**Tiered Storage: Enterprise TurboBoost™ HDD and Flash SSD – Better Together**

# Seagate® Enterprise TurboBoost™ HDD
## Part of an Enterprise Tiered Storage Strategy
## Enterprise TurboBoost™ HDD and Flash SSD – Better Together

### Performance, Availability, Capacity, Energy and Economic Effectiveness

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## July 9, 2014

**This Industry Trends and Perspectives White Paper is compliments of**

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*The best I/O is the one that you do not have to do. The second best I/O or IOP is the one with least impact and most benefit to your applications.*

### Introduction

The question to ask yourself is not if flash Solid State Device (SSD) technologies are in your future. Instead the questions are when, where, using what, how to configure and related themes. SSD including traditional DRAM and NAND flash-based technologies are like real estate where location matters; however, there are different types of properties to meet various needs. This means leveraging different types of flash SSD technologies in different locations in a complementary and cooperative aka hybrid manner.
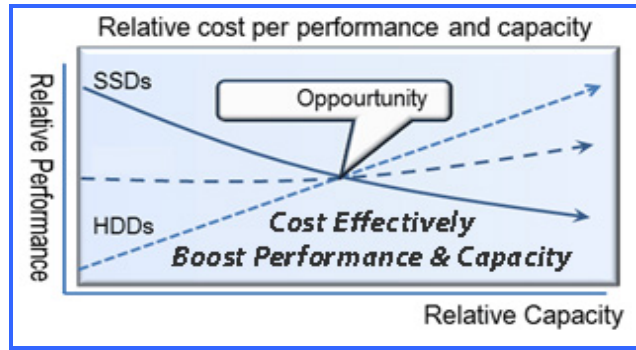


In this StorageIO Industry Trends Perspective thought leadership white paper, we look at how enterprise class TurboBoost™ Hard Disk Drives (HDDs)[1] address current and next generation tiered storage for virtual, cloud, traditional little and Big Data infrastructure environments.

### Background and Common Data Storage Challenges

There is no such thing as an information recession with more data being generated, processed, moved, stored and retained for longer periods. In addition, people and data are living longer as well as getting larger. We have continued growth with traditional little data (databases and traditional applications) along with Big Data and Very Big Data. These and other applications have the common characteristics of needing more performance to support transactions, videos, messages, pages and files served along with bandwidth and reduced latency (response time).

**Storage Tiers (device and mediums)**
**Tier 0 – SSD (DRAM or NAND flash)**
**Tier 1 – Fast HDD with TurboBoost™**
**Tier 2 – Slower high capacity HDD**
**Tier 3 – HDD, Tape or cloud service**

There are economic challenges requiring new outside of the box thinking boosting your return on innovation (the new ROI). Doing more with what you have or less includes consolidating data centers, servers and storage using virtualization. However, consolidation or aggregation also causes aggravation known as bottlenecks. The most common approach is to leverage lower cost, slower and high capacity HDD to support storage space consolidation along with various data footprint reduction (DFR) techniques including compression, dedupe and thin provisioning. Another approach is to leverage fast yet expensive lower space capacity NAND flash SSD to support IOPs or performance consolidation.

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[1] Note that these types of HDD have also been known or referred to as in the industry as Hybrid HDD (HHDD) that accelerate reads and Solid State Hybrid Drives (SSHD) that boost read and writes vs. traditional HDD by leveraging some amount of flash memory. Seagate Enterprise TurboBoost™ HDD boosts both read and write performance as shown in the proof points in this document.

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**Flash SSD in Different Locations that Matter**
SSD technology including NAND flash is like real estate in that location matters, as well as a relatively small amount in the right place can have a big impact. SSD can and should be deployed in different locations to meet various workload and data infrastructures demand requirements. This means that SSD are like real estate that comes in different varieties to meet various usage needs one of which is being close to where the IOPs are occurring. For applications and servers, this means caching as the best IO is the one that you do not have to do while the second is the one with least impact.

Using SSD in storage systems provides shared access benefit across multiple servers for both reads and writes. Seagate TurboBoost™ enterprise class HDDs compliment server and storage system based SSD by placing flash technology close to where actual reads and writes IOPs are performed to be more effective. Leveraging SSD technology inside, TurboBoost HDDs do more work (IOPs) effectively than traditional HDDs.

