SNIA

Education

The Why and How of SSD Performance Benchmarking

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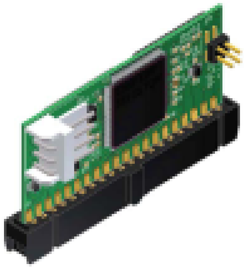
Abstract

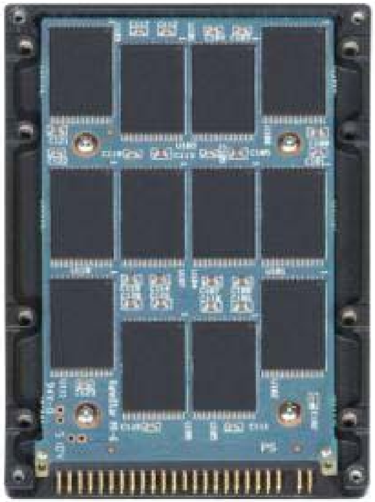
- A variety of parameters can influence the performance behavior of a solid state drive: current and previous workloads, fragmentation, block size, read/write mix, and queue depth to name a few
- SNIA's Performance Test Specification allows for performance benchmarking that result in repeatable and consistent test results
- This presentation will provide an overview of the SNIA SSD Performance Test Specification for both client and enterprise SSDs

Definition of SSS

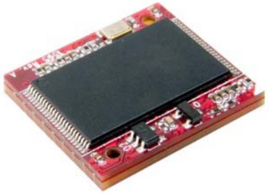
SSS = Solid State Storage



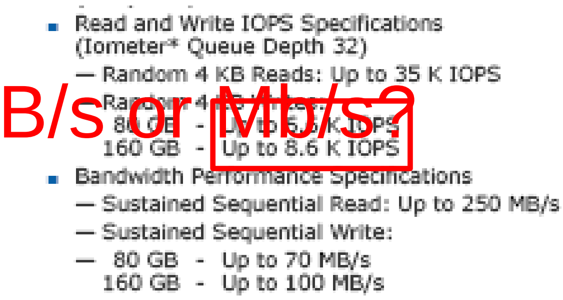
Traditional hard disk drive



Solid state hard drive

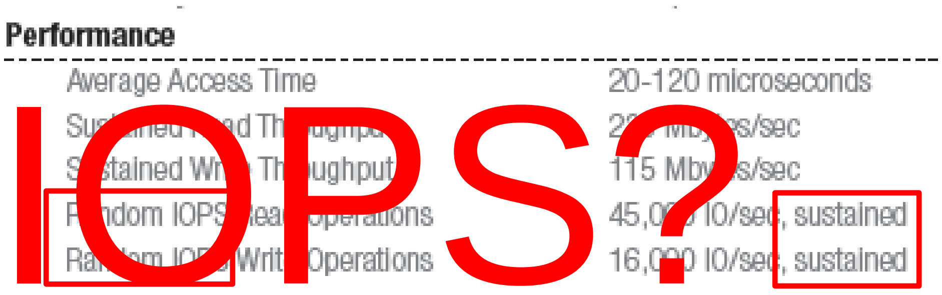


The Performance Landscape



- Read and Write IOPS Specifications (Iometer* Queue Depth 32)
  - Random 4 KB Reads: Up to 35 K IOPS
  - Random 4 KB Writes:
    80 GB - Up to 6.6 K IOPS
    160 GB - Up to 8.6 K IOPS
- Bandwidth Performance Specifications
  - Sustained Sequential Read: Up to 250 MB/s
  - Sustained Sequential Write:
  - 80 GB - Up to 70 MB/s
    160 GB - Up to 100 MB/s

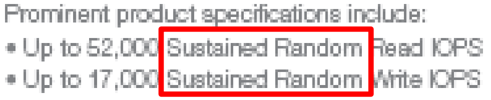
MB/s or Mb/s?



Performance

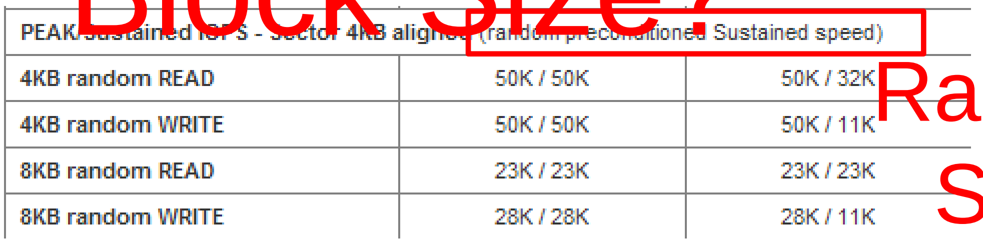
Average Access Time	20-120 microseconds
Sustained Read Throughput	2[illegible] Mbytes/sec
Sustained Write Throughput	115 Mbytes/sec
Random IOPS Read Operations	45,000 IO/sec, sustained
Random IOPS Write Operations	16,000 IO/sec, sustained

IOPS?



