The Inevitable Rise of NVM in Computing

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Nonvolatile Memory Seminar
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OBJECTIVE ANALYSIS

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Semiconductor Market Research

- Market consulting/research firm
  – Market analysis, strategies, white papers
- Highly-respected lead analysts
  – Jim Handy: Memories
  – Tom Starnes: Processors
- Industry experience & 25+ years in field
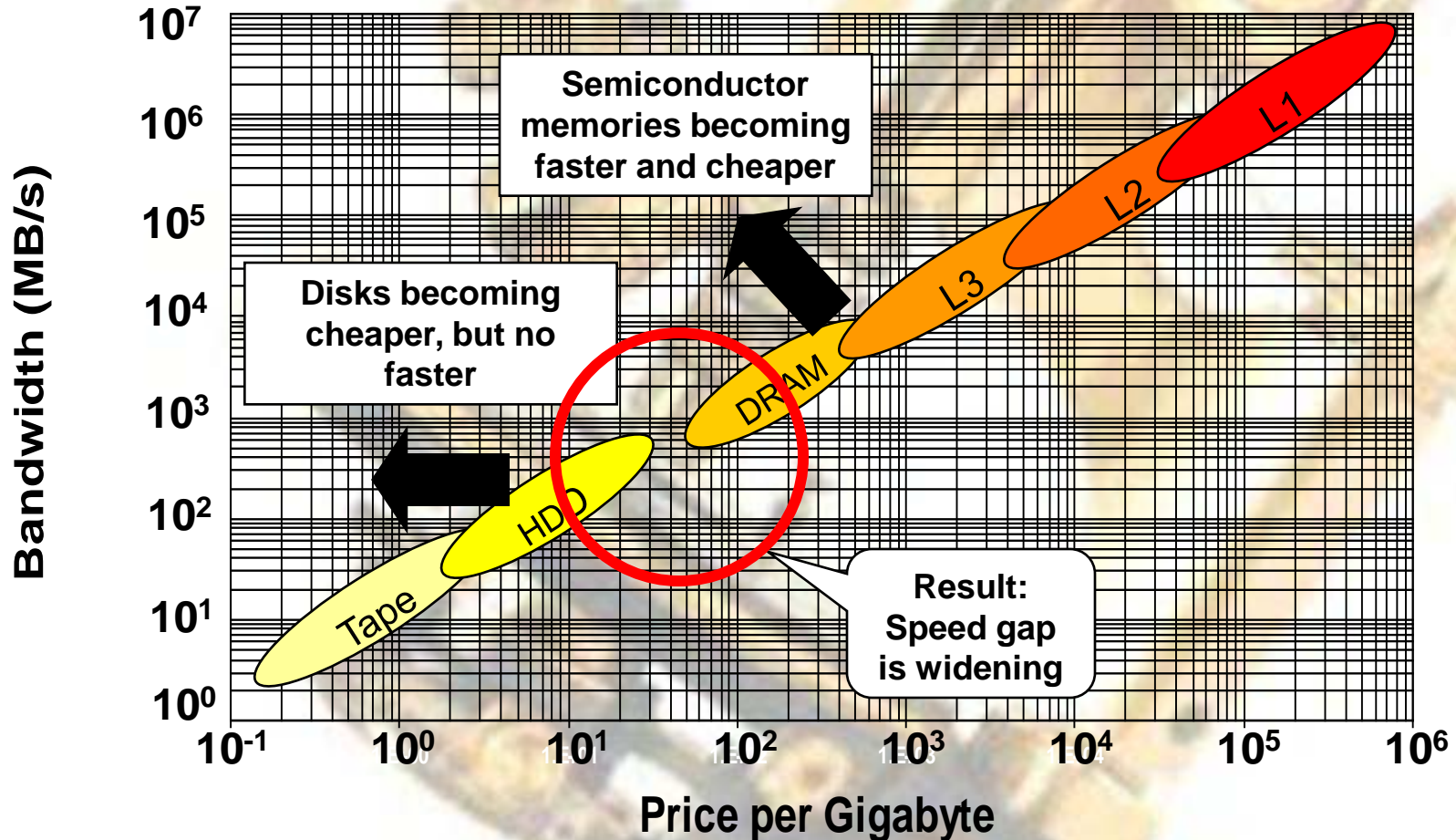- Reports, Competitive Analysis, Consulting

Agenda

- SSDs: Why now?

- Where do they fit?

- How will flash penetrate the PC?

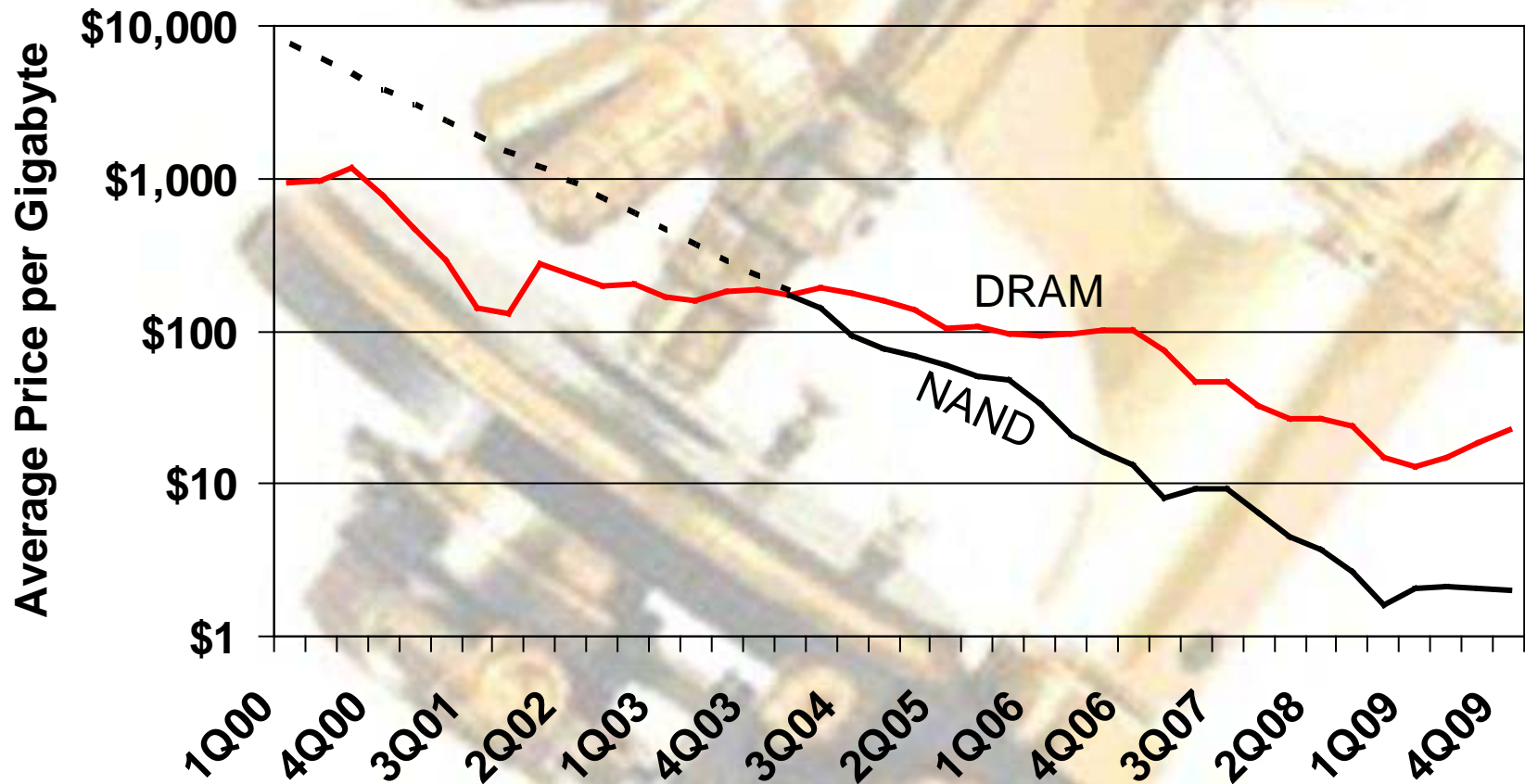- What challenges does flash present?

