Client Caching: Solving Challenges Beyond Performance

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Agenda

- Client PC storage caching trends
- Challenges beyond performance
  - New system formfactors
  - Power
  - Always-on-always-connected systems
  - Demonstrating value to consumers

Client PC Storage Trends

- SSD, SSD+HDD and Hybrid HDD solutions all growing
- Value: SSD-like responsiveness at near HDD cost/GB

Exhibit 25

Overall, SSDs and Hybrid Solutions Will Replace HDDs, and We Expect HDD Usage in All PCs to Fall Below 50% by 2015

Year	Pure SSD	Cache SSD	Hybrid HDD	HDD
2011	4%			95%
2012	6%	3%		90%
2013E	10%	5%	4%	81%
2014E	16%	10%	14%	61%
2015E	21%	12%	21%	46%
2016E	25%	13%	24%	39%
2017E	29%	13%	25%	33%

Legend: ■ Pure SSD ■ Cache SSD ■ Hybrid HDD ■ HDD

Hybrid HDD

Cache SSD (SSD+HDD)

SSD

Source: "Global Memory: A New Paradigm (Part 5) – "Solid State Drives" the Future of NAND Demand Growth" Bernstein Research, Mark Newman, Sanford C. Bernstein

Intel® Smart Response Technology Overview

NEW

HDD + Discrete SSD Cache

- Available now (first shipped Mid 2011)
- RAID Mode Support Only
- Supports all SATA HDD and mSATA SSD models
- Minimum 16GB NVM required

Solid State Hard Drives
(w/ internal NAND cache)

- Available in Mid 2013
- AHCI and RAID Mode Support
- Supports SSHD drives enabled with Hybrid Information Feature
- Minimum 12GB NVM required

Two available options to accelerate storage performance

(intel)

Performance is Solved

- Best in class HDD+SSD cache / SSHD solutions demonstrate near SSD performance

- Good performance at low $/GB

- Results of Intel internal testing using Windows 8* application workload with 200+ events measured
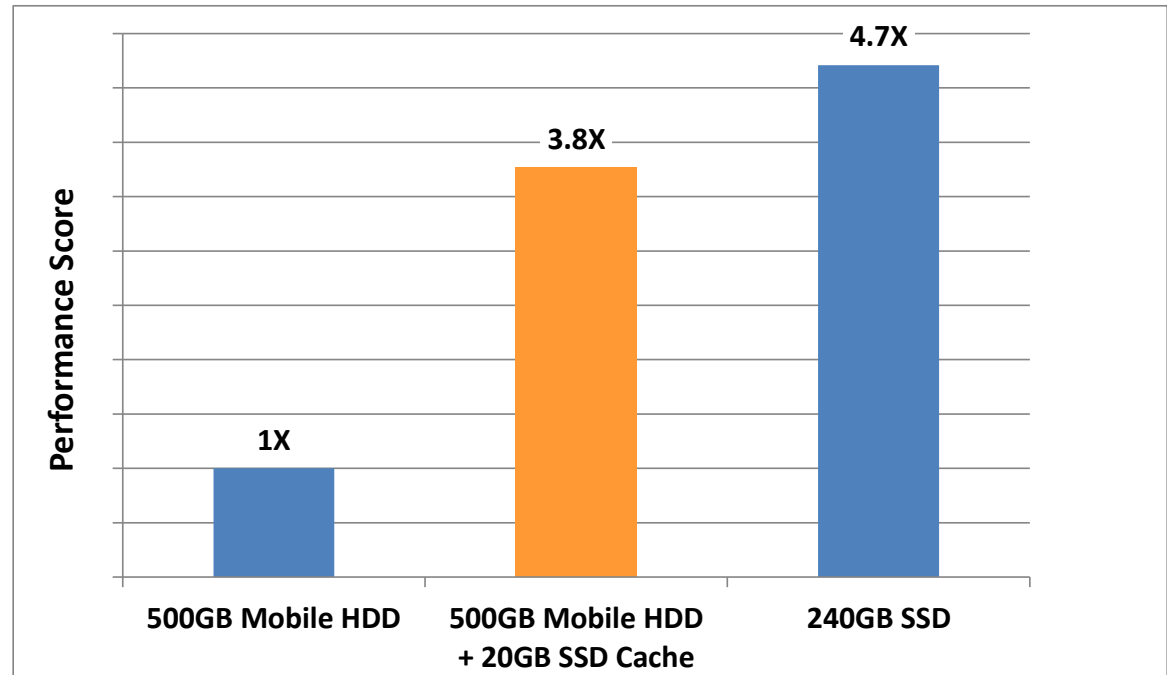
System Configuration: Intel(R) Core(TM) i7- CPU @ 2.90GHz, 3101 Mhz, 4 Core(s), 8 Logical Processor(s), 4GB DRAM, Intel® Smart Response Technology v11.6.0.1019, Microsoft Windows 8* x64, Intel 520 SSD, Intel 311 SSD, WDC WD5000BEVT-00A0RT0 500 GB HDD. Results have been estimated based on internal Intel analysis and are provided for informational purposes only. Any difference in system hardware or software design or configuration may affect actual performance.