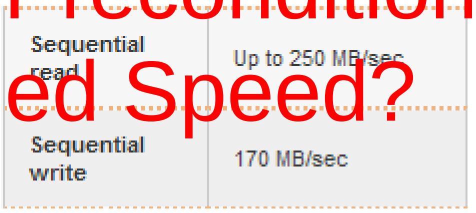
Prominent product specifications include:
- Up to 52,000 Sustained Random Read IOPS
- Up to 17,000 Sustained Random Write IOPS

Block Size?



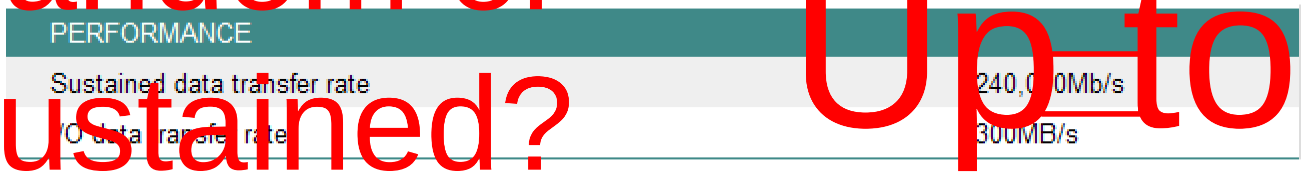
PEAK sustained IOPS - Sector 4KB aligned (random preconditioned Sustained speed)		
4KB random READ	50K / 50K	50K / 32K
4KB random WRITE	50K / 50K	50K / 11K
8KB random READ	23K / 23K	23K / 23K
8KB random WRITE	28K / 28K	28K / 11K

Random Precondition Sustained Speed?



Sequential read	Up to 250 MB/sec
Sequential write	170 MB/sec

Random or Sustained?



PERFORMANCE	
Sustained data transfer rate	240,000Mb/s
I/O data transfer rate	300MB/s

Up to?