**TurboBoost™ HDDs Complimenting other Flash-Based SSD Technologies**
Enterprise HDDs with TurboBoost™ technology are a good complement to other flash Solid State Devices (SSD) including PCIe cards, drives and storage systems as well as tiering and caching software tools. Too often in the IT industry and particularly around data infrastructure related discussions, technologies are positioned as competitive, this vs. that as opposed to how they can complement making each more effective. For example, your applications need more I/O performance (IOPs, bandwidth or lower response time/latency) than what traditional HDDs provide. Thus, you may want SSD type performance for your applications. However, your budget requires that you innovate to stretch it to support space capacity growth needs. This is where balancing performance, availability, capacity and economics (and energy) come into play along with tiered storage devices (mediums).

The traditional approach has been to use some amount of NAND flash-based SSD located in servers and storage systems along with tiering and caching software for performance, and HDDs for space capacity. SSHD help to close the gap between higher cost per capacity performance

> **TurboBoost™ Technology**
>
> A Hybrid, best of SSD and HDD
> Functions and appears as a HDD
> Combines NAND flash with an HDD
> More performance than HDD
> Read and write IO acceleration
> More capacity per cost than SSD
> Durability duty-cycle of HDD
> No special drivers or adapters
> Locate flash close to where needed
> Do more with less

based SSD, and lower cost higher capacity slower HDDs. In other words as a Hybrid you get best of benefits from both technologies (performance, availability, capacity, energy and economics). How you leverage TurboBoost™ HDD to compliment your SSD deployed in various locations will determine your return on innovation. For example using SSHD as fast disk storage to compliment flash-based SSD server or storage system based caching. Keep in mind that fast servers, fast memory, fast SSD also need fast underlying magnetic storage devices to remove complexities, cost and bottlenecks.

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**TurboBoost™ Technology Today**
Hybrid Hard Disk Drives (HHDD) desktop, workstation or client class devices have been in the market for several years. However, those HHDD only helped speed up some read operations. Current generation enterprise class HDD with technology such as Seagate TurboBoost™ accelerates both reads and writes. DRAM cache has been available in enterprise class HDDs for many years; NAND flash SSD technology is the next evolution step to improve performance in cost effect manner.

> **Seagate Enterprise TurboBoost™ HHD**
>
> 2.5" 6Gbps SAS 600GB device
> Faster than 10K and 15K HDDs
> Includes read and write acceleration
> 32GB flash & 128MB DRAM buffers
> Non-volatile persistent memory
> Low power energy efficient

**Enterprise class HDD with TurboBoost™ and SSD tiered storage – Better together**
By placing some amount of DRAM, plus NAND flash along with non-volatile memory inside the HDD combined with intelligent TurboBoost™ algorithms results in a device able to deliver more performance (read and write) vs. traditional HDDs.  For example, writes can be buffered with persistency using non-volatile memory to maintain data integrity and application transaction state consistency while reducing response, the result is faster application performance. Another example is that reads can be optimized by increasing read ahead or other predictable activities leveraging flash to provide servers and storage systems with data in advance. The result is to reduce the amount of IOPs they may have to do (e.g. help their read and other cache functions). Intelligent cache algorithms also help to reduce the wear and increase the duty life cycle of nand flash to help protect your investment.

Collectively these enhancements make enterprise HDDs with TurboBoost™ a good option complimenting SSD based cache solutions that rely on underlying magnetic HDD for data storage. An example being VMware VSAN and caching for virtual server including VDI environments where SSD is used for reads with write-thru cache to fast TurboBoost™ enabled HDDs.

> **When to use Enterprise TurboBoost™ HDDs**
>
> ✓ Compliment SSD based solutions
> ✓ Fast magnetic storage needed
> ✓ Function as a fast write cache
> ✓ Replacement several slower HDDs
> ✓ Eliminate HDD based short stroking
> ✓ Server virtualization and VDI
> ✓ Virtual SAN (VSAN) caches
> ✓ Little and Big Data Meta Data
> ✓ Virtual, cloud and physical servers

As mentioned, the Seagate Enterprise HDD with TurboBoost™ is an example of leveraging the space capacity of a HDD while increasing performance in a cost effective manner. As tested in the following proof-points, the Seagate Enterprise class HDD with TurboBoost™ provides up to 600GB of storage space capacity along with faster performance compared to traditional enterprise 15K RPM HDDs. The performance boosts comes from read and write optimizations that leverage flash and other technology integrated within the drive itself.

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The technical benefit of using TurboBoost™ technology is providing higher performance compared to traditional HDDs at a lower cost vs. standard SSD devices. Table-1 (below) shows how Seagate Enterprise class HDDs with TurboBoost™ can be used as a high-performance storage tier, including with SSD based solutions.

