SSD: The Next Killer App in NAND Flash

Jim Elliott

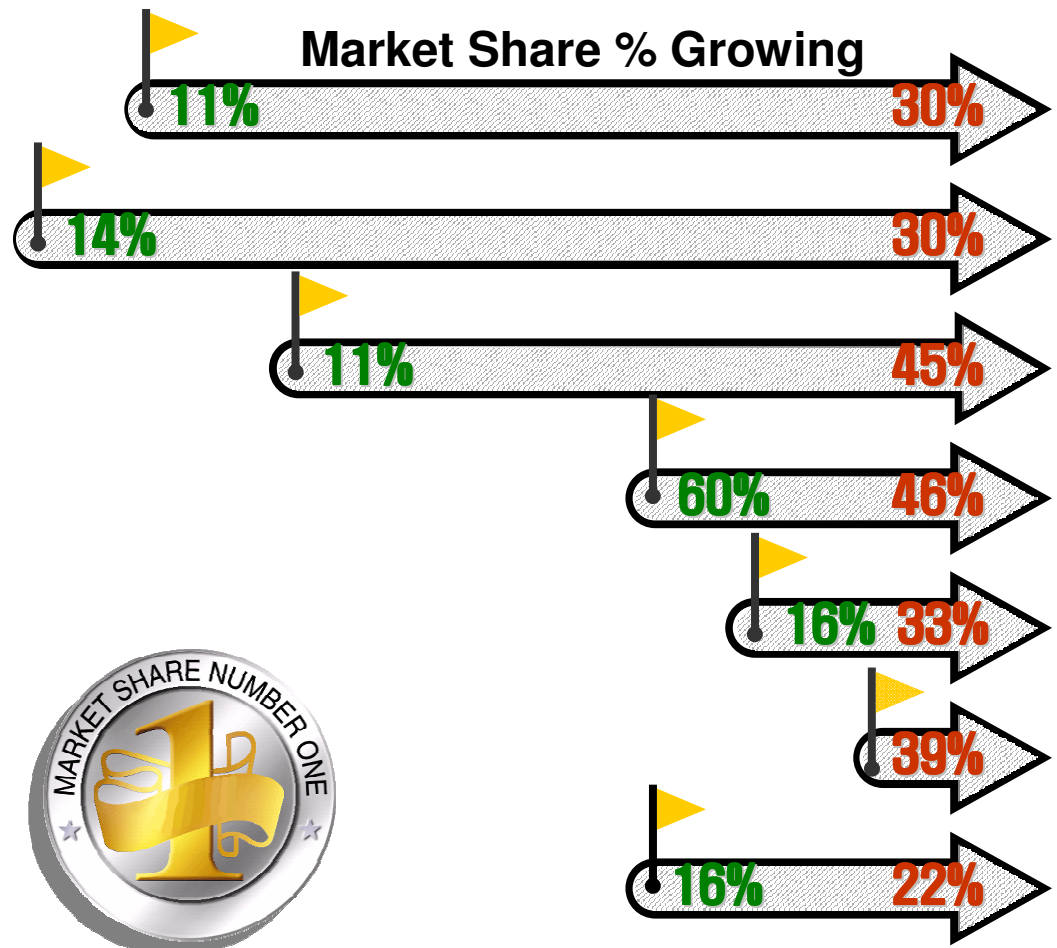### Director of Flash Marketing

August 8, 2007

Presentation Agenda

❑ Samsung Electronics Overview

❑ NAND Flash Evolution

  ❖ Flash Market Overview

  ❖ NAND Dichotomy: Disruptor + Enabler

  ❖ SSD Opportunity and Outlook

❑ Concluding Remarks

Samsung #1 Semiconductor Position(s)

'92 '93 '95 → → '03 '04 '05 '06

#1 For

Market Share % Growing

MEMORY	11% → 30%	14 years
DRAM	14% → 30%	15 years
SRAM	11% → 45%	12 years
NAND	60% 46%	4 years
FLASH	16% 33%	3 years
MCP	39%	2 years
DDI	16% 22%	4 years

MARKET SHARE NUMBER ONE

Flash Memory SUMMIT

SAMSUNG

SEC Revenue and CAPEX Overview

$B

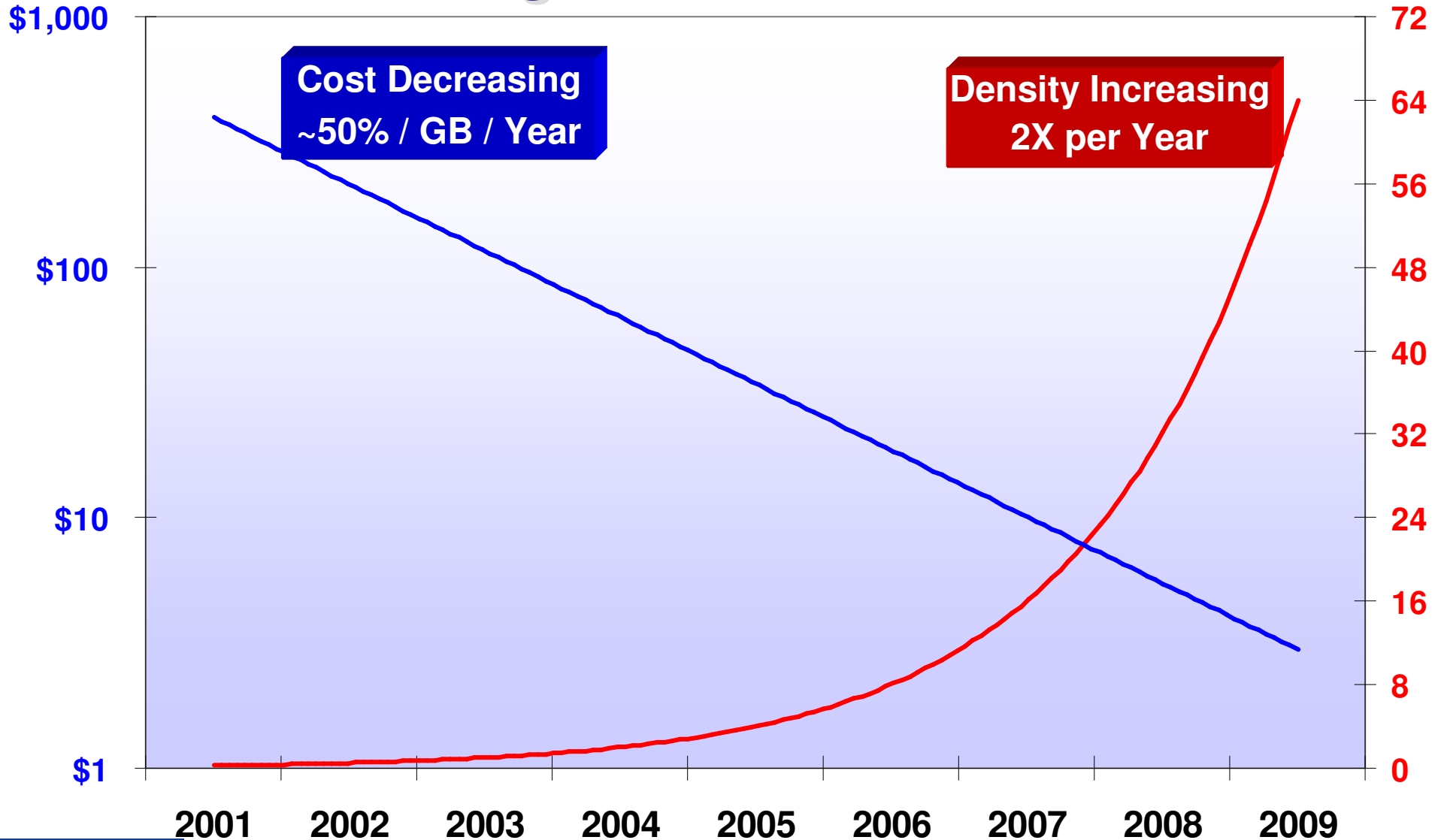| Year	Revenue	CapEx ($B)
2003	41.8	5.6
2004	55.2	7.4
2005	56.7	9.9
2006	63.2	10.7

■ Revenue ■ CapEx ($B)
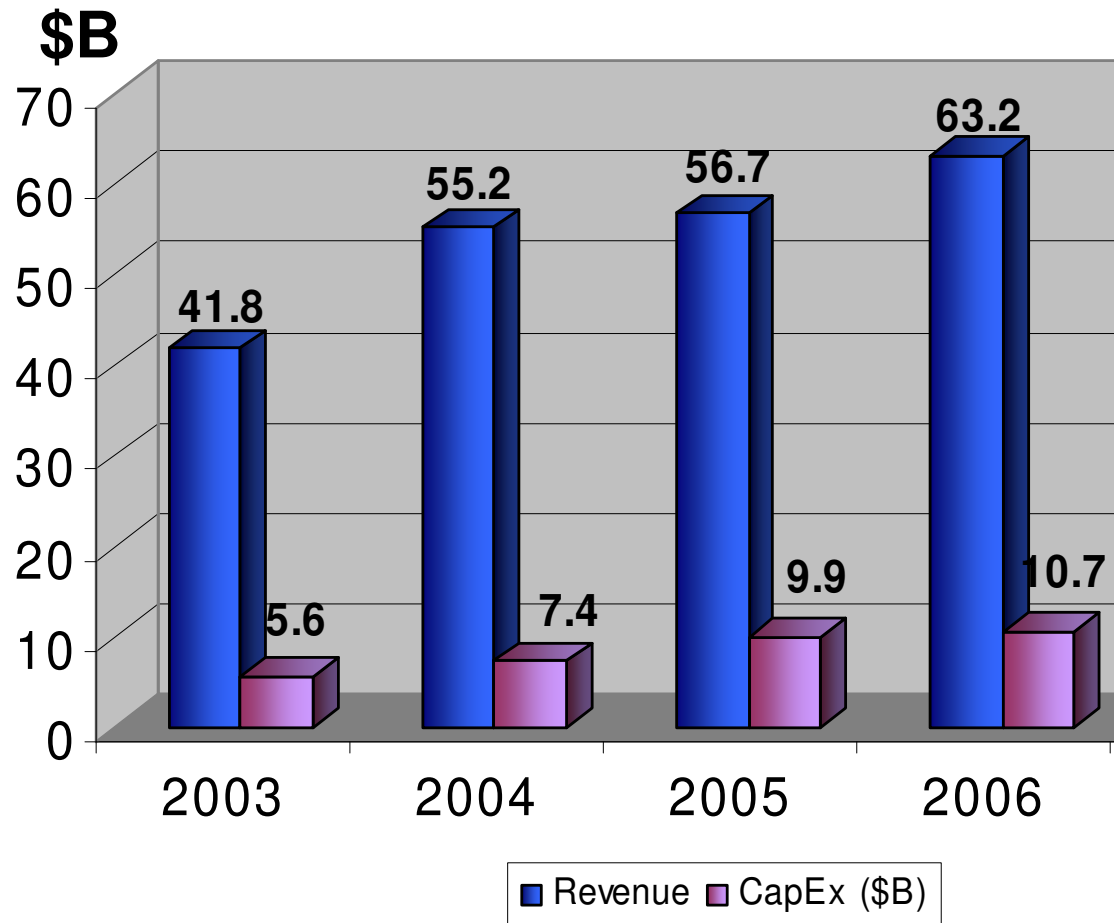
Largest CAPEX in Semiconductor Industry: >$7B in 2007
New Austin Fab is Largest US Foreign Investment Ever…

