Intel Ultrabook™ Responsiveness and NVM Caching

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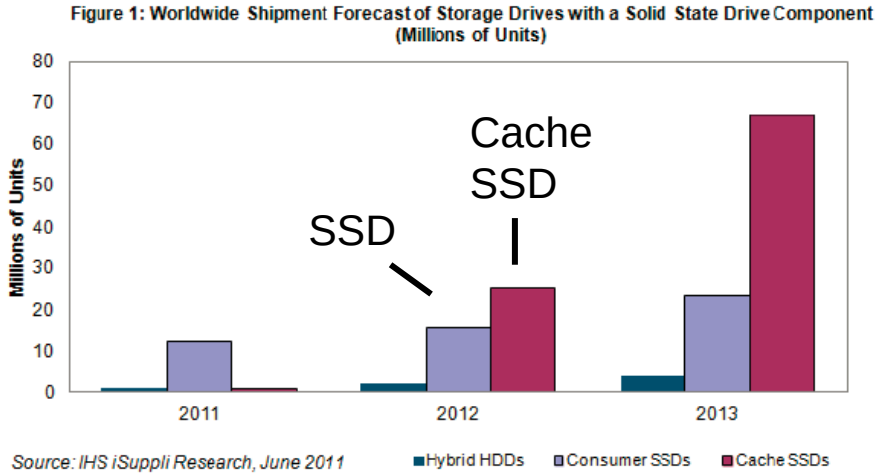
Agenda

- Ultrabook™ Storage Overview
  - Intel Responsiveness Technologies
  - Intel® Smart Response Technology
- Criteria for effective caching solutions
- Hybrid Drives in Ultrabook™

Ultrabook™ Storage Overview

- Responsiveness and capacity are key attributes of Ultrabook™ storage
- Ultrabooks™ require NVM
  - SSD-only
  - SSD cache
- How many GB's?
  - More is still better - primary system purchase criteria
  - Instant access to my content stored locally
  - Security, cost, 3G/4G bandwidth concerns with public cloud storage



Ultrabooks™ with high capacity storage highly desireable

2012 Responsiveness Requirement

- Three aspects to Ultrabook™ Responsiveness requirement
  - Demonstrated performance benefits > 4x of typical HDD
  - Minimum NVM size for caching of 16GB to cover typical workloads
  - Presenting a single drive for ease of use benefits

2012 Ultrabook™ Responsiveness Requirement	***1)Wake Up*** ***Baseline****: Awaken S4 to KBD: < 7 sec* ***AND***
	2) While Using: *Baseline: A storage solution that achieves a PCMark Vantage HDD Sub Score Overall ≥16,000** and a PCMark Vantage HDD Sub Score Video Editing Score of 80 MB/s. A minimum capacity of 16GB of solid state storage is required. The storage solution shall transparently present a single drive to the user.* *Recommended*: SSD

** Assumed score of 4000 points on PCMark* Vantage HDD Suite based on 500GB 7200RPM SATA Gen2 Mobile Drive with 16MB Drive Cache. Benchmark does not reflect encrypted accesses.

Intel® Responsiveness Technologies

	Value Vectors	Description	Technology	Benefit
	**Startup**	BIOS and driver optimizations	Active Resume BIOS Updates[1], Fast Boot	Faster button to browser
	**Quick Access**	Real-time content refreshed, while minimizing power consumption	Intel® Smart Connect Technology	Instant access to fresh data
	**Active Consumption & Creation**	Great performance while actively using PC	Intel® Smart Response Technology	SSD-like performance with HDD capacity, Faster boot times, application loading
	**Energy Efficiency**	Save energy without sacrificing user experience	Intel® Rapid Start Technology	PC consumes less energy, resume to active OS in 6 secs

[1] The feature formerly known as "Quick Resume" will be referred to as "Active Resume BIOS update". It is not part of the Intel® Smart Connect Technology feature name. It provides incremental resume benefits (~300ms savings depending on HW requirements) when BIOS is optimized.

