What's up with these numbers?

The Need for Performance Benchmarking Standardization

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- Bandwidth Performance Specifications
  — Sustained Sequential Read: Up to 250 MB/s
  — Sustained Sequential Write: Up to 70 MB/s
- Read and Write IOPS specifications (IOmeter Queue Depth 32)
  — Random 4 KB Reads: Up to 35 K IOPS
  — Random 4 KB Writes: Up to 3 K IOPS

Read/Write Mix?

Performance

Average Access Time	20-120 microseconds
Sustained Peak Throughput	250 Mbyts/sec
Sustained Write Throughput	115 Mbyts/sec
Random IOPS Read Operations	45,000 IO/sec sustained
Random IOPS Write Operations	16,000 IO/sec sustained

Sustained?

IOPS?

Like other high-performance, enterprise-class flash drives, ▮▮▮▮▮ drive is being positioned as an alternative to traditional 15,000-rpm serial-attached SCSI (SAS) hard disk drives. ▮▮▮ said its new "performance-optimized" enterprise SSD can process IOPS (input/output per second) more than 10 times faster than the fastest SAS hard drive, with a sequential read rate of 230MB/sec. and a sequential write rate of 180MB/sec.

10 times faster than HDD?

Block Size?

Increased High Speed Performance
- 800 MByte Full Duplex Burst Rate
- Up to 230 MB/sec Sustained Rate
- Up to 55,000 IOPS
- 50 µsec Access Time

Random?

Table 3: Sustained and Random Read/Write Performance

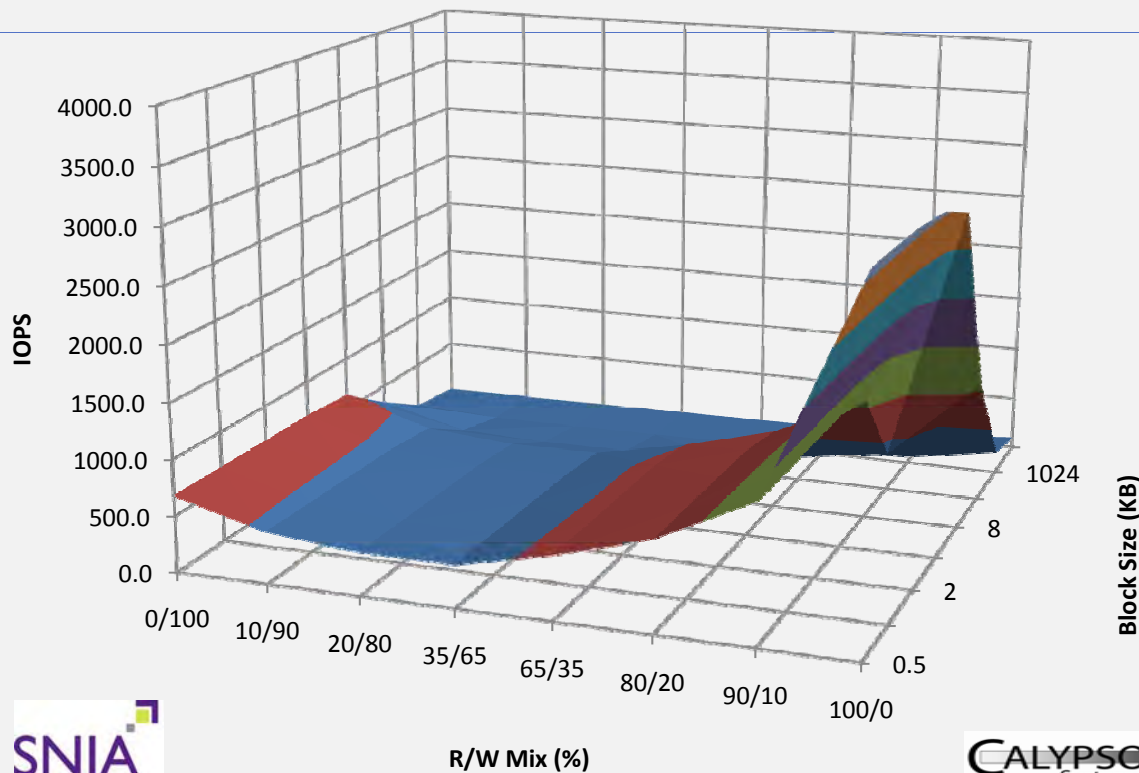| Parameter	Value
Burst Read	150 MBytes/sec [4]
Burst Write	150 MBytes/sec
Sustained Read	Up to 115 MBytes/sec
Sustained Write	Up to 95 MBytes/sec
Random Read [5]	6100 Input/Output Operations Per Second (IOPS)
Random Write	400 IOPS
Random 67% Read, 33% Write	1120 IOPS

Up to?

