Mommy, Daddy, Why is My New Laptop So Dog Slow?!

or

Recent Trends in Systems Research

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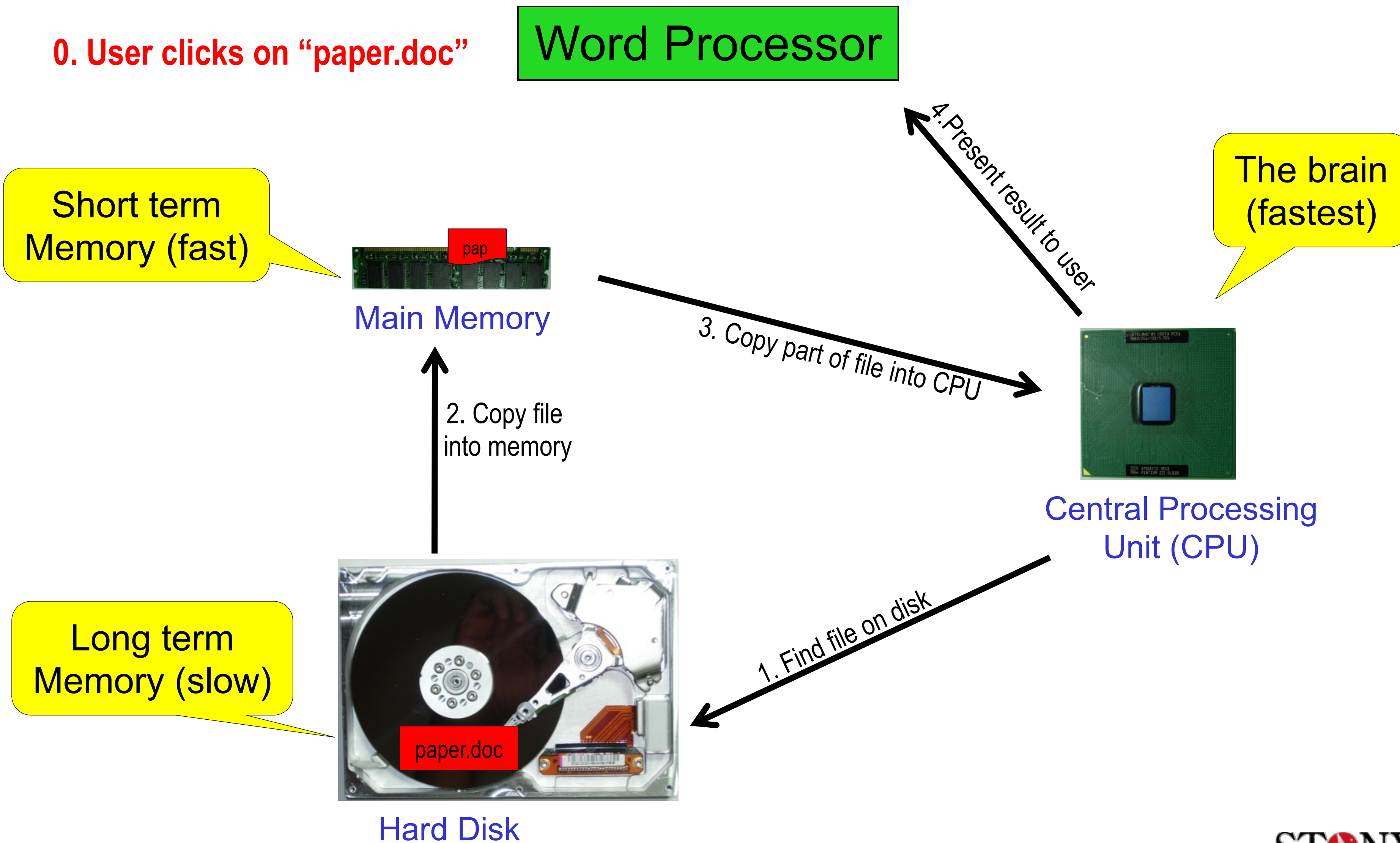
Outline

- Problem motivation
- How computers work today
- Some history
- What can you do?
- What are computer scientists doing?
- The future

Motivation

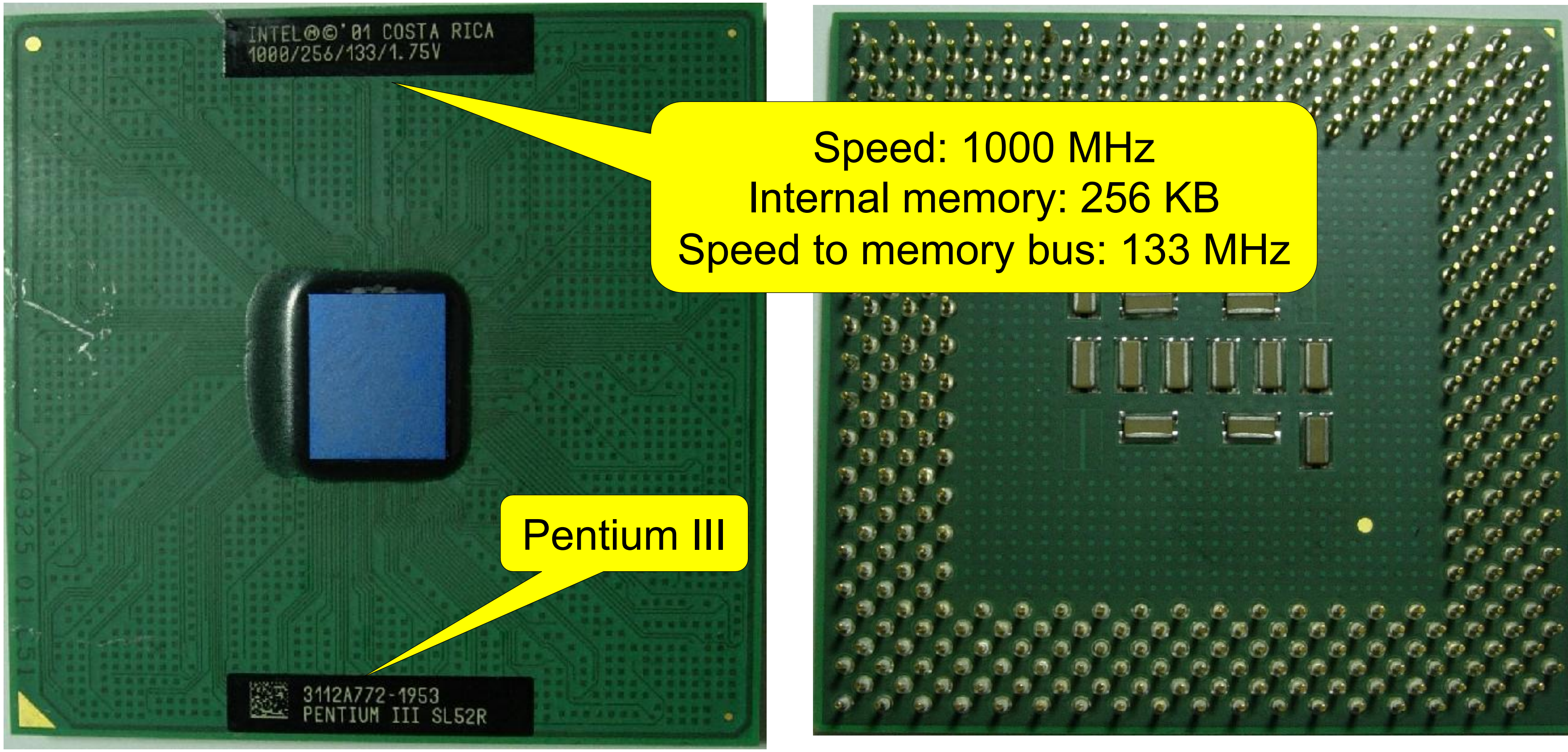
- Computers “become” slower over time
- Money spent ineffectively
- Power consumption
- E-waste