In addition to those shown below in Table-1, other candidate applications and workloads include medical imaging, home directors and general file sharing. Other uses include cloud and object storage, physical and virtual machine page and swap files, content distribution networks (CDN) as a high speed magnetic object store complimenting SSD cache and meta data lookup.

| | |
|---|---|
| Data Protection (Archiving, Backup, BC, DR) | Staging cache buffer area for snapshots, replication or current copies before streaming to other storage tier using fast read/write capabilities. Meta data, index and catalogs benefit from fast reads and writes for faster protection. |
| Big Data DSS Data Warehouse | Support sequential read-ahead operations and "hot-band" data caching in a cost effective manner using TurboBoost™ vs. slower similar capacity size HDDs for Data warehouse, DSS and other analytic environments. |
| Email, Text and Voice Messaging | Microsoft Exchange and other email journals, mailbox or object repositories can leverage faster read and write I/Os with more space capacity. |
| OLTP, Database Key Value Stores SQL and NoSQL | Eliminate the need to short stroke HDDs to gain performance, provide more space capacity and IOP performance per device for tables, logs, journals, import/export and scratch, temporary ephemeral storage. Leverage random and sequential read acceleration to compliment server side SSD-based read and write-thru caching. Utilize fast magnetic media for persistent data reducing wear and tear on more costly flash SSD storage devices. |
| Operating Systems | Paging or swap along with other temporary storage for reads and writes. |
| Server Virtualization | Fast disk storage for data stores and virtual disks supporting VMware vSphere/ESXi, Microsoft Hyper-V, KVM, Xen and others. Holding virtual machines such as VMware VMDKs, along with Hyper-V and other hypervisor virtual disks. Compliment virtual server read cache and I/O optimization using SSD as a cache with writes going to TurboBoost™. For example VMware V5.5 Virtual SAN (VSAN) host disk groups use SSD as a read cache and can use SSHD as the magnetic disk for storing data while boosting performance without breaking the budget or adding complexity. |
| Virtual Desktop Infrastructure (VDI) | TurboBoost™ enabled HDDs can be used as high performance magnetic disk for storing linked clone images, applications and other data. Leverage fast read to support read ahead or pre-fetch to compliment SSD based read cache solutions. Utilize fast writes to quickly store data enabling SSD-based read or write-thru cache solutions to be more effective. Reduce impact of boot, shutdown, and virus scan or maintenance storms while providing more space capacity. |

Table 1 – Example application and workload scenarios benefiting from TurboBoost™

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**Proof Points and Enterprise HDD with TurboBoost™ Validation**
StorageIO has conducted various hands-on testing with the Seagate® Enterprise TurboBoost™ HDD in our StorageIO lab environment across different real world like application workload scenarios. These include general storage I/O performance characteristics profiling (e.g. reads, writes, random, sequential or various IOP size) to understand how these devices compare to other HDD, HHDD and SSD storage devices in terms of IOPS, bandwidth and response time (latency). In addition to basic storage I/O profiling[2], the Enterprise TurboBoost™ HDD was also used with various SQL database workloads including TPC; along with VMware server virtualization among others use case scenarios.

**Proof Point: Email Messaging**
Email and messaging are popular applications that combine the need for cost effective performance and space capacity. This proof point looks at how TurboBoost™ enabled enterprise class HDDs perform for Email or messaging activity handling repositories such as Exchange Databases (EDBs). For this scenario, Microsoft Jet Stress Exchange performance workloads were placed (e.g. EDB file) on each of the different devices under test with various metrics shown including activity rates and response time for reads as well as writes.

| | 400GB SSD 12GSAS | Ent. 15K HDD TurboBoost™ 600GB | Ent. 15K V4 HDD 600GB | 6TB 7.2K v4 HDD 12Gb SAS | 3TB 7.2K HDD |
|---|---|---|---|---|---|
| Avg. Total IOP/second | 2,791 | 334 | 252 | 174 | 95 |
| Avg. Reads resp. (msec) | 1.4 | 6.6 | 8.2 | 11.6 | 17.4 |
| Avg. Writes resp. (msec) | 1.3 | 4.7 | 33.9 | 33.0 | 49.2 |
| Avg. IOP (Read)/second | 1,486 | 181 | 139 | 89 | 52 |
| Avg. IOP (Write)/second | 1,305 | 154 | 113 | 85 | 42 |

Table 2 – Email - Microsoft Exchange JetStress workload (single device)[3]

Table-2 above results show performance improvements with the Exchange workload simulation using the Seagate Enterprise TurboBoost™ HDD compared to SSD and HDDs. As a Hybrid device, the SSHD demonstrate good performance and space capacity (best of both worlds) between SSD speed and HDD space capacity.