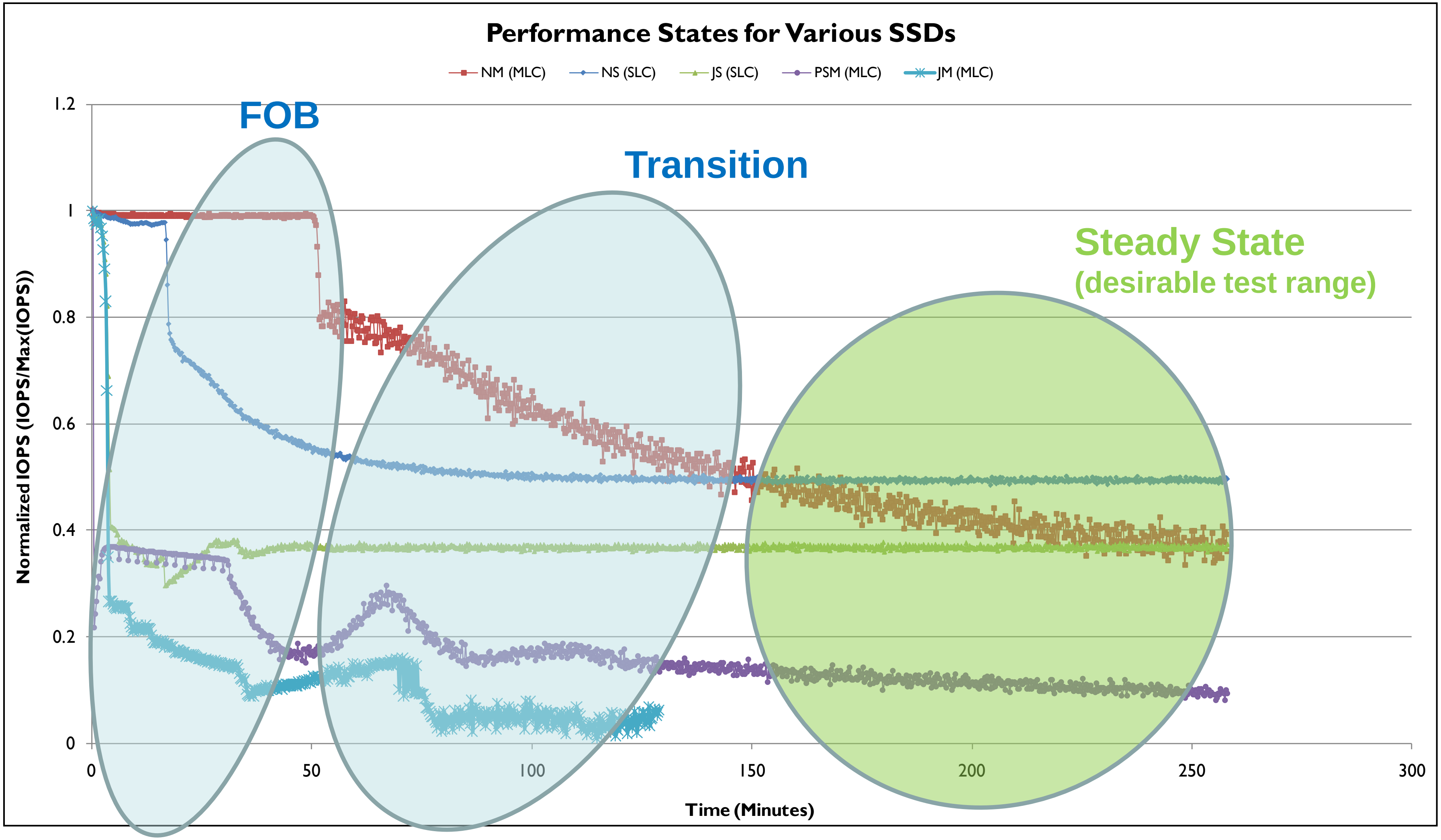
Variables influencing Performance

- Platform
  - Test Hardware (CPU, interface, chipset, etc)
  - Software (OS, drivers)
- SSS Device Architecture
  - Flash geometry, cache, flash management algorithm, etc