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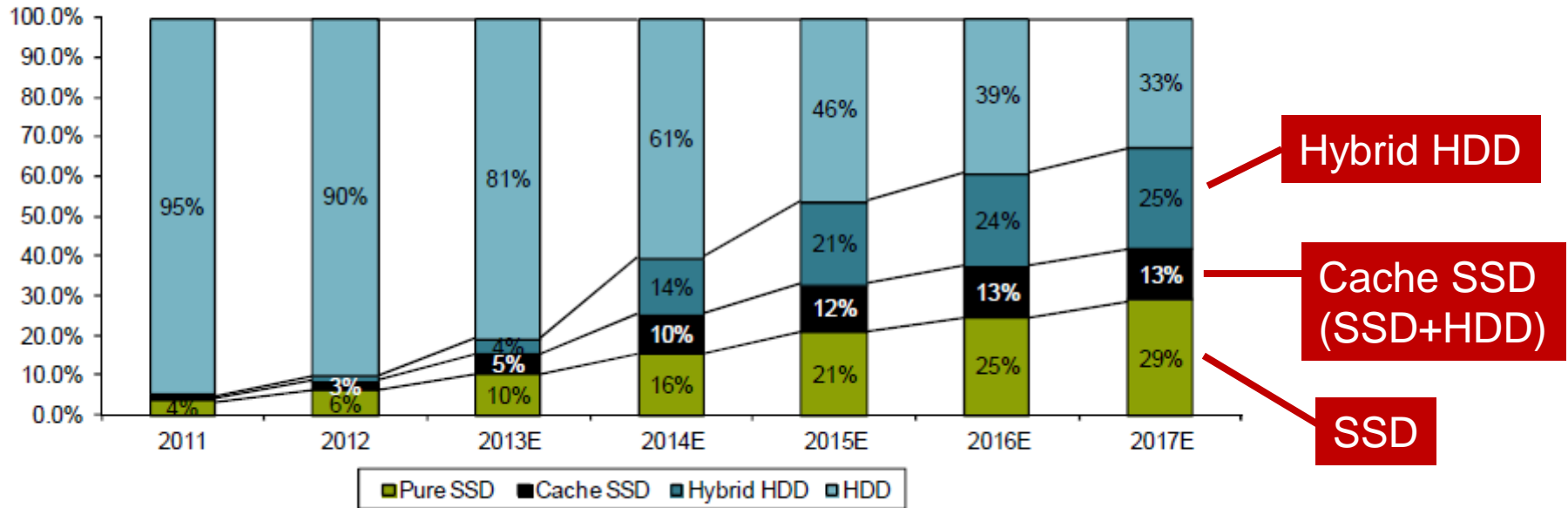 - Demonstrating value to consumers

New Formfactors: PC or Tablet? Both!