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[2]  Read more about basic Storage I/O profiling IOPs, latency and bandwidth at StorageIOblog.com
http://storageioblog.com/part-ii-iops-hdd-hhdd-ssd/

[3]  Test configuration: Seagate 400GB 12000 2.5" SSD (ST400FM0073) 12Gbps SAS, 600GB 2.5" Enterprise 15K with TurboBoost™ (ST600MX) 6 Gbps SAS, 600GB 2.5" Enterprise Enhanced 15K V4 (15K RPM) HDD (ST600MP) with 6 Gbps SAS, Seagate Enterprise Capacity Nearline (ST6000NM0014) 6TB 3.5" 7.2K RPM HDD 12 Gbps SAS and 3TB 7.2K SATA HDD. Email server hosted as guest on VMware vSphere/ESXi V5.5, Microsoft SBS2011 Service Pack 1 64 bit. Guest VM (VMware vSphere 5.5) was on a SSD based datastore, had a physical machine (host), with 14 GB DRAM, quad CPU (4 x 3.192GHz) Intel E3-1225 v300, with LSI 9300 series 12Gbps SAS adapters in a PCIe Gen 3 slot with Jet Stress 2010.  All devices being tested were Raw Device Mapped (RDM) where EDB resided. VM on a SSD based separate data store than devices being tested. Log file IOPs were handled via a separate SSD device also persistent (no delayed writes). EDB was 300GB and workload ran for 8 hours.

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Figure 1 below provides a graphical representation of the TurboBoost(TM) enabled HDD performance characteristics compared to the SSD and HDDs that were tested show read and write rates along with response times.
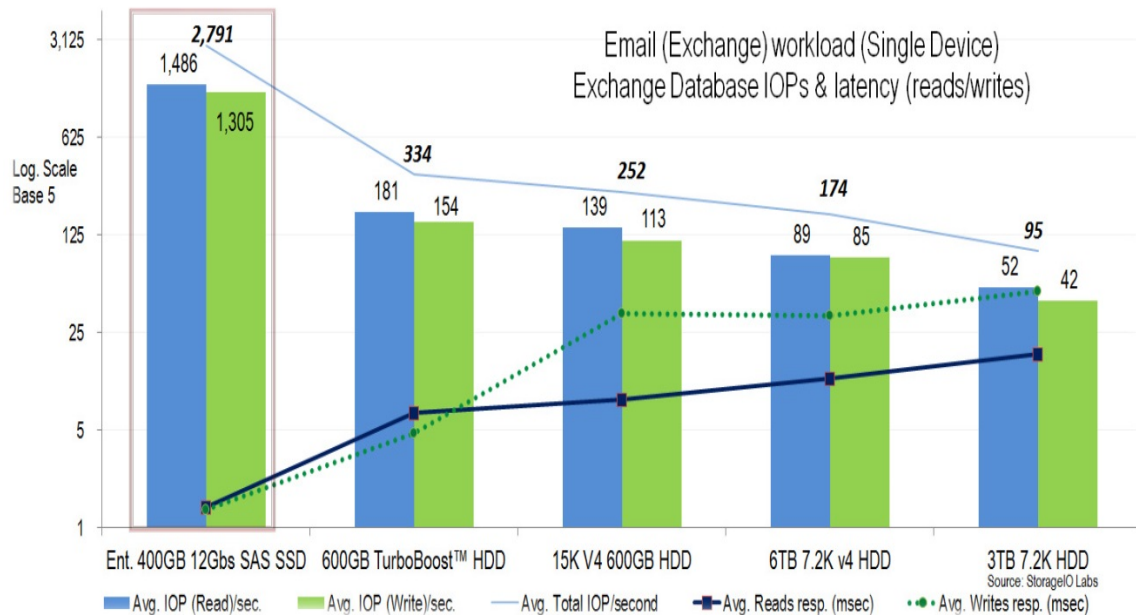


Figure 1 - Microsoft Exchange Jetstress workload (Database reads/writes and latency)

**Proof Point: Database, Data Warehouse Batch Update**

Enterprise class TurboBoost™ HDDs are a good fit for both transaction database activity with reads and write as well as query-based decision support systems (DSS), data warehouse and big data analytics. The following are proof points of enterprise class TurboBoost™ HDD capabilities for database activity. Two database workload profiles were tested including batch update (write-intensive) and transactional.