How a Computer System Works



Show-n-Tell: CPU

TOP VIEW **BOTTOM VIEW**



1. **CPU speeds are in the nano-seconds (billions of operations per second)**
2. **CPU's internal speed is ~10-100 times faster than its access to main memory.**
3. **Typical CPU's internal memory: 256MB to several GB, multiple caches/cores**

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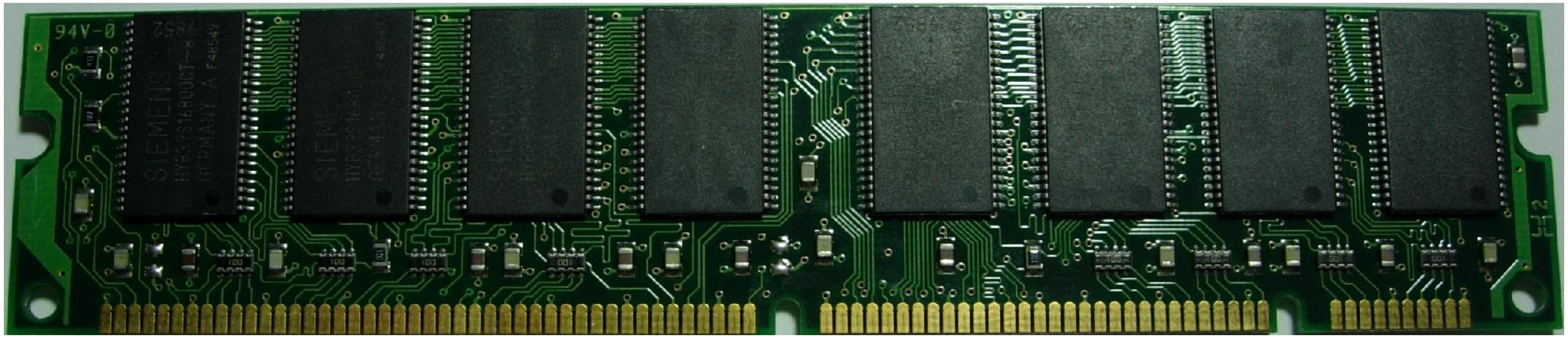
Show-n-Tell: CPU Heat Sink

Note: modern faster CPUs require an ever larger CPU fan

Show-n-Tell: Main Memory

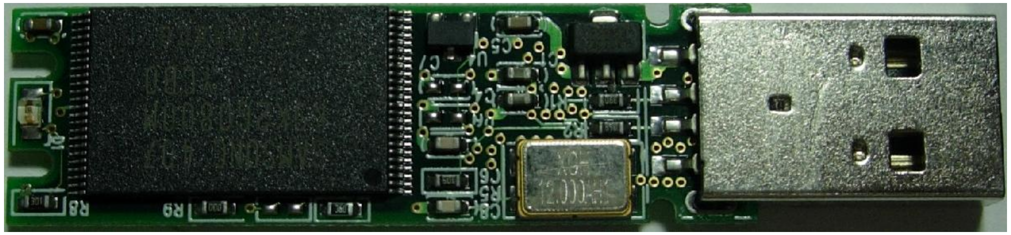
Common name: Dynamic Random Access Memory (DRAM)



Typical memory sizes today: 4-16 GB (Giga Bytes), or billion characters

Typical memory speeds: micro-seconds (millions of operations per second)

Show-n-Tell: Flash Memory



USB port

Major advantage: persistent (non-volatile) memory

Typical flash memory sizes today: 32GB–2TB (Giga Bytes), or billion characters

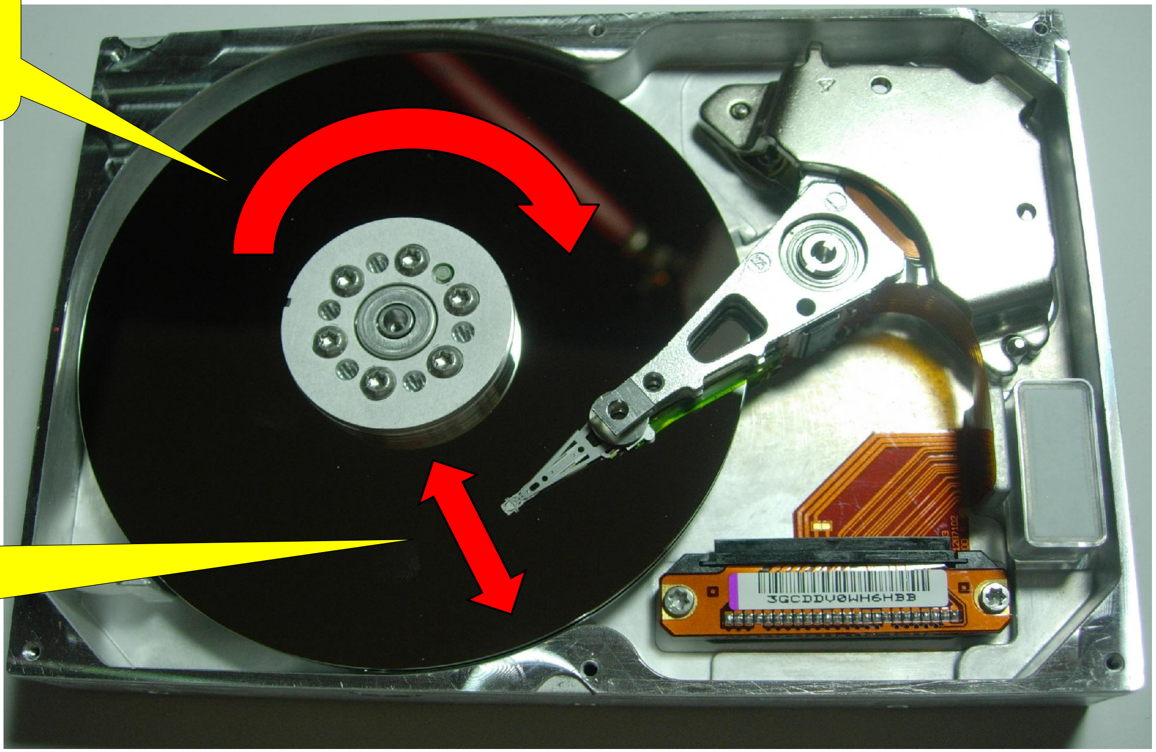
Typical flash speeds: between DRAM and hard disks