[4] One megabyte, or MByte, equals 1,048,576 bytes.
[5] Random performance values are based on 4 KByte transfers.

# The 3 dimensions of SSD performance

3D IOPS Surface Profile

Legend:
- 0.0-500.0
- 500.0-1000.0
- 1000.0-1500.0
- 1500.0-2000.0
- 2000.0-2500.0
- 2500.0-3000.0
- 3000.0-3500.0
- 3500.0-4000.0

IOPS axis: 0.0, 500.0, 1000.0, 1500.0, 2000.0, 2500.0, 3000.0, 3500.0, 4000.0

R/W Mix (%): 0/100, 10/90, 20/80, 35/65, 65/35, 80/20, 90/10, 100/0

Block Size (KB): 0.5, 2, 8, 1024

- Performance depends on read/write mix **AND** block size

- 3D IOPS image can be created by SNIA SSSI Standard Reference Test Platform

Note: Shown 3D IOPS image courtesy of Calypso Systems

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Performance over Time

Performance Over Time

— 4K RND Write
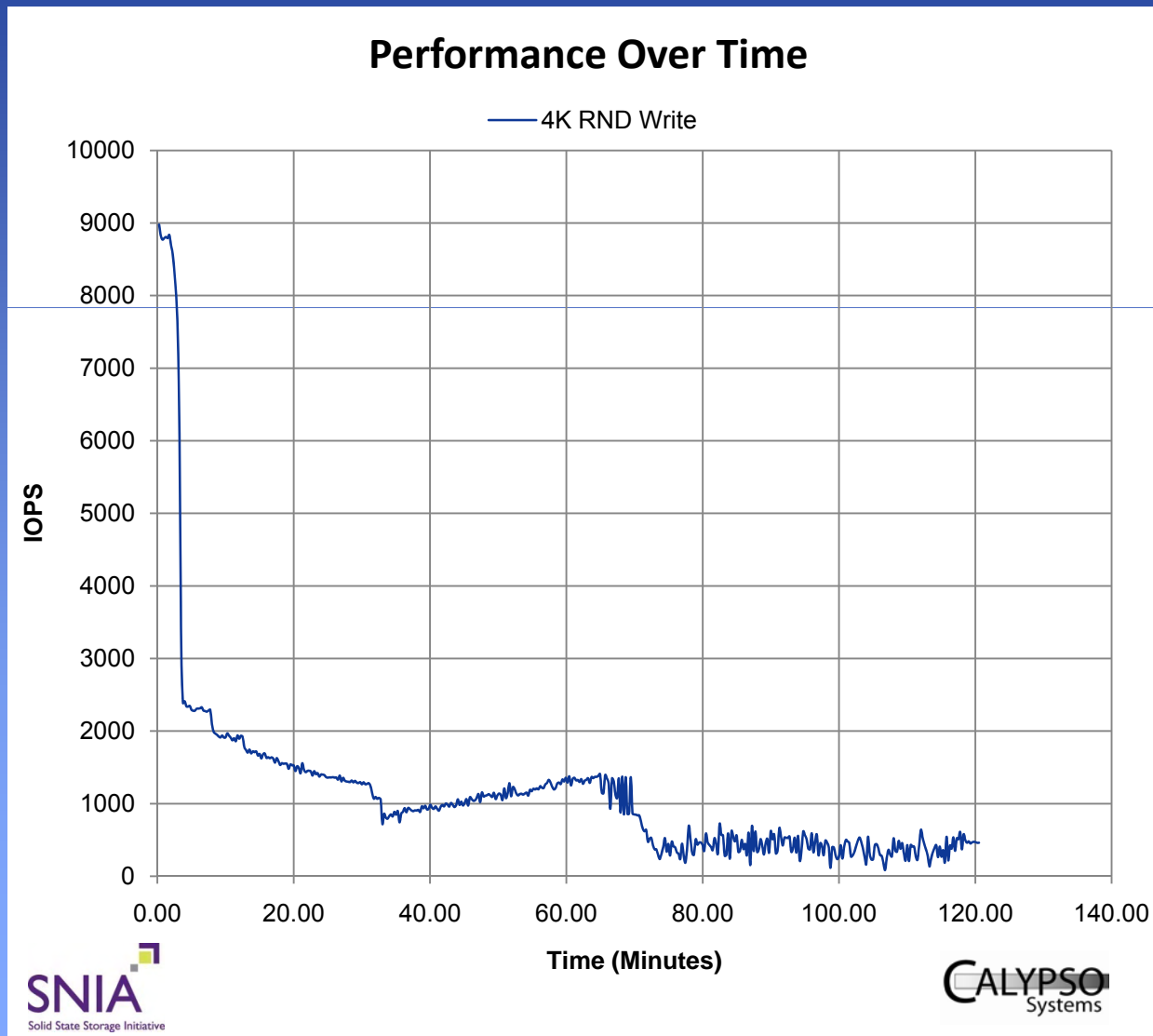
- Increased data fragmentation can result in performance drop over time
- Result of flash management algorithms that are not optimized for performing background operations
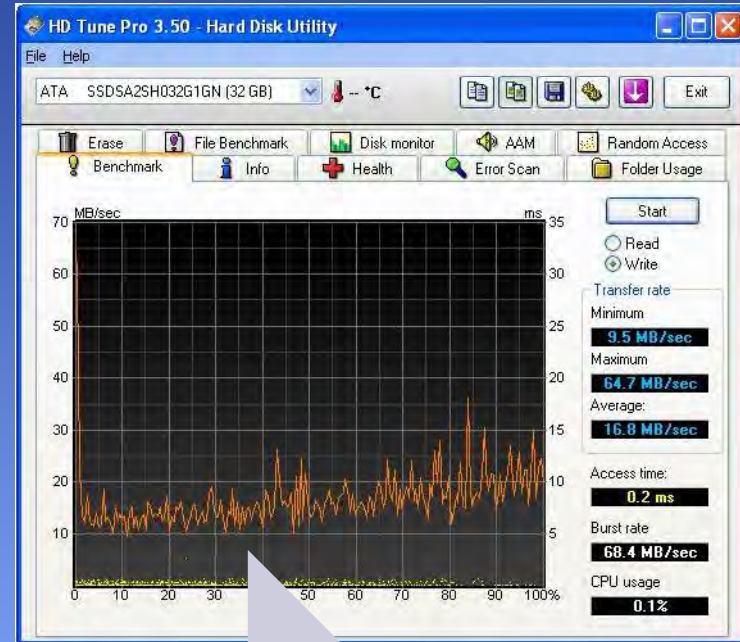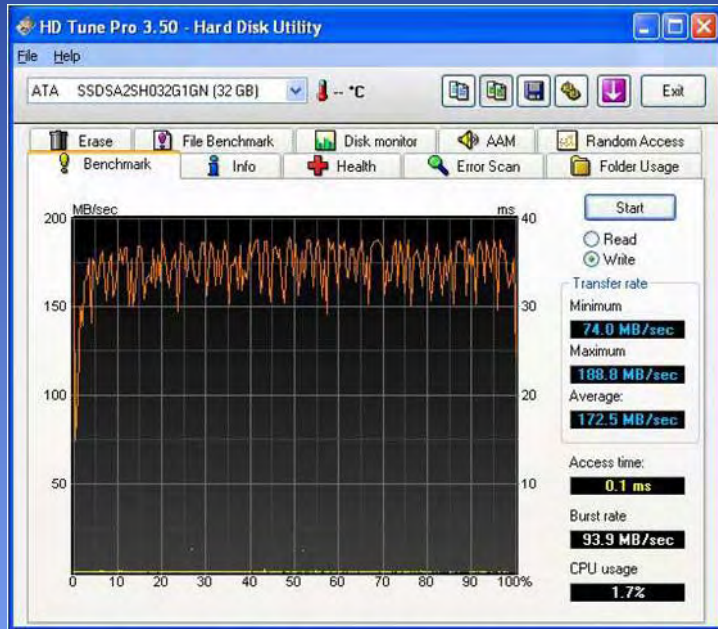
- Pre-conditioning is a must!