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The DRAM/HDD Speed Gap

Bandwidth (MB/s) vs Price per Gigabyte

- Semiconductor memories becoming faster and cheaper
- Disks becoming cheaper, but no faster
- Result: Speed gap is widening

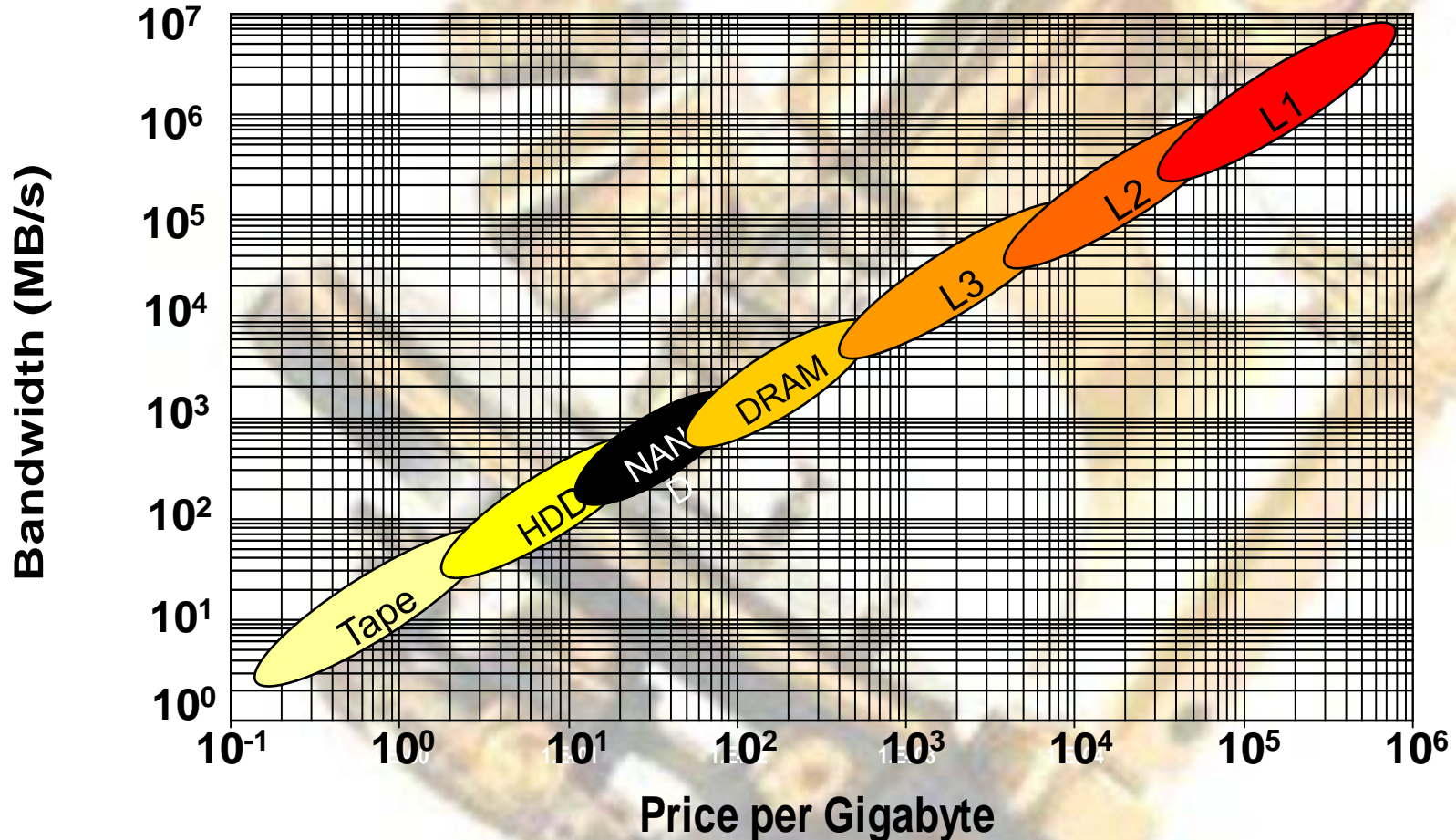Regions: Tape, HDD, DRAM, L3, L2, L1

From: *Solid State Drives in the Enterprise*

NAND Shot Past DRAM's Price per GB

From: *Hybrid Drives: How, Why, & When?*
