Making the Case for SSDs - October 2011

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Demartek Company Overview

- Industry analysis with on-site test lab
- Lab includes servers, networking and storage infrastructure
  - Fibre Channel: 4 & 8 Gbps (16Gb soon)
  - Ethernet: 1 & 10 Gbps (NFS, CIFS, iSCSI & FCoE)
  - Servers: 8 cores, very large RAM
  - Virtualization: ESX, Hyper-V, Xen
- We prefer to run real-world applications to test servers and storage solutions
  - Currently testing various SSD and other technologies
  - We create our own data sets for application workloads
- Web: www.demartek.com

Demartek News

- Demartek Deployment Guides
  - Completed: iSCSI – May 31, 2011
  - In-progress: SAS, SSD, 16Gb Fibre Channel, FCoE
- Free Monthly Newsletter
  - www.demartek.com/Newsletter
- Storage Networking Interface Comparison
  - www.demartek.com/SNIC
  - Internet search: “Storage Interface Comparison”
  - Includes FC, FCoE, IB, iSCSI, PCIe, SAS, SATA and USB

Agenda

- Solid State Storage technology overview (DRAM and NAND Flash)
- Power & cooling
- Performance vs. cost
- Flash in Enterprise Products
- SSD: Cache vs. Primary Storage
- Demartek lab results

Solid-State Storage Overview

- Uses memory as the storage media and appears as a disk drive to the O.S.
- Very fast, no moving parts
- Variety of form factors
- Prices dropping
- Some SSDs use DRAM and NAND-Flash together
- Capacities doubling almost yearly

New Acronyms & Buzzwords

- SSD: Solid-State Drive (or Disk)
- SSS: Solid-State Storage
- SLC: Single-Level Cell
- MLC: Multi-Level Cell
- P-E Cycle: Program-Erase Cycle
- EFD: Enterprise Flash Drive
- SCM: Storage Class Memory

DRAM SSD

- Same type of memory that is in servers
- Volatile: needs battery or disk backup
- Highest IOPS: 70K – 5M+
- Latencies in microseconds
- Can be used as a cache in front of other storage

NAND-Flash SSD

- Non-volatile
- Quiet, low-power, low-weight, low-heat
- Types: SLC & MLC
- Variety of form factors
  - Disk drive
  - PCIe card
  - DIMM sockets
  - Motherboard module

NAND-Flash SSD

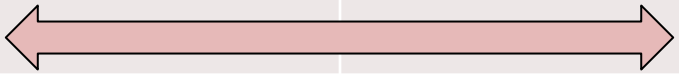
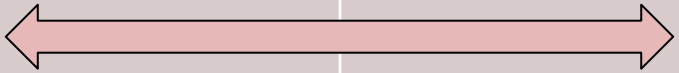
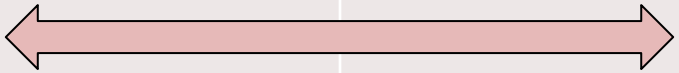
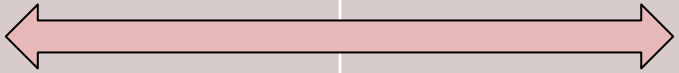
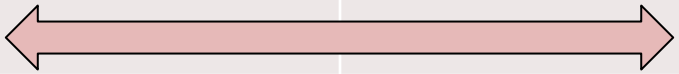
- IOPS
  - 10K – 250K reads per device
    - Enterprise HDDs: 100-200 IOPS
    - Desktop HDDs: < 100 IOPS
  - Writes are generally slower than reads
- Capacities
  - Individual devices
    - Drive form factor: 1.6 TB
    - PCIe card: 5.1 TB
    - DIMMs: 480 GB
  - Arrays: Up to 250 TB (“all-SSD” arrays)

NAND-Flash: What Is It?

- A specific type of EEPROM
  - EEPROM: Electrically Erasable Programmable Read-Only Memory
  - The underlying technology is a floating-gate transistor that holds a charge
- Bits are erased and programmed in blocks
  - Process is known as the Program-Erase (P-E) cycle
  - Flash blocks are typically 4KB, some larger

NAND-Flash Technologies

- Single-Level Cell (SLC) – One bit per cell
- Multi-Level Cell (MLC) – Two or more bits per cell
  - Triple Level Cell (TLC) – Three bits per cell
  - First announcements of MLC-3 & MLC-4 were made in 2009

	SLC	MLC-2	MLC-3	MLC-4
Bits per cell	1	2	3	4
Performance	Fastest			Slowest
Endurance	Longest			Shortest
Capacity	Smallest			Largest
Error Prob.	Lowest			Highest
Price per GB	Highest			Lowest
Applications	Enterprise	Mostly Consumer	Consumer	Consumer

NAND-Flash: Endurance & Price

- Endurance
  - SLC typically 10-20 times better than MLC-2
  - SLC typical life of 100,000 write cycles
    - Newer “Enterprise SLC” may have 3x write cycles
  - MLC-2 is much better than MLC-3 or MLC-4
  - MLC typical life 10,000 or fewer cycles
    - Newer “Enterprise MLC” may have 3x write cycles
- Price
  - SLC typically greater than 2x the price of MLC-2

NAND-Flash: Endurance

- JEDEC Standards (www.jedec.org)
  - JESD218A: SSD Requirements and Endurance Test Method
  - JESD219: SSD Endurance Workloads
- SSD Endurance Classes and Requirements

Application Class and Workload	Active Use (power on)	Retention Use (power off)	Functional Failure Rqmt. (FFR)	UBER
Client	40°C 8 hrs/day	30°C 1 year	≤3%	$\leq 10^{-15}$
Enterprise	55°C 24 hrs/day	40°C 3 months	≤3%	$\leq 10^{-16}$