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Not all F/W is equal

- Some flash management algorithms create non-deterministic latency
- Performance vs. time plot is important to characterize performance stability profile
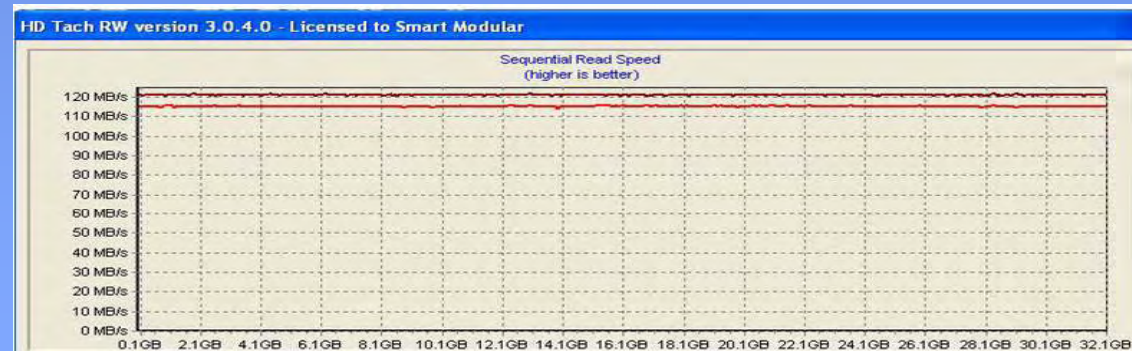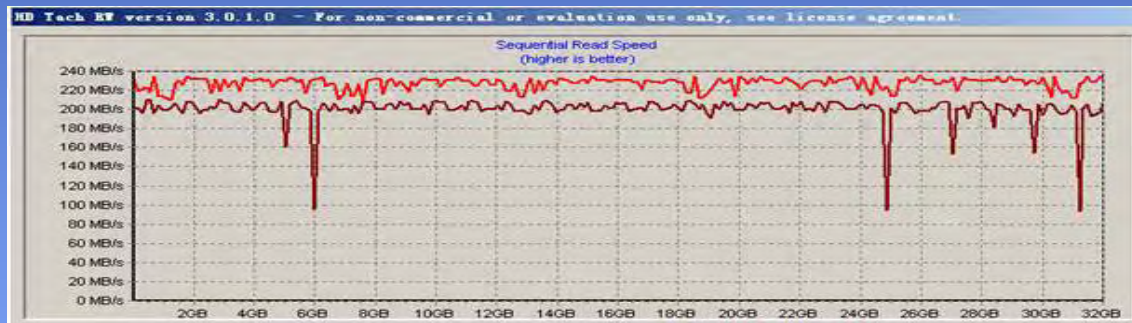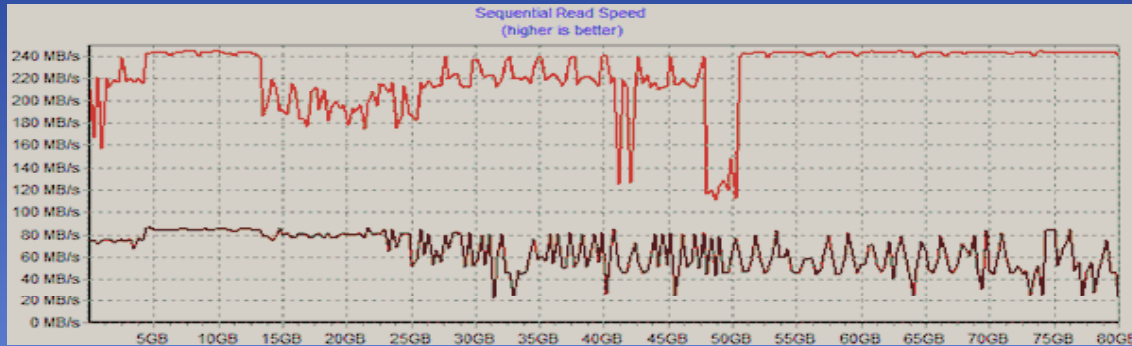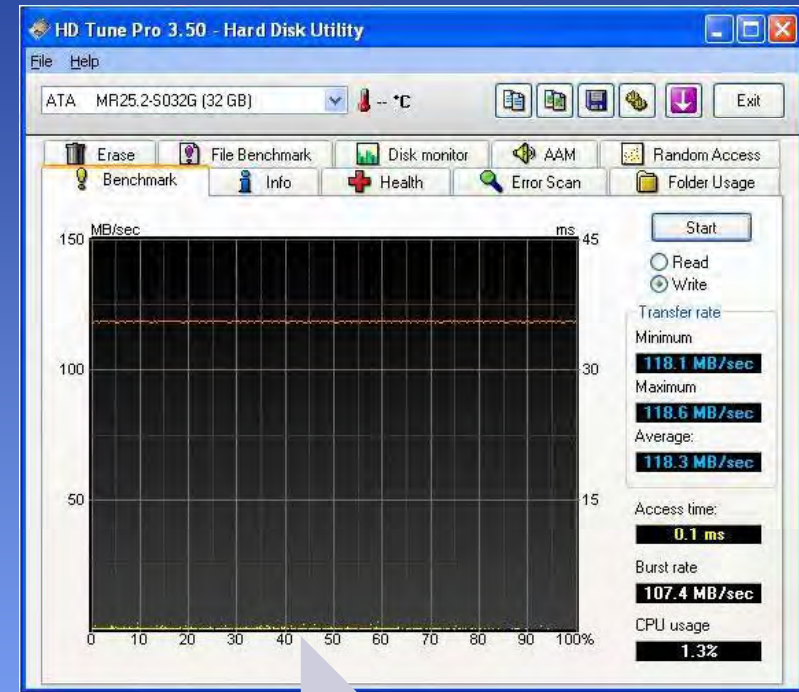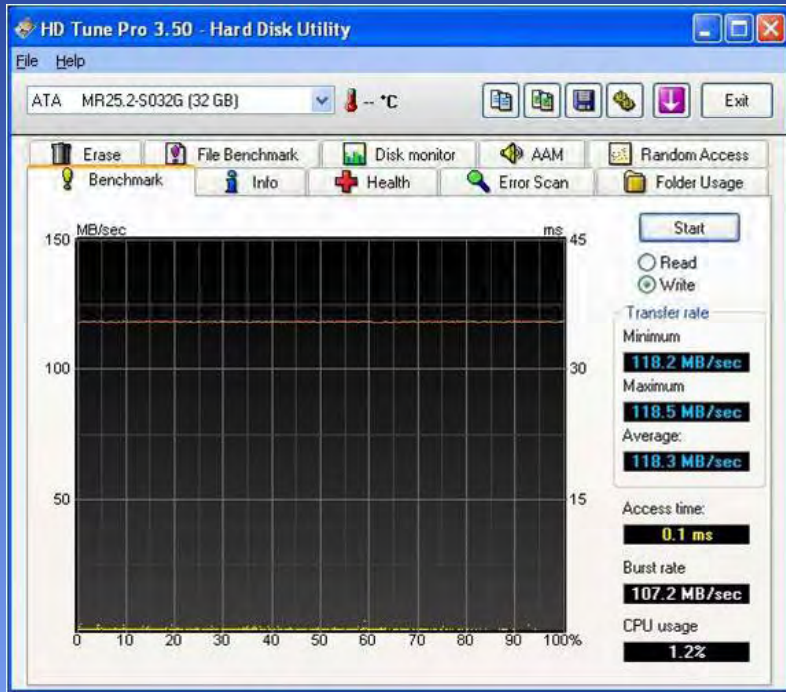
Workload dependency - 1