Intel® Smart Response Technology

Small SSD

Large HDD

Versus 7200 RPM HDD

Ultrabook™
over 4x gains[1]

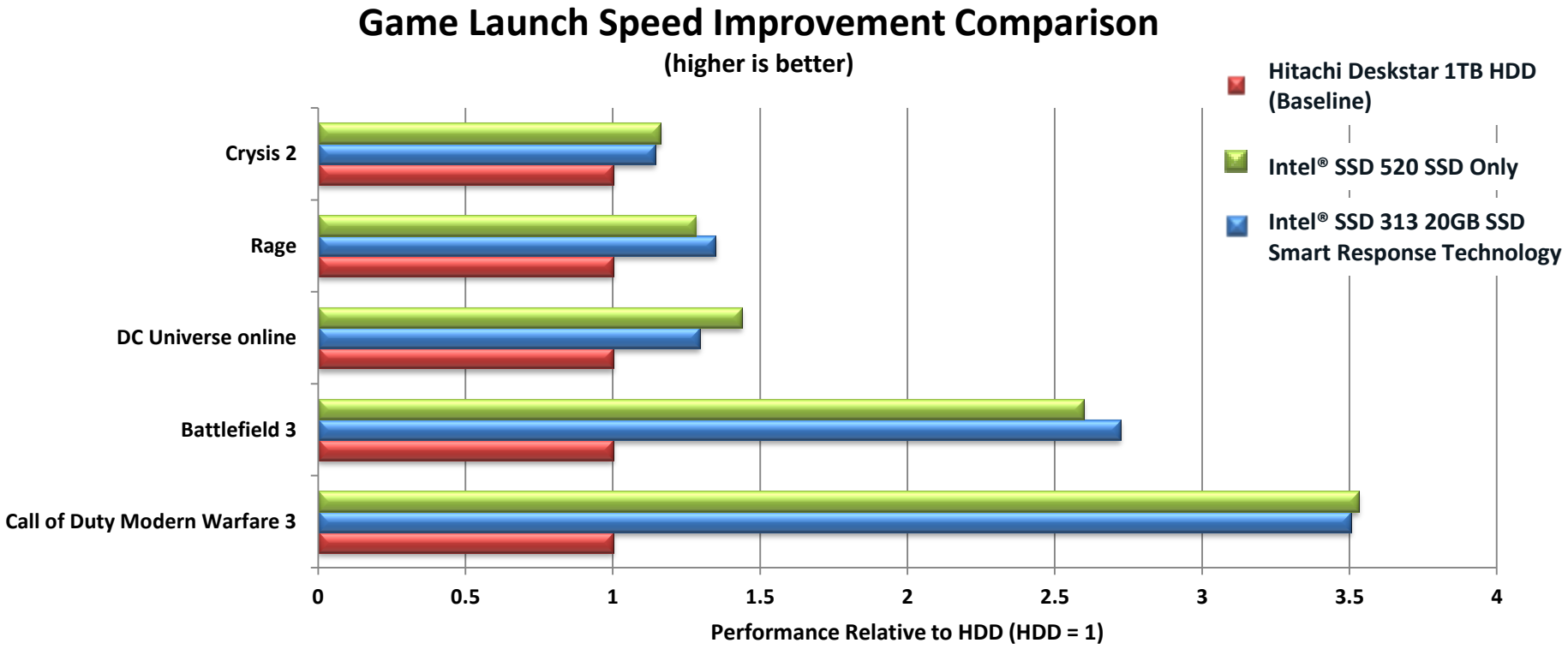
Benefits:

- SSD-like performance, HDD capacity without the high cost of a large capacity SSD - significantly lower cost per GB
- Faster boot performance
- Faster application loading
- User sees SSD (32GB) + HDD (e.g. 500GB) as one drive of 500GB

[1]As measured by PCMark* Vantage HDD suite.

Intel® Smart Response Technology Accelerates Game Performance

- Smart Response Technology matches the dramatic benefits of an SSD only system for game launch performance



Tests conducted by Intel STG. System configuration: Intel® Core i7 CPU, 4GB DDR3, Win7 Enterprise 64b Intel® Smart Response Technology v10.6.0.1002. Consists of game (executable) launch and level load.