NAND-Flash: General Trends

- Data retention, endurance, and performance are decreasing as bits per cell increase
  - For consumer applications, endurance becomes less important as density and capacity increase
- Power consumption increases somewhat as bits per cell increase beyond 2 bits per cell
- Newer NAND flash controllers bring some SLC features to MLC flash

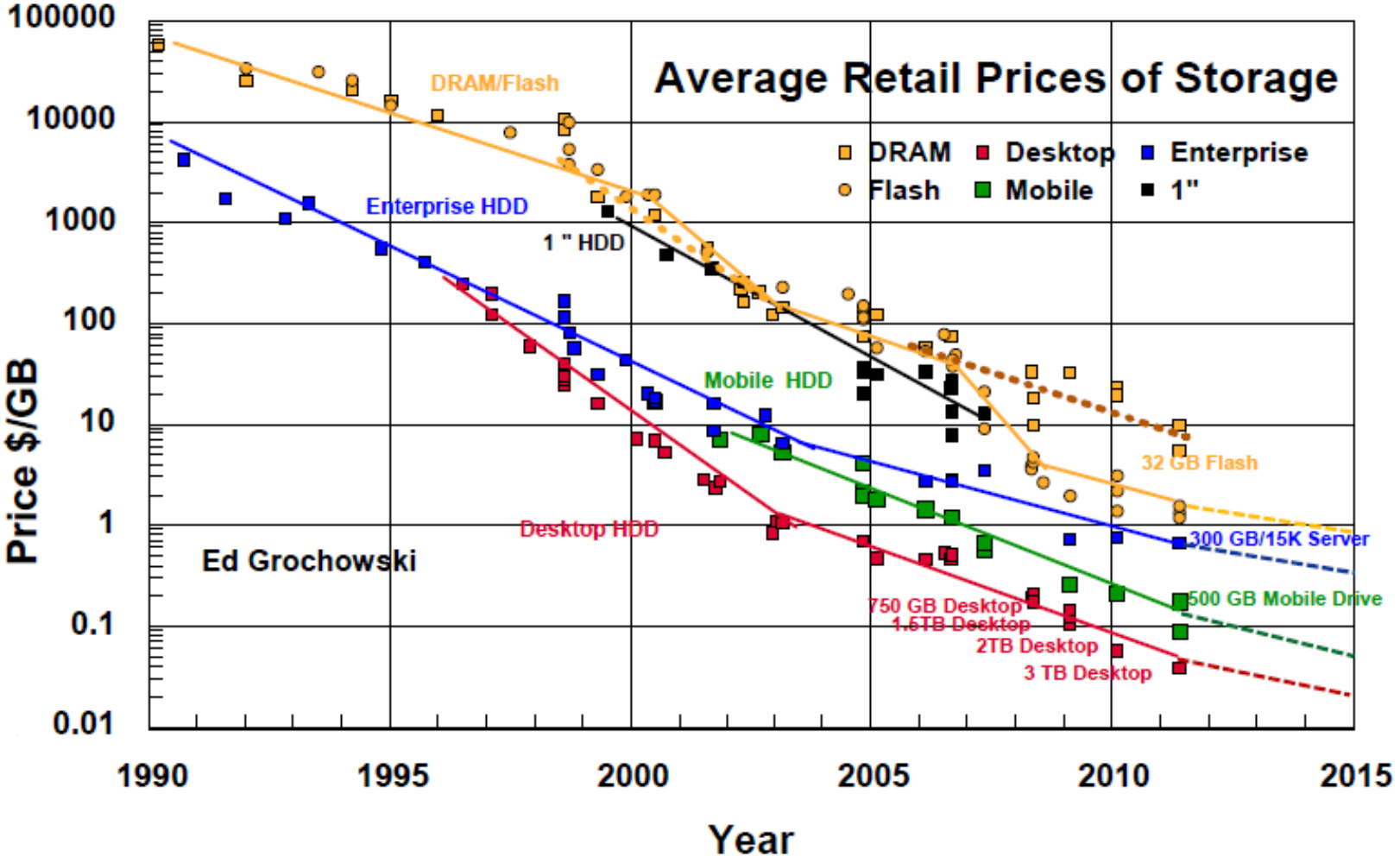
Power & Cooling

Device type	RPM	Form factor	Interface	Watts Typical	Watts Idle
Spinning disk	15K	3.5”	FC/SAS	13 – 19	8 – 14
Spinning disk	15K	2.5”	SAS	8 – 14	5 – 7
Spinning disk	10K	3.5”	FC/SCSI	11 – 18	6 – 13
Spinning disk	10K	2.5”	SAS	8 – 14	3 – 6
Spinning disk	7.2K	3.5”	SAS/SATA	7 – 13	3 – 9
Spinning disk	7.2K/5.4K	2.5”	SATA	1 – 4	0.7 – 1
SSD: SLC-flash	-	*	SAS/SATA	1 – 8	0.05 – 4
SSD: MLC-flash	-	*	SAS/SATA	0.1 – 3	0.05 – 0.5

Typically in datacenters, every watt of power consumed by computing equipment requires another watt of power to cool it.