NAND Flash Evolution:
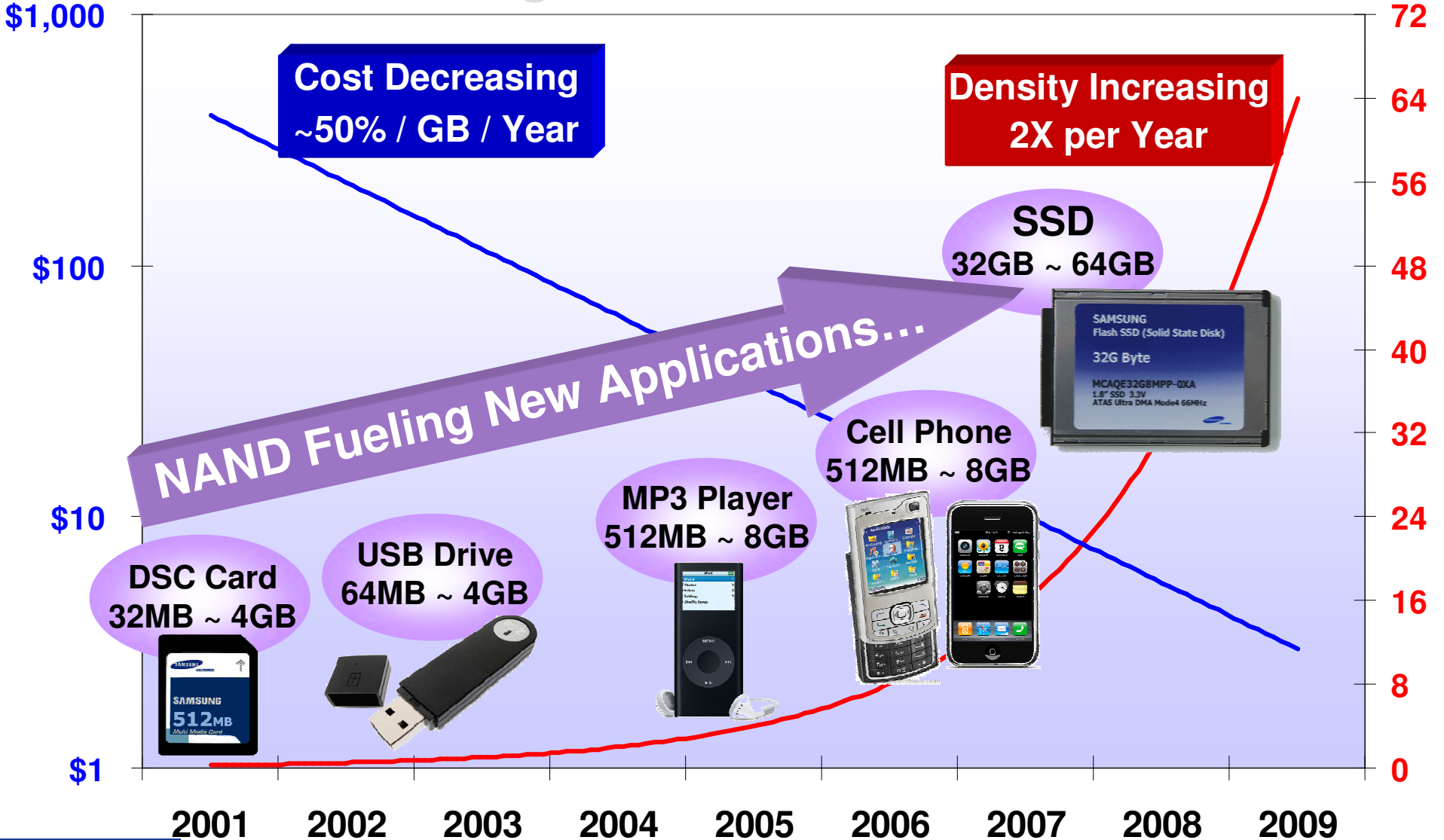## Enabling New Market Creation
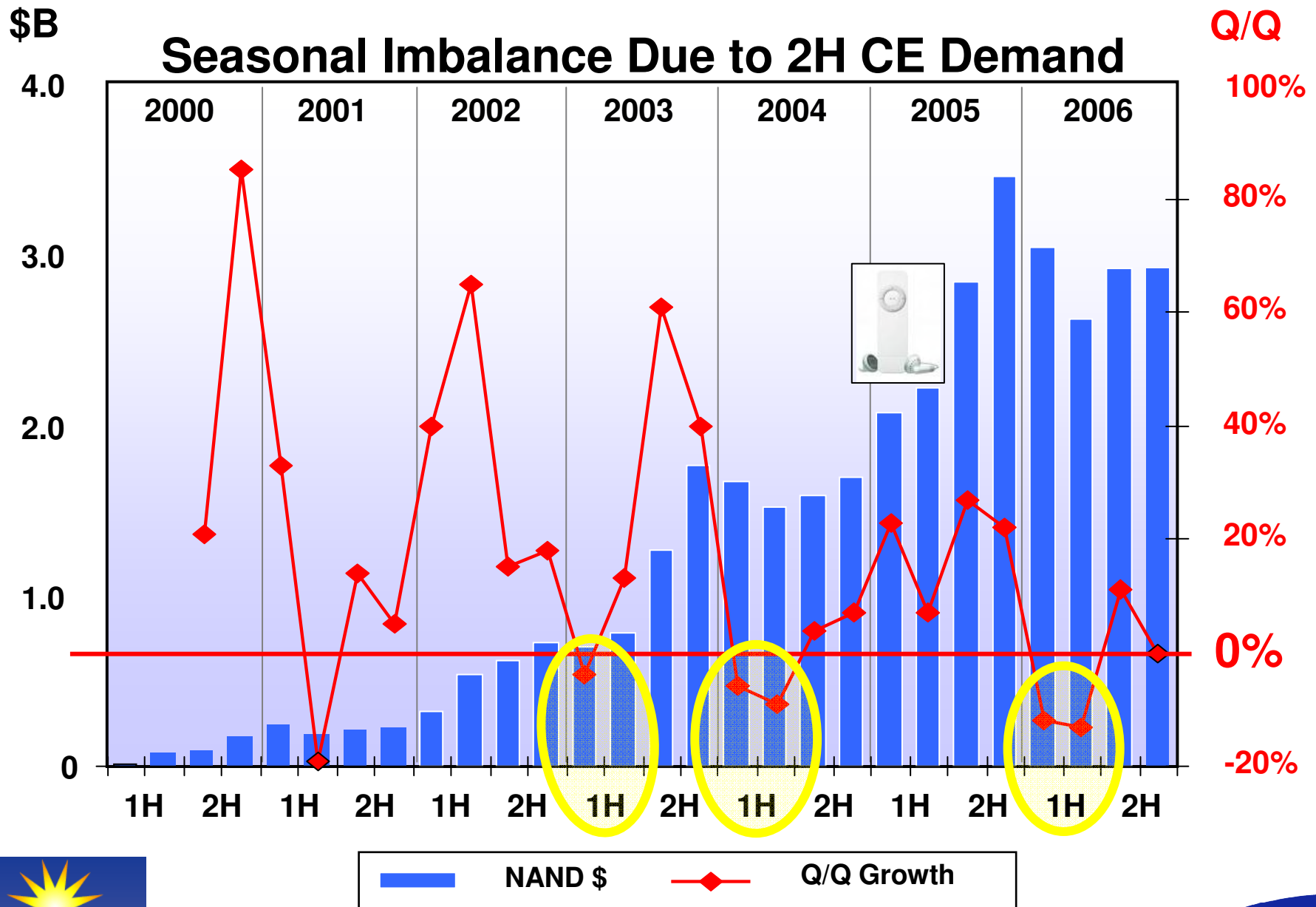
NAND Cost/GB

Component Density, Gb

Cost Decreasing ~50% / GB / Year

Density Increasing 2X per Year

SSD 32GB ~ 64GB

SAMSUNG
Flash SSD (Solid State Disk)
32G Byte
MCAQE32G8MPP-0XA
1.8" SSD 3.3V
ATAS Ultra DMA Mode4 66MHz

NAND Fueling New Applications…

Cell Phone 512MB ~ 8GB

MP3 Player 512MB ~ 8GB

USB Drive 64MB ~ 4GB

DSC Card 32MB ~ 4GB

SAMSUNG 512MB Multi Media Card

$1,000

$100

$10

$1

72
64
56
48
40
32
24
16
8
0

2001 2002 2003 2004 2005 2006 2007 2008 2009

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NAND Industry Quarterly Revenue History

Seasonal Imbalance Due to 2H CE Demand

Source: WSTS

NAND Application Trends: 2006

Pie chart (2006):
- Card — 46%
- MP3 & PMP — 23%
- USB Drive — 15%
- Phone — 8%
- Other — 8%
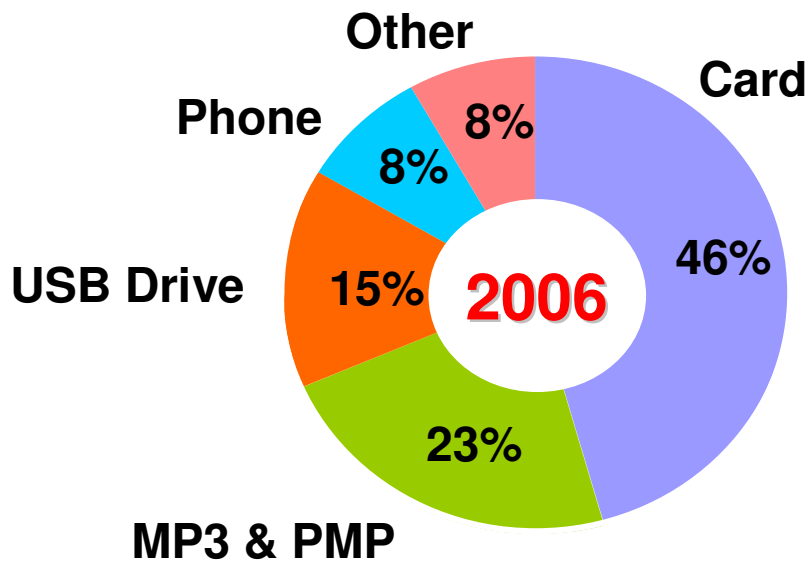
2006 NAND Market

Dominated by Card and MP3: 70%

Over-dependence on CE, Black Friday…

Source : WSTS

NAND Application Trends: 2011

Other 9% / 8%

Phone 13% / 8%

USB Drive 8% / 15%

MP3 & PMP 13% / 23%

Card 30% / 46%

2006

2011

27%

PC: SSD
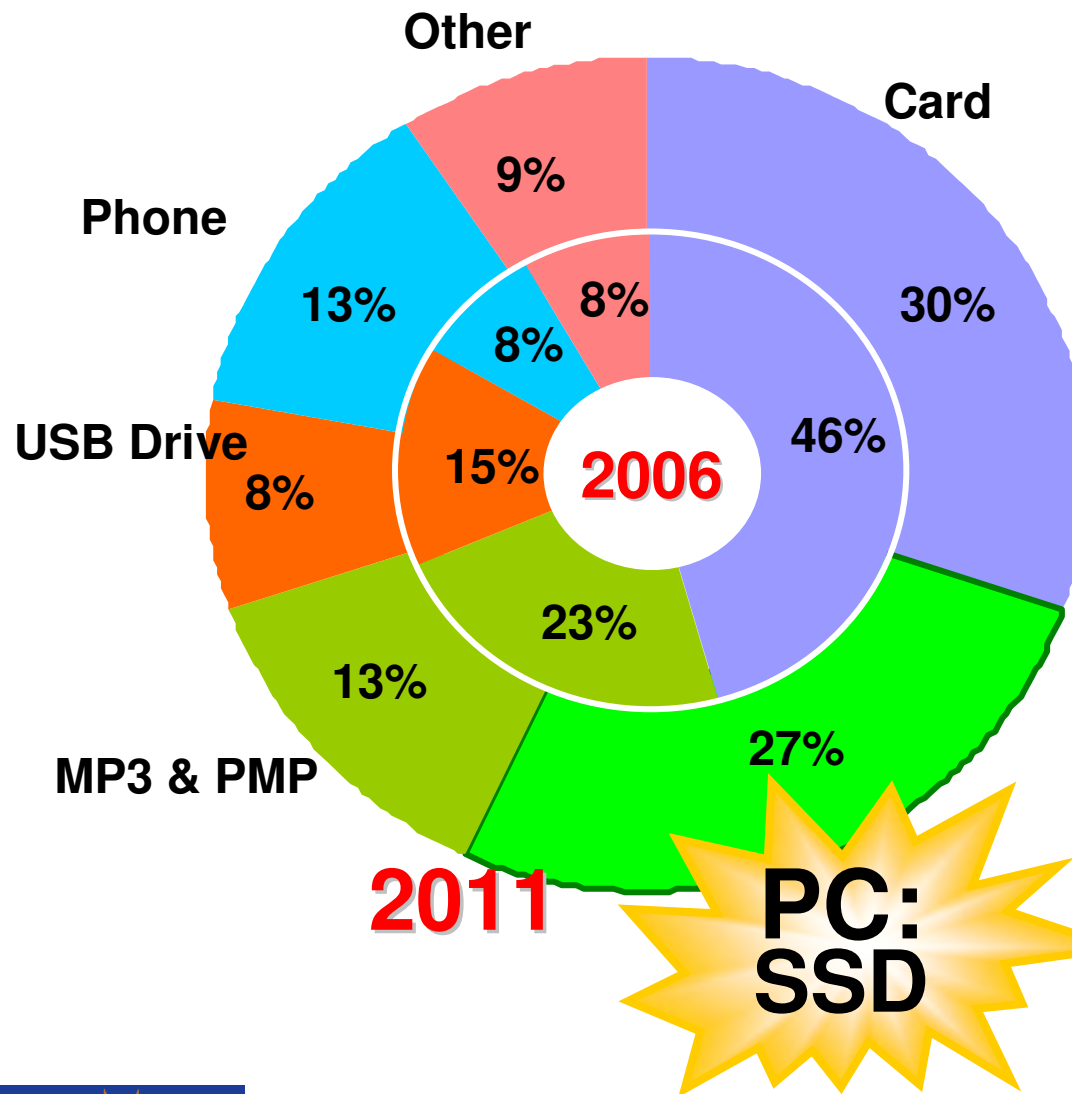
2011 NAND Market

Market is Diversifying

PC Category Emerging

Less CE-centric

Reduced Seasonality

SSD Will Dampen Seasonal Volatility...