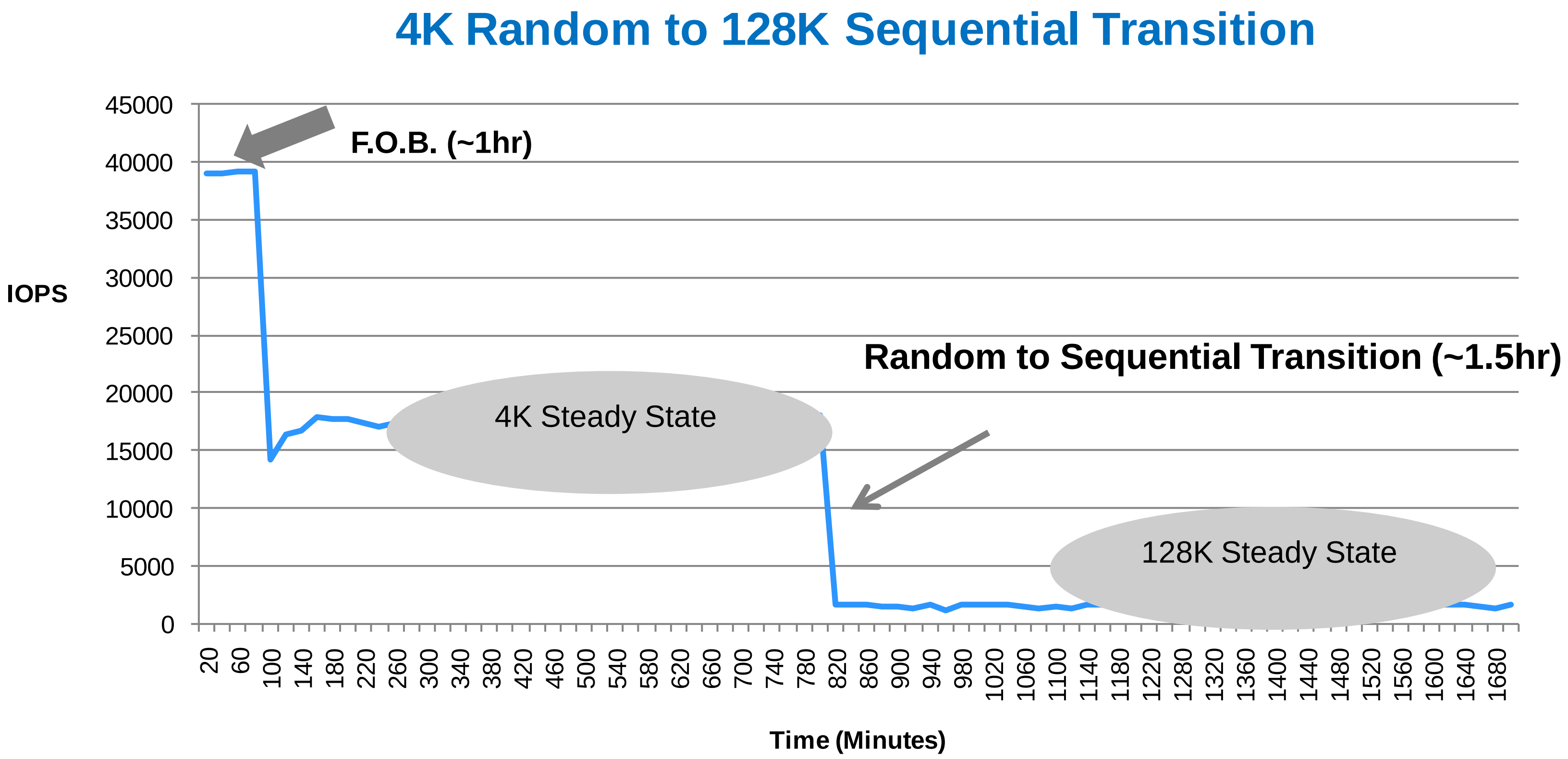
Variables influencing Performance

- Platform
  - Test Hardware (CPU, interface, chipset, etc)
  - Software (OS, drivers)
- SSS Device Architecture
  - Flash geometry, cache, flash management algorithm, etc
- Workload
  1. Write history & preconditioning: State of device before testing