Lifetime: only thousands/millions of writes

Performance depends on fullness, age, and internal processes (GC, defrag)

Show-n-Tell: Hard Disk

Disk platter rotates
(4-18 KRPM)

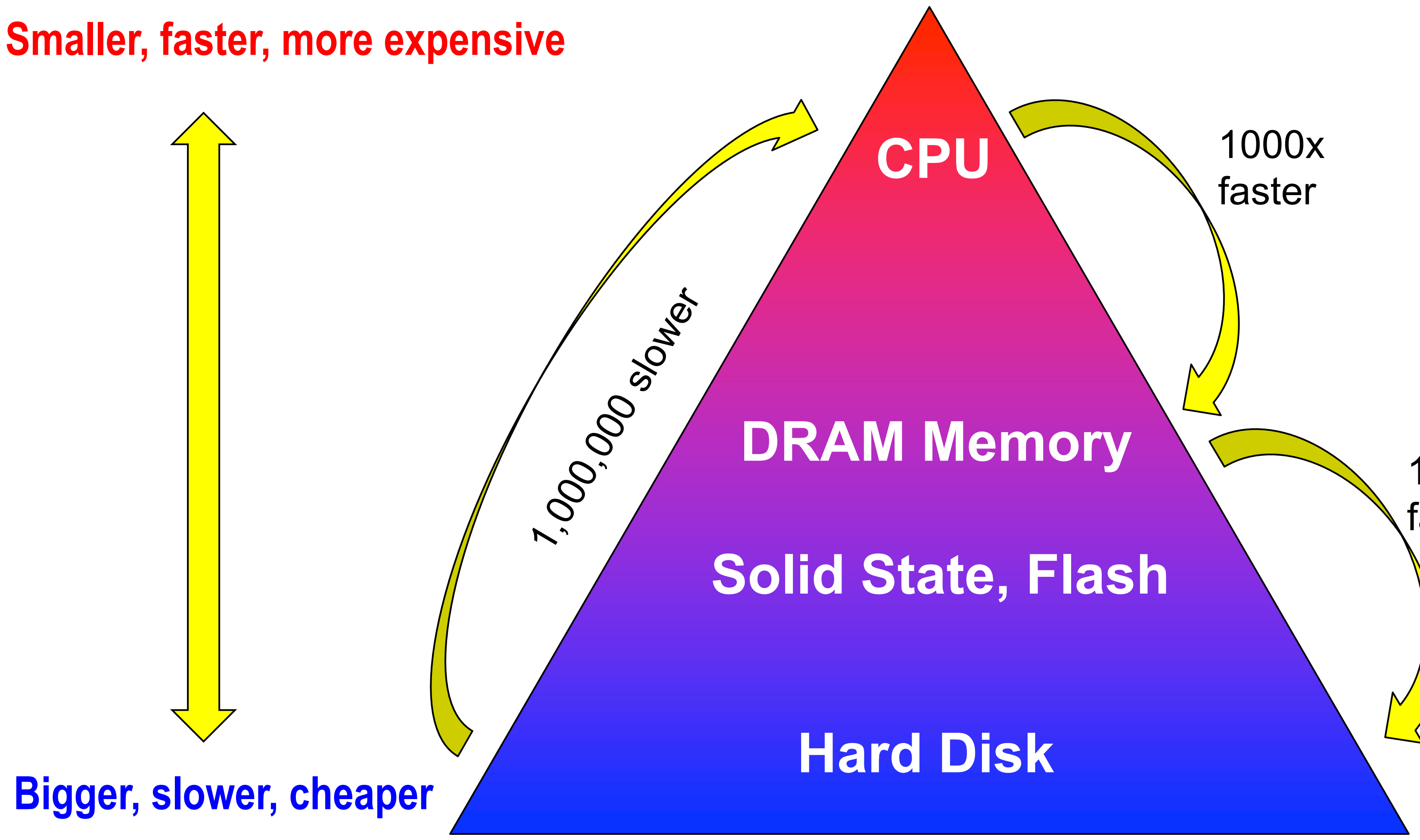


Disk head moves
From side to side
(milli-seconds)

Typical disk sizes today: 2-12 TB (Giga Bytes), or billion characters

Typical disk speeds: milli-seconds (thousands of operations per second)

