Solving the I/O bottleneck with Flash

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Agenda

- Performance bottlenecks in HDD
- Alternative solutions
- SSD value proposition
  - Benchmark results
- The future of SSD in notebook PCs
- Summary

Hard Disk Drives (HDD) evolution

- New perpendicular technology
- Higher capacities:
  - 40GB → 1TB with multiple platters (mobile HDD 200GB)
- Faster RPM:
  - 4200RPM → 5400RPM → 7200RPM (→10k and 15k RPM for enterprise)
  - Higher sequential transfers (MB/s)
  - But more power consumption
- Lower cost per GB

Not all is Rosy for HDDs

- HDD's inherent mechanical design limits system performance improvements

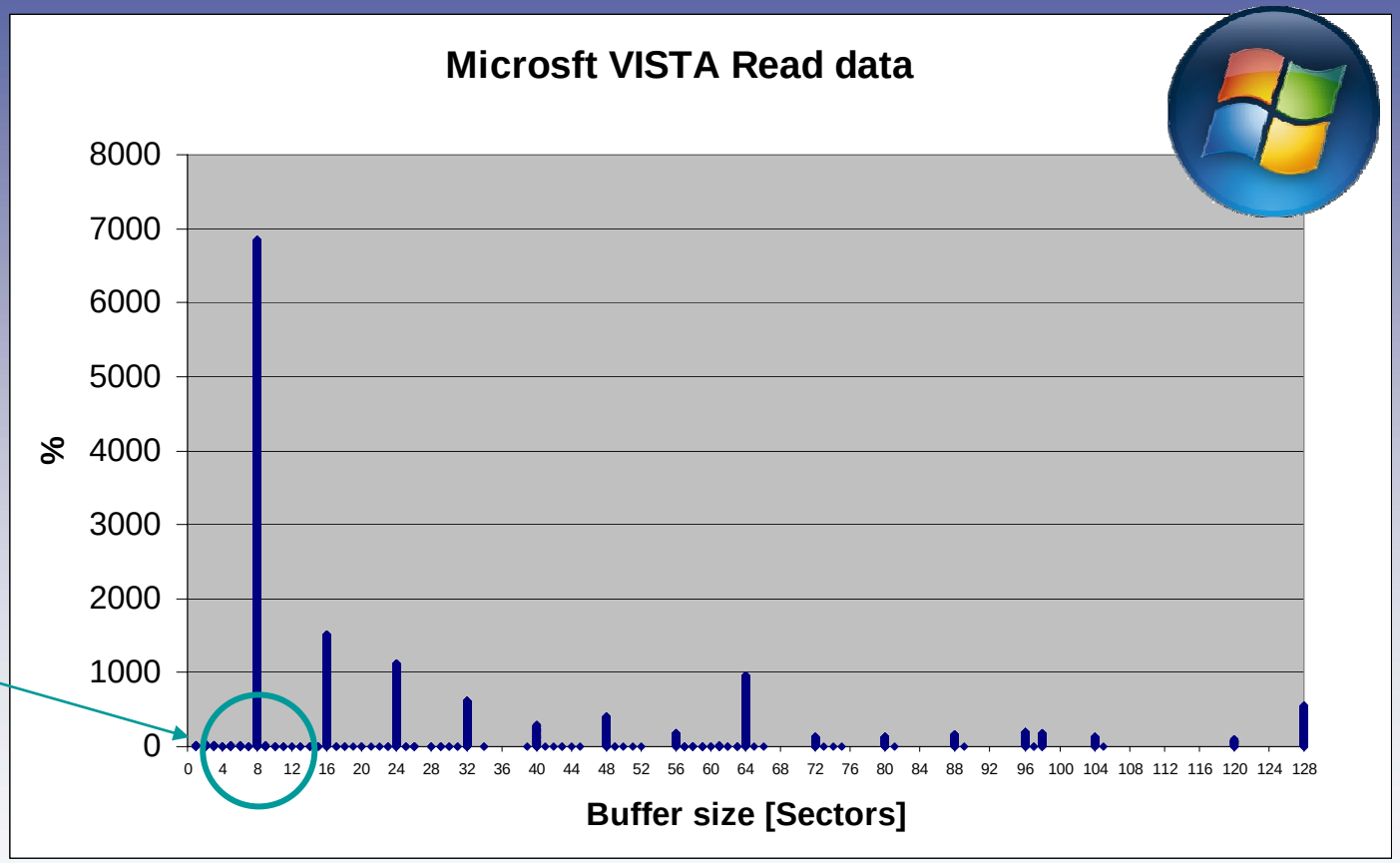
WHY?

Terminologies: Random vs. Sequential

- Random and sequential terms are used while discussing disk behavior
- Random activity means the disk accesses blocks from random locations on disk, usually incurring a time penalty while the disk heads seek and the disk itself rotates
- Sequential activity means the disk accesses blocks one after the other as they are located on the same sector

Windows Vista file transactions

Windows Vista file size



4KB size

When Random and Sequential are used?