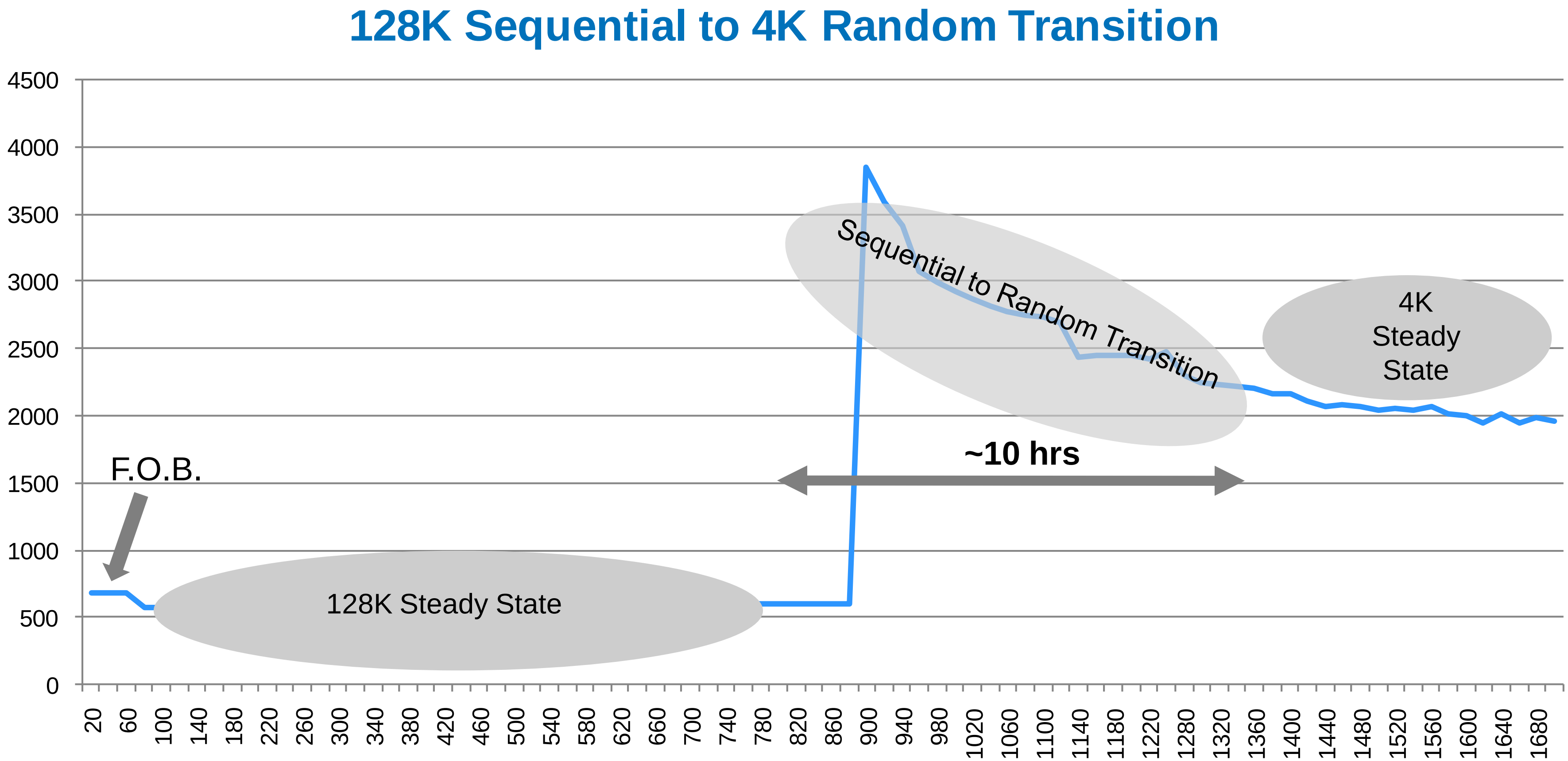
The need for Preconditioning



Write History - 1



Write History - 2

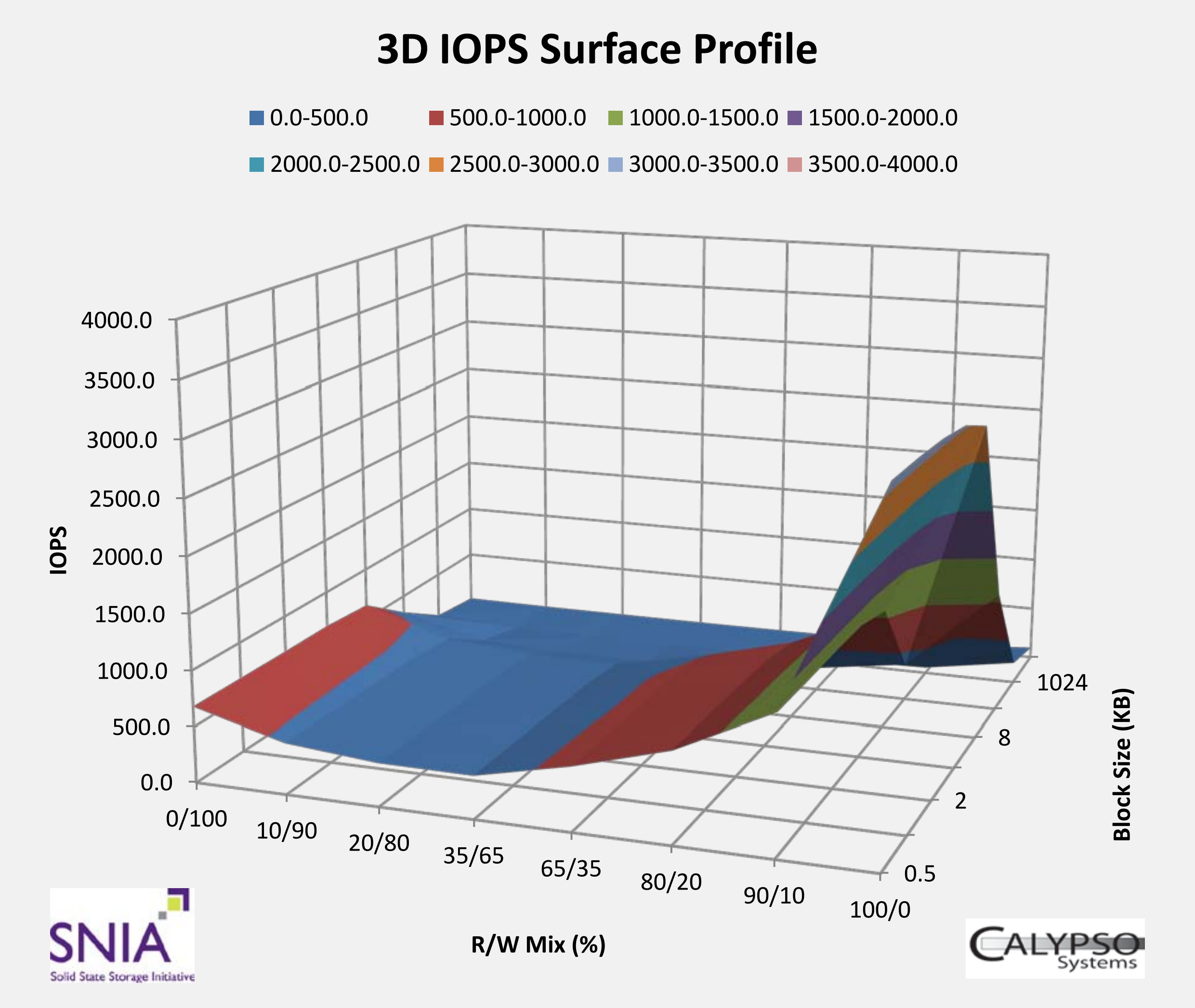


Variables influencing Performance

- Platform
  - Test Hardware (CPU, interface, chipset, etc)
  - Software (OS, drivers)
- SSS Device Architecture
  - Flash geometry, cache, flash management algorithm, etc

- Workload
  1. Write history & preconditioning: State of device before testing
  2. Workload pattern: Read/write mix, transfer size, sequential/random