* SSDs are available in 3.5”, 2.5” and 1.8” HDD form factors and other form factors

Storage Price History



Source: Dr. Ed Grochowski, Flash Memory Summit 2011

Performance vs. Cost

	$/GB	$/IOPS	IOPS/watt
SSD (SLC)	$10 – $40	$0.005 – $0.15	1000 – 15000
SSD (MLC)	$1 – $3	$0.004 – $0.05	1000 – 15000
HDD (enterprise)	$0.50 – $1	$1 – $3	10 – 30
HDD (desktop)	$0.05 – $0.10	$1 – $4	10 – 40

- SSDs are dollars per gigabyte and pennies per IOPS
- HDDs are pennies per gigabyte and dollars per IOPS

O.S. Behavior with Flash

- Operating systems need to behave differently with flash SSDs
  - Trim – notify the underlying device regarding data that is no longer needed
    - Trim is currently available for SATA interfaces only. The SAS committee has added UNMAP to the SAS/SCSI spec.
  - Windows 7 and Windows Server 2008 R2
    - Defragmenting is off by default for flash SSDs
  - RHEL 6 with EXT4, but Trim is not enabled by default
- Utilities (Intel RapidStorage 9.6+, etc.)

Flash in Enterprise Products

- Disk array vendors
  - Primary storage: SSDs in standard HDD slots
  - Cache: SSD technology used as cache
- Appliance vendors – “Accelerators”
- Server vendors
  - Add flash on a PCI-Express bus card
  - Add flash directly onto the motherboard
  - Blade server mezzanine cards
- Is enterprise flash storage or memory?

Vendor Product Trends

- Automated data movement
  - Applies to primary storage
  - Moves hot data to SSD tier
  - Scheduled by minutes, hours, days, etc.
  - Used at LUN level today; beginning to see sub-LUN level automated data movement
- SSDs together in cache and primary storage
- Controllers (internal and external) are adapting to SSD speeds

SSD: Cache

- Caching controller identifies any frequently accessed data (“hot data”)
- Caching controller automatically moves a copy of the hot data to SSD media
- Multiple applications can benefit from the SSD cache simultaneously
- Performance improves over time, as cache is populated with data
- Overall HDD I/O load is reduced: fewer I/Os

SSD: Primary Storage

- User decides what data to place on SSD
- User decides when to place data on SSD
- User moves specific data to SSD
- SSD benefits only the applications that use the data placed on the SSD
- Performance improves instantly
- Automation software can help select and move data to SSD

SSD Performance Test: Web Server Workload

- Must maintain consistent response times
- Must handle sudden increases in traffic
- Must be cost-effective

Web Server Response Time

- Jakob Nielsen's Alertbox, June 21, 2010
  - www.useit.com/alertbox/response-times.html

- Response-Time Limits
  - 0.1 seconds: gives the feeling of instantaneous response
  - 1 second: user's flow of thought is seamless
  - 1-10 seconds: users feel at the mercy of the computer and wish it was faster
  - 10+ seconds: users start thinking about other things

Web Server Setup

- Windows Server 2008 R2 with IIS 7.5
  - Default data compression disabled
  - 8dot3 short names removed and disabled
- 40GB of web server content
- 1.48 million files
  - 80000 HTML text pages
  - 1.4 million graphic images (JPEG and PNG)
- Represents a web hosting server with many sites and many pages

Two Sets of Tests

1. Comparing small configuration of desktop-class 7200 RPM SATA interface disk drives to SLC SSDs in caching configuration

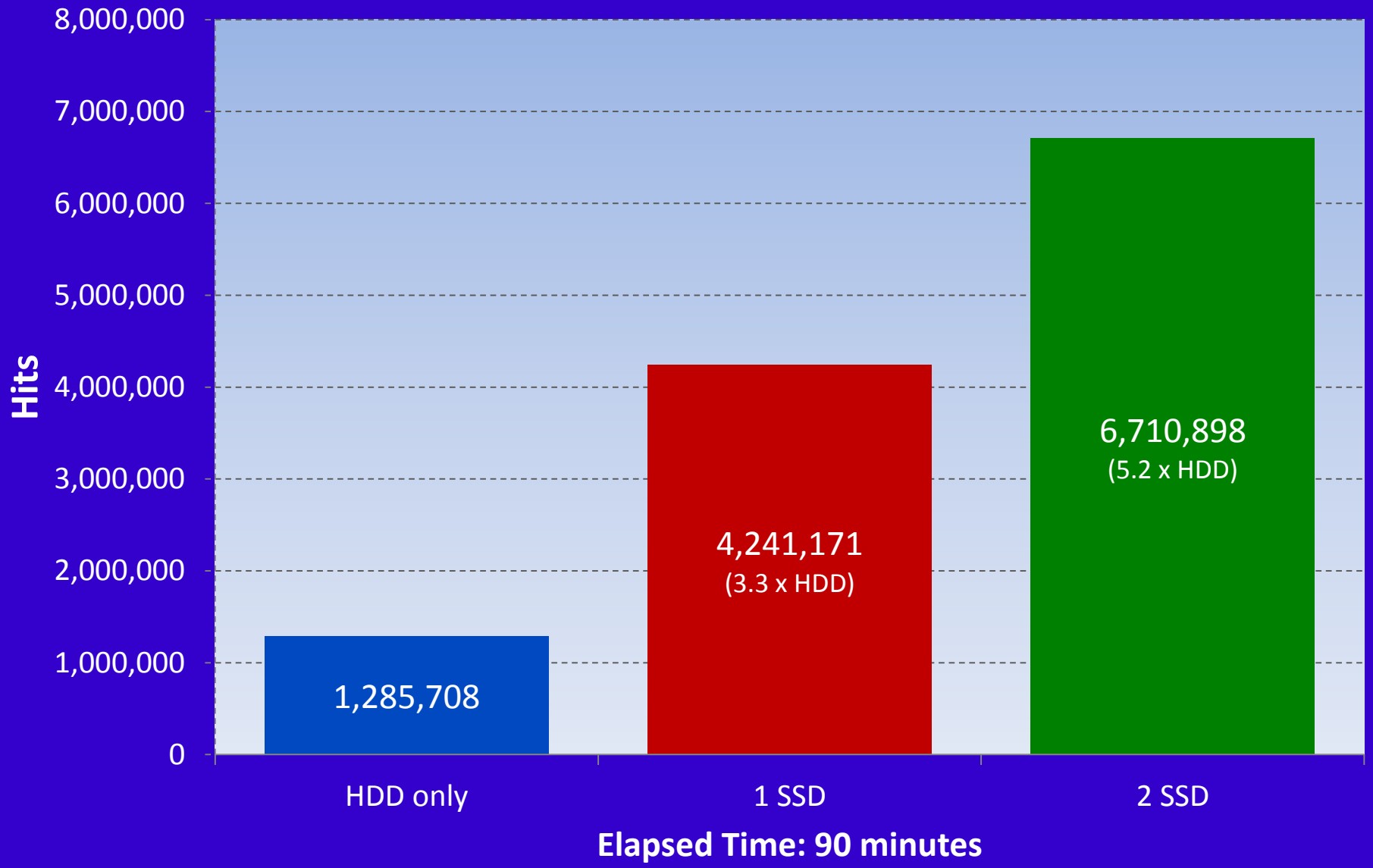
2. Comparing large configuration of enterprise-class 15K RPM SAS interface disk drives to PCIe SSD accelerator card in primary storage configuration