Source : WSTS

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NAND: Enabling as it Disrupts…

Removable Storage: Floppy → USB

>10,000X Higher Capacity (1.44MB vs 16GB)

Faster Performance, Superior Industrial Design

MP3: μHDD → NAND

Superior ID → NAND Based MP3 now >85%

Phenomenal Segment Growth

Camcorder: Analog → Digital → NAND

Superior Industrial Design
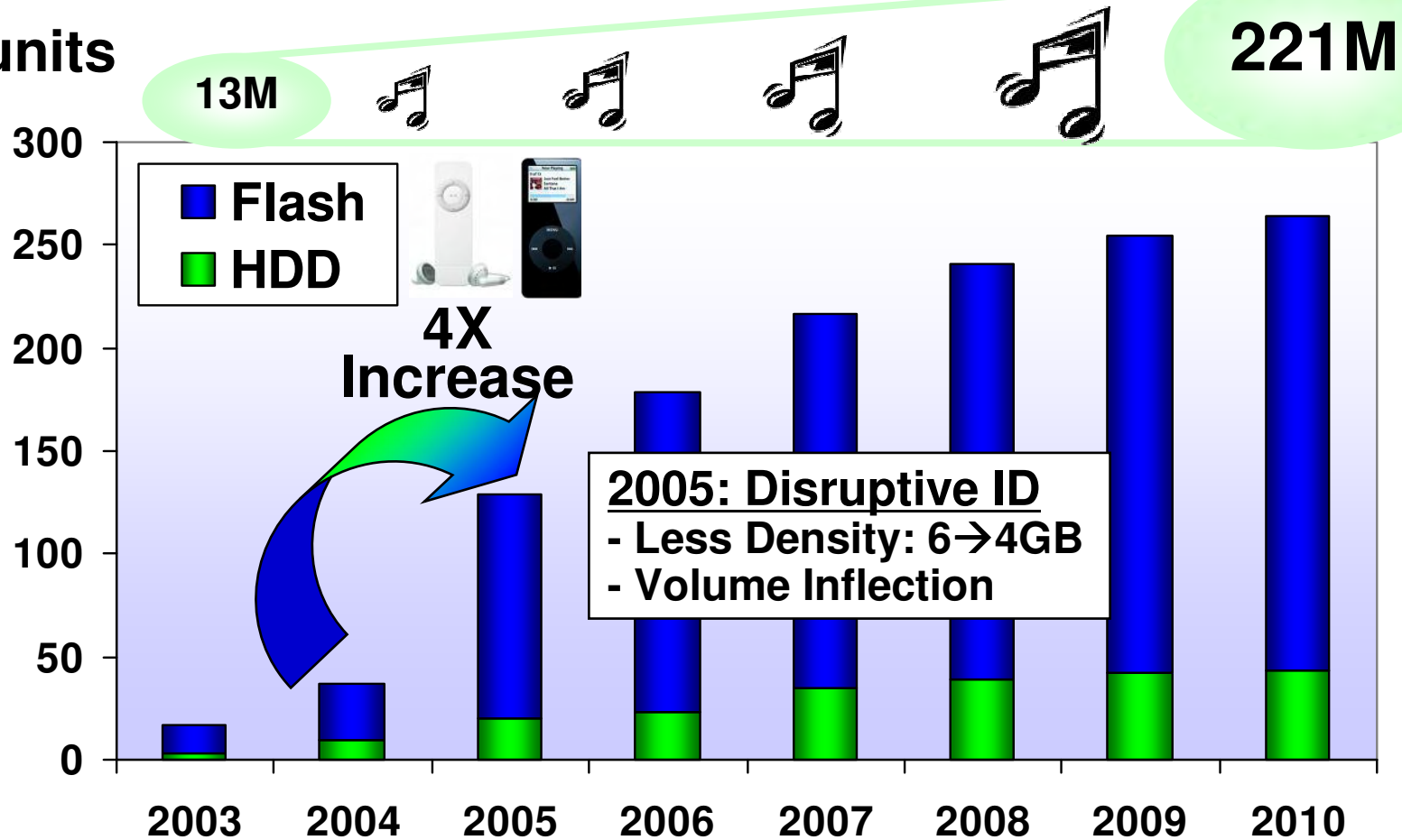
Huge Potential Segment Growth…

Primary Storage: 100% HDD → SSD

High Reliability, High Performance

Superior Industrial Design

MP3: NAND Driving Category Growth

M units

13M

221M

4X
Increase

Flash
HDD

2005: Disruptive ID
- **Less Density: 6→4GB**
- **Volume Inflection**

300
250
200
150
100
50
0

2003 2004 2005 2006 2007 2008 2009 2010

- NAND Dominating MP3 Segment with <u>Industrial Design</u>
- NAND MP3: More than 17X Growth in 7 Years

Source: SEC

Camcorder: Inflection Point with ID

Analog Era

Beta

VHS → VHS-C

Total US
Annual Sales:
3~5M / Yr

Digital Era

DVD

HDD

Total US
Annual Sales:
3~5M / Yr

Solid State Era

NAND

NAND

NAND Catalyst:

Form Factor / ID,
Mobility, Cost

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Video Market Rapidly Emerging

❖ Camcorder is an Under-Capitalized Market

    ❖ Annual US Sales: 5M (vs 27M for DSC)

    ❖ US HH Penetration: 25% (vs 75% for DSC)

    ❖ Flat Sales Despite 25% Price Decline Since '01

❖ Online Video Capturing / Sharing Growth

    ❖ 122M Unique US Users Viewed Video Online in Jan '07

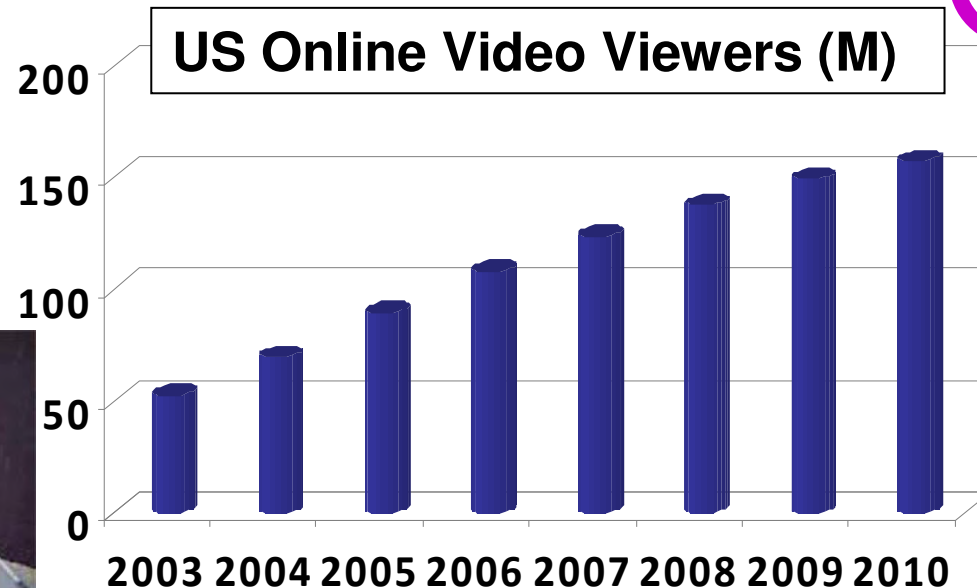   ❖ Social Networking: >150M People by 2010…

Social Networking

"Jedi Knight" Video

US Online Video Viewers (M)

2003	2004	2005	2006	2007	2008	2009	2010

Source: ComScore, eMarketer

NAND + Video = Symbiosis

Still Camera: US Sales, ASP

- 24M — $179 (Point & Shoot)
- 3M — $437 (SLR)

Extrapolate
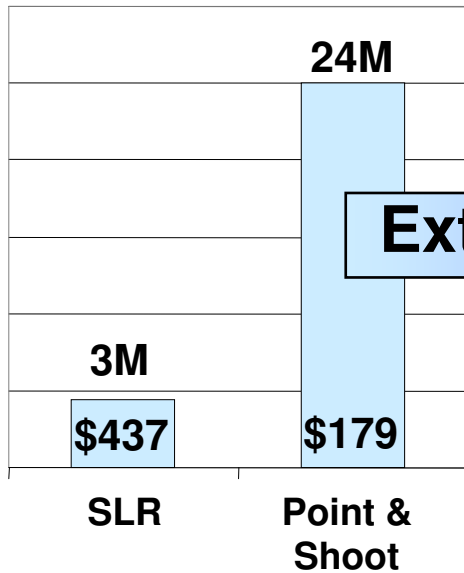
Camcorder Projections: US Sales, ASP

- 24M — $129 (Point & Shoot Potential)
- 5M — $450 (Traditional DVC)
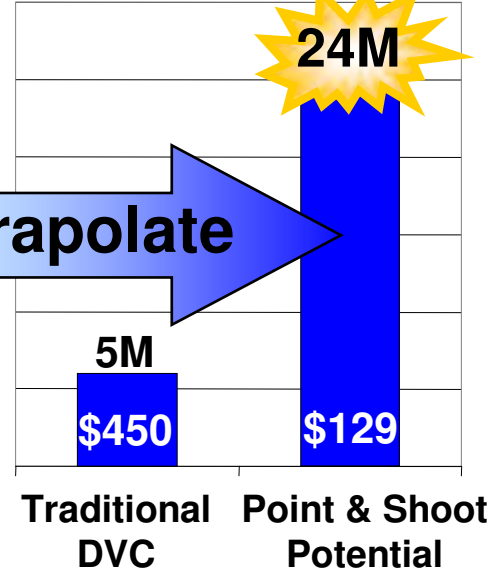
Camcorder Storage Trends

- Tape
- DVD
- HDD
- NAND

(Chart axis: 0.0% to 60.0%, years 2005–2010)
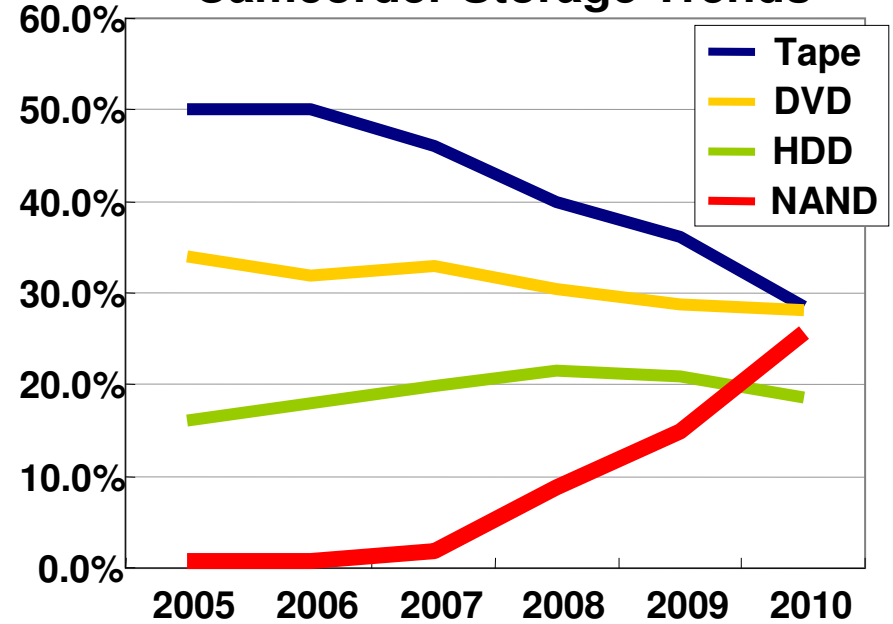
Pure Digital- Flip Video Camcorder

#1 Best-Selling Camcorder at amazon.com

30/60 Minutes of VGA Video: $129/$149

512MB, 1GB Embedded NAND

purepress
Check out the latest press coverage about us

"... stunningly simple to use."

THE WALL STREET JOURNAL

Flash Memory SUMMIT

Source: ComScore; eMarketer

The Next Killer App: SSD.
Product Definition

Solid **S**tate **D**rive uses NAND Flash
Memory to Store Digital Data

Consists Entirely of NAND FLASH Memory.