Criteria for Effective Caching Solutions

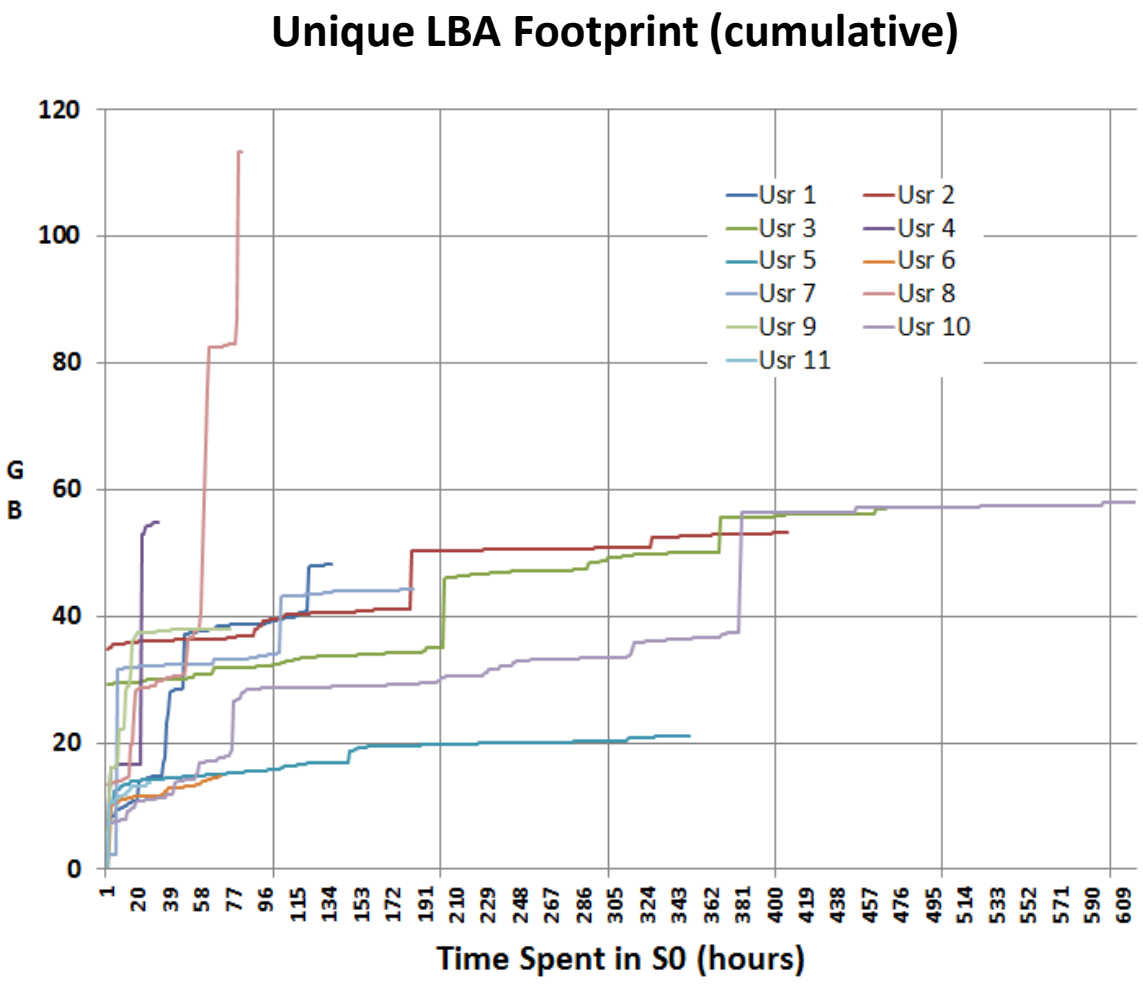
1. **Proper cache algorithms:**
   - Immediately puts the right things in the cache *and makes sure it stays it there*
   - Writeback cache for max performance and power savings
2. **Proper cache capacity:** contains the user data & OS persistent I/O working set
   - Required capacity depends primarily on user workload, but also on the cache algorithm
   - **System benchmarks like Sysmark, PCmark are not representative of I/O working set of actual system usage**

- **Good enough cache SSD:** demonstrably superior to HDD speeds in all metrics, with acceptable endurance

Good caching solutions deliver SSD like responsiveness

Sizing the Cache – I/O Footprint

- Benchmarks are often not reflective of the life of a real user
  - For example, PCMark* Vantage HDD has a footprint of ~ 2.5GB
- To determine minimum NVM size for caching, need to study real users' system
  - Traced home user systems on Win8** for 2 months
    I/O footprint exceeds 20GB for all users after just a few days of usage
  - Far larger than any existing system benchmarks