- Each test ran for 90 minutes

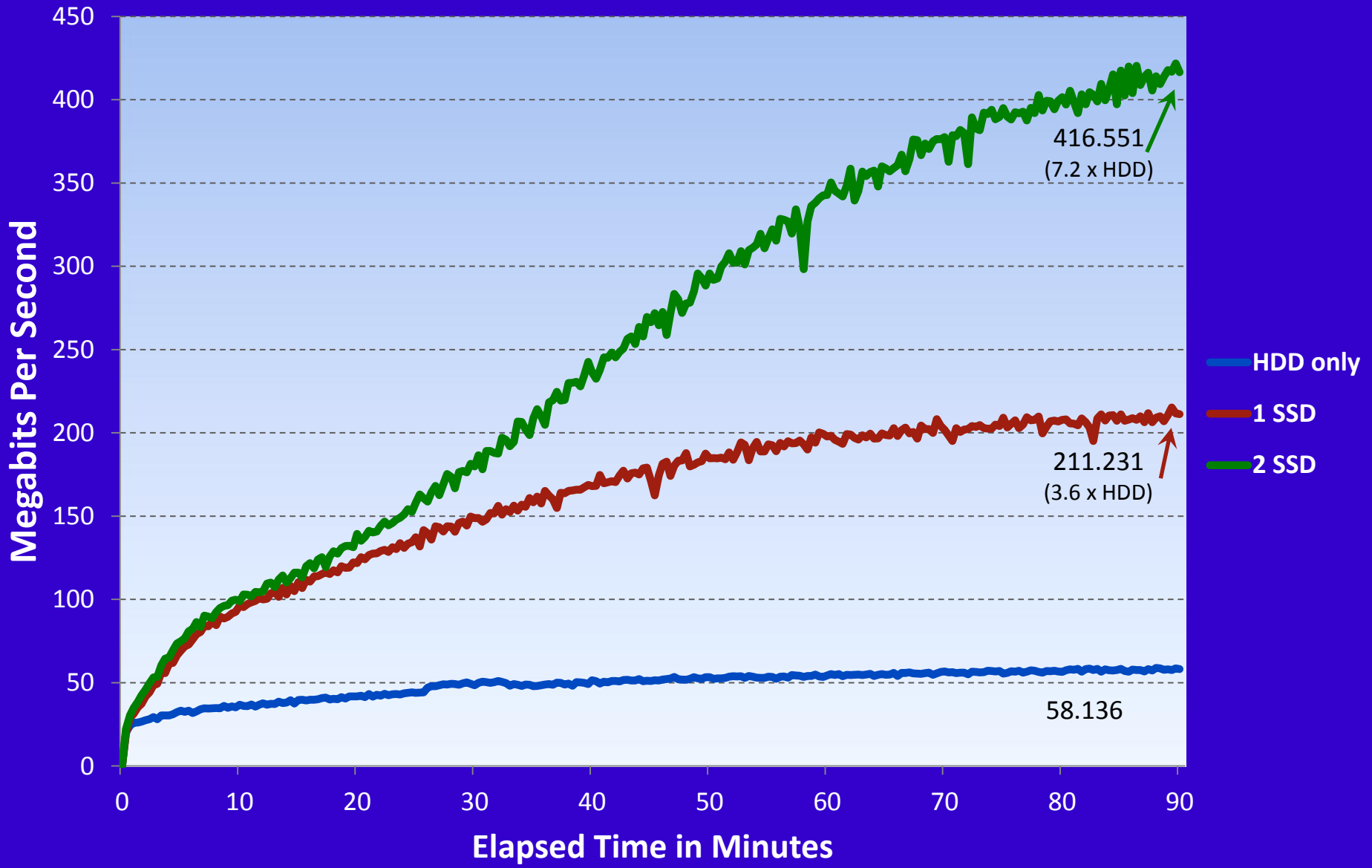
Test 1: Caching
O.S. & Web Content

- Configuration 1
  - 6 disk drives: 500GB SATA, 7200 RPM, 3.5-inch, RAID10
- Configuration 2
  - 6 disk drives: 500GB SATA, 7200 RPM, 3.5-inch, RAID10
  - 2 SSDs (cache): 32GB, SLC, 2.5-inch, SATA interface
- Network: 1GbE
  - Teamed NICs