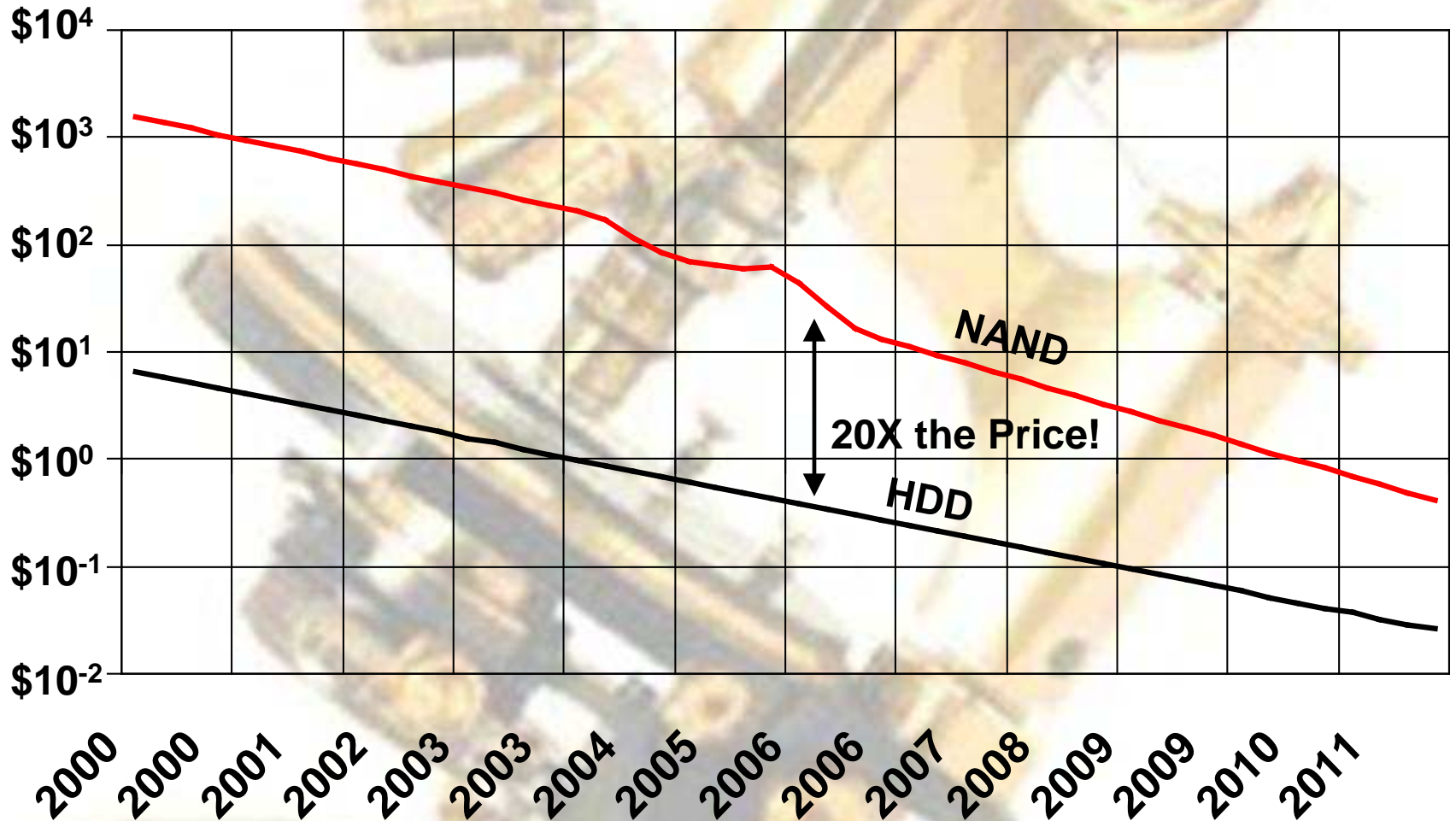
Now NAND Fits in Computers

From: *Solid State Drives in the Enterprise*

NAND Unlikely to Match HDD $/GB

Price per Gigabyte

Chart axis labels:
- Y-axis: 10^4, 10^3, 10^2, 10^1, 10^0, 10^{-1}, 10^{-2}
- X-axis: 2000, 2000, 2001, 2002, 2003, 2003, 2004, 2005, 2006, 2006, 2007, 2008, 2009, 2009, 2010, 2011
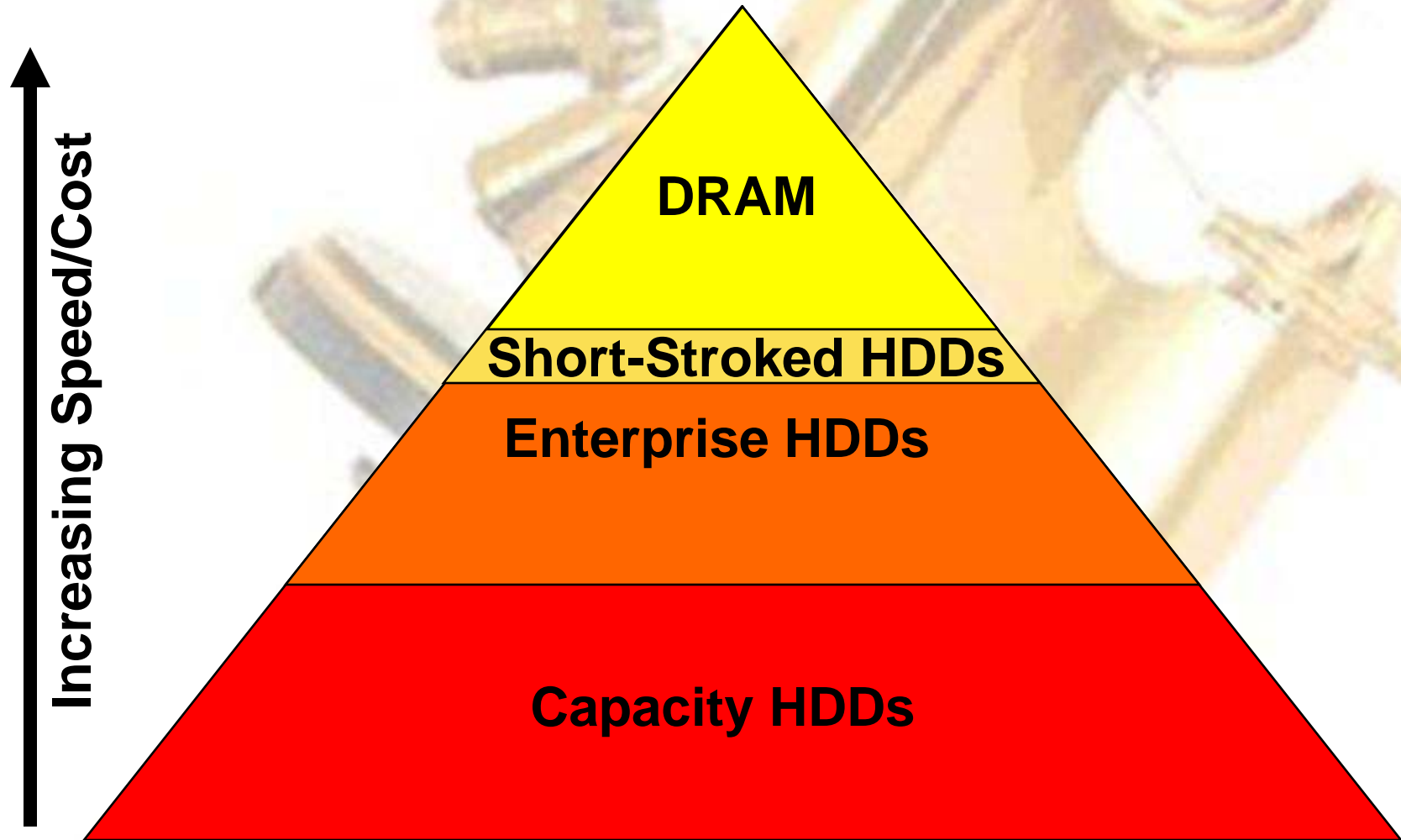- Curve labels: NAND, HDD
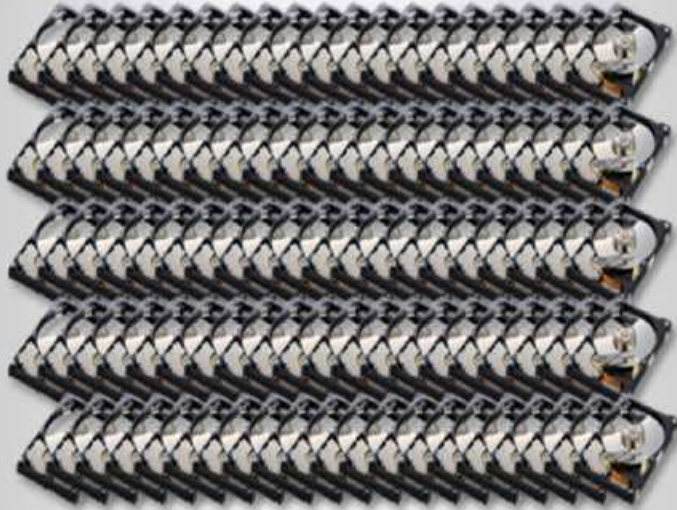- Annotation: 20X the Price!