A New "2 in 1" Mobile Computing Experience

Surfing the Web
Social Networking
Advanced or Casual Games
Watch Movies
Read e-books, news
Entertain kids

Convertible & Detachable

Play

Work

Full Windows* 8
Modern and DT apps
E-mail, calendaring
Presentations, spreadsheets
Homework

*Other names and brands may be claimed as the property of others

All products, computer systems, dates and figures specified are preliminary based on current expectations, and are subject to change without notice.

Reducing I/O Caching Storage Power

- SSD power is lower than HDD+SSD cache and SSHD solutions

- Differences magnified in system idle case

Workload	Typical SSD	Typical HDD (incl. HDD+SSD or SSHD)	Approximate Difference
Web Browsing	50-60mw	500-700mw	10X
Media Playback	< 100mw	1W	10X
Idle (powered)	5mw	500-700mw (rotating)	100X
		100-200mw (spun down)	20X

Source: Intel internal projections and estimates based on system with Intel ® 4th generation Core™ CPU, 4GB DRAM, Windows* 8 RTM. Results have been estimated based on internal Intel analysis and are provided for informational purposes only. Any difference in system hardware or software design or configuration may affect actual performance.

Idle Power Savings Opportunity

- Limited windows of opportunity for > 1 sec I/O idle times

- Addition of NVM cache creates more idle time on the HDD
  - Particularly true for WB cache

- However, lowest power spindle states incur approximately 2-5 sec wake latency

Cumulative Distribution of Windows 8 I/O arrival times with idle notebook
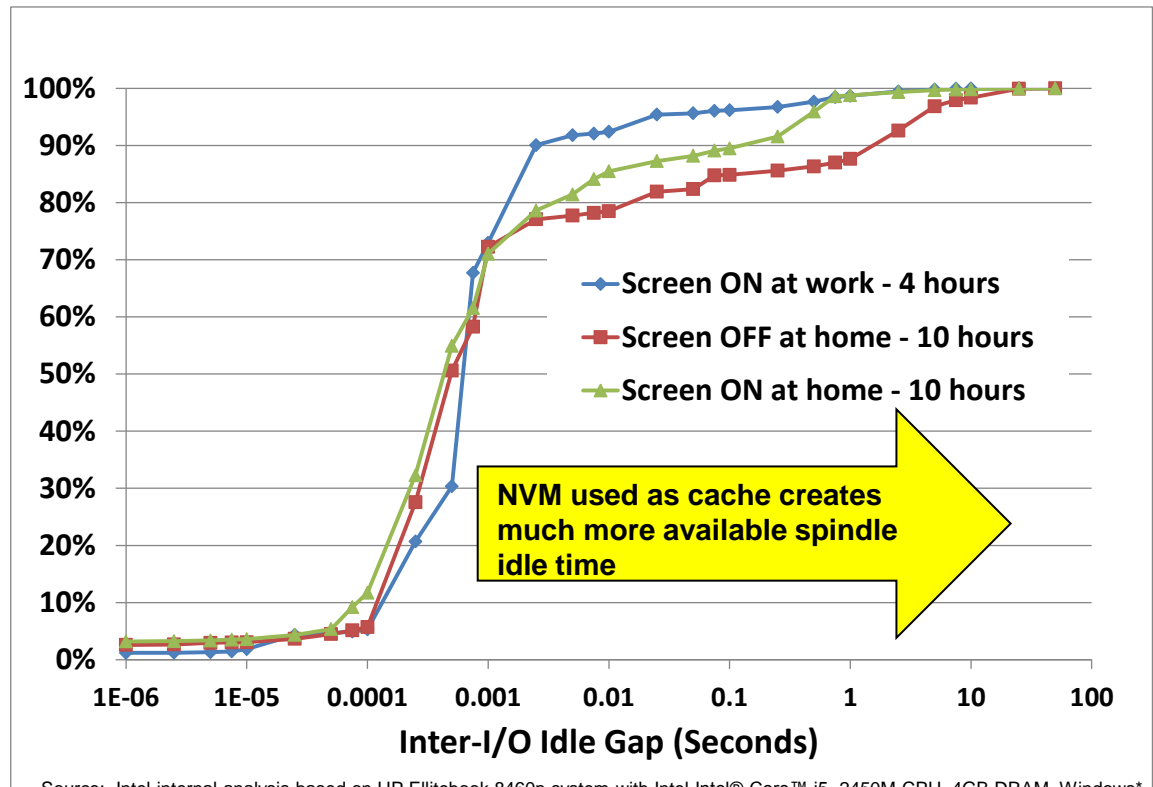
Legend:
- Screen ON at work - 4 hours
- Screen OFF at home - 10 hours
- Screen ON at home - 10 hours