The Storage Hierarchy Pyramid



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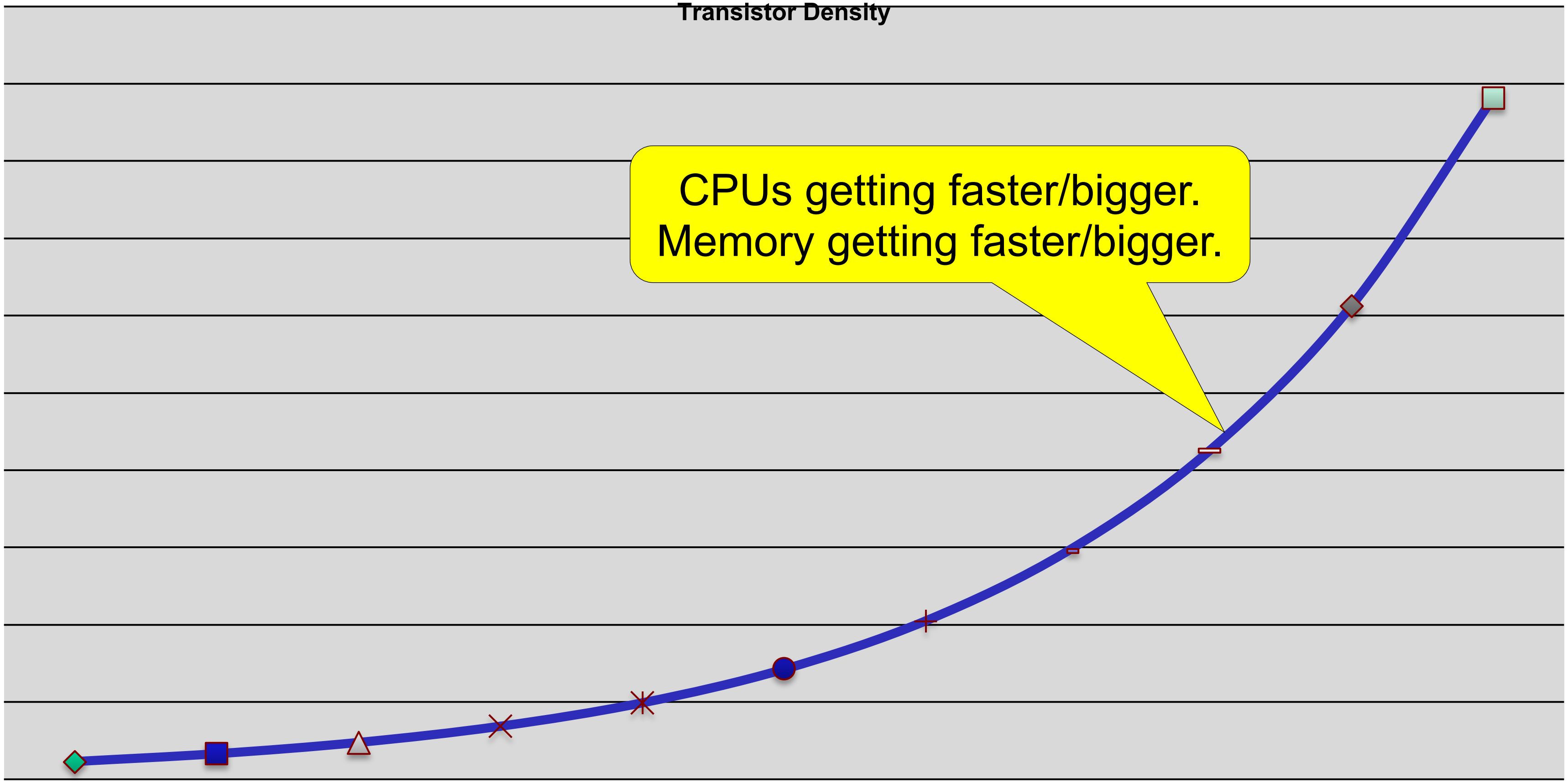
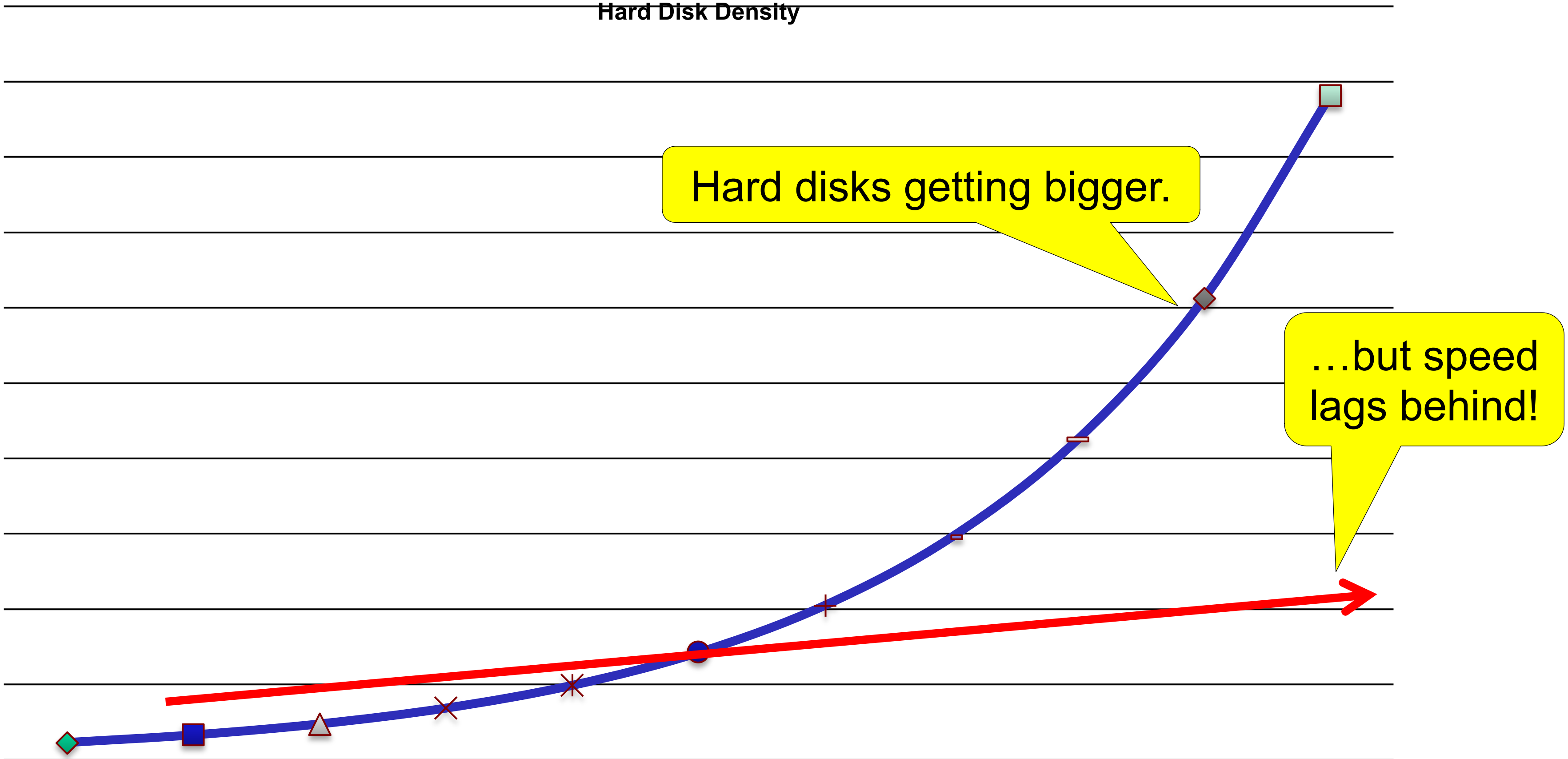
Moore's Law