From: *Understanding the NAND Market*

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Storage Hierarchy

Increasing Speed/Cost

DRAM

Short-Stroked HDDs

Enterprise HDDs

Capacity HDDs

SSDs in the Enterprise

100 Enterprise HDDs

Capacity: **30TB**
Performance: **30K IOPS**
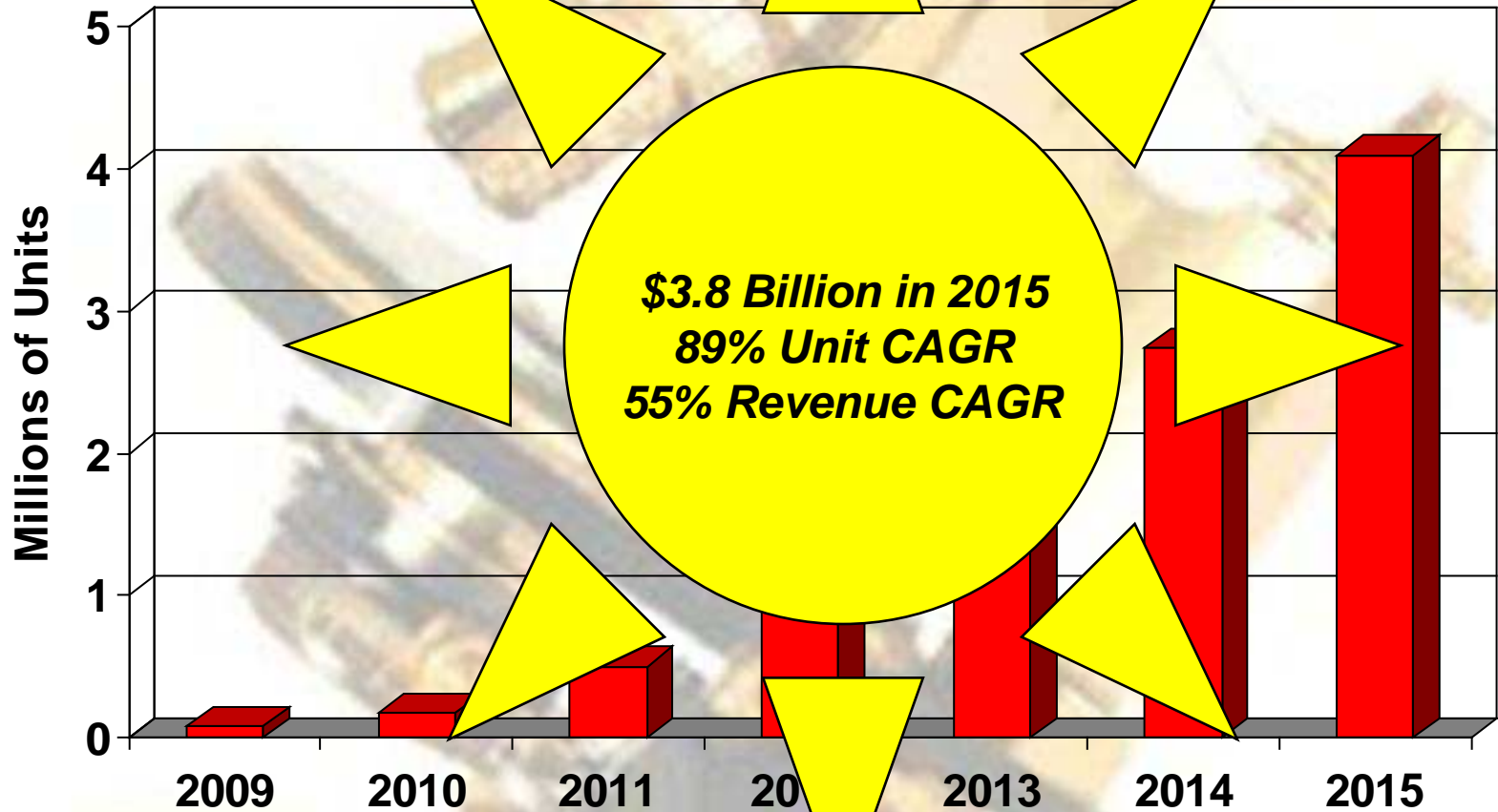Cap/Op-X: **$55,000 – 1.75kWh**