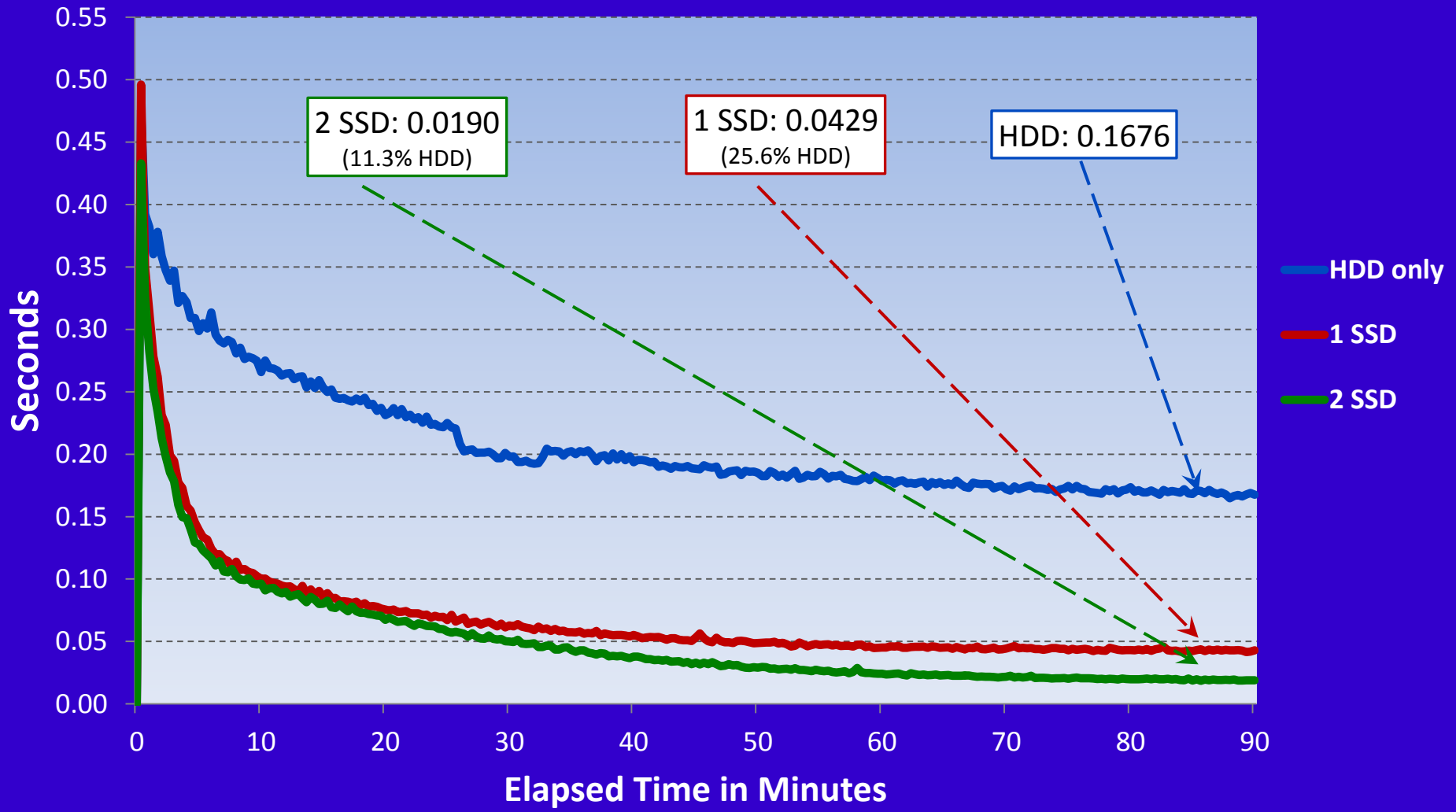
Total Hits: Caching Configuration



Throughput: Caching Configuration



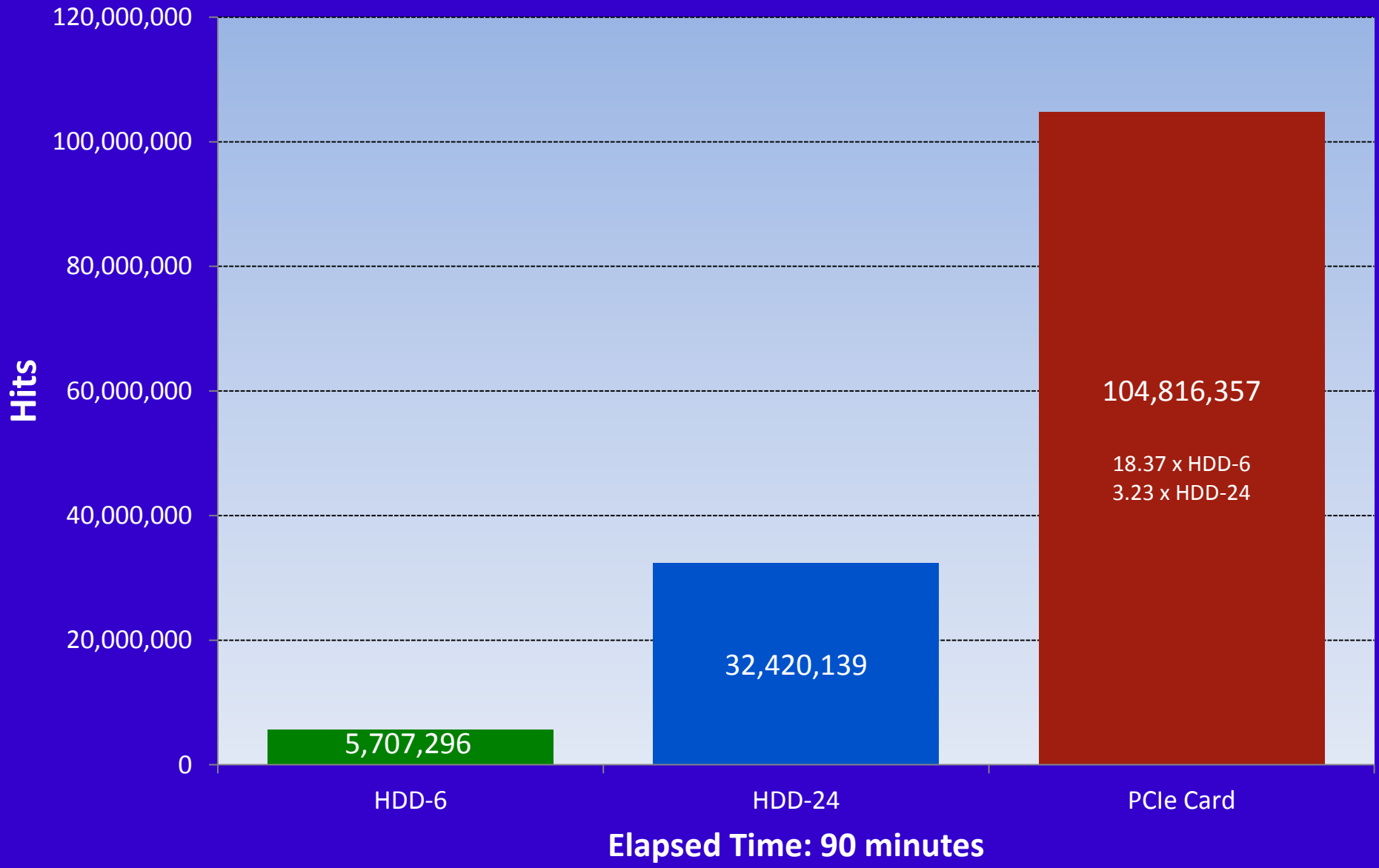
