WILL CONTINUE TO EMERGE AS WELL AS NETWORK STORAGE APPLICATIONS**
- **FOCUS WILL BE ON:**
  - **PERFORMANCE**
  - **COST**
- **VALUE WILL BE ADDED TO THE DRIVES AND COMPANIES, WE MIGHT EVEN SEE SOME PRODUCT DIFFERENTIATION**
- **AREAL DENSITIES WILL CONTINUE TO INCREASE, MAYBE AT A SLOWER RATE**
- **MORE COMPONENT INTEGRATION WILL BE REQUIRED**
- **TESTING WILL COME OUT OF DRIVES AND COMPONENTS TO REDUCE COSTS**

“Things are more like they are  
now than they ever were before.”

Dwight Eisenhower