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Proof-points activity involved running Transaction Performance Council (TPC) workloads [4] TPC-B (batch update) and TPC-E (transaction/OLTP simulate financial trading system) against a SQL server database. Each test had the SQL database (MDF) on a different device with transaction log file (LDF) on a separate SSD. TPC-B for a single device results are shown for various user workloads in table 3.

| Device | User Load | TPC-B TPS | Avg. Resp. Time (Sec.) |
|---|---|---|---|
| 400GB Enterprise  SSD | 1 | 174 | 0.004 |
| 12Gbps SAS | 20 | 1,145 | 0.13 |
| | 50 | 1,165 | 0.03 |
| | 100 | 1,205 | 0.07 |
| 600GB Enterprise  15K HDD | 1 | 69 | 0.01 |
| TurboBoost™ | 20 | 243 | 0.08 |
| 6Gbps SAS | 50 | 287 | 0.17 |
| | 100 | 300 | 0.33 |
| 600GB Enterprise  15K HDD | 1 | 65 | 0.13 |
| 6Gbps SAS | 20 | 216 | 0.09 |
| | 50 | 230 | 0.21 |
| | 100 | 245 | 0.40 |
| 6TB 7.2K RPM HDD | 1 | 26 | 0.02 |
| 12Gbps SAS | 20 | 82 | 0.11 |
| | 50 | 111 | 0.20 |
| | 100 | 127 | 0.39 |
| 3TB 7.2K RPM HDD | 1 | 31 | 0.30 |
| 6Gbps SATA | 20 | 75 | 0.26 |
| | 50 | 82 | 0.61 |
| | 100 | 81 | 1.23 |

Table 3 - TPC-B (batch update write) with 1, 20, 50 and 100 users (single device)

These results are for a single device under test and additional performance could be expected using multiple drives in RAID or other system configurations. Scaling of performance should be linear with additional drives and adequate available system resources (CPU, memory, and PCIe and I/O bandwidth) to support more user workload.

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[4] Test configuration: Seagate 400GB 12000 2.5" SSD (ST400FM0073) 12Gbps SAS, 600GB 2.5" Enterprise 15K with TurboBoost™ (ST600MX) 6 Gbps SAS, 600GB 2.5" Enterprise Enhanced 15K V4 (15K RPM) HDD (ST600MP) with 6 Gbps SAS, Seagate Enterprise Capacity Nearline (ST6000NM0014) 6TB 3.5" 7.2K RPM HDD 12 Gbps SAS and 3TB Seagate 7.2K SATA HDD Workload generator and virtual clients Windows 7 Ultimate 64 bit. A SQL database was on Windows 7 guest. Guest VM (VMware vSphere 5.5) had a dedicated 14 GB DRAM, quad CPU (4 x 3.192GHz) Intel E3-1225 v300, with LSI 9300 series 12Gbps SAS adapters in a PCIe Gen 3 slot along with TPC-B (www.tpc.org) workloads. VM with guest OS along with SQL tempdb and masterdb resided on separate SSD based data store from devices being tested (e.g., where MDF (main database tables) and LDF (log file) resided). All devices being tested were Raw Device Mapped (RDM) independent persistent with database log file on a separate SSD device also persistent (no delayed writes) using VMware PVSCSI driver. MDF and LDF file sizes were 142GB and 26GB with scale factor of 10000, with each step running for one hour (10-minute preamble).

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TPC-B (write intensive) results in figure 2 below show how TPS work being done (blue) increases from left to right (more is better) for various numbers of simulated users. Also shown on the same line for each amount of TPS work being done is the average latency in seconds (right to left) where lower is better.