Random

- OS changes and updates
- Applications and documents changes and updates
- Access user data

Sequential

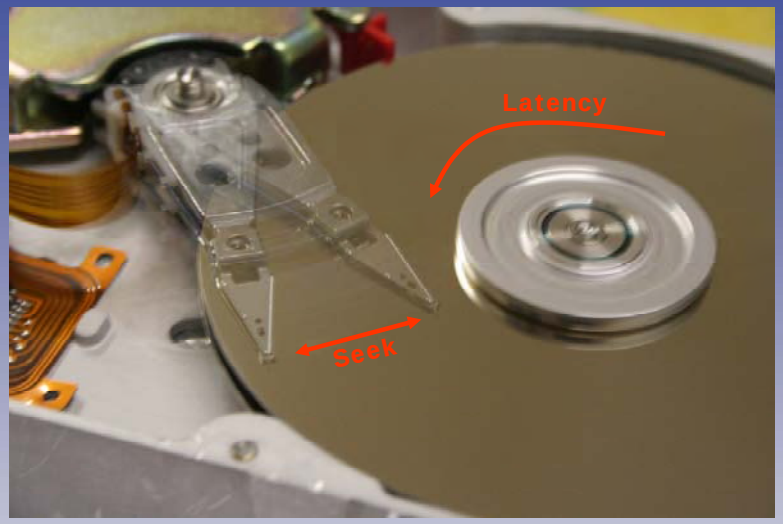
- Boot
- Hibernate
- Application load (main file)

For example:

When opening an application, the data files will be read in a sequential manner; however, all the associated DLL's (~100 in average) will be read and loaded in random from 5-6 disk locations per DLL

Overall system performance is mainly dependant on random read performance (IOPS) rather than sequential transfers

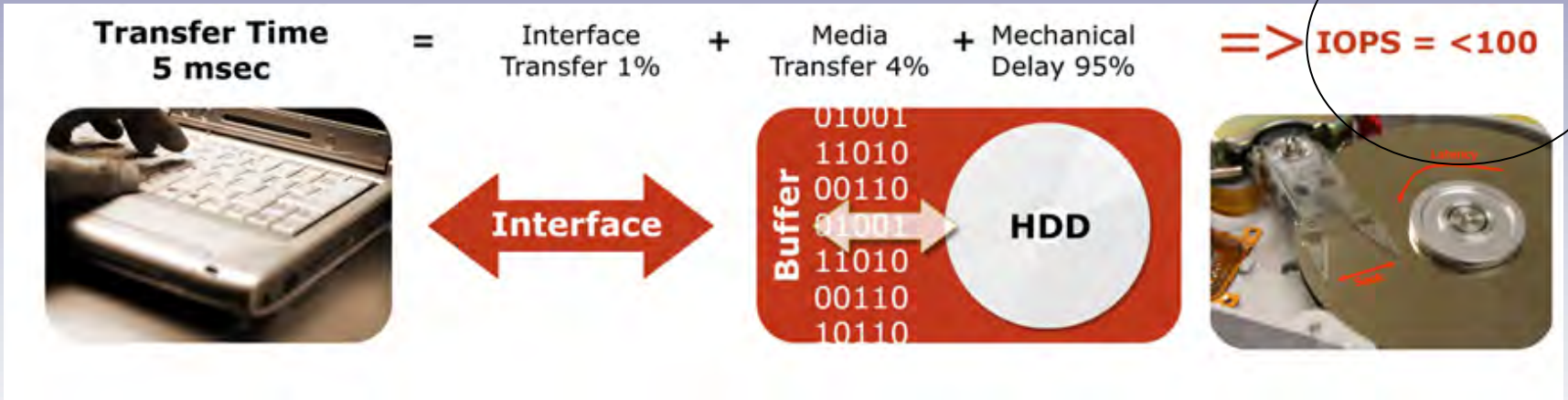
Hard Disk Drive: Seek & Latency



- When a request for data is issued, the drive head is most likely not in the right place to read the data.
- The first step in retrieving the data is for the armature to move the head over the track where the data resides.
- The second step is for the disk drive to wait for the desired sector to rotate under the head so that the data can be read/written.

Result: slow random read on HDD

- HDD transfer time = Interface transfer + media transfer + mechanical latency (in ms)
- Typical 4KB request:

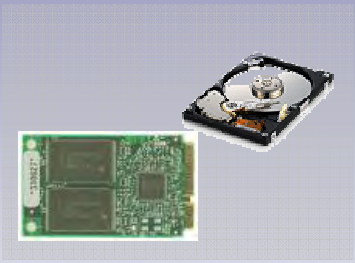


Low IOPS limits system performance

How to solve the low IOPS problem?

- System memory

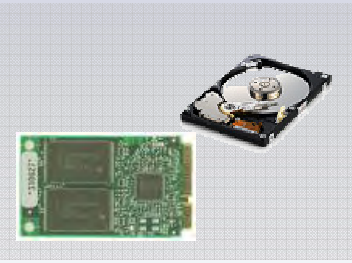
- Caching



- SSD

Not all solutions are equally good

- System memory:
  - Fast
  - Expensive
  - Limited capacity
  - Volatile
- Caching:
  - Limited capacity
  - No proven value
  - Inherent HDD limitations
  - Not plug-n-play



Testimonials

"The hybrid hard drive concept works, and I believe that there is a lot of room for improvement, but I would not pay any premium today to get an H-HDD today. Performance-hungry enthusiasts should wait for decent Flash-only hard drives…."