Step 1: HD Tune Pro Sequential Write Test

Average write: 172.5MB/s

Step 2: IOMeter Random Write Test

Step 3: HD Tune Pro Sequential Write Test

Average write: 16.8MB/s

90% drop

Workload dependency - 2

Step 1: HD Tune Pro Sequential Write Test

Average write: 118.3MB/s

Step 2: IOMeter Random Write Test

Step 3: HD Tune Pro Sequential Write Test

Average write: 113.3MB/s

4% drop

Benchmark Suites

	Test Suite	Commercial/ Client SSD	Enterprise SSD
PCMark	HDD Score, OS and application loading timing, user simulation (surfing web, windows media player...)	√	
SysMark	System-level, Me... performance...		
IOMeter	Sequen... workload... ser...		√
HDTach/ H2benchw	Performance s... performance, ...ccess...		√
HD Tune	Performance stability, Sequential/Burst performance, Access Time		
Everest	Random Access Time (Read/Write)	√	√

Type of preconditioning and order of benchmarks can influence results

Performance benchmark steps

1. Pre-condition the drive

2. Run IOMeter for 3D IOPS view
   - Block size 512b-1MB
   - Entire Read/Write Mix range

3. Validate performance stability
   - Performance vs. time plot

4. Validate workload independency
   - Run sequential test, random test, sequential test
   - Run work load simulations (i.e. File server, web server. etc)

5. Run multiple composite benchmark tests to validate results

Standardization initiatives

- ## Technical Work Group (TWG) of SNIA
  - Performance Benchmark Standard: defines preconditioning, reference test platform, benchmark profiles, etc.
  - First draft available to public: 4Q09
- ## JEDEC 64.8
  - Specification for SSD endurance measurement
- ## SSDA
  - Testing of reliability (power cycling, data retention, endurance, etc) and OS compatibility (Windows 7)

Questions?