Results are shown from top to bottom for each group of users (100, 50, 20 and 1) for the different drives being tested (top to bottom). Note how the TurboBoost™ device does more work at a lower response time vs. traditional HDDs.
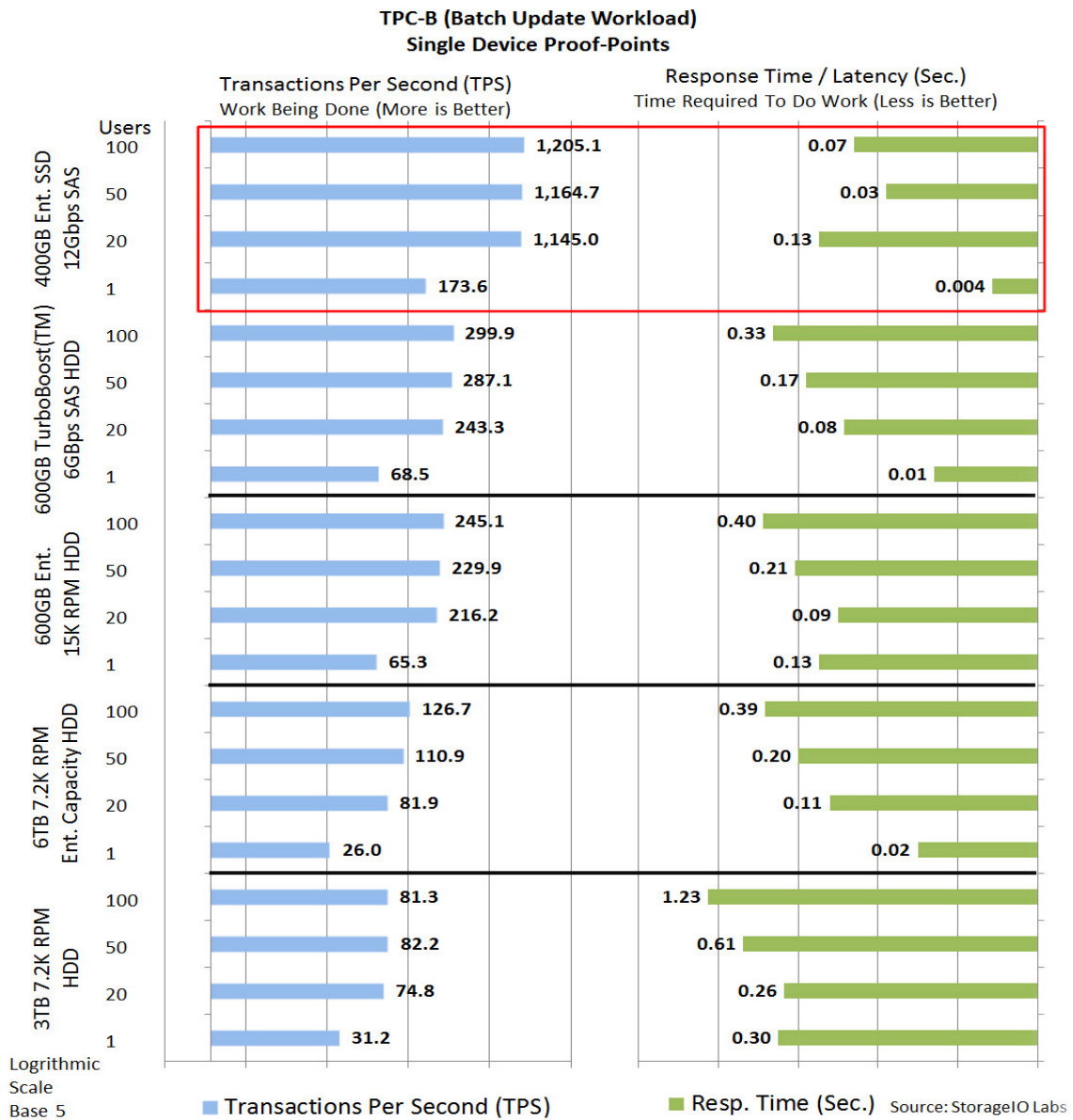


Figure 2 – TPC-B (batch update write) with 1, 20, 50 and 100 users (single device)

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**Proof Point: Database OLTP and Transactional**

Table 4 shows results from TPC-E test (OLTP/transactional workload) simulating a financial trading system. TPC-E is an industry standard workload that performs a mix of reads and writes database queries. Test simulations were performed with various numbers of users from 10, 20, 50 and 100 to determine (TPS) Transaction per Second (aka I/O rate) and response time in seconds.

| Device | User Load | TPC-E TPS | Avg. Resp. Time (Sec.) |
|---|---|---|---|
| Seagate Enterprise 1200 | 10 | 188.3 | 0.38 |
| 2.5" 400GB MLC flash SSD | 20 | 185.4 | 0.23 |
| 12Gbps SAS | 50 | 156.1 | 0.11 |
| | 100 | 123.4 | 0.07 |
| Seagate Enterprise 15K HDD | 10 | 10.2 | 2.58 |
| 2.5" 600GB with TurboBoost™ | 20 | 9.4 | 0.16 |
| 6Gbps SAS | 50 | 9.4 | 0.86 |
| | 100 | 6.1 | 0.7 |
| Seagate Enterprise 15K | 10 | 4.2 | 5.73 |
| 2.5" 600GB HDD | 20 | 4.1 | 3.2 |
| 6Gbps SAS | 50 | 4.1 | 1.61 |
| | 100 | 4.0 | 0.1 |
| Seagate Enterprise Capacity 6TB | 10 | 3.7 | 25.57 |
| 3.5" 7.2K HDD | 20 | 3.7 | 12.59 |
| 12Gbps SAS | 50 | 3.1 | 6.0 |
| | 100 | 2.1 | 4.51 |