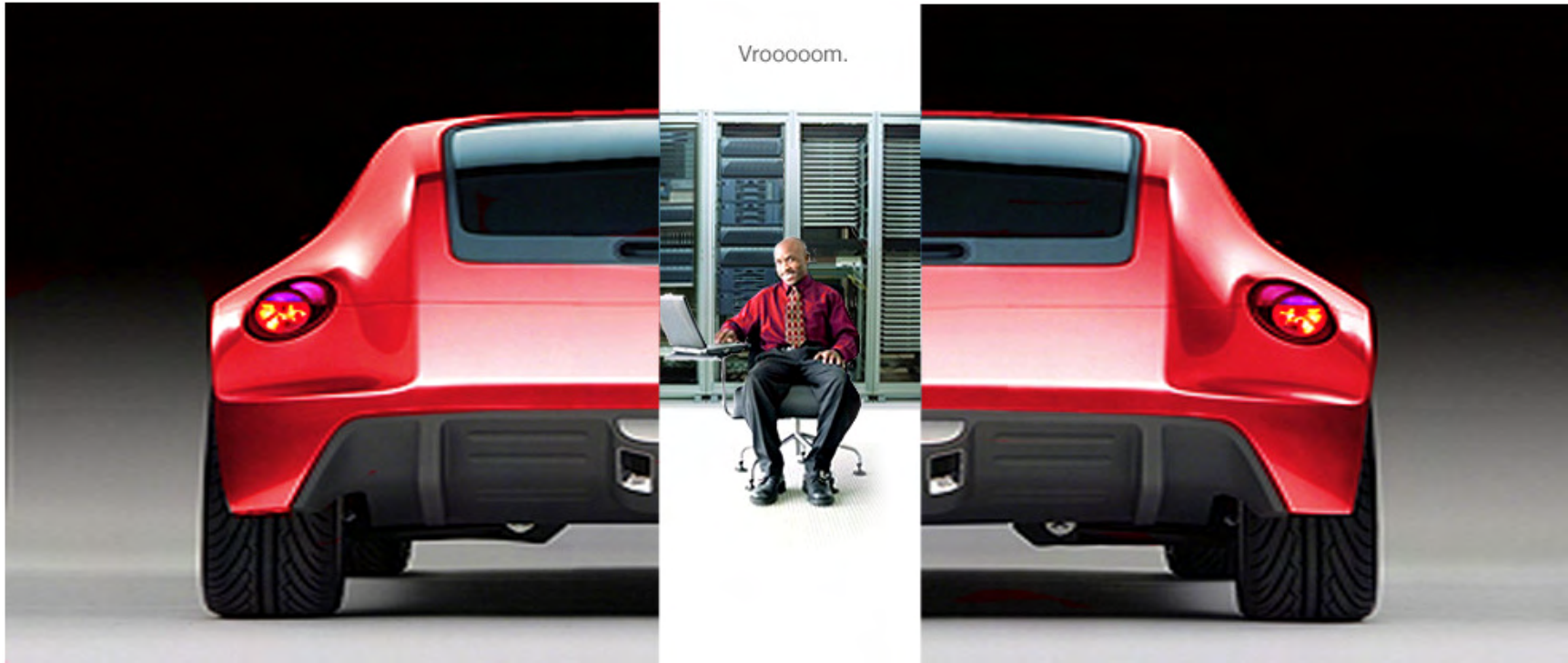**Can Functionally and Physically Replace HDD.**

SSD Benefits (1/2)

Protection
On All Sides.

High Reliability

- **Resistance Against Extreme Impact:** **1,500G ↑**
- **MTBF: 2M Hours**
- **No Mechanical parts**
- **No Noise, Virtually No Heat**
- **Light Weight**

SSD Benefits (2/2)

Vrooooom.

Excellent Performance

- **Sequential Read Speeds:**
  57MB/s (PATA)→ 100MB/s (SATA-2)
- **Sequential Write Speeds:**
  34MB/s (PATA)→ 80MB/s (SATA-2)
- **Low Power Consumption:**
  Operation: 0.5W,   Sleep: 0.06W

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Look, Ma – No Hard Drive!

Larry Magid Tries Out PCs With Solid State Flash Drives

CBS NEWS

SciTech Main Page >
Eye On Technology >
Blog: Tech Talk >
GameCore >
Larry Magid: PC Answer >
Bill Harwood's Space Place >
Eye On The Storm >
CNET Product Reviews >
High Tech News >
SciTech Video >

> WIRELESS NEWS & ALERTS
> E-MAIL ALERTS
> PODCASTS
RSS - ALL FEEDS

July 17, 2007

Solid state flash drives (above: Samsung's 64 gigabyte model) can be faster than hard drives, as well as lighter, more rugged, and more energy-efficient, which is good news for the life of PC batteries. **(Samsung)**

(CBS) I'm writing this column on a computer that looks and acts pretty much like most other notebook PCs running Microsoft Windows. It has a typical screen and keyboard, it's running Microsoft Office and other standard Windows applications and it's equipped with an Intel processor.

But there is one thing missing. The machine I'm using doesn't have a hard drive. Where the drive would normally be located, there is a 32 gigabyte solid state flash drive. The machine, from a non-disclosed PC vendor, is a prototype that isn't yet on the market.

Samsung, which makes the memory but not the PC, says it will soon offer 64 gigabyte drives. Dell already offers a 32 gigabyte solid state drive as an option, albeit an expensive one, on some of its Latitude notebook PCs.

While even 64 GB is far below the capacity of the hard drives used in many of today's notebook PCs, it's an adequate amount of storage for Windows XP or Vista, numerous applications and typical storage requirements for many business users.

The 32 gigabyte PC I tested had enough room for Windows XP, Microsoft Office and several applications with 12 gigabytes left over for data storage. I wouldn't

"MySpace Unraveled" by Larry Magid and Anne Collier
> BUY NOW

IN THE SPOTLIGHT

The iWait
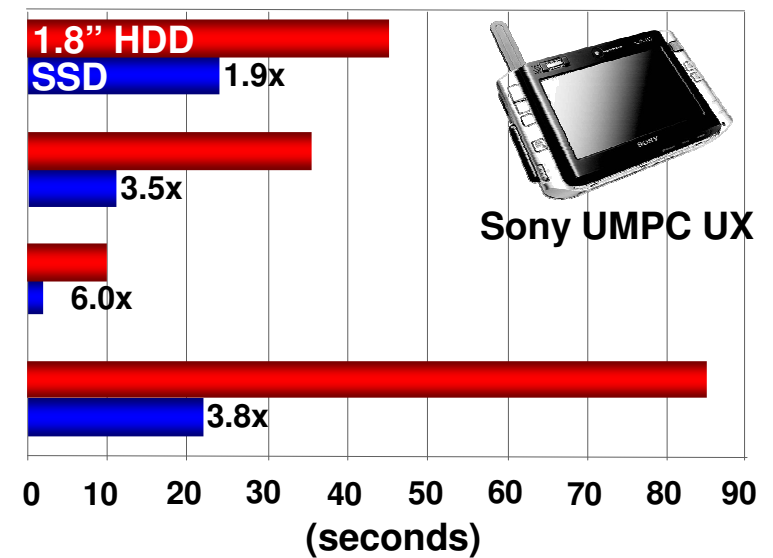People are camping out and lining up to be among the first to get Apple's new iPhone

"The advantages of solid state storage became evident as soon as I turned on the machine…"

Flash Memory SUMMIT

SSD User Benefits Comparison
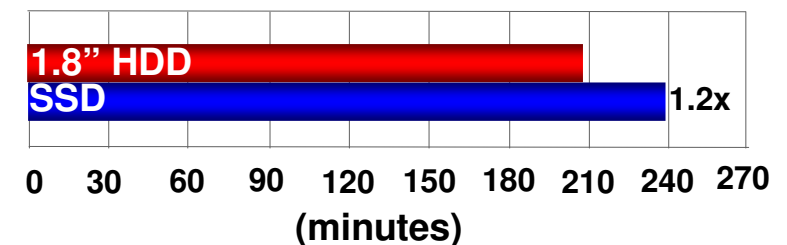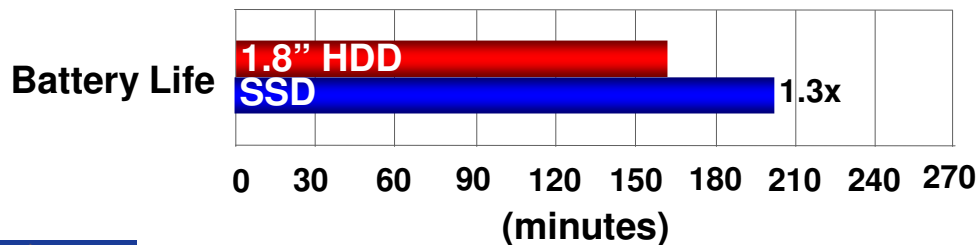
❑ **SSD Optimizes Mobile User Experience**

- **Fast Booting / Resume / Application launching**

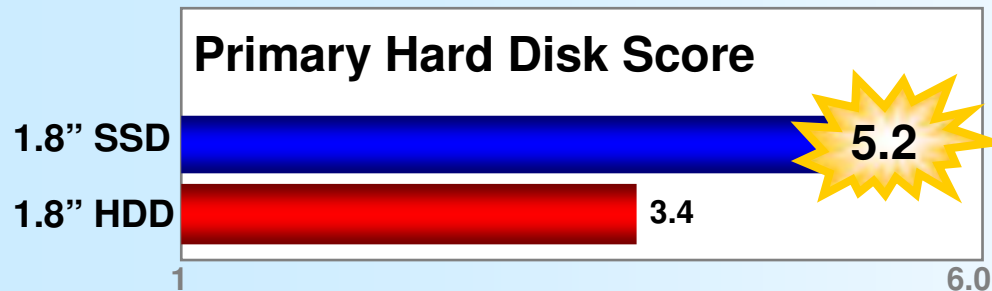- **Longer battery life with SSD**
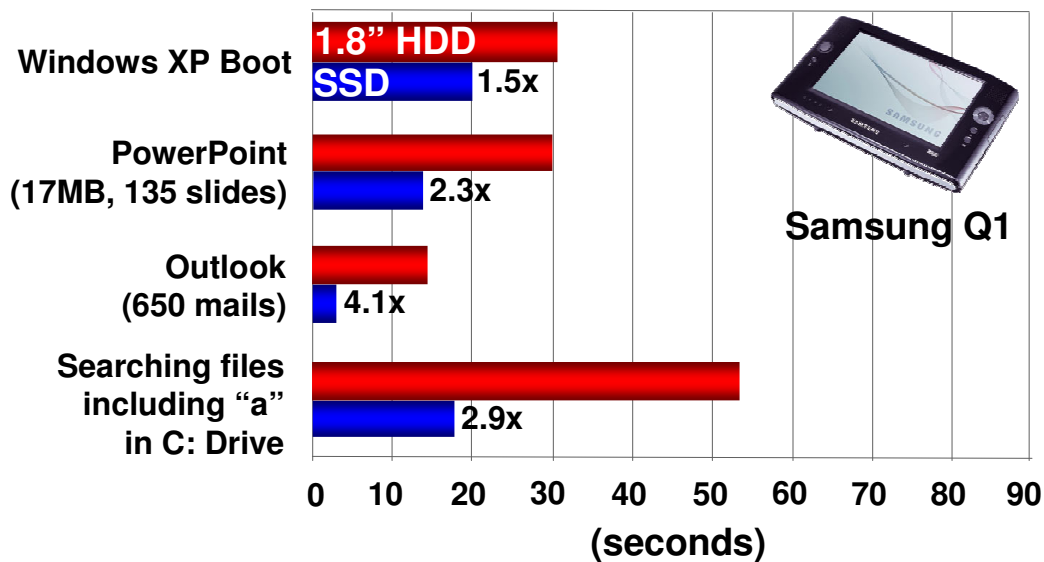
Samsung Q1

Sony UMPC UX

Source: Nikkei Electronics

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SSD is Ready for Vista

❑ Window Express Index*

Standard Performance Diagnostic for Vista OS

Primary Hard Disk Score

1.8" SSD	**5.2**
1.8" HDD	3.4

1 — 6.0

Test Environment
System: Sony VAIO type G
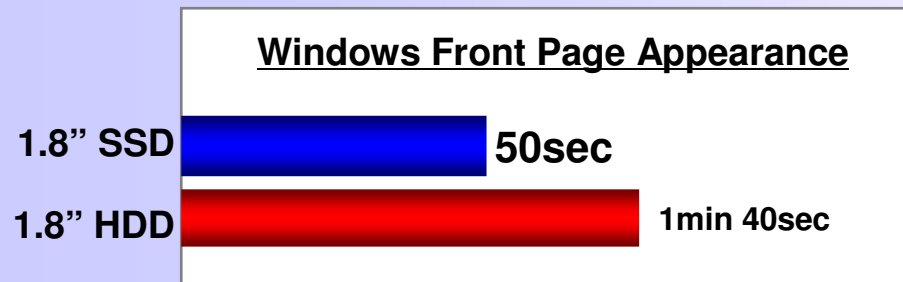CPU: Core Solo U1400(1.2 GHz),
OS: Windows Vista Business
SSD: 32GB, HDD: 1.8" 60GB

❑ Boot Time Comparison

(Source : Itmedia.co.jp)

➢ **50% Improvement on Windows Front Page Appearance**
➢ **50% Improvement on All Task Ready Tray**