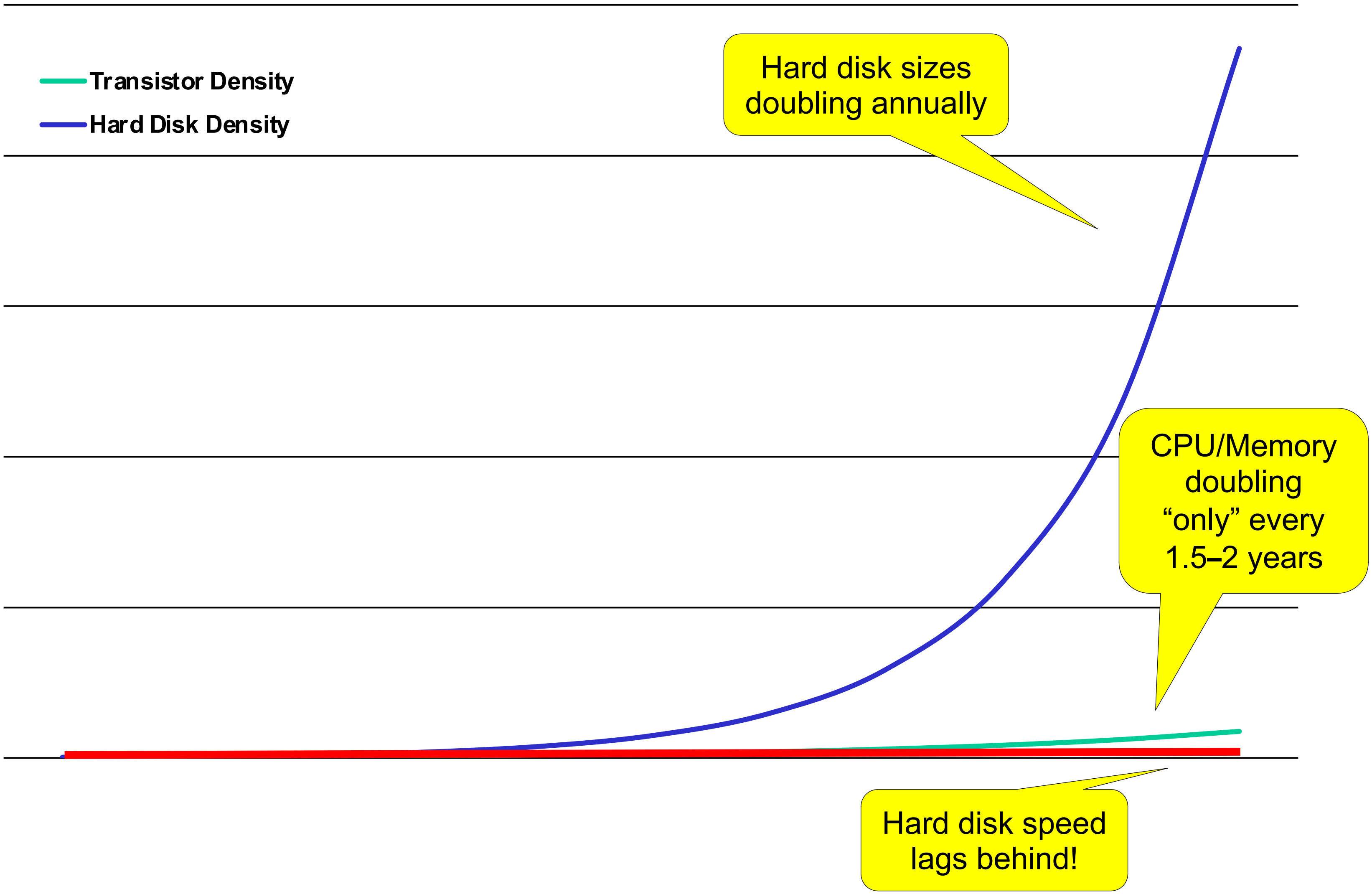
"Transistor density doubles every 18–24 months" (c. 1965)

Kryder's Law



"Magnetic storage density doubles annually" (c. 1995)