NVM used as cache creates much more available spindle idle time

X-axis: Inter-I/O Idle Gap (Seconds)

Power Management of HDD part must use rich system state info to avoid exposing user to spindle wake latency

"Always Fresh" Data on Ultrabook™ PCs

Flash Memory

Intel® Smart Connect Technology "Mostly Off"

S0 — Active Workloads
- Lid Open, Display On
- User interaction with PC
- Battery Life measured by active workloads (for example: 6 hrs for media playback)

S0ix — Connected Standby
- Display Off, Apps & Devices Suspended
- Systems "wakes up" periodically to Refresh Apps or take incoming Skype*, IMs
- Battery Life measured by Activity Factor (for example, <5% battery drain over 16hours, > 10days in Standby)
- Fastest Resume Time from Display Off

Microsoft* Connected Standby "Always On"

S3 — Sleep
- All components powered off (display off)
- OS resident in memory (only memory has power)
- Battery Life measured by min power taken by memory (for example, >20 days in Standby)
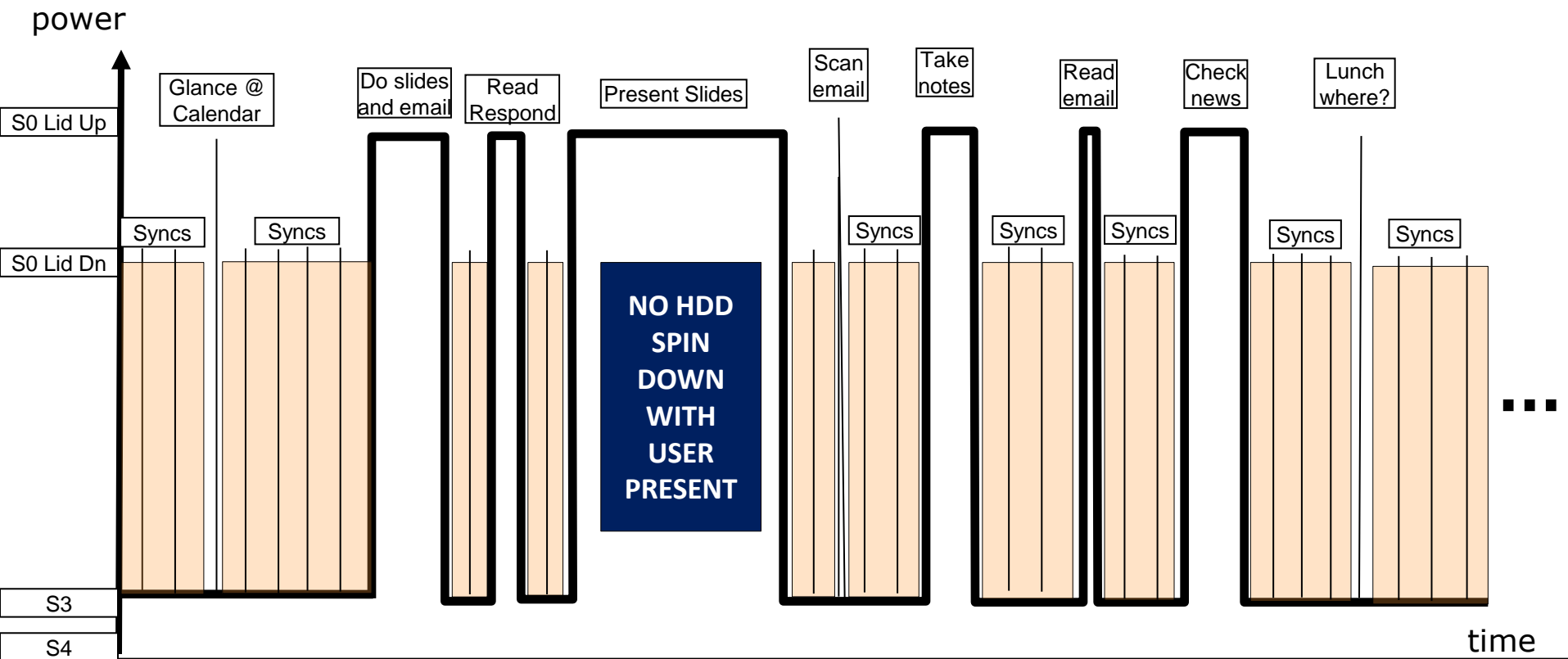
- Microsoft* Connected Standby currently "SSD only" (rotational media not supported for boot volume)