Tom's hardware July 13th, 2007

"**But, in contrast, HP claims that Turbo Memory represents poor value for money and that it limits flexibility**…".

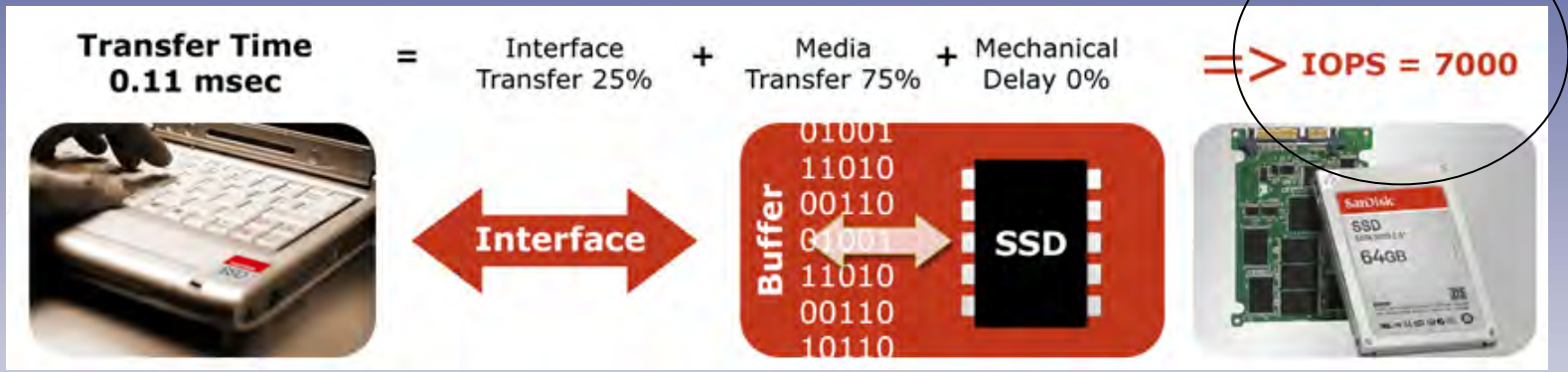
ZDNet June 4th, 2007

"There is no customer benefit right now [so] we decided not to integrate Robson and H-DD in the summer lineup [of new notebooks]…H-DDs are only available with 256MB integrated memory — too little to make a real difference. "