Moore’s vs. Kryder’s Law



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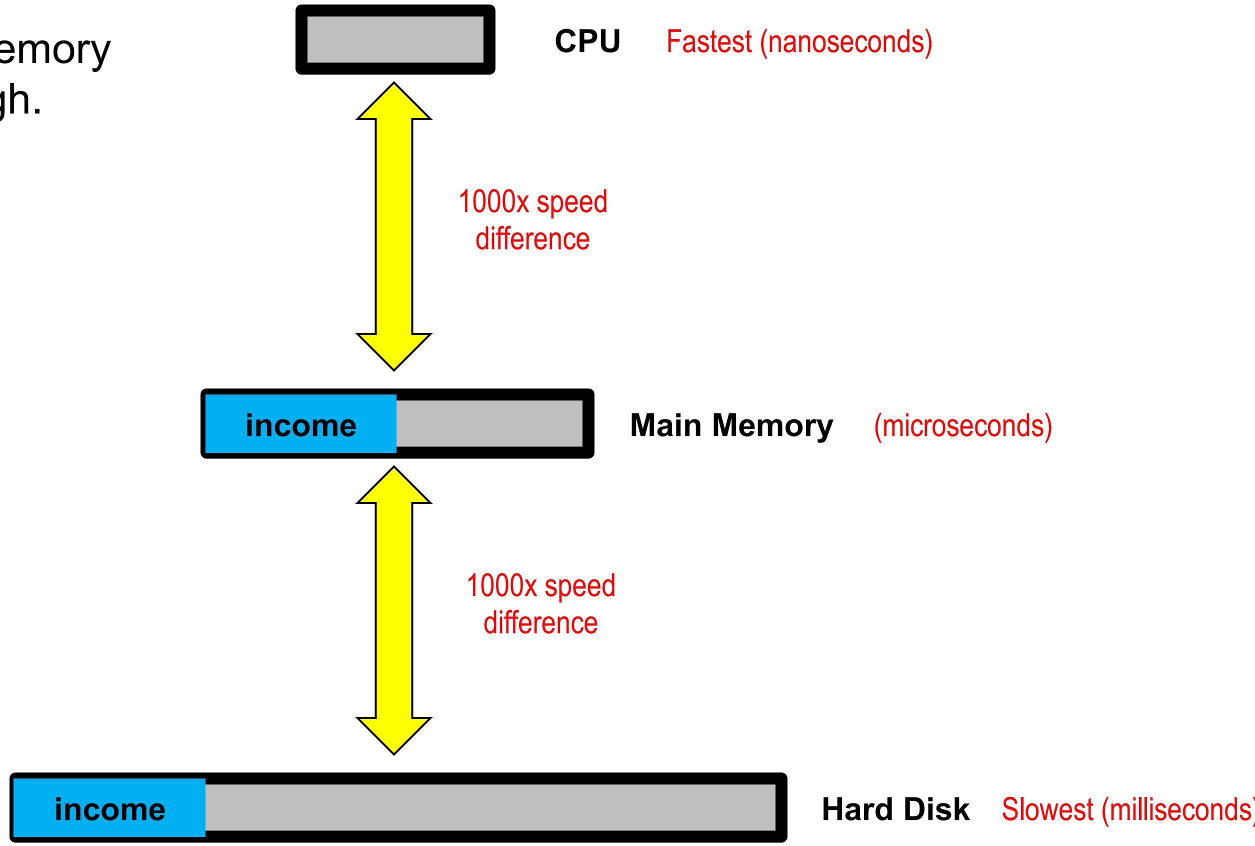
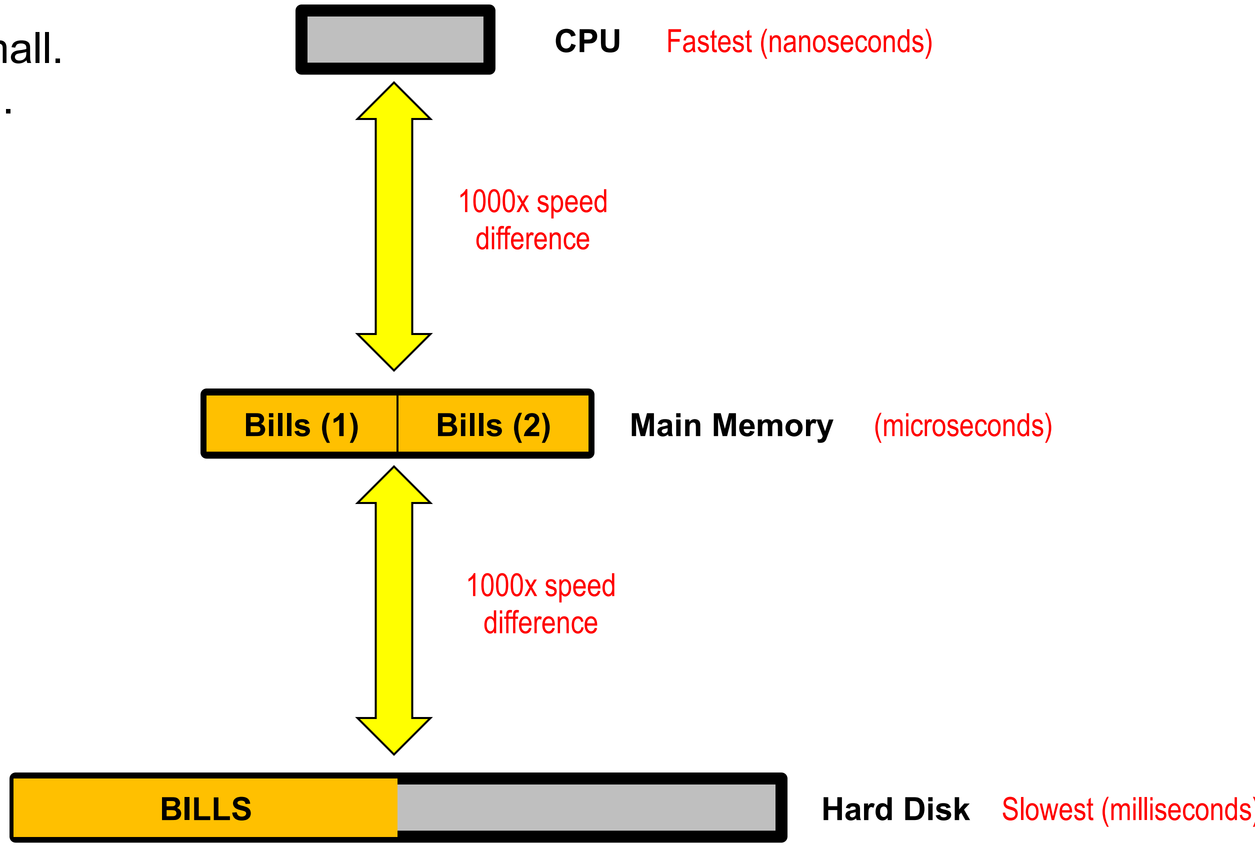
How Computers REALLY Work (1)

Scenario 1: CPU and memory are large and fast enough.



How Computers REALLY Work (2)

Scenario 2: CPU **too** small.
Memory is large enough.



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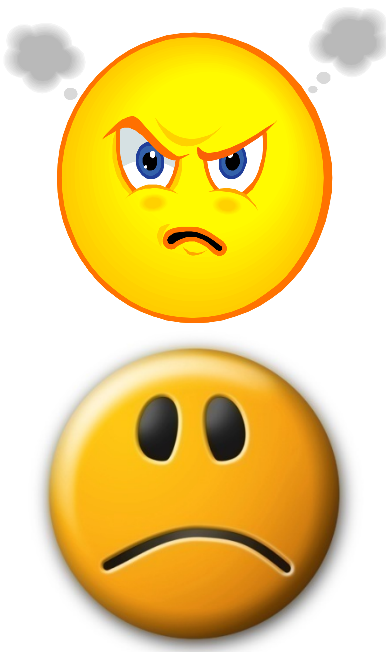
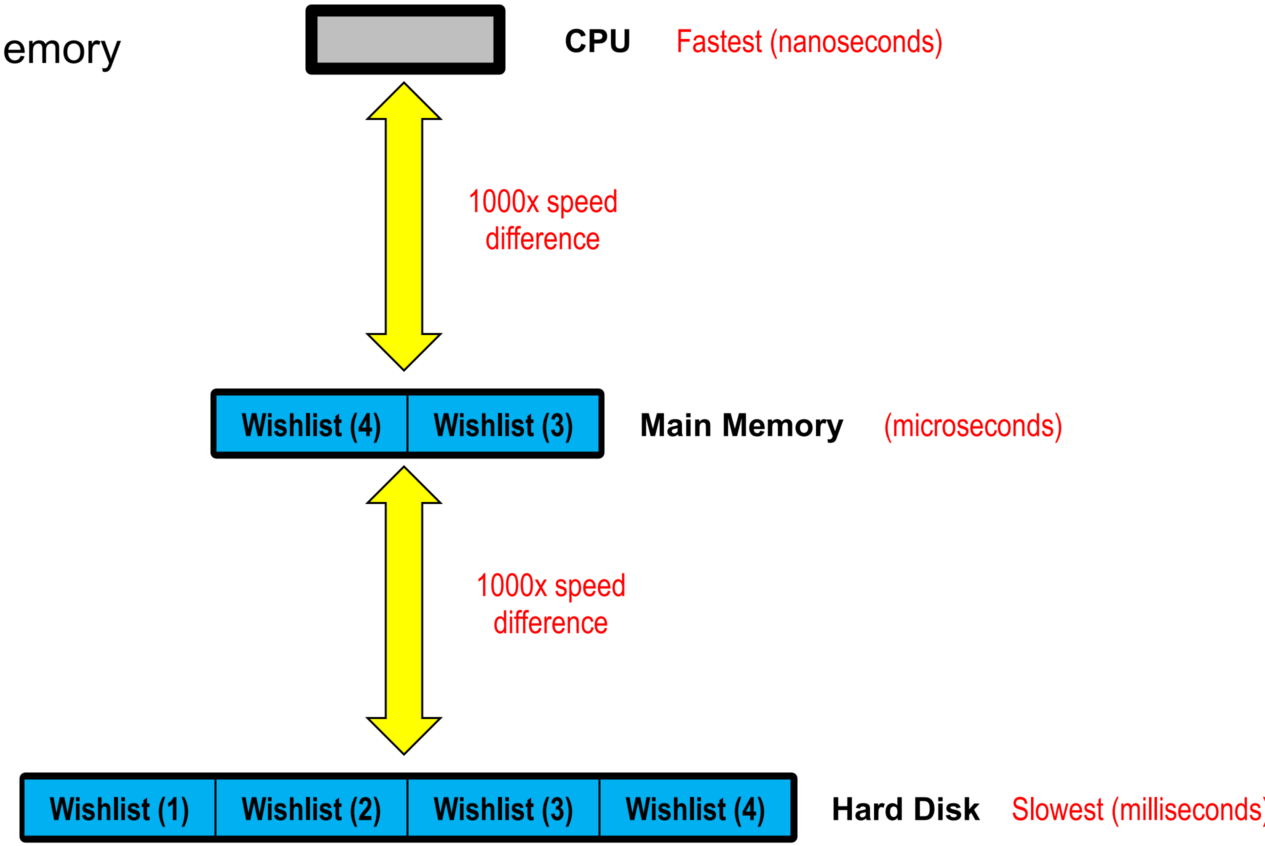
How Computers REALLY Work (3)