- Intel® Smart Response Technology caching solution is engineered and validated to work with Intel Smart Connect Technology

Always Fresh Data

- A morning in the life of an Intel® Smart Connect Technology and Intel® Smart Response Technology equipped Ultrabook™ system

power

| S0 Lid Up |
| S0 Lid Dn |
| S3 |
| S4 |

Glance @ Calendar

Do slides and email

Read Respond

Present Slides

Scan email

Take notes

Read email

Check news

Lunch where?

Syncs

NO HDD SPIN DOWN WITH USER PRESENT

time

- Intel® Smart Connect Technology syncs typically 5-15 seconds S0 time

=HDD spun down

Always Fresh Data Challenges

- Systems should look, feel and sound OFF when unattended wake events happen for "always fresh" data on NVM cache equipped systems
  - SSD-only systems set the bar
- HDD spin suppression required = PUIS enabled HDD, WB cache NVM
  - Cache preloading also beneficial

- HDD spin suppression has multiple benefits
  - Acoustics: not perceptible on a nightstand in a quiet room
  - Lower power
  - Reliability: approximates SSD with on-the-go usage, requires high HDD off time

Example Calculations of Annualized Failure Rate

HDD Range 2.5" Laptop

Guard Banded SSD Only

Guard Banded SSD + HDD@99.9% no-spin

Guard Banded SSD + HDD@85% no-spin

Best in Class SSD Only

Best in Class SSD + HDD@99.9% no-spin

Best in Class SSD + HDD@85% no-spin

Annualized Failure Rate

At 99.9% power-on spin suppression, failure rate for SSD+HDD is same as SSD
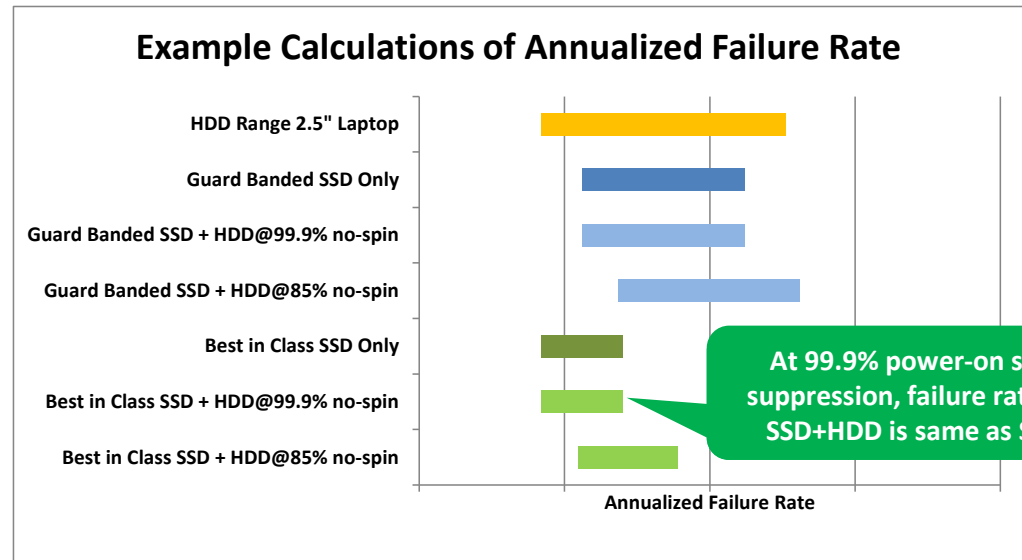
Source: Intel internal projections and estimates. System configuration: Intel® Core i7 CPU, Intel ® QM67 Express Chipset, 2GB DRAM, Windows 7* Ultimate x32, Results have been estimated based on internal Intel analysis and are provided for informational purposes only. Any difference in system hardware or software design or configuration may affect actual performance.

*Intel's engineering tests show > 90% spindle-off time acheiveable*

Performance is Solved - Almost

- HDD-equivalent cost goal is pressuring NVM cache capacity

- Cache too small may threaten basic value proposition of "SSD-like" performance

- Mitigation: cache sizing recommendations by user type/workload

	Entry 8GB cache w/ HDD or 8GB SSHD	**"Media Editor"** 16GB+ cache w/ HDD or 16GB SSHD	**"Gamer + Media Editor"** SSD or 32GB+ cache w/HDD
General Productivity	√	√	√
Photo & Video Editing	Some	√	√
Gaming		Some	√

(intel)