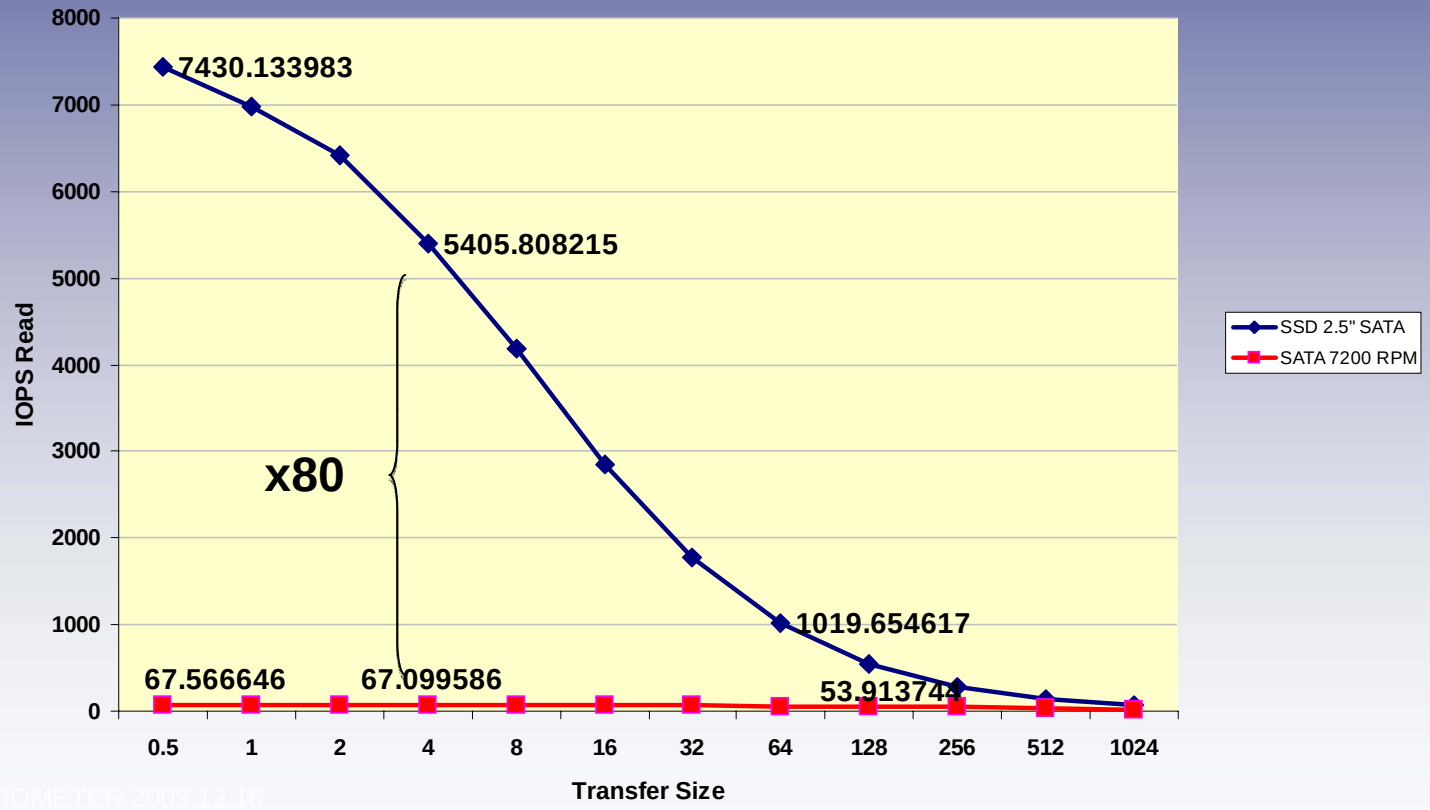
Sony to ZDNet, June 2007

SSD: No seek and latency

SSD offers high IOPS



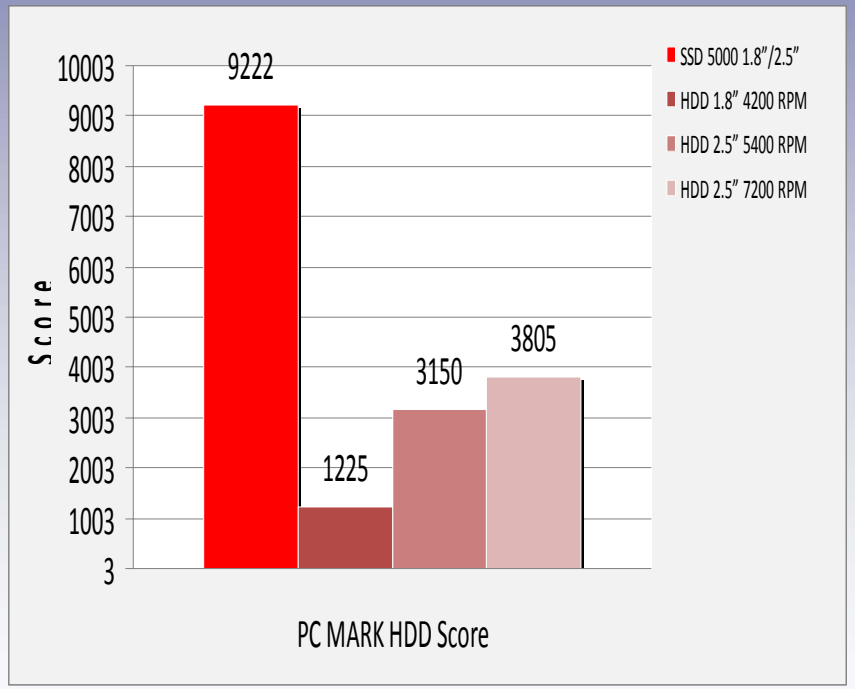
IOPS SSD vs. HDD



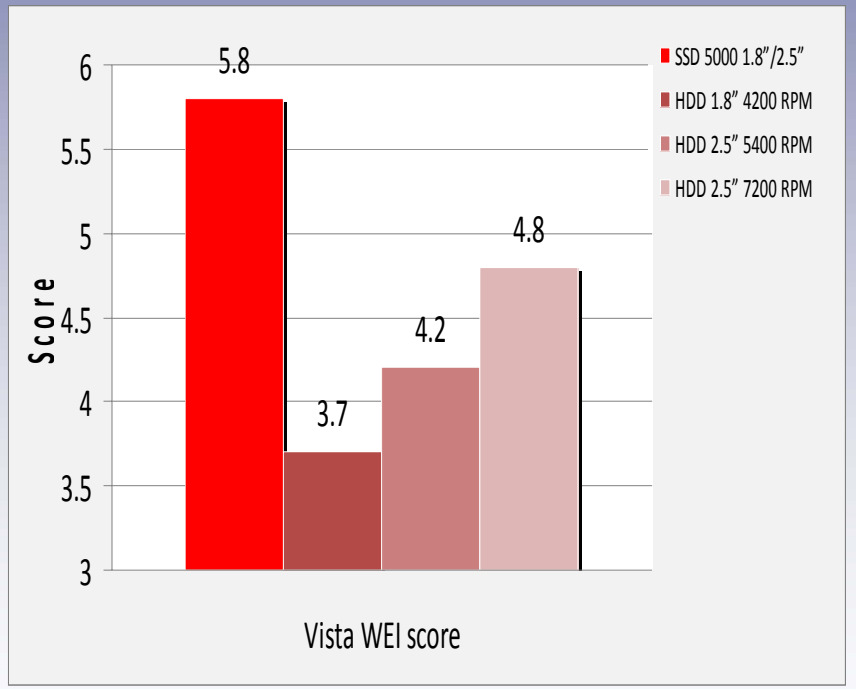
Based on IOMETER 2003.12.16

Performance

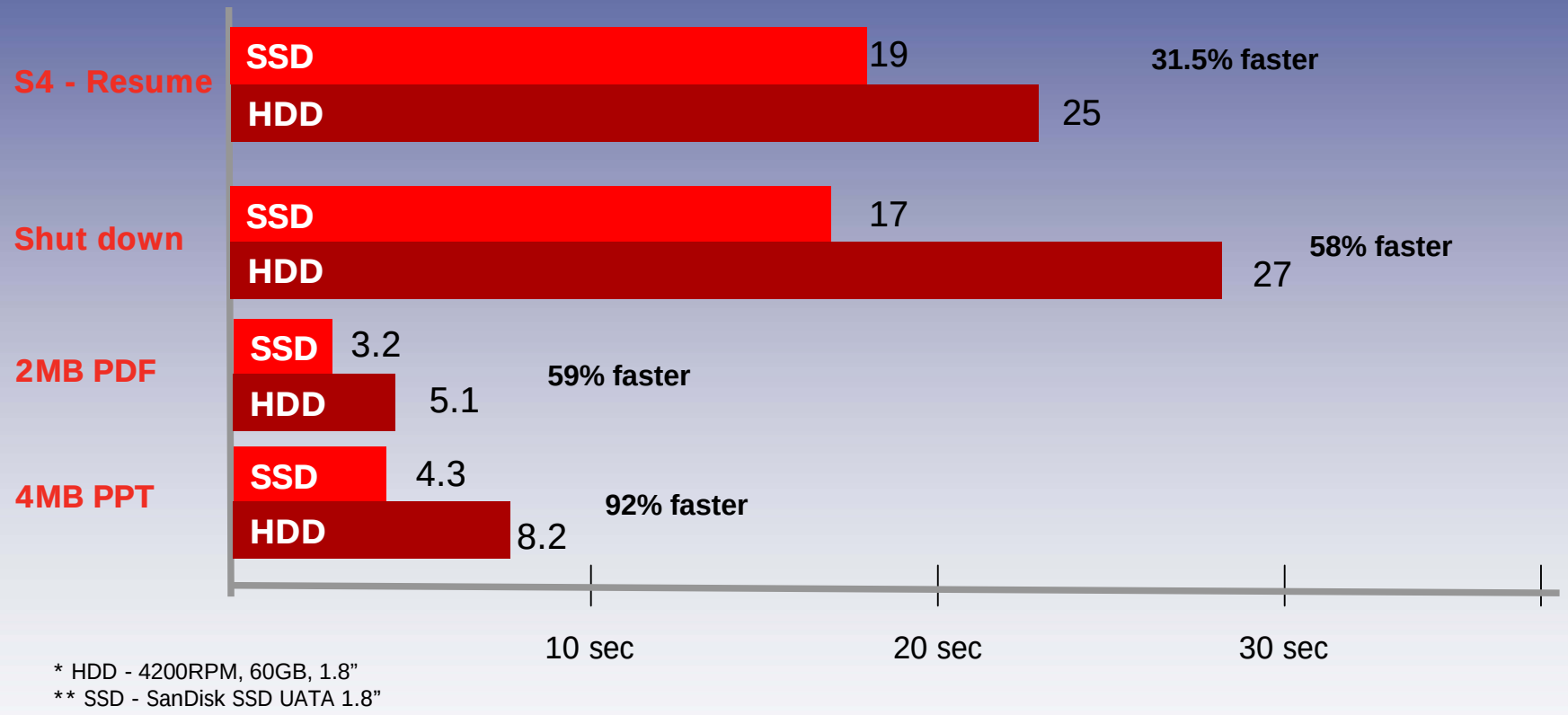
PCMARK 2005 Score for XP



Microsoft WEI Score for Vista