Hybrid Storage Pool

1 SSD

30 High Capacity HDDs

1/5th the Power
1/10th the Cost

Capacity: **30TB**
Performance: **30K IOPS**
Cap/Op-X: **$6,040 - 0.392kWh**

Source: Sun Microsystems, August 2008

OBJECTIVE ANALYSIS – www.OBJECTIVE-ANALYSIS.com

Enterprise SSD Forecast

Millions of Units

$3.8 Billion in 2015
89% Unit CAGR
55% Revenue CAGR

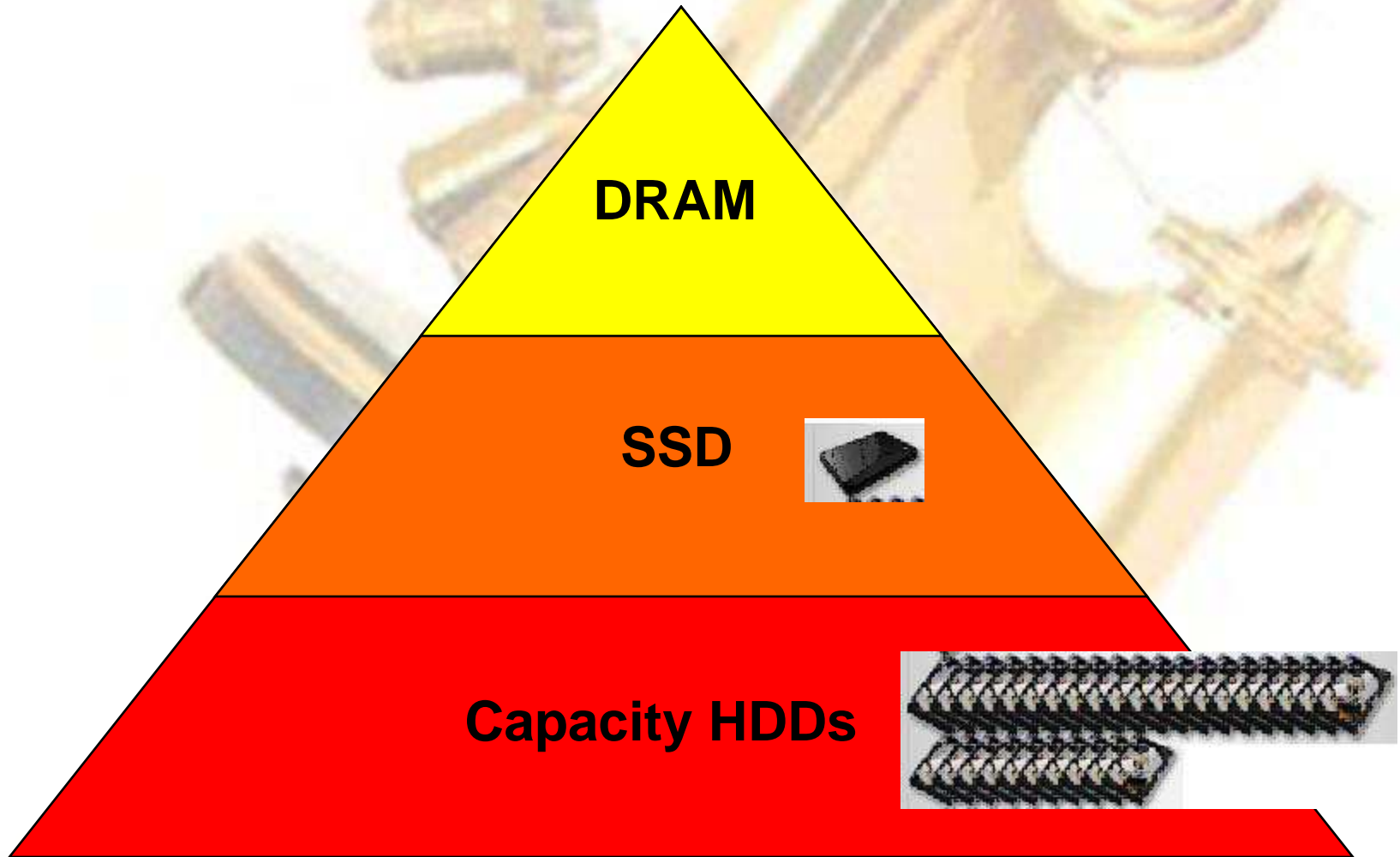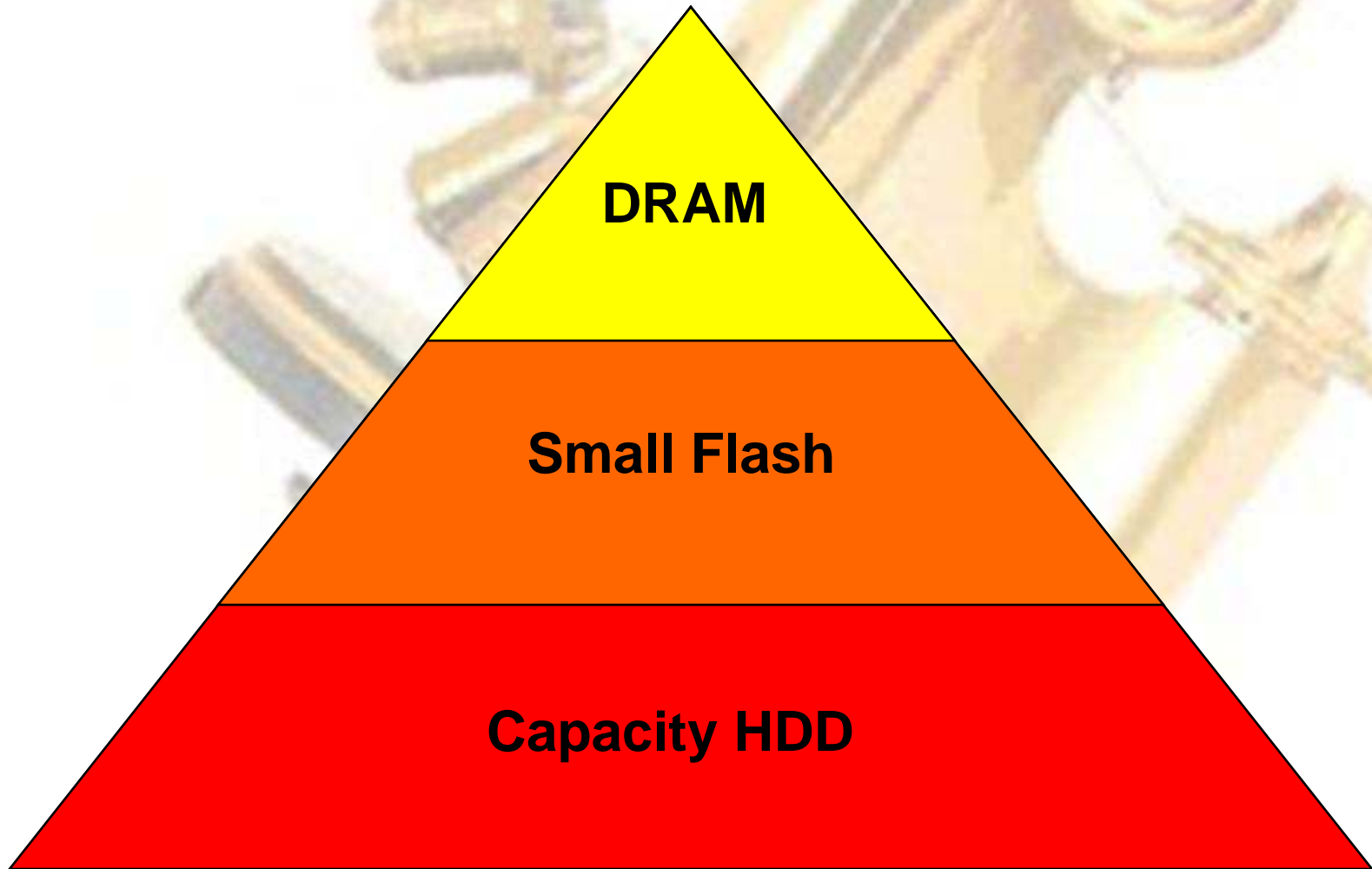2009 2010 2011 20 2013 2014 2015