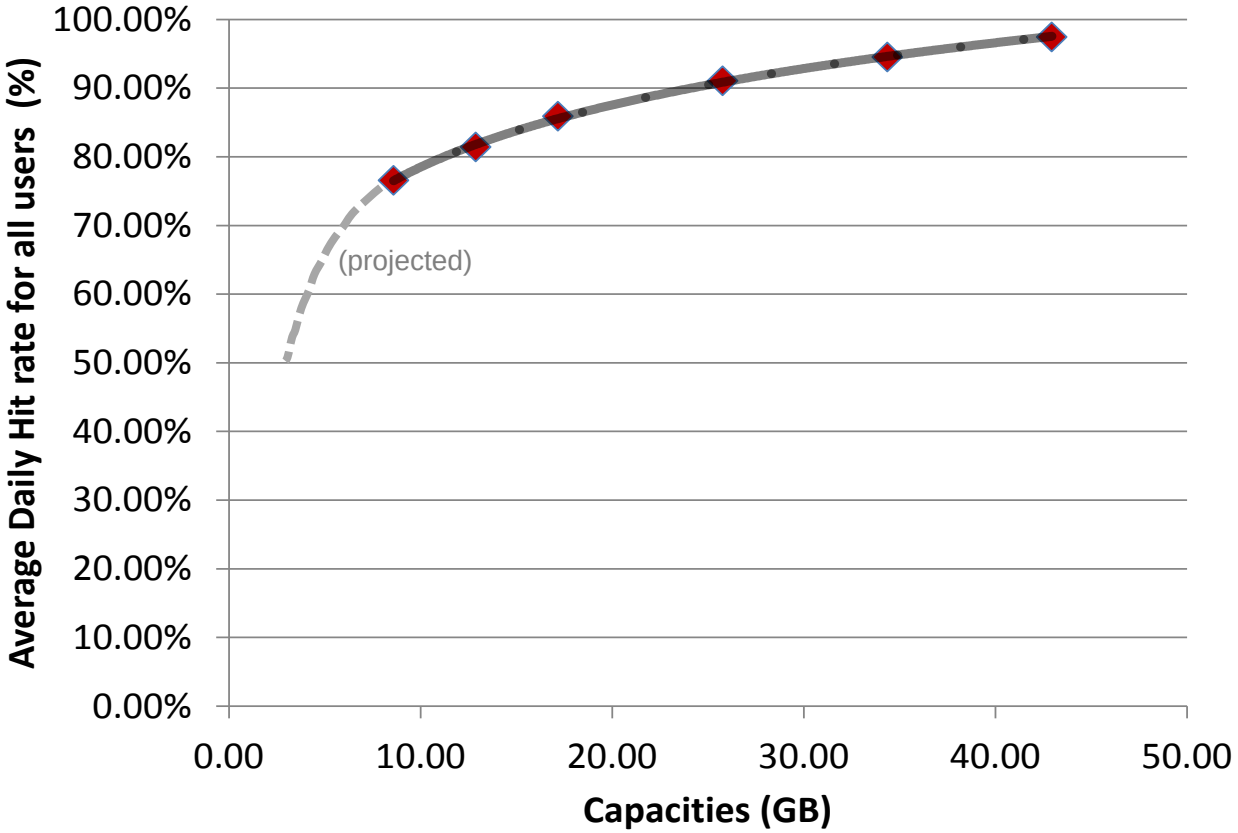


** Win8 pre-Beta Consumer Preview version

Good caching algorithms needed for responsiveness in real usage with 10s of GBs accessed per week.

Cache Hit Rate vs. Capacity

- Windows 8** user study simulation results
- Average daily read hit rate with aggressive cache algorithm (all writes cached)