Workload Pattern



Performance depends on

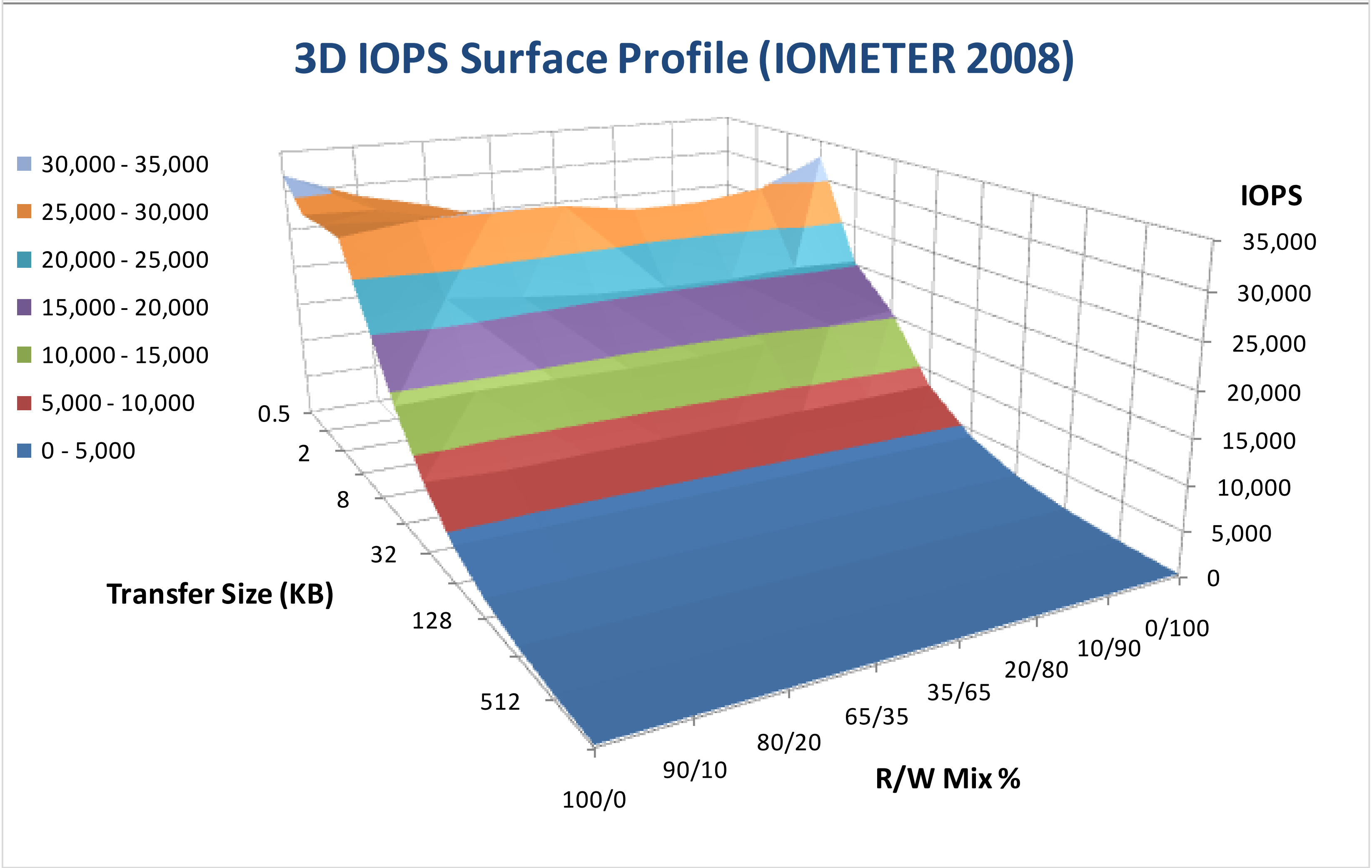
- Read/Write Mix
- Block Size
- Queue Depth (not shown)

Variables influencing Performance

- Platform
  - Test Hardware (CPU, interface, chipset, etc)
  - Software (OS, drivers)
- SSS Device Architecture
  - Flash geometry, cache, flash management algorithm, etc