Windows Front Page Appearance

1.8" SSD	**50sec**
1.8" HDD	1min 40sec

All Task Tray Ready

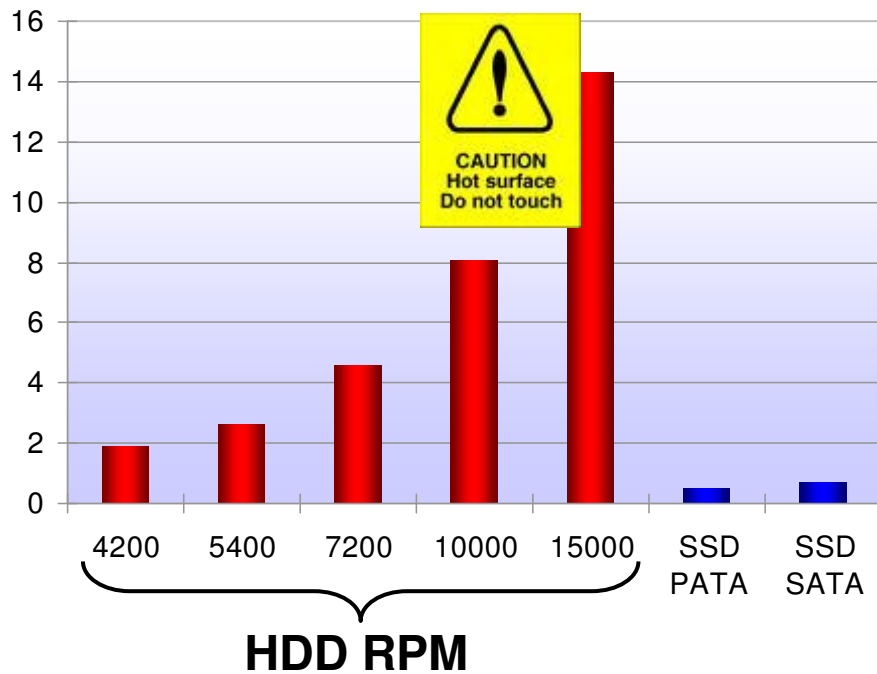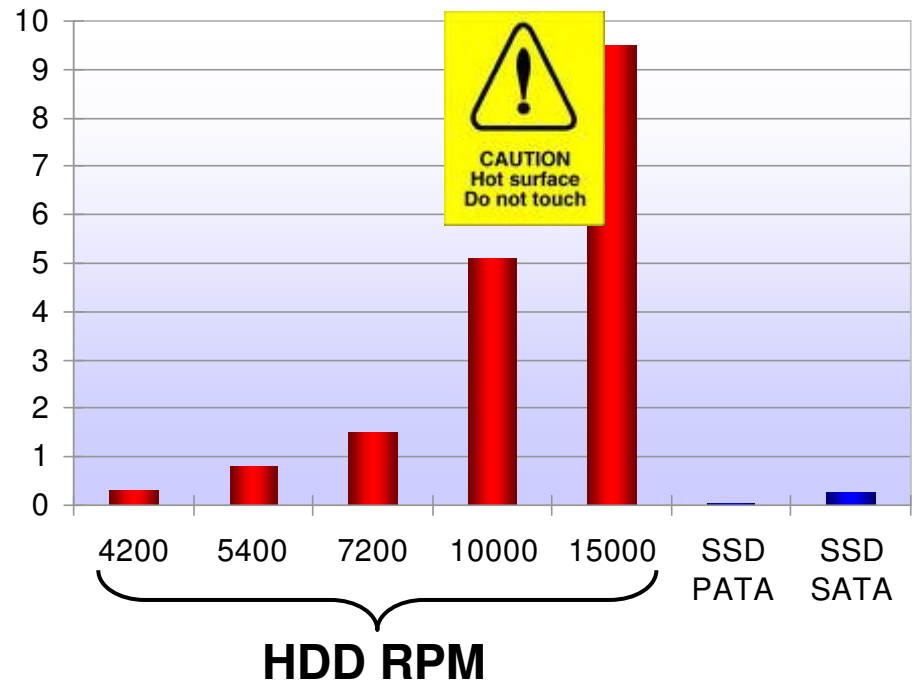|	
1.8" SSD	**1min 30sec**
1.8" HDD	3 min

SSD Power Savings Comparison

❑ HDD: Higher RPM = Higher Performance

    ❖ Downside: Higher Power, More Heat

❑ SSD: Less Power, Cooler = Lifetime Energy Cost Savings
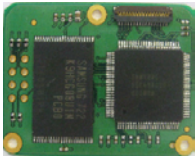
Watts - Operation Mode

HDD RPM

Watts - Idle Mode

HDD RPM
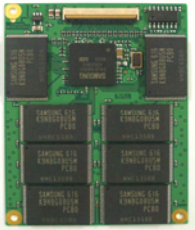
RPM	Drive
4200	Hitachi GST Travelstar 4k120
5400	Toshiba MK1032GSX
7200	Hitachi GST Travelstar 7k100
10000	Seagate Savvio 10K.1
15000	Seagate Cheetah 15K.4

* HDD DATA

Samsung SSD Form Factors

	Standard FF			Special FF	
	1.8''	**2.5''**	**1.0''**	**SLIM**	**So DIMM**
Density	4~64GB	4~64GB	4~16GB	4~64GB	8~16GB
Dimension (H x W x T)	78.5x54x8.0	100.2x70x9.5	30x40x4.0	70.6x53.6x: 3.0: 16/32GB 2.5: 4~8GB	53.6x70.6x3.0
Connector	ZIF/IDE 50pin	IDE 44pin	ZIF 35pin	ZIF 40pin	200pin
Weight	44g	46g	TBD	20g	TBD
Market	Notebook	Sub-Note / Tablet	DVC/GPS/ UMPC	UMPC	Custom

SSD is Form-factor Agnostic...
Long-Term: New ID to Redefine Aesthetics
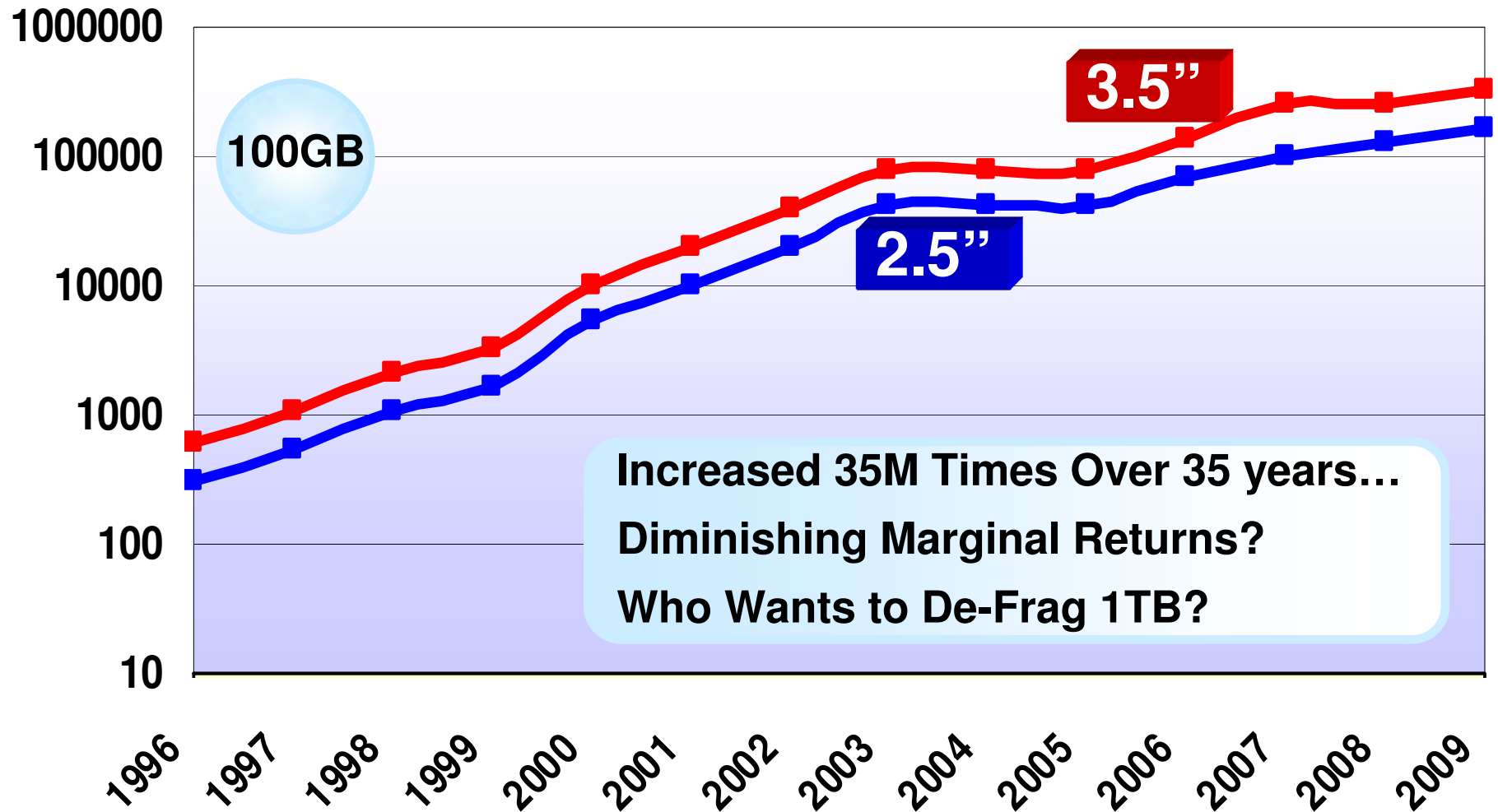
Addressing SSD F.U.D. Factors

❑ **Barrier #1:**

"SSD Density Points are too Low"

❑ **Barrier #2:**

"SSD Costs too Much"

HDD Capacity Growth

HDD MB per Platter

100GB

3.5"

2.5"

Increased 35M Times Over 35 years…

Diminishing Marginal Returns?

Who Wants to De-Frag 1TB?

1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009

Source: IBM, Intel, Samsung

Flash Memory SUMMIT
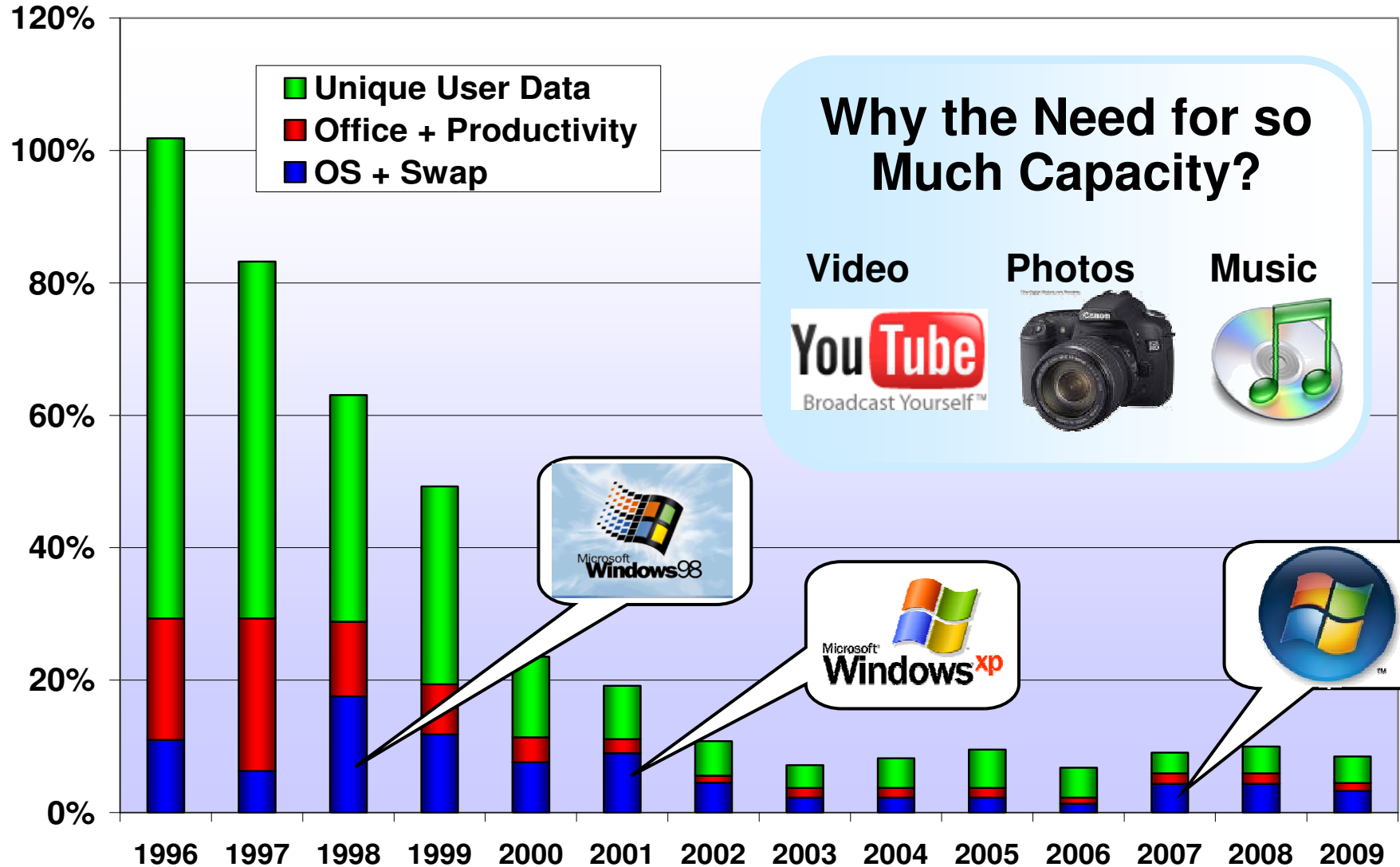
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Business Notebook Challenge...