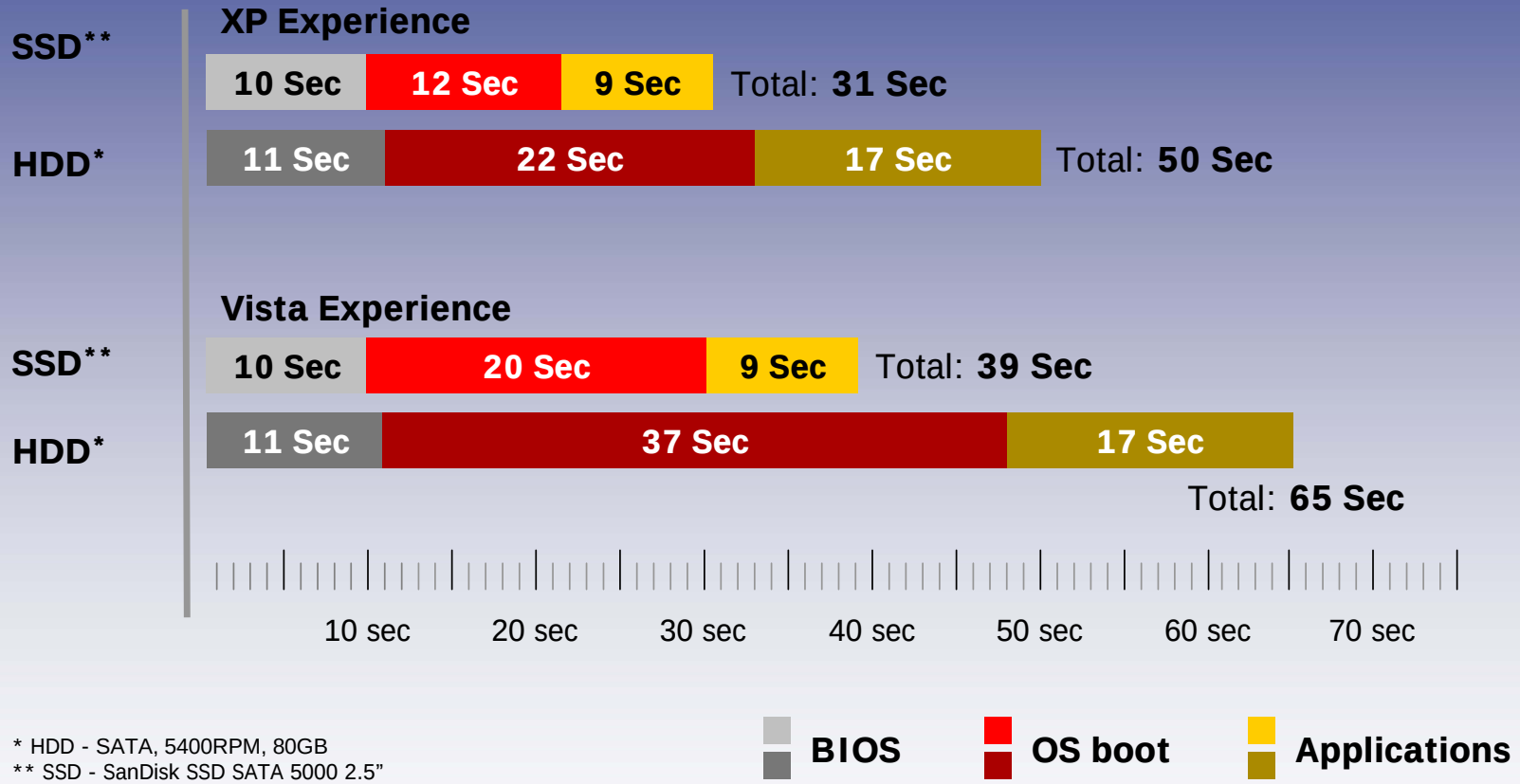
Vista User Scenario



* HDD - 4200RPM, 60GB, 1.8”
** SSD - SanDisk SSD UATA 1.8”

Conducted on Dell Latitude D420 notebook
(Intel Core Duo Processor ULV U2500, 1.20GHz, 533MHz, 1.0GB, DDR2-533 SDRAM)

User Scenario – boot and application launch



* HDD - SATA, 5400RPM, 80GB
** SSD - SanDisk SSD SATA 5000 2.5”

Conducted on Dell Latitude D620 notebook, (Intel Core 2 Processor T7200, 2.00GHz, 997MHz, 1.0GB RAM DDR2-533 SDRAM);

SSD offers more than performance → Reliability

- No failures from mechanical moving parts → Enhanced user experience over HDD
- Higher MTBF** (6x) resulting in lower failure rates and much lower chances for data loss
  - 2M hours vs. 300K hours