Scenario 3: CPU and memory are **BOTH** too small.





The Perfect Storm

- Disk sizes getting larger the fastest
- CPU/Memory getting larger/faster
  - But lagging behind disk-size growth rates
- Disk speeds lagging far behind the rest
- Software getting larger
  - Fills disks to capacity
  - Software updates & system service packs
- E.g., anti-virus/spyware scanners
  - How long to scan a 5TB disk?

Buying a New Computer (1)

- Given a fixed budget, spend your $$$ on the following, by importance:

1. More main memory (4–32 GB+)
   - Try to keep a free memory upgrade slot
2. Larger CPU caches
3. Faster disks (SSD)

Caveat: may increase power consumption

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Buying a New Computer (2)

- Where to cut back on (if fixed budget):

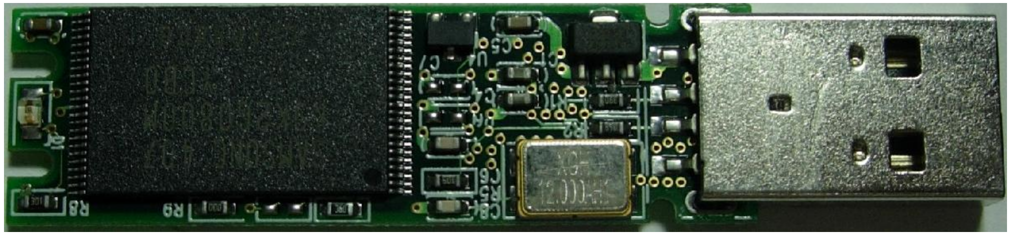
1. Don't get the fastest CPU (in MHz)
   - E.g., get a 2.8GHz instead of a 3.2GHz
   - How many cores do you really need?
2. You may skip on multi-core CPUs
   - Extra "brains" but share same CPU cache
3. Consider a smaller disk

Recommend: avoid "canned" solutions

Ongoing Comp. Sci. Research

- How to use multi-core CPUs effectively?
  - Trade CPU for reduced I/O?
- How to reduce the need to go to disk?
  - Compressing data (spare CPU cores)
  - Prediction/AI algorithms, prefetch disk data
- Use new storage devices
  - E.g., FLASH memory, NVMe-DIMMs

Show-n-Tell: Flash Memory



USB port

Major advantage: persistent (non-volatile) memory

Typical flash memory sizes today: 128MB–4GB (Giga Bytes), or billion characters

Typical flash speeds: between DRAM and hard disks

Lifetime: only millions of writes

The Future of FLASH Memory

- Intermediate cache between main memory and hard disks
- Staging device inside hard disks
  - Hybrid disks
- Replace spinning disks
  - Solid State Disks (SSDs)
    - MacBook Air (2008)
- SMR: Shingled Magnetic Recording
- Future: Glass & DNA-based storage

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Q&A

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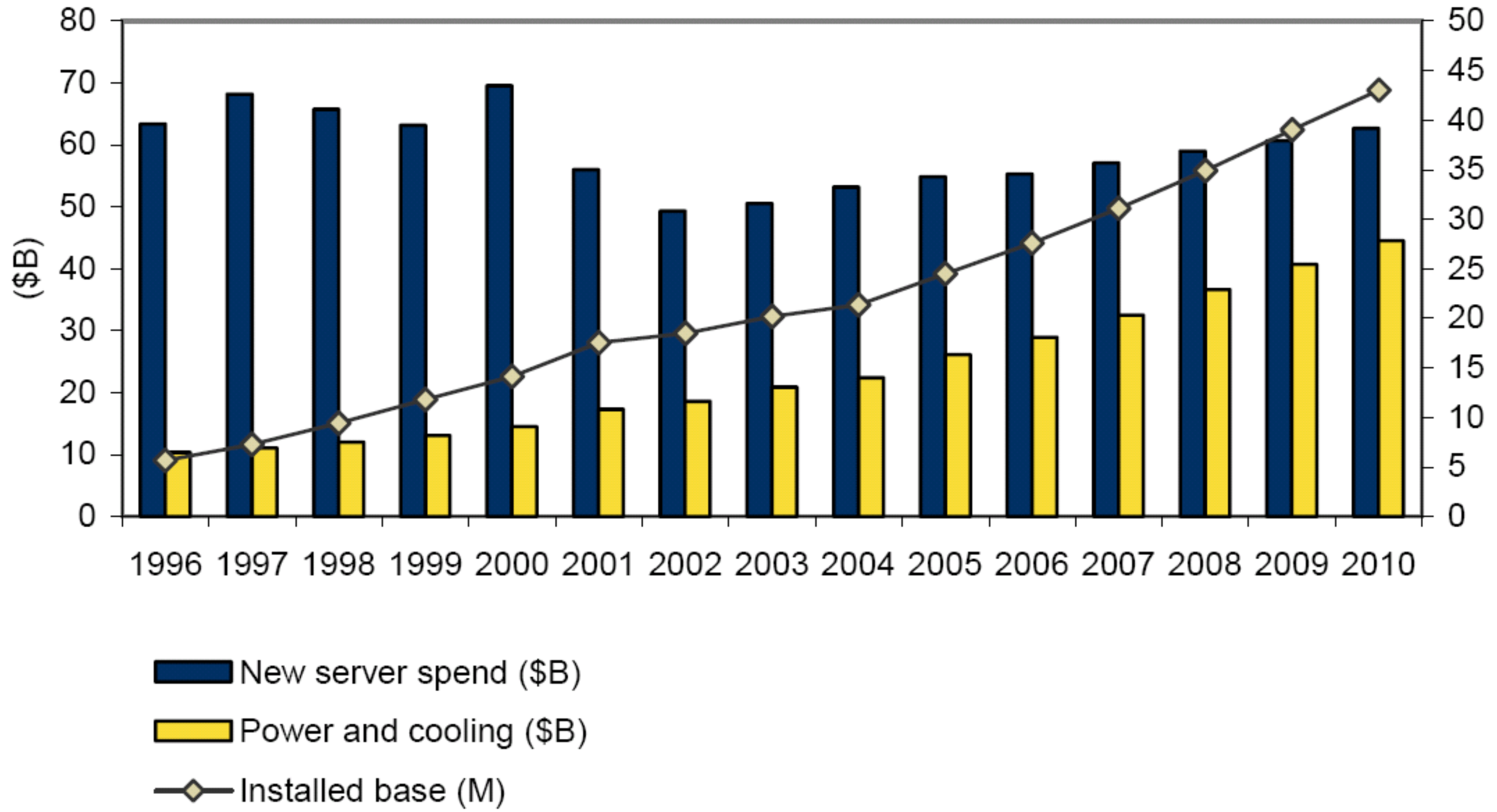
Worldwide Cost to Power and Cool Server Installed Base, 1996–2010