Average Page Response Time
Caching Configuration
(Lower is better)



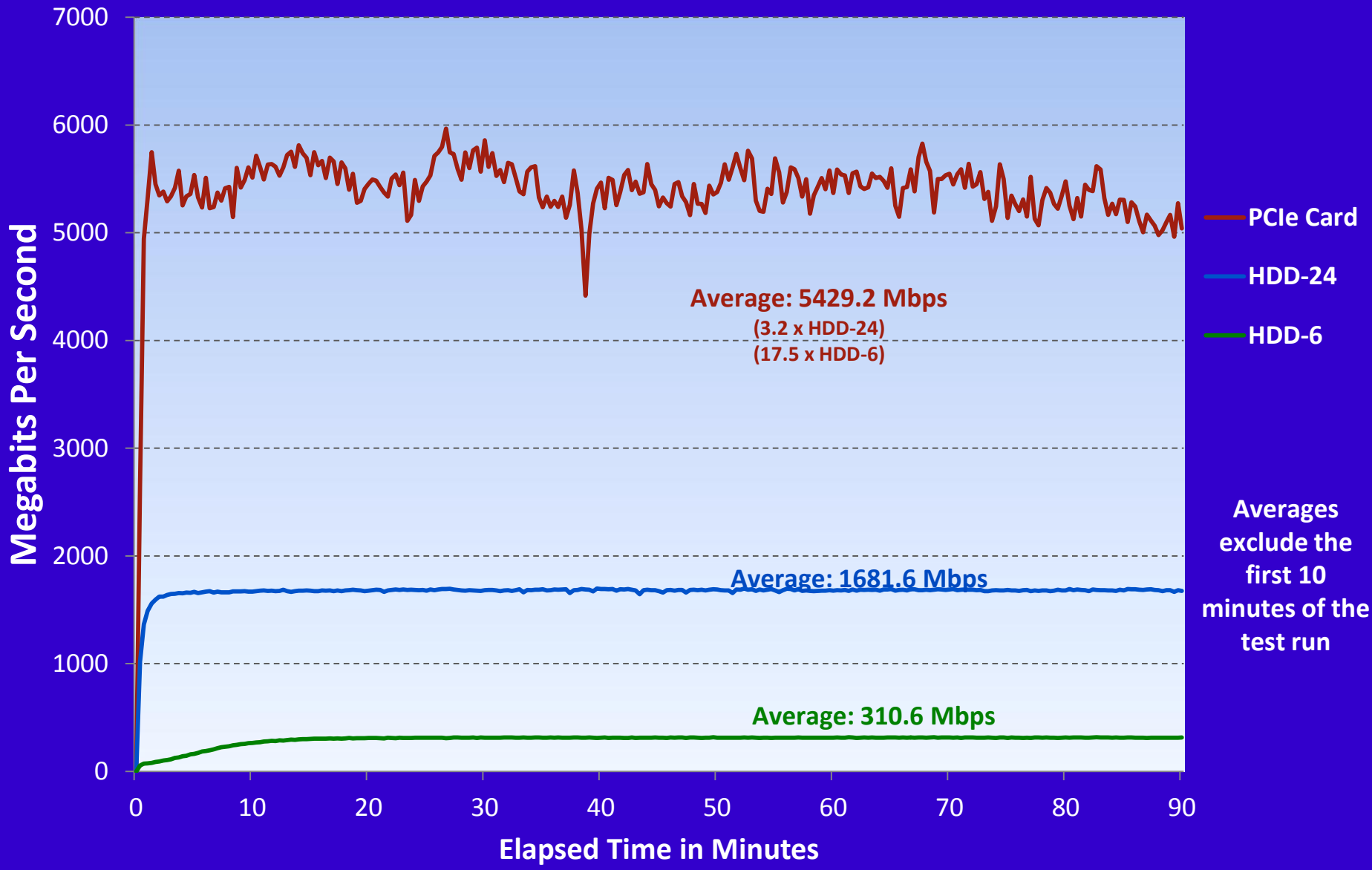
Test 2: Primary Storage
Web Content Only