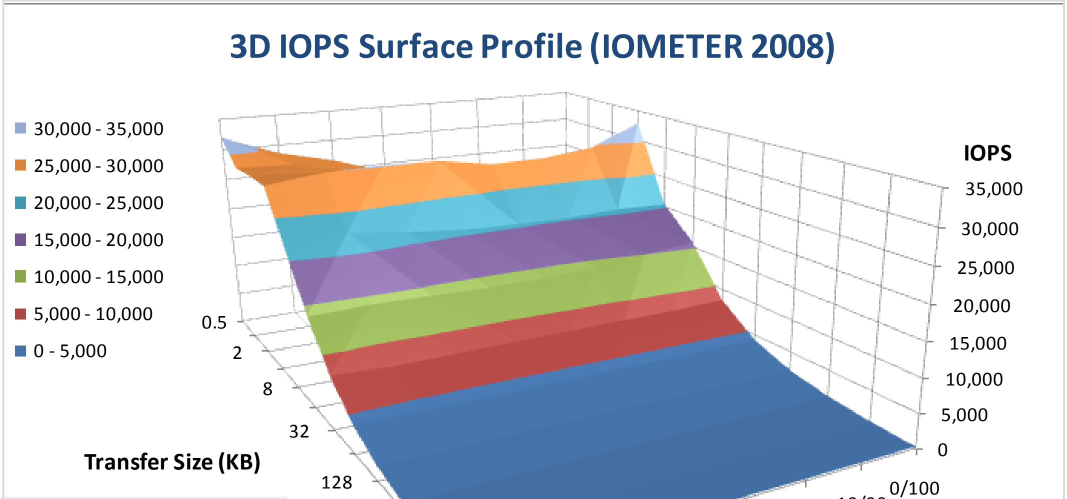
- Workload
  1. Write history & preconditioning: State of device before testing
  2. Workload pattern: Read/write mix, transfer size, sequential/random
  3. Data Pattern: The actual bits in the data payload written to the device

Dependency on data content - I

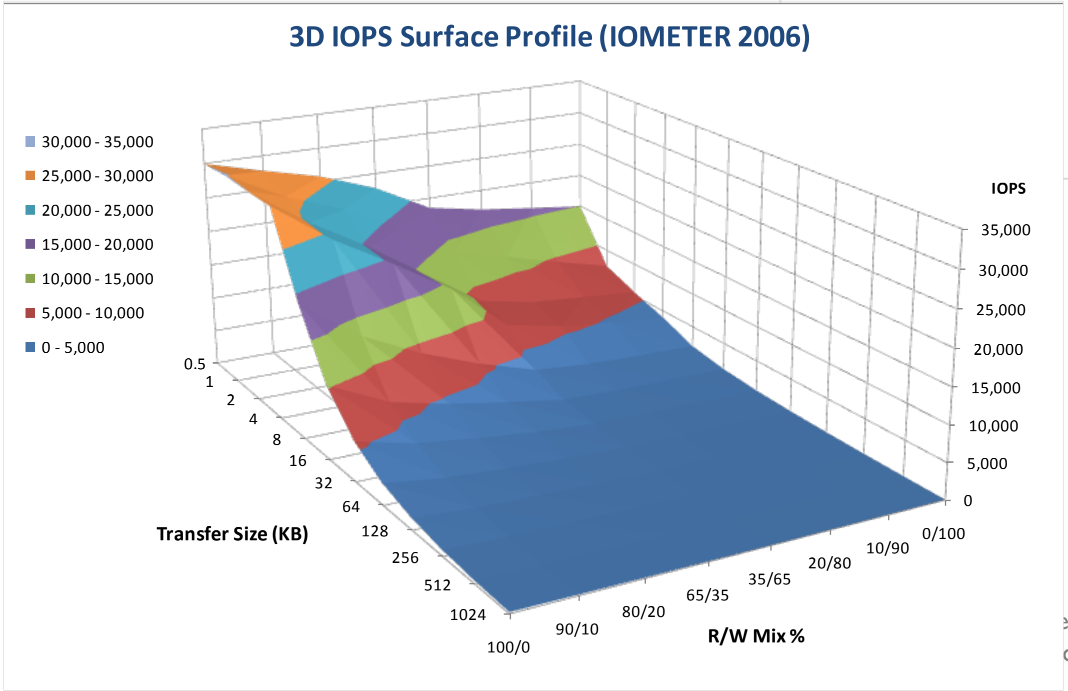


Dependency on data content - 2

IOMeter 2008
Low Entropy Data Content



3D IOPS Surface Profile (IOMETER 2008)



3D IOPS Surface Profile (IOMETER 2006)

IOMeter 2006
High Entropy Data Content

The Need for Industry Standardization!

- SNIA Technical Working Group (TWG)
  - Created in early 2009
- Specification for tests procedures to enable comparative testing of SSS performance
  - **Agnostic** – Does not favor any one technology
  - **Relevant & Repeatable** – Meaningful to end users
  - **Practical** – Complete with reasonable time and effort
- Performance Test Spec (PTS) 1.0 Client Released
- PTS 1.0 Enterprise Released
  - PTS 1.1 in progress, target release 4Q11

Benchmark Types

Synthetic

IOMeter, VDBench

- Test specific scenario (QD, block size, transfer rate)
- Good to determine corner case behavior

Application-based

SysMark, PCMark

- Test performance of specific application (ignores QD, transfer size, etc.)
- Illustrates real world differences