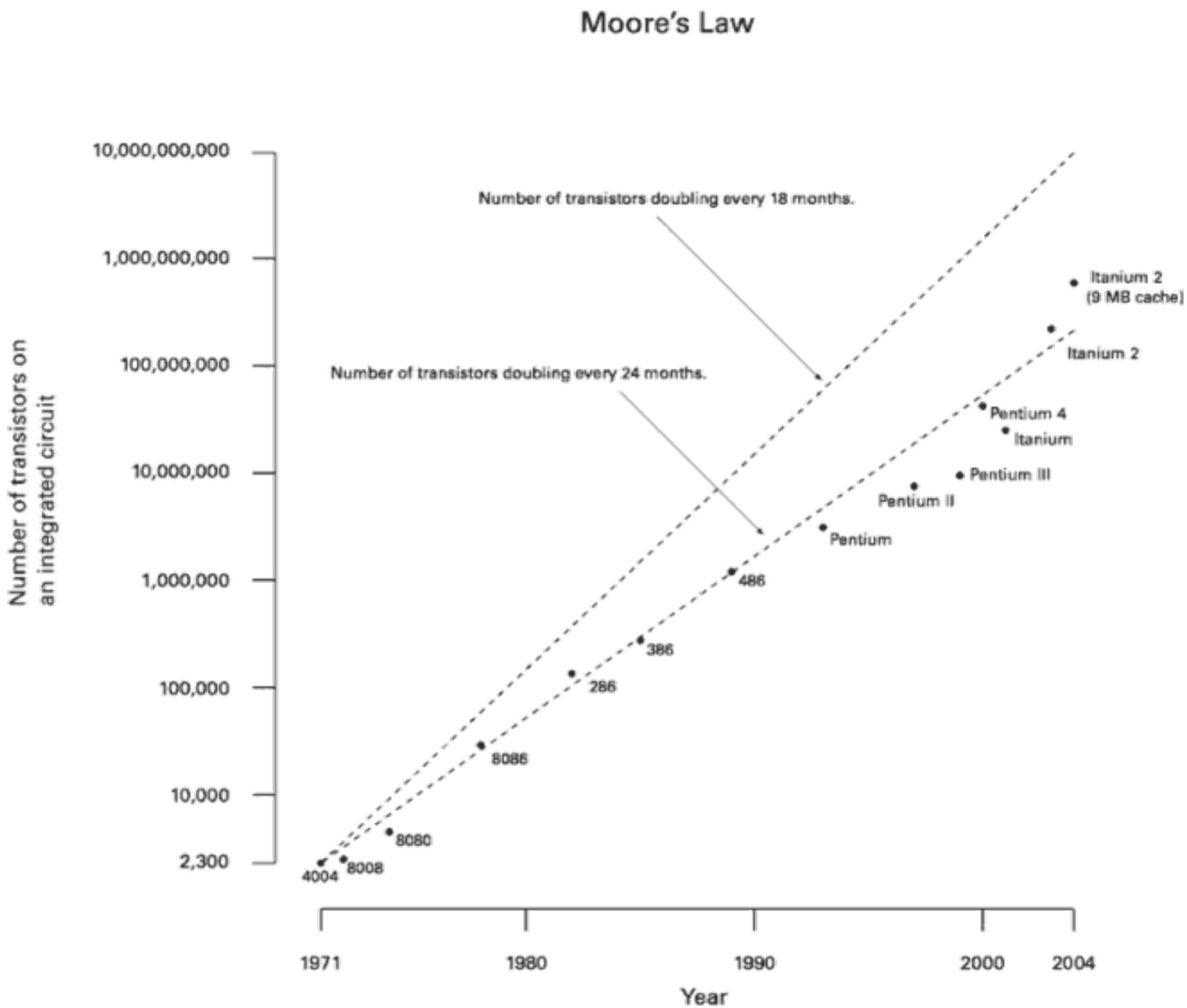
Source: IDC, 2007

Computer Power Use

- Energy savings trails off everything
  - Small percentage improvements annually
- Energy consumption secondary design consideration:
  - Idle laptop: 20–30 Watts
  - Idle workstation: 60–80 Watts
  - Idle server: 200+ Watts

“Green” Research

- Turn off components automatically
  - Without annoying users
- Better hardware components
  - Without slowing down the system
- Use FLASH to store data
  - Lower costs, improve reliability
- Lightweight software
  - Without reduced functionality


Moore's Law
10,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
2,300
Number of transistors on an integrated circuit
Number of transistors doubling every 18 months.
Number of transistors doubling every 24 months.
Itanium 2 (9 MB cache)
Itanium 2
Pentium 4
Itanium
Pentium III
Pentium II
Pentium
486
386
286
8086
8080
8008
4004
1971
1980
1990
2000
2004
Year

Today's Storage Hierarchy Pyramid