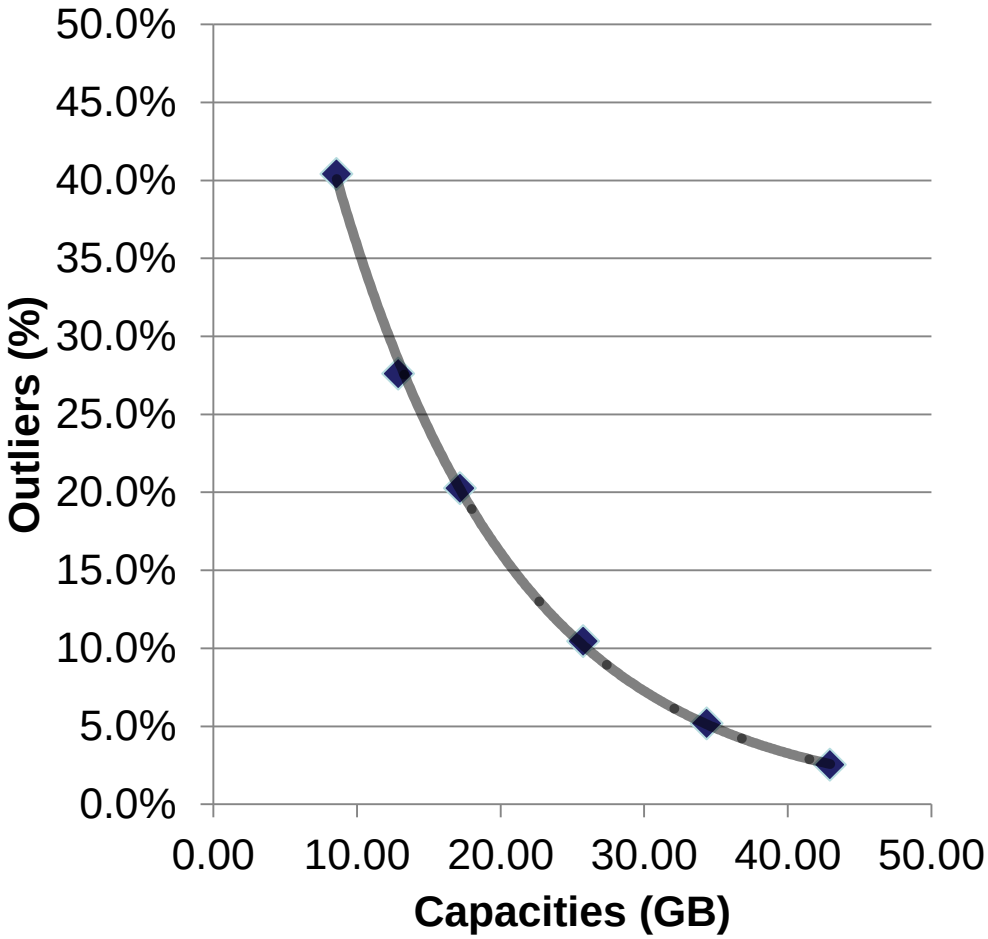


- Data set:
  - 9 notebook users
  - 521 total days of tracing (and growing)
  - Average 58 days traced per user, with average 140 hours in S0
  - Average 2.4 hours per day in S0

** Win8 pre-Beta Consumer Preview version

Cache Capacity vs. Hit Rate - 2nd Look

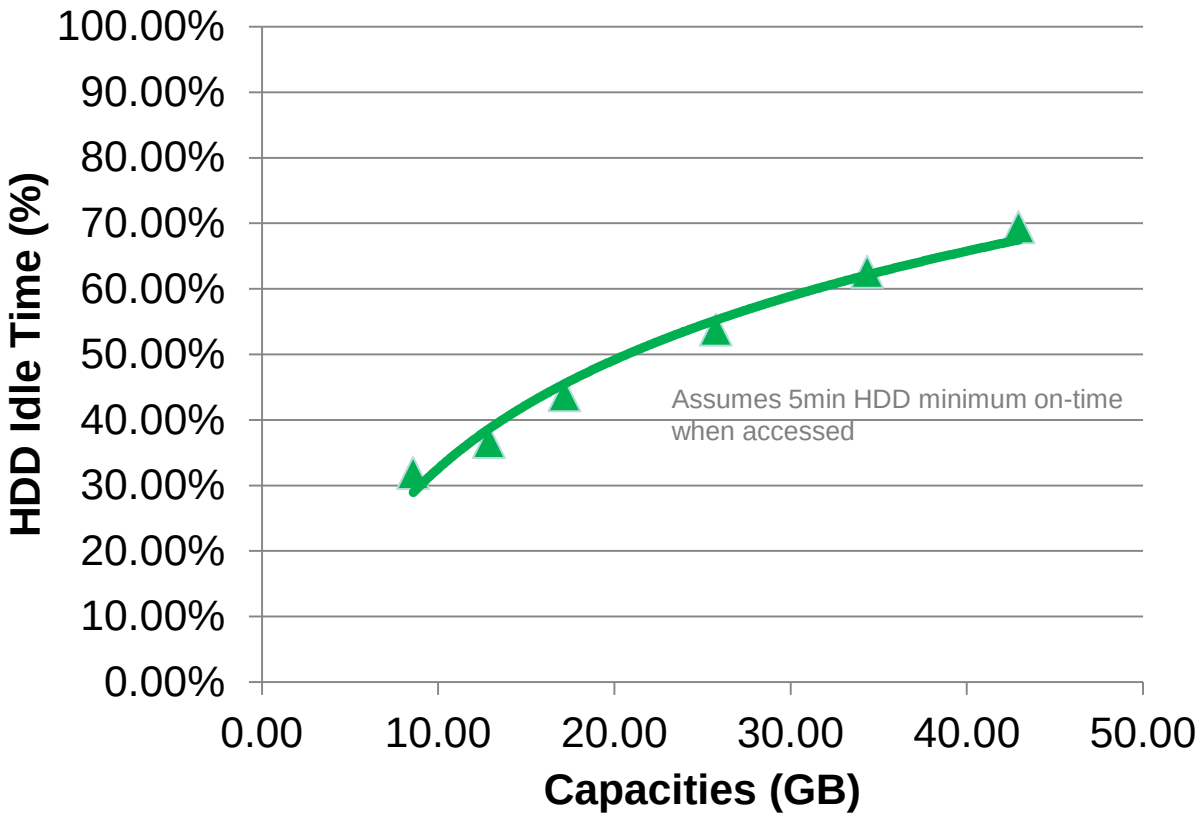
- "Outlier days" are days where hit rate < 90%
- Increasing cache capacity decreases frequency of outlier days
  - At 8 Gb, 40% of user days will see HDD like performance
  - At 24GB, 10% of user days will see HDD like performance
  - Exponential performance degradation