Table 4 – TPC-E[5] (OLTP transactional) with 1, 20, 50 and 100 users

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[5] Test configuration: Seagate 400GB 12000 2.5" SSD (ST400FM0073) 12Gbps SAS, 600GB 2.5" Enterprise 15K with TurboBoost™ (ST600MX) 6 Gbps SAS, 600GB 2.5" Enterprise Enhanced 15K V4 (15K RPM) HDD (ST600MP) with 6 Gbps SAS, Seagate Enterprise Capacity Nearline (ST6000NM0014) 6TB 3.5" 7.2K RPM HDD 12 Gbps SAS. Workload generator and virtual clients Windows 7 Ultimate 64 bit. A SQL database was on Windows 7 guest. Guest VM (VMware vSphere 5.5) had a dedicated 14 GB DRAM, quad CPU (4 x 3.192GHz) Intel E3-1225 v300, with LSI 9300 series 12Gbps SAS adapters in a PCIe Gen 3 slot along with TPC-E (www.tpc.org) workloads. VM with guest OS along with SQL tempdb and masterdb resided on separate SSD based data store from devices being tested (e.g., where MDF (main database tables) and LDF (log file) resided). All devices being tested were Raw Device Mapped (RDM) independent persistent with database log file on a separate SSD device also persistent (no delayed writes) using VMware PVSCSI driver. MDF and LDF file sizes were 148GB and 98GB created with scale factor of 15, with each step running for one hour (10-minute preamble).

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In figure 3 below, the TPC-E transactional results are shown for each device being tested across different user workloads. The results show how TPC-E TPS work (blue) increases from left to right (more is better) for larger numbers of users along with corresponding latency (green) that goes from right to left (less is better). The TurboBoost™ device (e.g. 600GB Enterprise TurboBoost™ enabled HDD) is shown on the top of figure 3 with a red box around its results. Note how the TurboBoost™ device has a lower latency while doing more work compared to the other traditional HDDs. This shows NAND flash and HDDs being better together providing a hybrid between SSD performance and HDD space capacity while balancing economics.
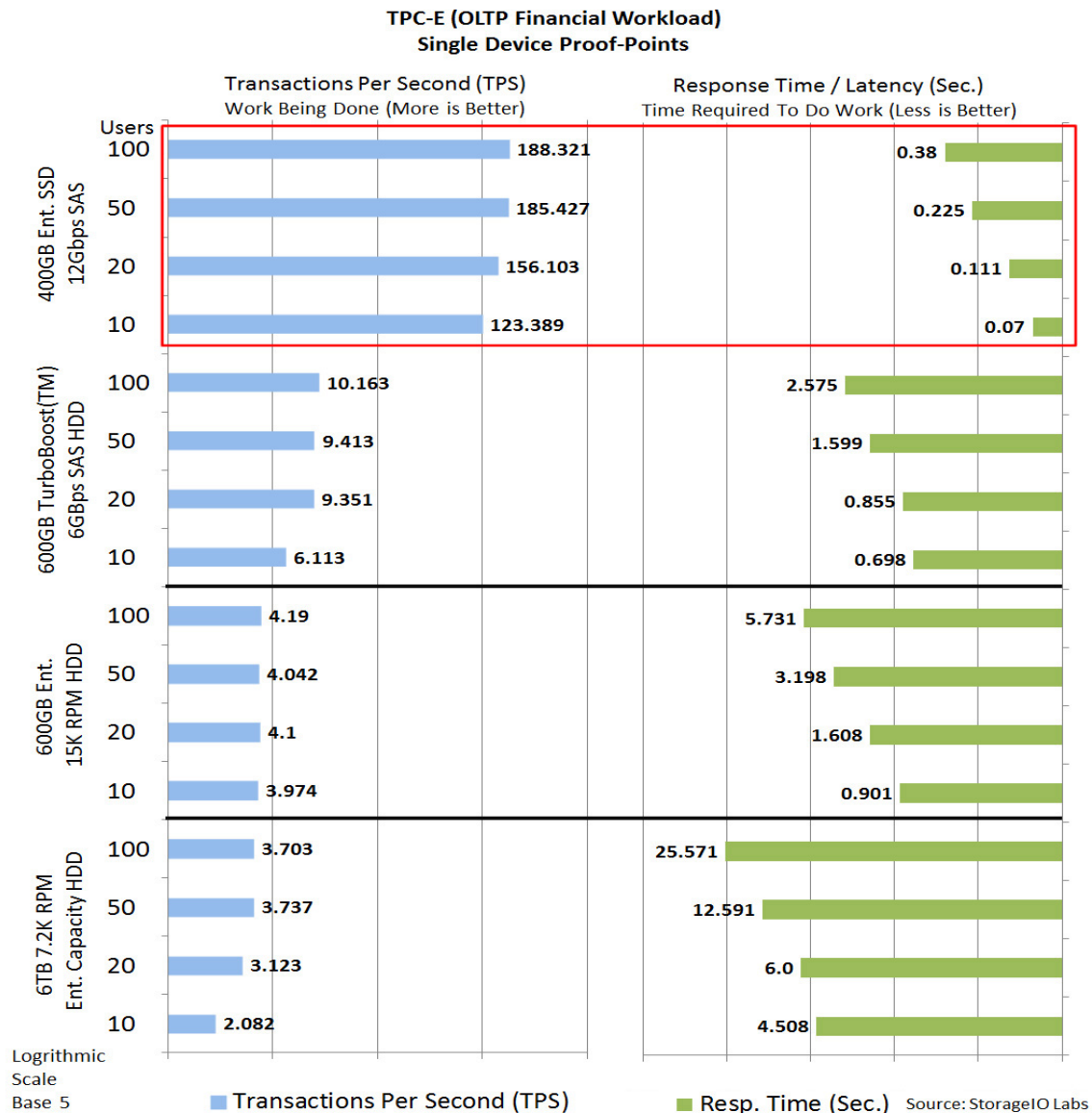
**TPC-E (OLTP Financial Workload)**
**Single Device Proof-Points**