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Flash in Enterprise Storage

DRAM

SSD

Capacity HDDs

The Same Model in a PC

DRAM

Small Flash

Capacity HDD

Many Alternatives Coming

- Intel Braidwood
  - NAND on the motherboard
    - Managed by chipset & firmware
  - Preceded by Robson/Turbo Memory
- Seagate Momentus XT Hybrid HDD
  - Uses internal NAND management
- NVELO (formerly Denali) Dataplex
  - NAND management for SSD/HDD combo
- Others coming soon

Why Early Attempts Failed

- Robson/Turbo Memory
  - Small size (4MB)
  - Poor Windows Vista Support
    - Invoking support sometimes <u>degraded</u> performance
- Hybrid HDD
  - As above: Small size and Vista problems
  - Weak industry support: Samsung & Seagate

Taking Control of the Flash

- Intel's Braidwood
  - Firmware, chipset, drivers
  - NAND on ONFi DIMMs
- Seagate Momentus XT
  - HDD controller manages flash
  - Flash sits inside HDD
- NVELO's Dataplex
  - Just sell the control software
  - OEM decides whose HDD & flash to use

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Problem 1: HDD Interfaces

- HDD interfaces designed around HDDs
  - Slow I/O needs queuing
  - Single internal data path
  - Overwrite old data at any time
- SSDs are really different:
  - Very fast reads
  - Erase before write
  - Multiple internal data paths
  - Wear-out mechanism

Why the Interface Matters

32 NAND Chips

DRAM

I/O Bus

Controller

1GB NAND

1GB NAND

Many Potential Data Paths
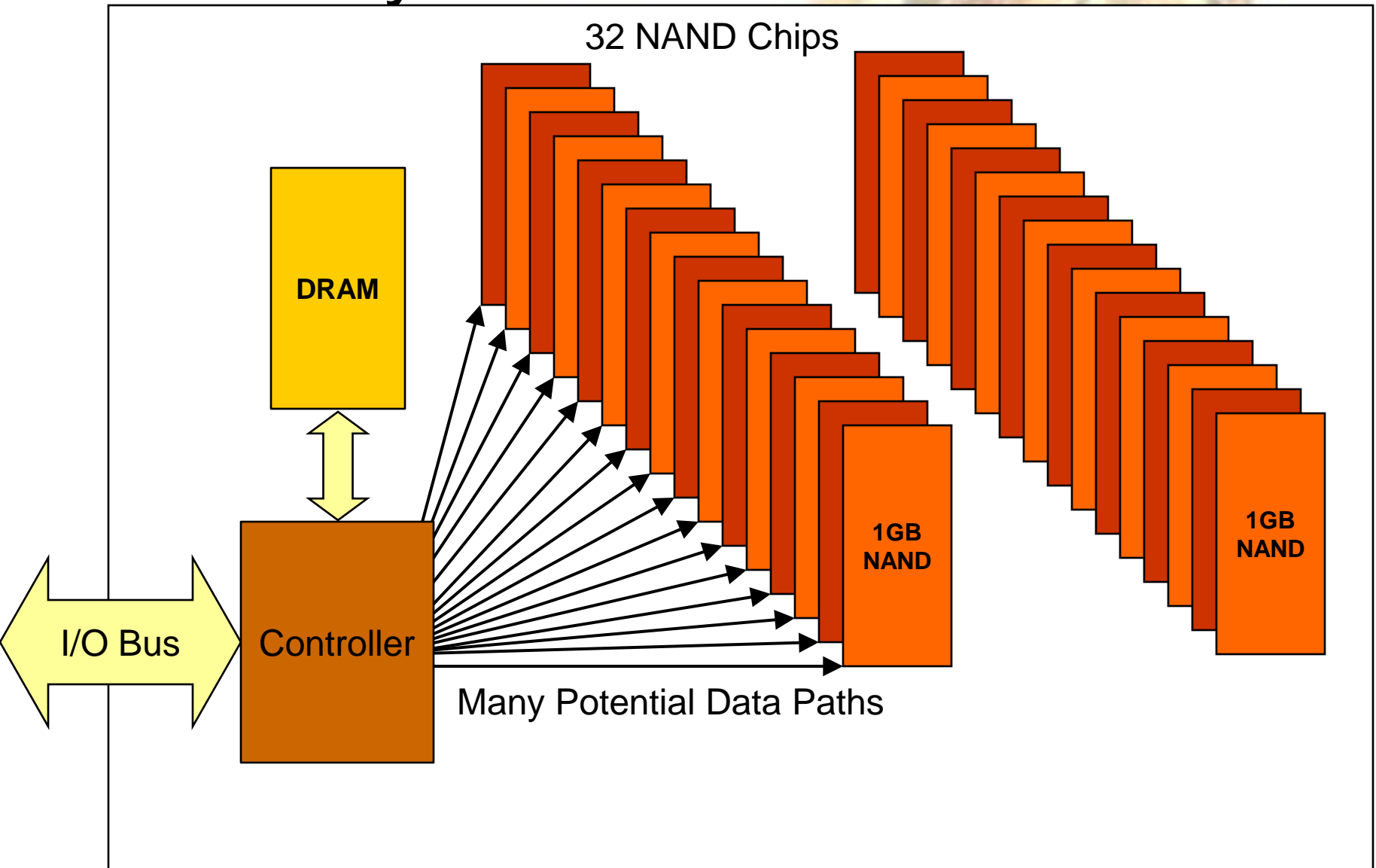
Problem 2: Erase & Write Timing