Local Disk (C:) Properties
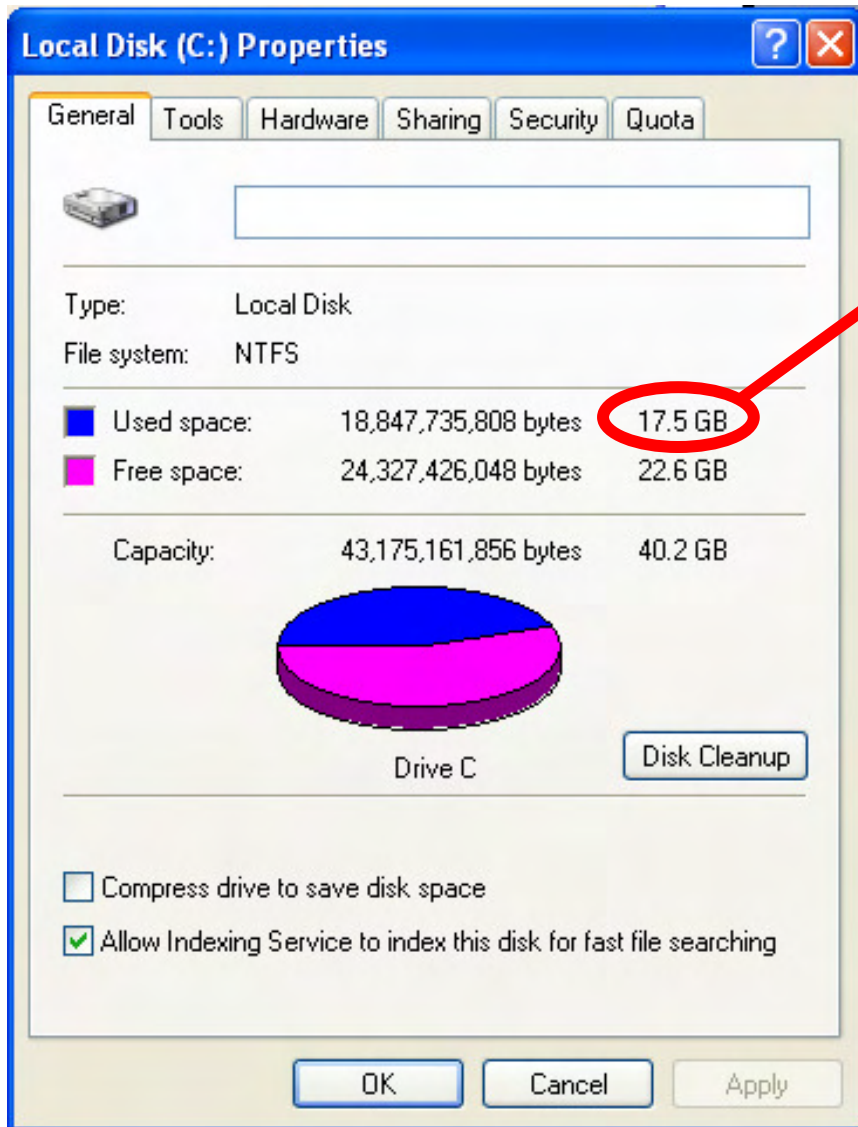
| General | Tools | Hardware | Sharing | Security | Quota |

Type: Local Disk
File system: NTFS

Used space: 18,847,735,808 bytes — 17.5 GB
Free space: 24,327,426,048 bytes — 22.6 GB

Capacity: 43,175,161,856 bytes — 40.2 GB

Drive C

Disk Cleanup

☐ Compress drive to save disk space
☑ Allow Indexing Service to index this disk for fast file searching

OK | Cancel | Apply

Jim Elliott's Work Notebook

- ❖ **17.5GB Used Total**
- ❖ Windows XP + Office
- ❖ 6+ Years at Samsung
- ❖ Extensive Presentations

MIS Prefers:

- ❖ Centralized Data Storage

HR Prefers:

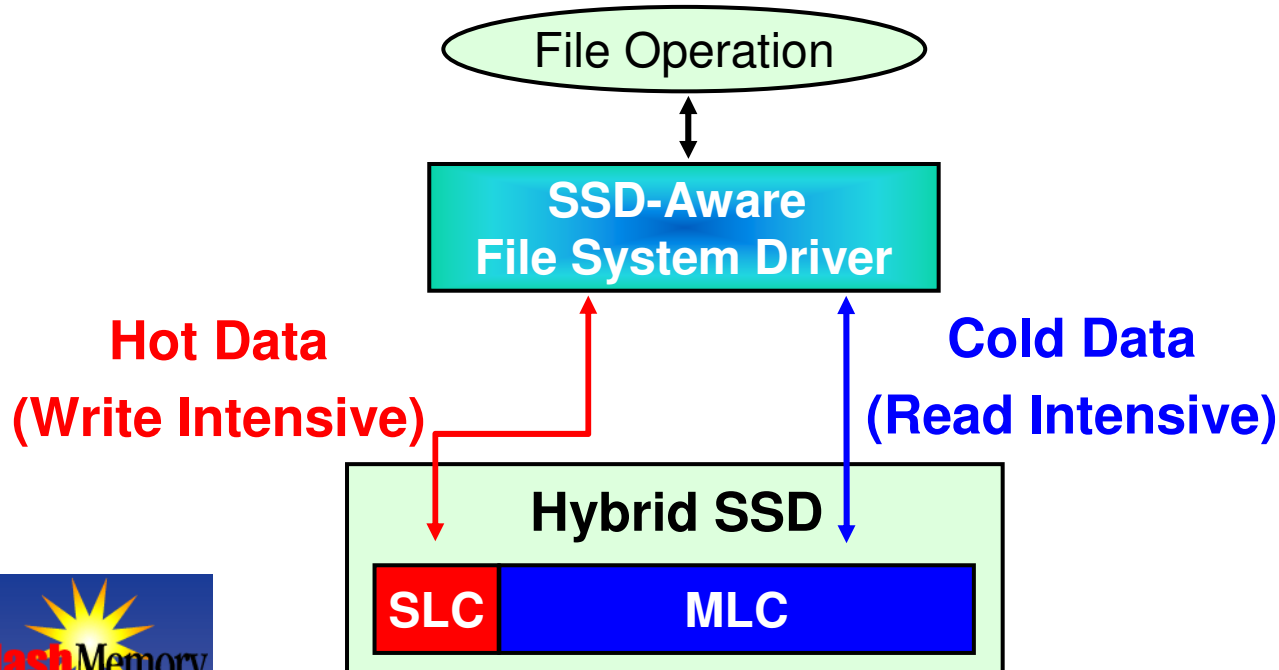- ❖ No Personal Files: Video, Music, Photos, etc.

64GB is Sufficient for Most Business Notebooks

Source: Jim Elliott - June '07

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"Hybrid" SSD Concept

❑ Concept: Mixed Composition of SLC + MLC NAND

❑ Meet High Endurance Requirements for PC Storage

- ❖ SLC → Write-intensive data, High Performance
- ❖ MLC → Read-intensive data, Cost Reduction

Combo SSD System Architecture

File Operation

**SSD-Aware
File System Driver**

**Hot Data
(Write Intensive)**

**Cold Data
(Read Intensive)**

Hybrid SSD

| SLC | MLC |

Price Impact:
Up to 50% Reduction
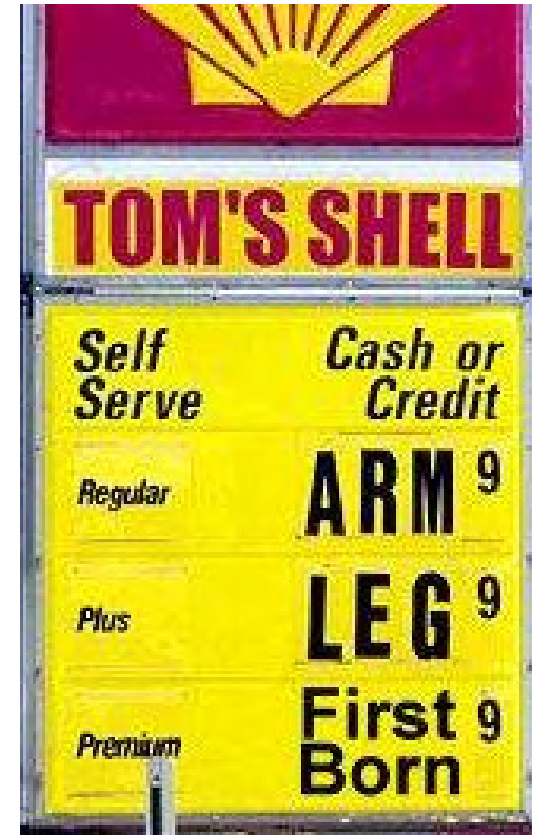
Introducing "TCO" Concept

Hybrid Automobiles

❖ Acquisition Cost is Higher, but…

Total **C**ost of **O**wnership Benefits:

❖ Less Gas at ~$3.50 per Gallon

❖ "Solo" Carpool Lane → Time = $Money

❖ Prius is #1 in Santa Clara County

TOM'S SHELL

Self Serve — Cash or Credit

Regular — ARM 9

Plus — LEG 9

Premium — First Born 9

NYC Hybrid Cabs

SSD Business Notebook TCO

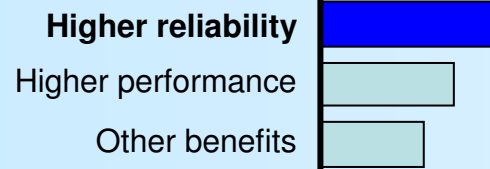## Business Notebook: IT Survey Results

Pain Points:
HDD Field Failure Rates
Associated Downtime Costs

SSD Value Proposition:
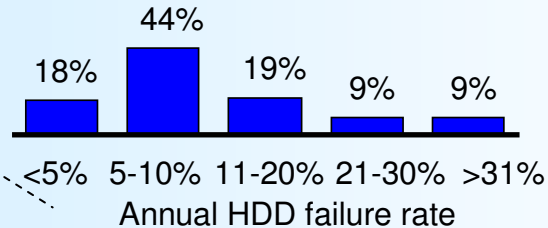Reduce TCO of Laptop Fleet
Improve Productivity

Benefits of SSD Laptops

Higher reliability
Higher performance
Other benefits

Laptop Annual HDD Failures

18% 44% 19% 9% 9%

<5% 5-10% 11-20% 21-30% >31%
Annual HDD failure rate

Actual NB Capacity Requirements

39% <20GB
18% 20-40GB
13% 40-60GB
29% >60GB

Source: McKinsey Study

SSD Business Notebook TCO

Business Notebook: IT Survey Results

Pain Points:

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SSD Value Proposition:

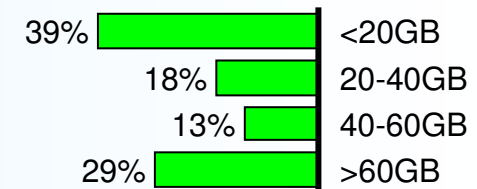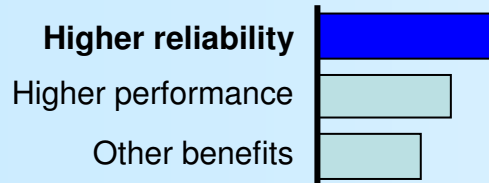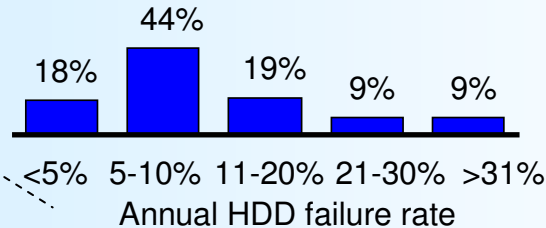Reduce TCO of Laptop Fleet

Improve Productivity

Benefits of SSD Laptops

Higher reliability

Higher performance

Other benefits

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39%   <20GB

18%   20-40GB

13%   40-60GB

29%   >60GB

Typical Corporate Notebook Scenario:

1000's of NB's Deployed for Mobile Workforce

50X Failure rate reduction over 3 years w/SSD

Efficiency / Productivity Gains

TCO Savings: Downtime, MIS, Data Recovery, etc…

Source: McKinsey Study

Flash Memory SUMMIT

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SSD Business Notebook TCO

Business Notebook: IT Survey Results

Pain Points:

HDD Field Failure Rates

Associated Downtime Costs

SSD Value Proposition:

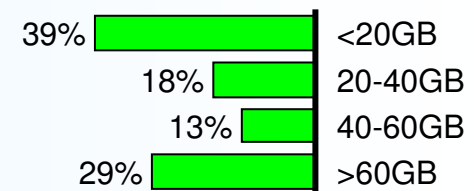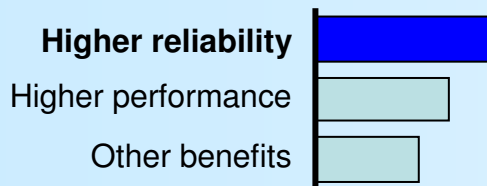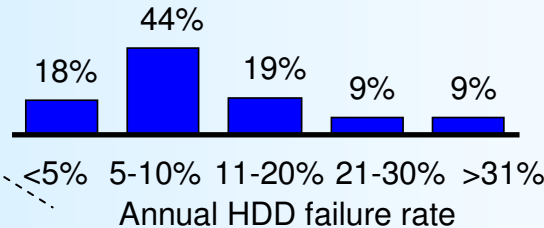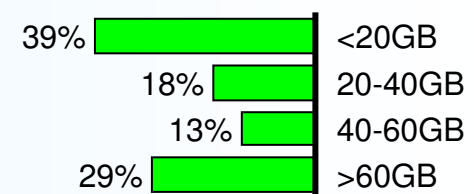Reduce TCO of Laptop Fleet

Improve Productivity
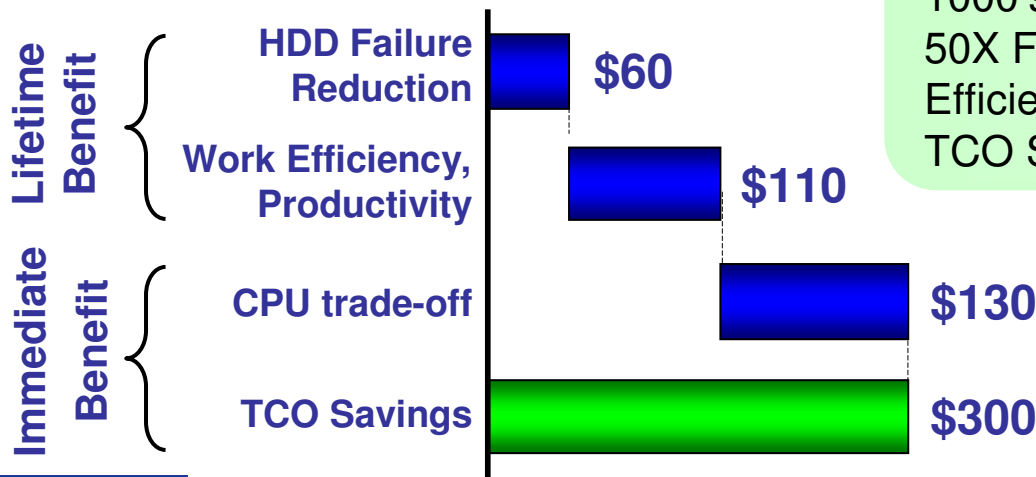
Benefits of SSD Laptops

- **Higher reliability**
- Higher performance
- Other benefits

Laptop Annual HDD Failures

44%

18%   19%

9%   9%

<5%   5-10%   11-20%   21-30%   >31%

Annual HDD failure rate

Actual NB Capacity Requirements

39%	<20GB
18%	20-40GB
13%	40-60GB
29%	>60GB

SSD TCO for NB, $

Lifetime Benefit

HDD Failure Reduction — $60

Work Efficiency, Productivity — $110

Immediate Benefit

CPU trade-off — $130

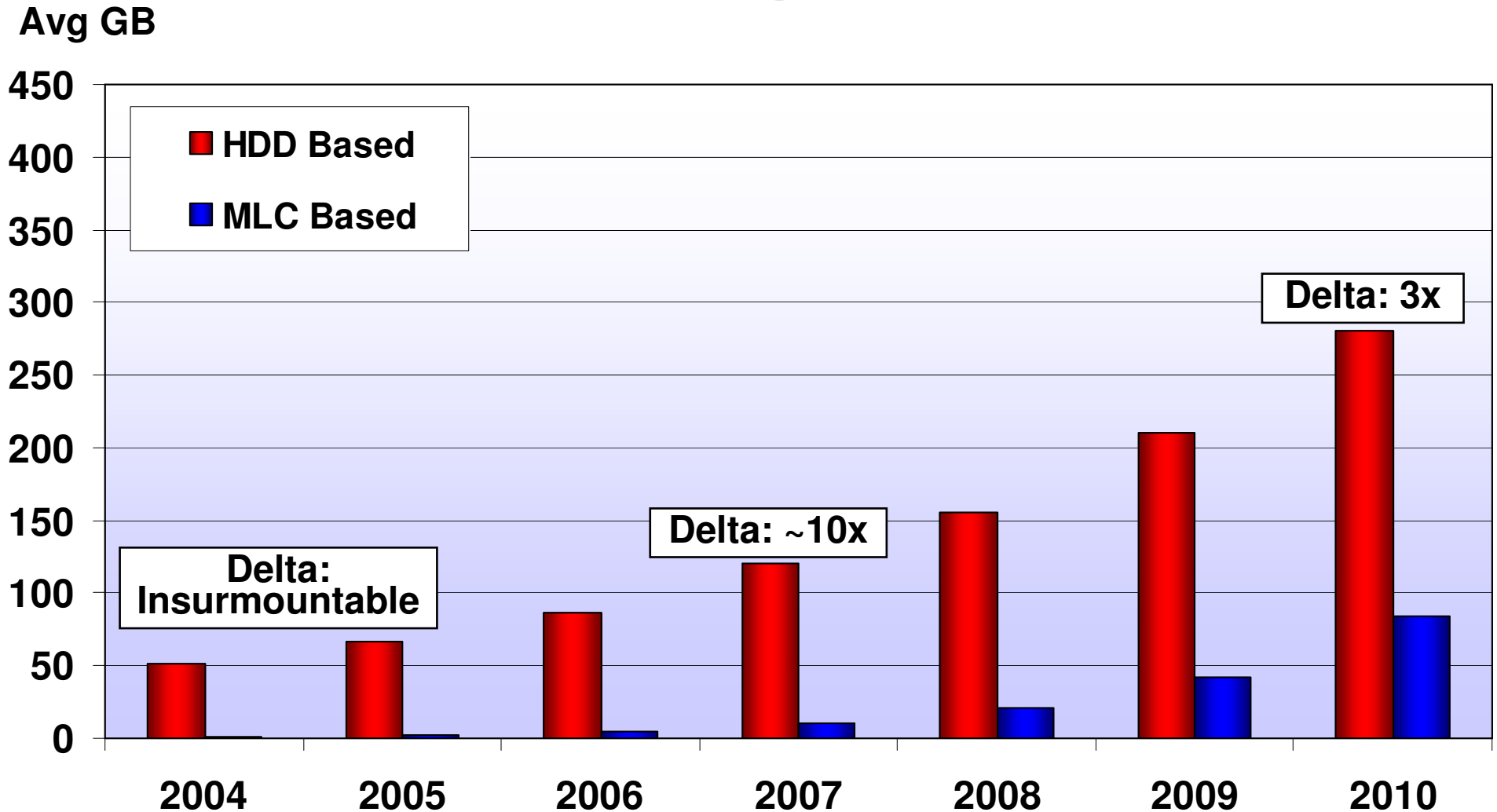TCO Savings — $300

Typical Corporate Notebook Scenario:

1000's of NB's Deployed for Mobile Workforce

50X Failure rate reduction over 3 years w/SSD

Efficiency / Productivity Gains

TCO Savings: Downtime, MIS, Data Recovery
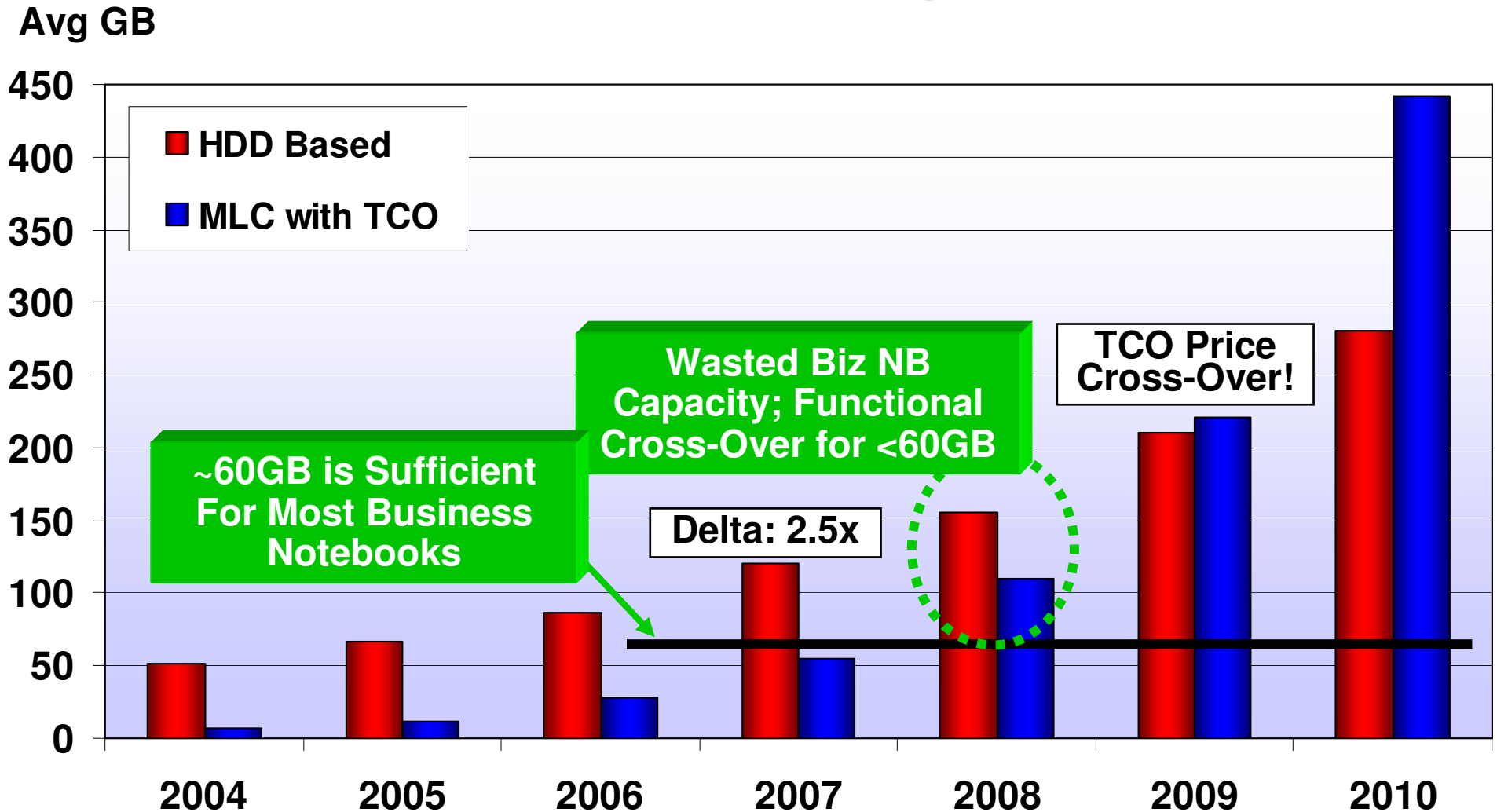
Source: McKinsey Study

Comparing $70 NB Storage Budget:
SSD Closing the GAP

Avg GB

- HDD Based
- MLC Based

Delta: 3x

Delta: ~10x

Delta: Insurmountable

2004 2005 2006 2007 2008 2009 2010

Source: Citigroup, McKinsey

Comparing $70 NB Storage Budget:
SSD Cross-Over Factoring $300 TCO

Avg GB

- HDD Based
- MLC with TCO

~60GB is Sufficient For Most Business Notebooks

Wasted Biz NB Capacity; Functional Cross-Over for <60GB

TCO Price Cross-Over!