| | Transactions Per Second (TPS) Work Being Done (More is Better) | Response Time / Latency (Sec.) Time Required To Do Work (Less is Better) |
|---|---|---|
| **400GB Ent. SSD 12Gbps SAS** | | |
| 100 | 188.321 | 0.38 |
| 50 | 185.427 | 0.225 |
| 20 | 156.103 | 0.111 |
| 10 | 123.389 | 0.07 |
| **600GB TurboBoost(TM) 6Gbps SAS HDD** | | |
| 100 | 10.163 | 2.575 |
| 50 | 9.413 | 1.599 |
| 20 | 9.351 | 0.855 |
| 10 | 6.113 | 0.698 |
| **600GB Ent. 15K RPM HDD** | | |
| 100 | 4.19 | 5.731 |
| 50 | 4.042 | 3.198 |
| 20 | 4.1 | 1.608 |
| 10 | 3.974 | 0.901 |
| **6TB 7.2K RPM Ent. Capacity HDD** | | |
| 100 | 3.703 | 25.571 |
| 50 | 3.737 | 12.591 |
| 20 | 3.123 | 6.0 |
| 10 | 2.082 | 4.508 |

Logrithmic Scale Base 5

■ Transactions Per Second (TPS)   ■ Resp. Time (Sec.)   Source: StorageIO Labs

Figure 3 – TPC-E (OLTP transactional) with 10, 20, 50 and 100 users

## Additional and Future Proof Points - Server Virtualization

Additional testing and workload proof points are being performed including VMware vSphere based among others. Watch for additional proof points involving VMware V5.5 with various workloads including I/O caching to be posted at www.storageioblog.com.

## Summary

Similar to flash-based SSD technologies the question is not if, rather when, where, why and how to deploy hybrid solutions such as Seagate HDDs enabled with TurboBoost™. If your applications and data infrastructures environment have the need for storage I/O speed without loss of space capacity and breaking your budget, SSD enabled devices like the Seagate Enterprise TurboBoost™ 600GB are in your future.

## Learn more at Seagate landing page located at:

http://www.seagate.com/internal-hard-drives/solid-state-hybrid/enterprise-turbo-sshd/

## About the author

Greg Schulz is Founder and Sr. Analyst of independent IT advisory consultancy firm Server and StorageIO (StorageIO). He has worked in IT at an electrical utility, financial services and transportation firms in roles ranging from business applications development to systems management, architecture, strategy and capacity planning. Mr. Schulz is author of the Intel Recommended Reading List books "Cloud and Virtual Data Storage Networking" and "The Green and Virtual Data Center" via CRC Press and "Resilient Storage Networks" (Elsevier). He is a five-time VMware vExpert. Learn more at www.storageio.com.