Cache hit rate is a proxy for SSD-like system responsiveness

Cache Capacity vs. HDD Activity

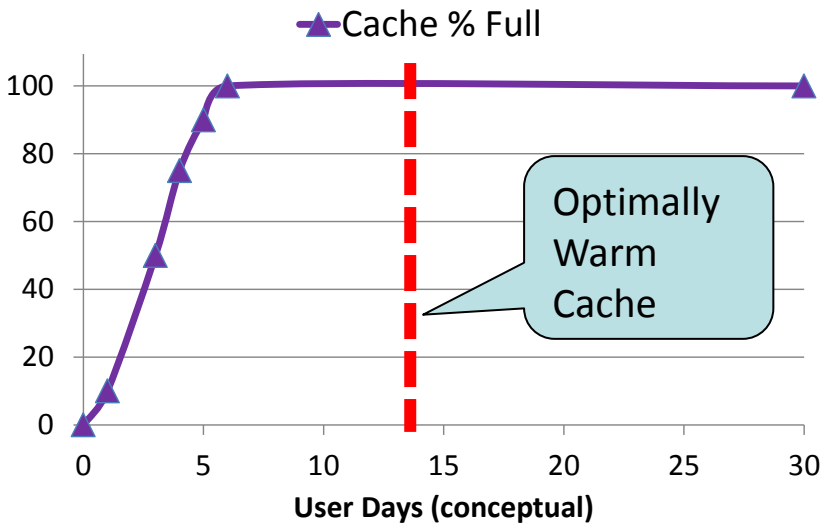
- HDD idle time in S0 w/aggressive cache algorithm simulation results



- Increasing cache capacity leads to more HDD idle time
- Saves power
  - HDD: 2.5 W active vs. 0.75W idle
- Without write caching HDD idle time is effectively 0%

Challenges of Measuring Goodness of a Cache Solution

- In actual usage, the cache steady state experienced by the user will be full and "warm" to the workload
  - Several days or weeks of system usage may be required to reach this state in real usage
- Accurate measurements of caching effectiveness need to account for this
  - Large workloads required that emulate user I/O footprint
  - Workload sequence that starts cache in known state then warms with this user footprint



- Existing benchmarks are an imperfect measure of responsiveness especially for I/O caches
  - User footprint and process for generating repeatable and accurate starting state are unique to I/O caching

Intel is targeting an accurately sized workload with user experience-driven responsiveness measurement in the future.

Intel® Smart Response Technology

Extending the Benefits to Hybrid Drives

- Hybrid drives (aka SSHD) combine a large capacity hard drive with NAND
  - E.g., 320GB hard drive + 16GB NAND
- Hybrids offer unique benefits compared to a separate SSD/HDD caching solution
  - Consumes less physical space
  - Consumes less power (e.g., one SATA i/f)
  - Lower BOM (e.g., one circuit board)
- Hybrids have unique caching challenges
  - What is the file type and who is accessing?
  - SATA devices only see logical blocks

Intel and Seagate* prototype shows hinting software can provide up to ~30% performance gain PCMark* Vantage HDD over no hinting

Summary

- Ultrabooks™ require NVM to meet a specific responsiveness criteria
  - SSD-only
  - SSD cache
- Responsiveness and capacity are key attributes of Ultrabook™ storage
- Correctly engineered SSD Caching solutions provides SSD-like responsiveness at HDD cost/GB