Performance is Solved - Almost

- PCMark* HDD is a popular storage benchmark
- Today's consumers may have muddied picture on what storage device will give them the user experience they desire
- Example: PCMark 7* score is significantly different from PCMark Vantage*. What do these scores communicate about user experience?
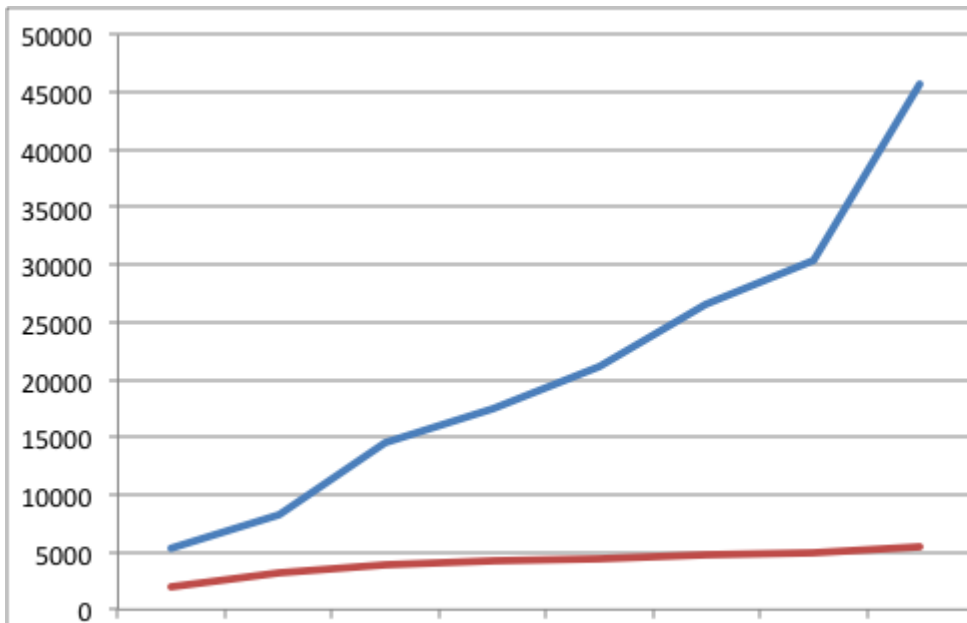
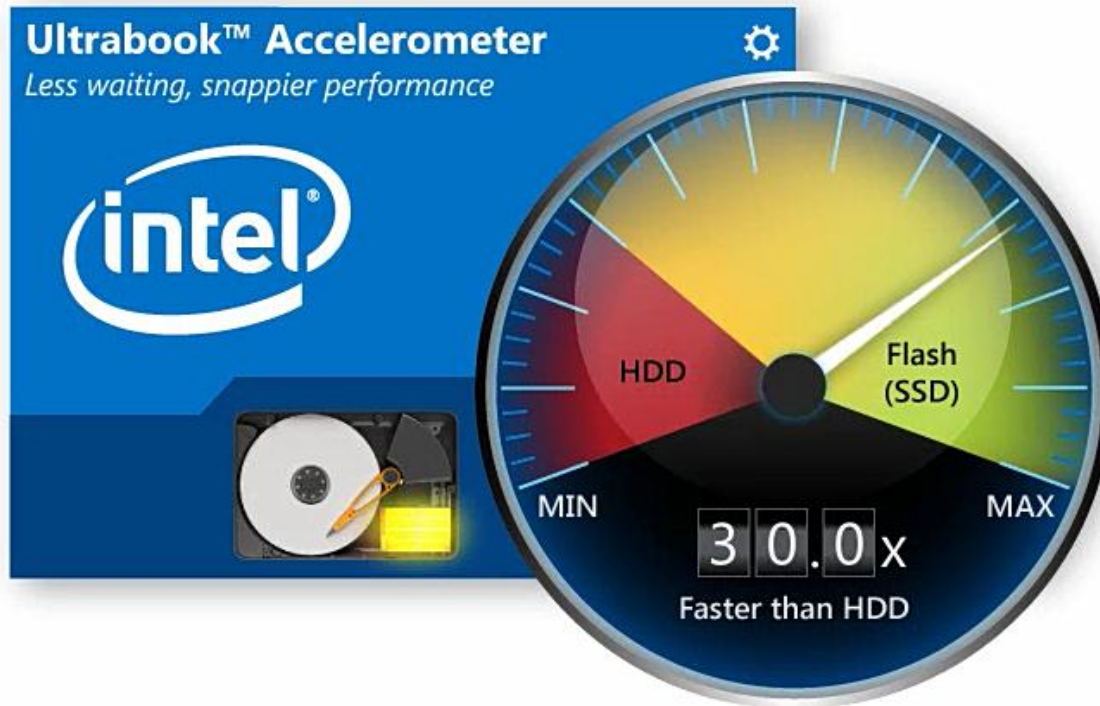|	Scaling
PCMark Vantage HDD	5.5x
PCMark 7 System Storage Suite	1.6x

Intel® Core i5-2400 CPU, 4GB DRAM, Intel DH67CF motherboard

Alternate approaches to measure User Perceived Responsiveness Needed

- Concept: visualizing the benefits of NVM at point-of-sale

Above graphic and video clip of is a concept showing simulated representation of operational characteristics, does not represent actual measured results

Educating end users about NVM performance key to driving up SSD/SSHD/HDD+SSD cache adoption

Summary

- Local storage: more is still better
    - Primary system purchase criteria / OEM differentiator
    - Instant access to my content stored locally
    - Local storage capacity continues to grow: security, cost, bandwidth concerns with public cloud storage
- SSHD and HDD+SSD cache solutions are evolving to achieve as close to full SSD experience as possible
- Call to action: end user education on the benefits of NVM