- Erase required before write
  - HDD simply overwrites data
  - Requires erase strategy
- Slower write than read
  - Page read ~25µs setup, then 50ns/byte
  - Page write ~1ms
  - Block erase ~5ms
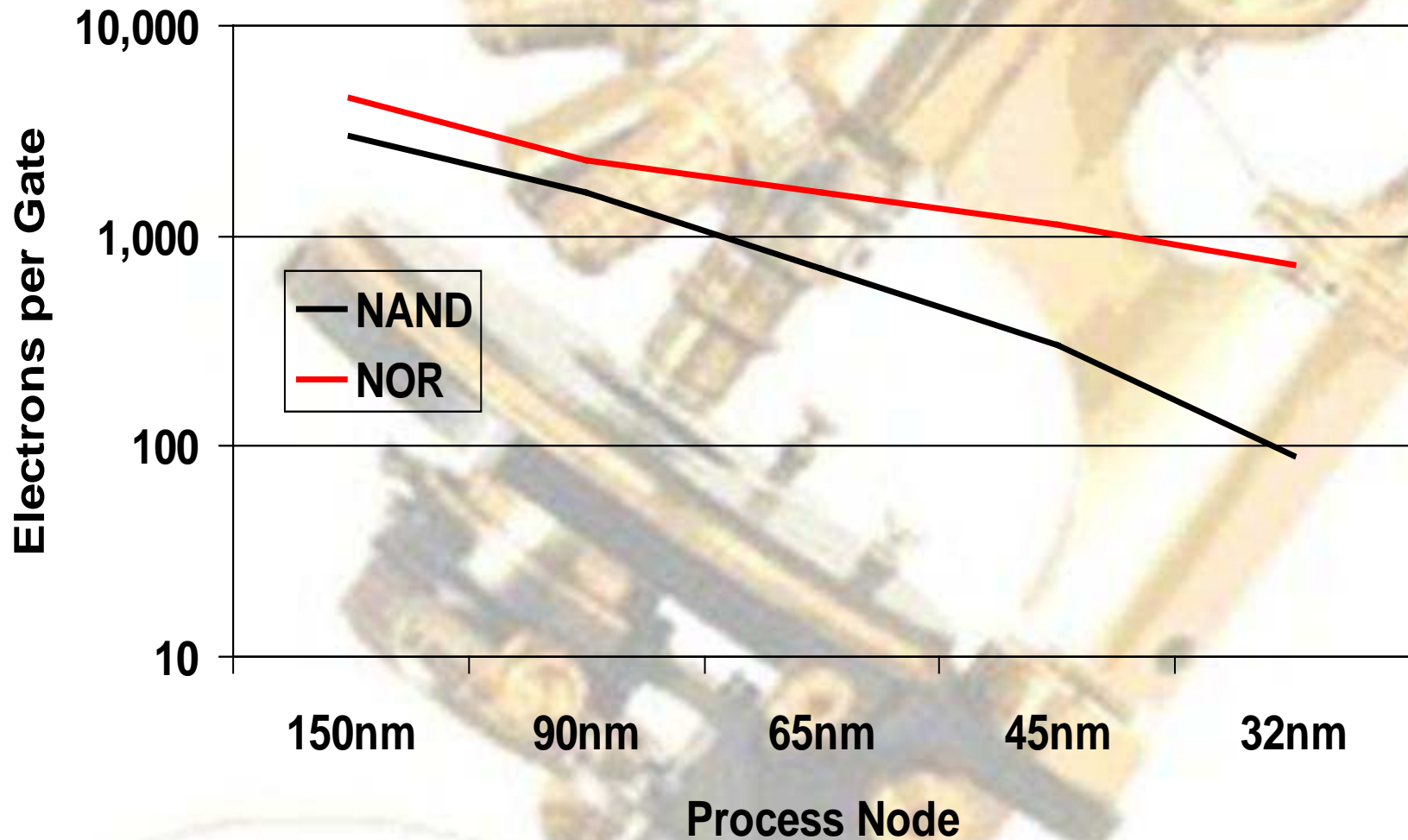- Today's software expects balanced R/W

How Software Can Help

- Frequent reads/infrequent writes
- Cues for housekeeping
  - "Trim" command today
- Understanding the hierarchy
  - Fast things onto flash
  - HDD stores other stuff
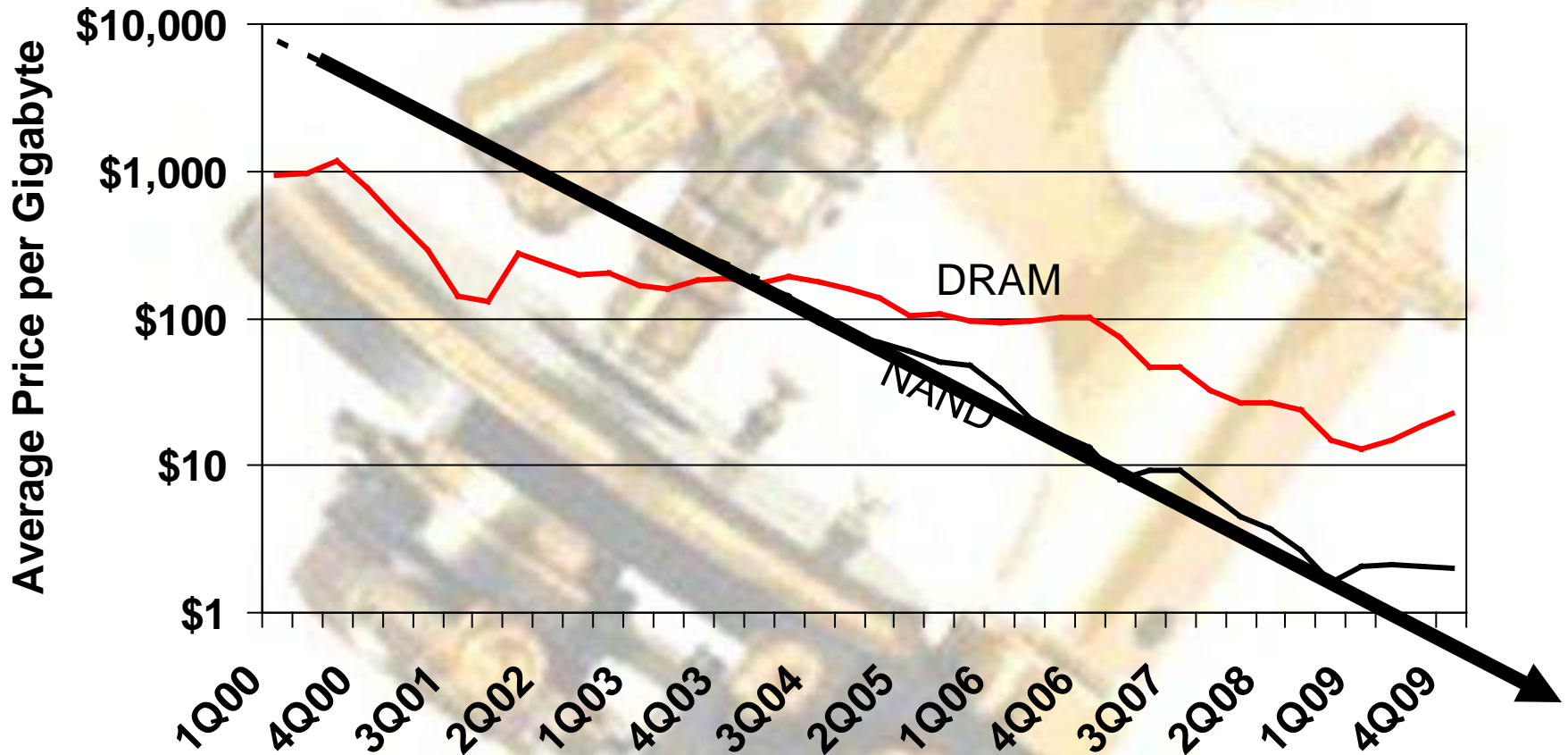 - Just like cache memory, virtual memory, etc.