Delta: 2.5x

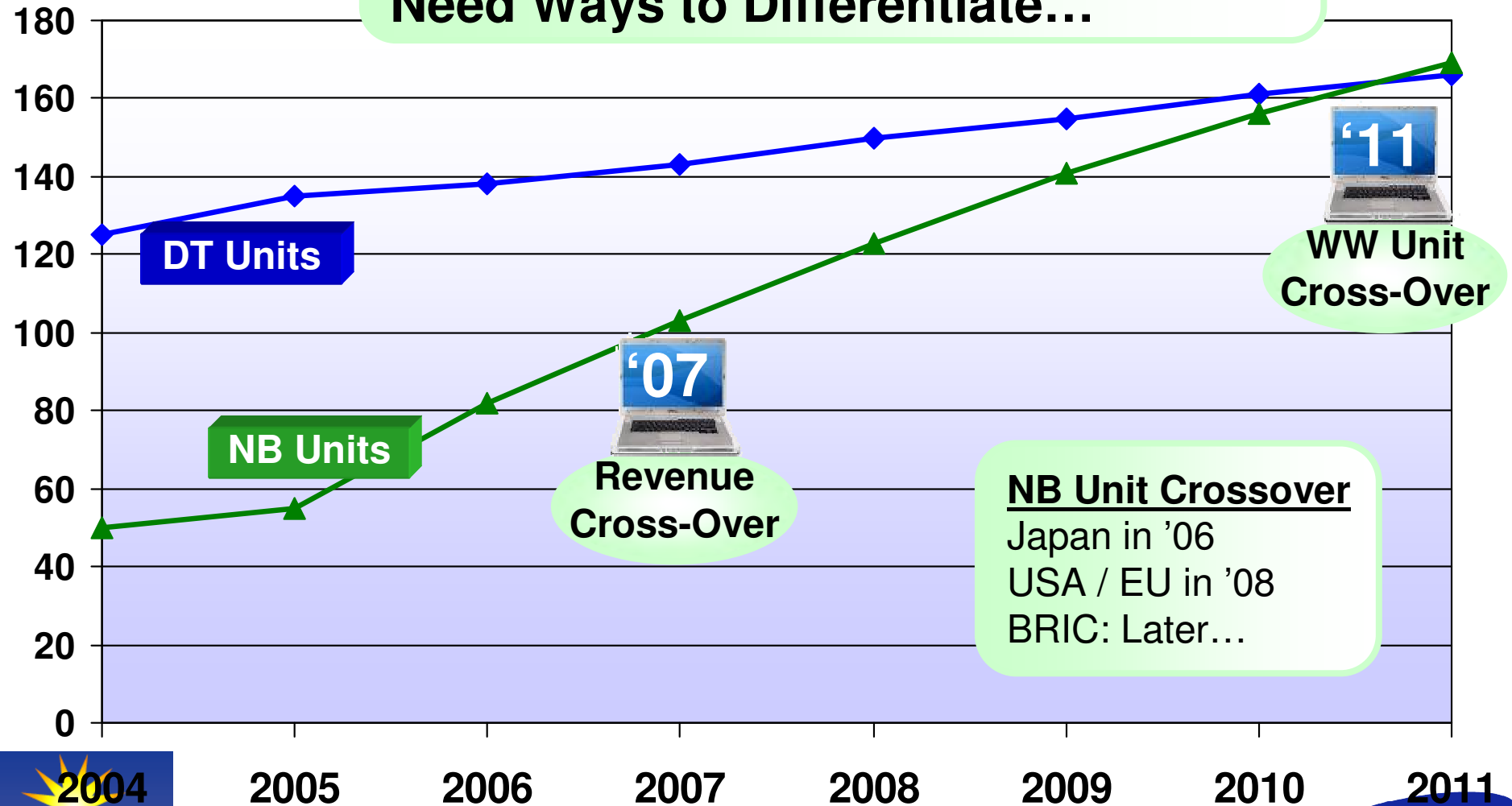2004 2005 2006 2007 2008 2009 2010

Source: Citigroup, McKinsey

NB Altering PC Market Dynamics

Notebook ASP: 50% more than DT
Sub $600 PC Category: > 50% by 2010
Need Ways to Differentiate…

PC Shipments, WW, M Units

DT Units

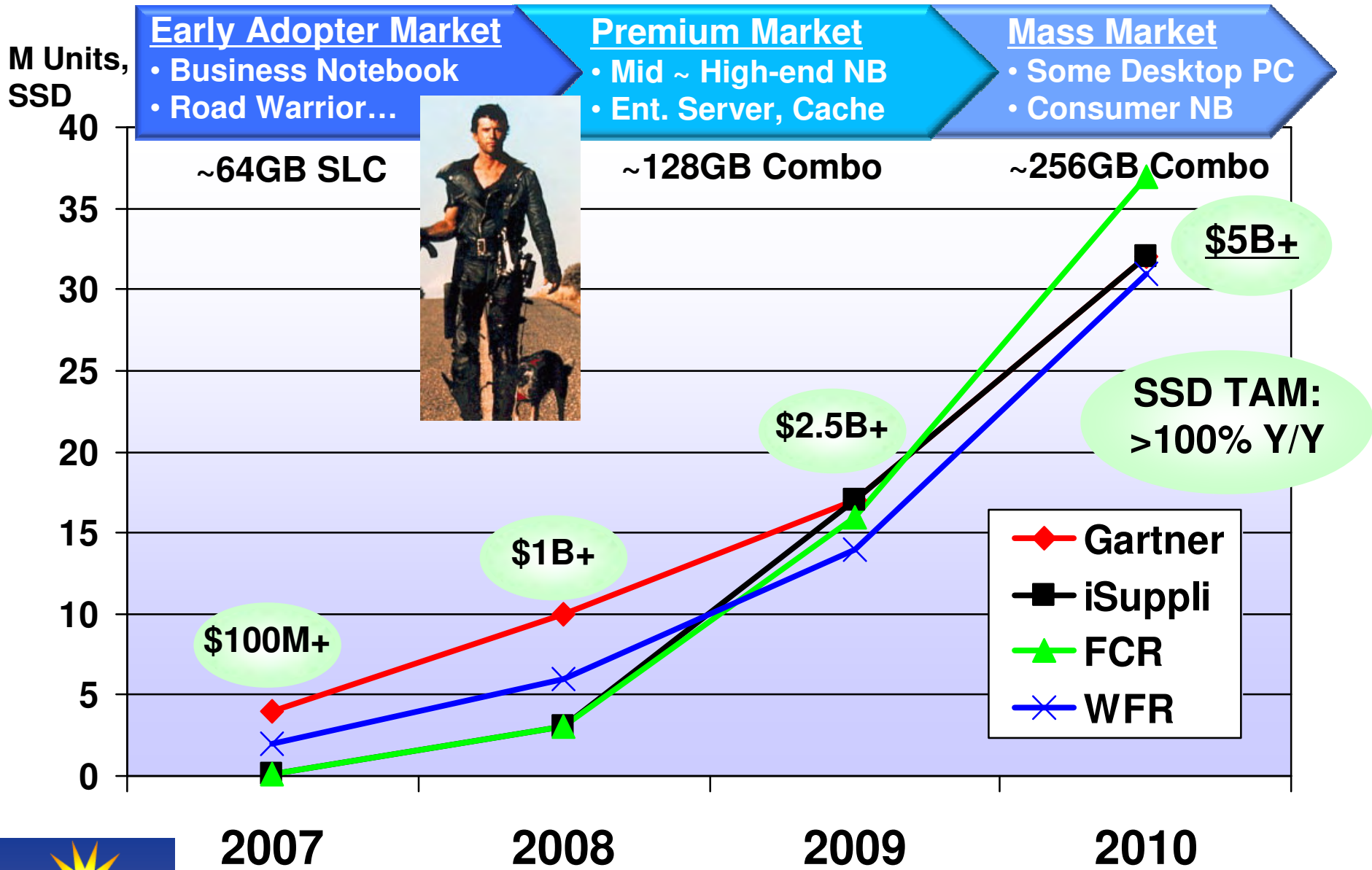**NB Units**

'07
Revenue Cross-Over

'11
WW Unit Cross-Over

NB Unit Crossover
Japan in '06
USA / EU in '08
BRIC: Later…

180
160
140
120
100
80
60
40
20
0

2004   2005   2006   2007   2008   2009   2010   2011

SSD Market Potential

M Units, SSD

Market phase	Details
Early Adopter Market	• Business Notebook • Road Warrior…
Premium Market	• Mid ~ High-end NB • Ent. Server, Cache
Mass Market	• Some Desktop PC • Consumer NB

~64GB SLC ~128GB Combo ~256GB Combo

$100M+ $1B+ $2.5B+ $5B+

SSD TAM: >100% Y/Y

Legend:
- ◆ Gartner
- ■ iSuppli
- ▲ FCR
- ✕ WFR

Y-axis values: 0, 5, 10, 15, 20, 25, 30, 35, 40

X-axis: 2007 2008 2009 2010

Concluding Thoughts

❑ NAND Will Catalyze New Markets
- ❖ Camcorder for Video
- ❖ SSD for Notebook, PC, Server / Cache

❑ New Markets Temper NAND Seasonality
- ❖ Less Seasonality → Market Stability

❑ NAND Will Continue to Disrupt / Enable…

- ❖ **Higher Reliability**
- ❖ **Better ID / Form Factor**
- ❖ **Lower Power**
- ❖ **Superior Performance**
- ❖ **Extrapolate NAND Cost, Density Curves**

NAND Value Prop

PC Storage Attribute Model
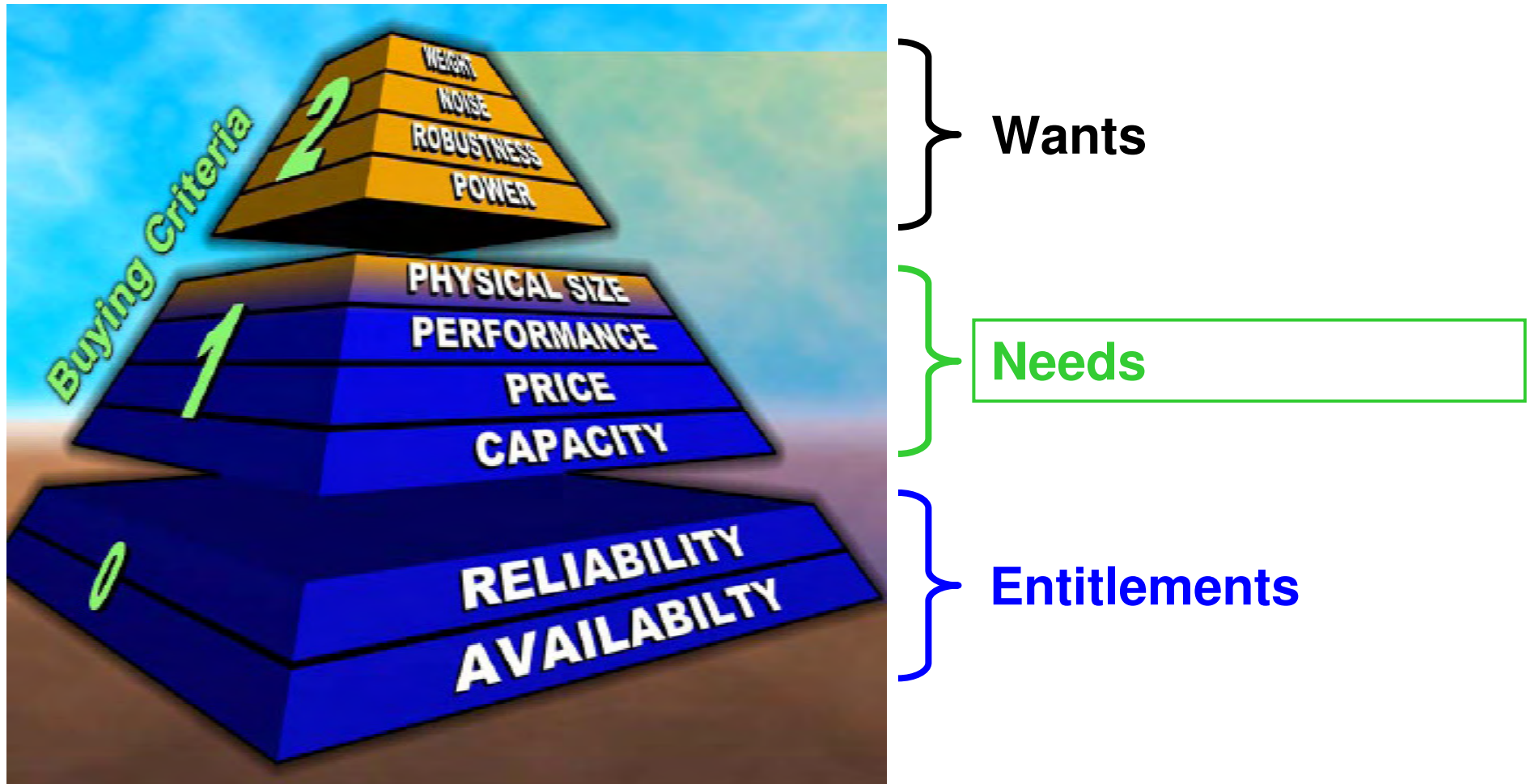
Source: John Squire, Founder of Conner Peripherals, 1989

Notebook Storage Attribute Model

Thank You!