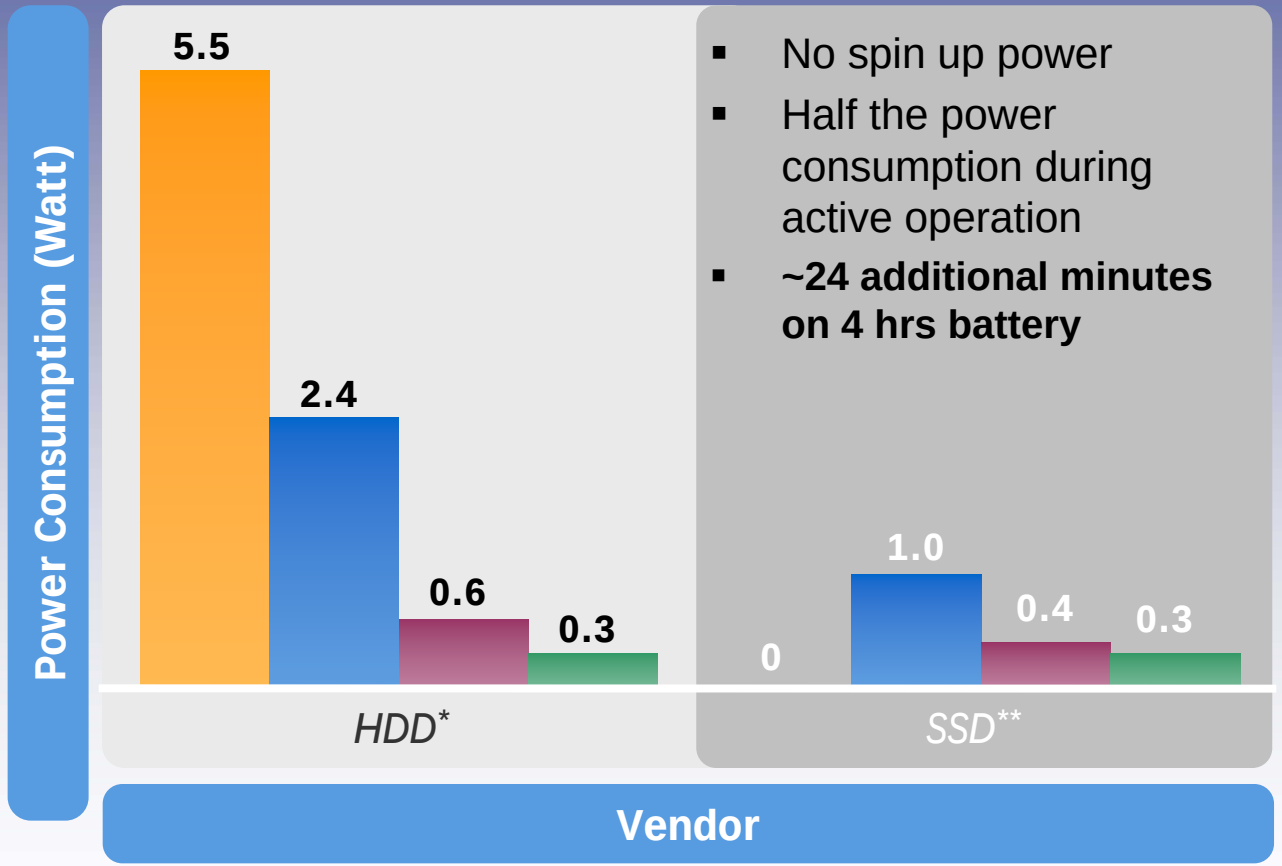
  → Minimal support requests
- Highly durable:
  - Operating shock 1500G vs. 300G
  - Operating vibration 2.17G vs. 1.0G
  - Up to 117% improved shock tolerance in operating mode

* HDD - MHV2080BH, 5400RPM, 80GB, SATA
** MTBF is calculated based on Parts Stress Method of Telcordia SR-332

SSD Lower Power Consumption

Longer battery life → Enhances user experience

Power Spin up *Power Read/Write* *Power Idle* *Power Sleep*



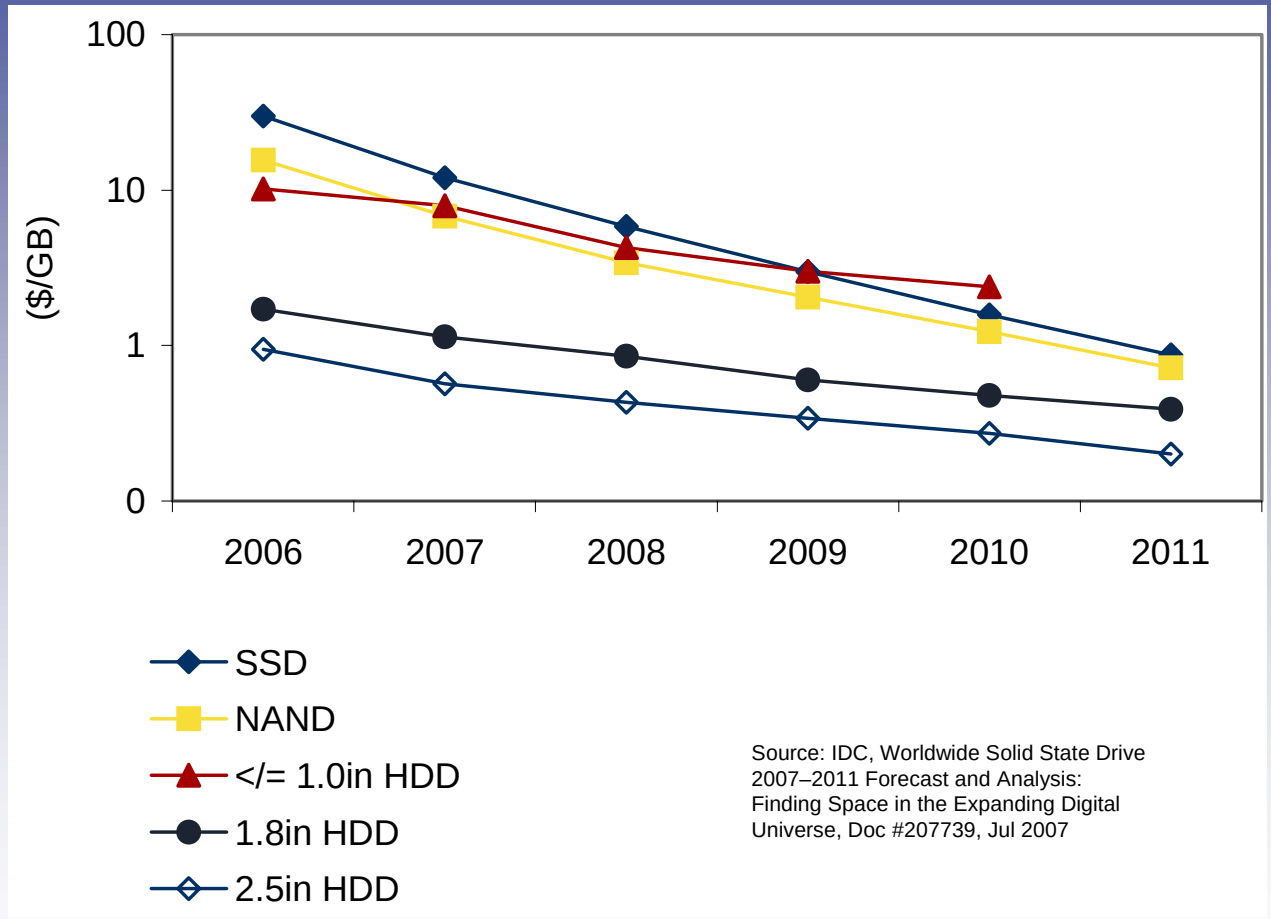
- No spin up power
- Half the power consumption during active operation
- **~24 additional minutes on 4 hrs battery**