Problem 3: NAND Scaling Limit

- NAND will reach a limit
  - Too few electrons per gate
  - Needs constant shrinks for cost reductions
  - 4-bit/cell hard to make
    - This may be the maximum possible
- Other technologies will scale past NAND
  - PCM, MRAM, RRAM, FRAM….
    - Not yet clear which will win
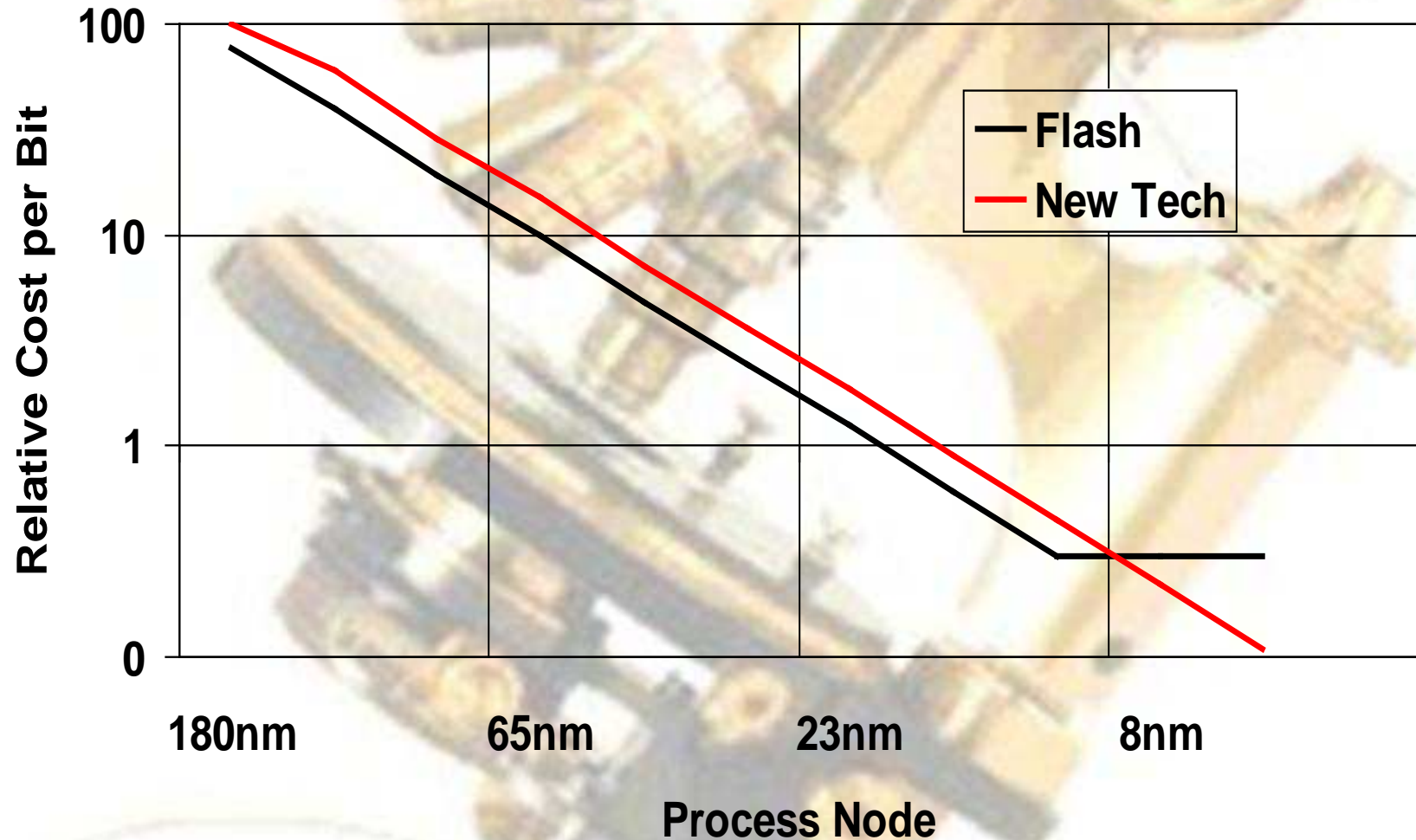
Too Few Electrons per Gate

How to Maintain this Inertia?

Average Price per Gigabyte chart showing DRAM and NAND price trends from 1Q00 to 4Q09, with a declining trendline. Y-axis: $1, $10, $100, $1,000, $10,000.

How Alternatives will Emerge

Summary

- Flash belongs in <u>all</u> computers
  - So does HDD
- Many changes will result
  - Interface
  - Software
  - Even the memory technology!

Thank You!

Jim Handy

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