- Configuration 1
  - 6 disk drives: 73GB 6Gbps SAS, 15K RPM, 2.5-inch, RAID10
- Configuration 2
  - 24 disk drives: 73GB 6Gbps SAS, 15K RPM, 2.5-inch, RAID 10
- Configuration 3
  - 1 PCIe SSD: 300GB SLC Flash
- Network: 10GbE
  - SSDs and 10GbE go well together

Total Hits: Primary Storage Configuration

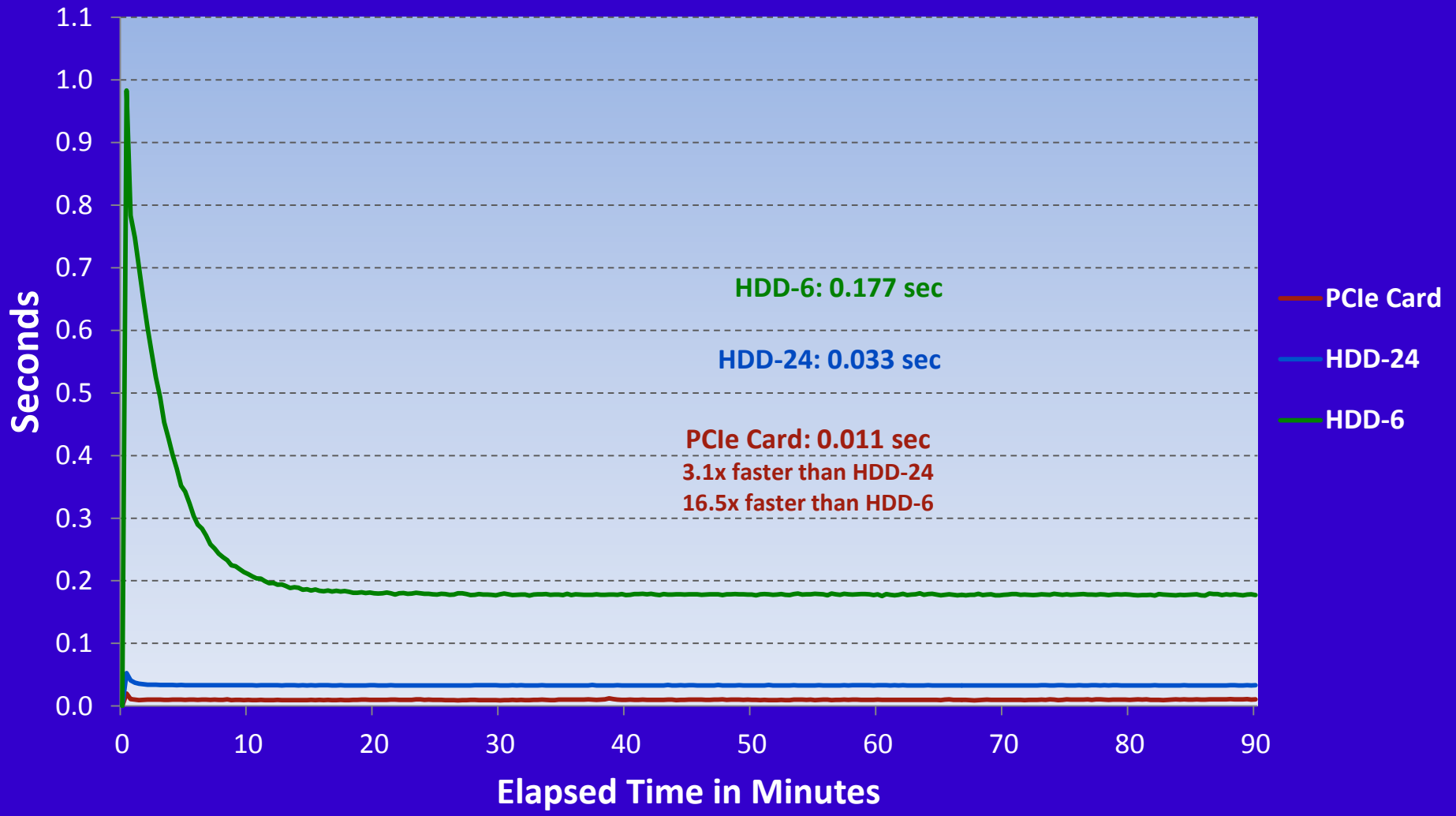


Throughput: Primary Storage Configuration

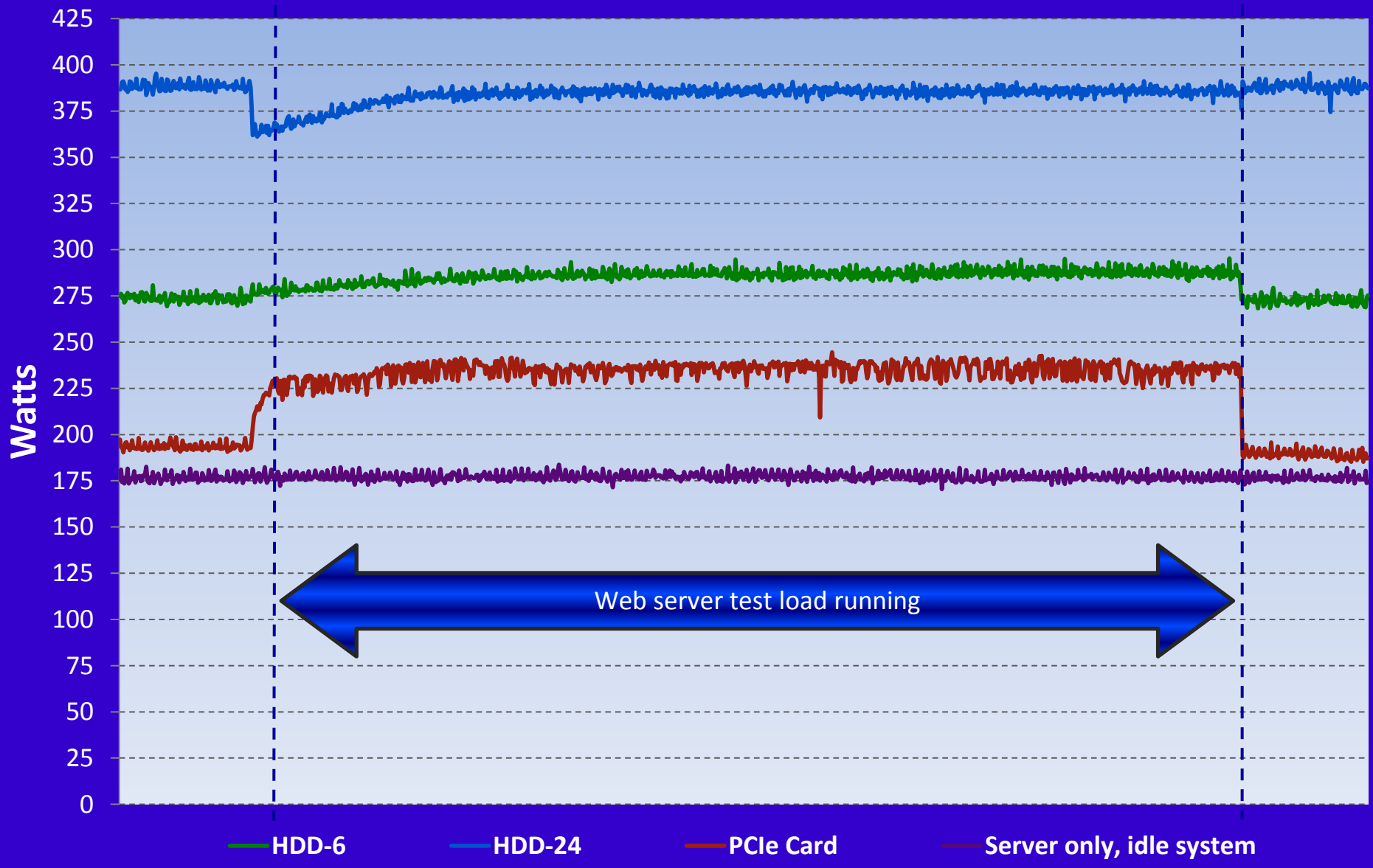


Average Page Response Time: Primary Storage Configuration

(Lower is better)



Web Server Power Consumption



Performance Comments

- SSD technology can move the bottleneck to unexpected places
  - The 1GbE network was the bottleneck during the initial PCIe card test, requiring us to go to the 10GbE network to get the full performance of the PCIe card
- SSD technology can drive up CPU utilization
  - Considerably more work can get done with SSD technology, which can significantly increase CPU utilization

Future

- Emerging technologies, especially in the flash controllers, will enable MLC flash to become suitable for the enterprise

- *Opinion*: I believe that at the current rate of price decreases and capacity increases, SSDs (probably flash) will become the new standard for tier-1 storage by 2012.

Ongoing Research

- Other types of memory technology that may become good candidates for storage devices (within 5 years)
  - PCM: Phase Change Memory (PC-RAM)
  - Solid Electrolyte
  - MRAM: Magnetic RAM (Racetrack)
  - FeRAM: Ferroelectric RAM
  - RRAM: Resistive RAM (Memristor)

Demartek SSD Resources