* HDD - ST10021AS, 7200RPM, 100GB, SATA

** SSD - SanDisk SSD SATA 5000 2.5”

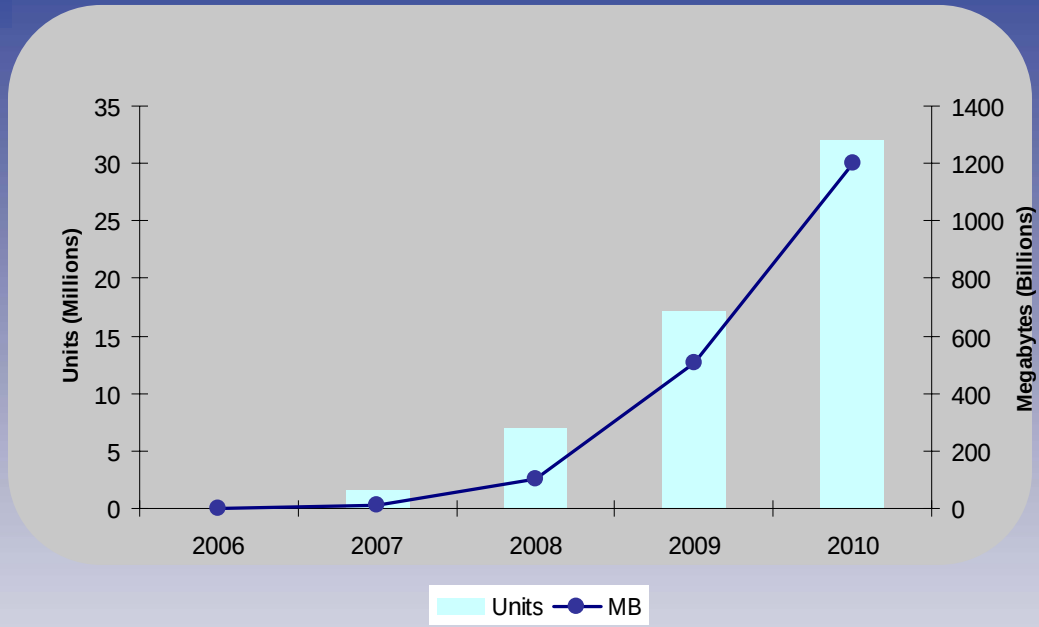
The Future of SSD in PCs

Average Price per GB comparison, SSD, NAND and HDD by Form Factors, 2006-2011



Source: IDC, Worldwide Solid State Drive 2007–2011 Forecast and Analysis: Finding Space in the Expanding Digital Universe, Doc #207739, Jul 2007

Projected SSD Penetration in Notebooks by 2010



- SSD penetration in ~20% of the notebook market = 32M units
- Penetration driven by elasticity and MLC adoption
- 1200 PB of NAND flash to be used in SSDs or about 11% of NAND output
- TAM >$3B in 2010 $100/system ASP

Source: Gartner, May 2007 Notebook market in 2010 is estimated at 153M units

Summary

- Random drive transfer rates are key to improve PC system's performance
  - IOPS and not sustained MB/s
- SSD design needs to focus on random read transfers to offer better system performance
- Caching or memory system solutions do not provide suitable solutions for I/O bottleneck and as long as HDD is used, overall system performance will be limited by its inherent mechanical delays
- Price elasticity will drive higher penetration to the PC market

Thank You