- Demartek SSD Zone
  - www.demartek.com/SSD.html
- Look for my article *Making the Case for Solid-State Storage* in June 2010 online edition of Storage Magazine
  - www.searchstorage.com
- Demartek Storage Interface Comparison
  - www.demartek.com/Demartek_Interface_Comparison.html
  - Or search for “storage interface comparison”

Other Demartek Resources

- Demartek iSCSI Deployment Guide 2011
  - www.demartek.com/Demartek_iSCSI_Deployment_Guide.html
- Demartek Exchange Server 2003 2007 2010 I/O comparison
  - www.demartek.com/Demartek_Exchange_2003_2007_2010_I-O_Comparison_Summary.html
- Demartek Presents Robocopy at March 2011 RMWTUG Meeting
  - www.demartek.com/Demartek_Presenting_RMWTUG_March_2011-03.html

Free Monthly Newsletter

Demartek publishes a free monthly newsletter highlighting recent reports, articles and commentary.

Look for the newsletter sign-up at www.demartek.com.

SSD Giveaway October 2011:
www.demartek.com/Demartek_SSD_giveaway_2011-10.html

Questions & Answers

Here are some of the questions and comments that were asked during the Oct. 21 presentation:

- It would be nice to show not only the cost to purchase drives (HDD and SSD) but also the cost to operate them. Is this data available?
- Is there any data available showing the life expectancy of SSDs that handle hardware encryption? In the case of one company that requires all laptop drives to be encrypted, they are getting far less than three years life from their laptop hard drives.

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