Trace-based

Storage Bench

- Measures performance as drive is used (traces)
- Most valid when similar applications are run (no two user workloads are the same)

SNIA PTS focuses on synthetic based benchmark tools

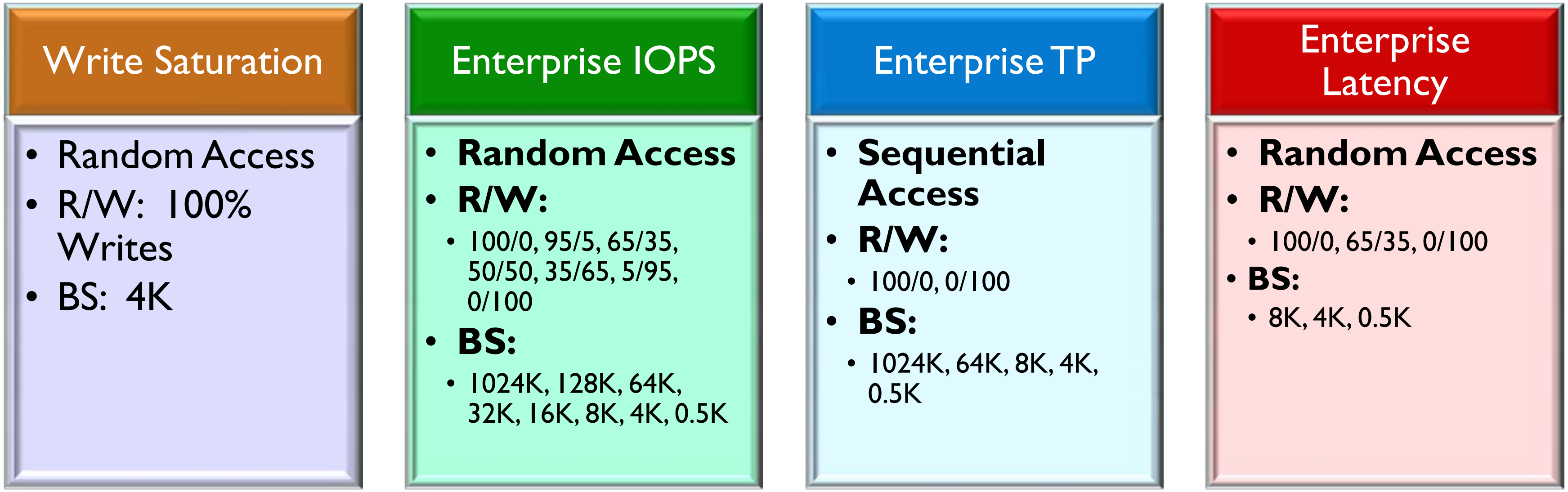
SSSI Reference Test Platform

- Intel S5520HC
- Single Intel W5580, 3.2GHz, Quad-core CPU
- 12GB, 1333MHz, ECC DDR3 RAM
- LSI 9212-4e4i 6Gb/s SAS HBA
- Intel ICH10R 3Gb/s SATA
- 8X Gen-II PCI-e

- CentOS 5.5
- Calypso RTP Backend V1.5
- Calypso Test Suite (CTS) V6.5

Tests Contained In Draft V1.0 Spec.

- The V1.0 Specification encompasses:
  - A suite of basic SSS performance tests



Write Saturation

- Random Access
- R/W: 100% Writes
- BS: 4K

Enterprise IOPS

- **Random Access**
- **R/W:**
  - 100/0, 95/5, 65/35, 50/50, 35/65, 5/95, 0/100
- **BS:**
  - 1024K, 128K, 64K, 32K, 16K, 8K, 4K, 0.5K

Enterprise TP

- **Sequential Access**
- **R/W:**
  - 100/0, 0/100
- **BS:**
  - 1024K, 64K, 8K, 4K, 0.5K

Enterprise Latency

- **Random Access**
- **R/W:**
  - 100/0, 65/35, 0/100
- **BS:**
  - 8K, 4K, 0.5K

- Preconditioning and Steady State requirements
- Standard test procedures
- Standard test reporting requirements

What Is NOT Covered In the Spec

- Application workload tests
- Matching to user workloads
- Energy efficiency
- Required test platform (HW/OS/Tools)
- Certification
- Device endurance, availability, data integrity

- Performance Test Specification v1.0 – Section 1.4

Basic Test Flow

1. Purge

- Security Erase, Sanitize, Format Unit, other proprietary methods where indicated

2. Set Conditions

- Set user selectable test parameters, such as Active Range, Data Pattern, Demand Intensity

3. Pre-Condition

- Workload independent (WIPC)
- Workload dependent (WDPC)

4. Run Until SS

- Reiterate loops until Steady State is reached, or run to a prescribed maximum number of loops

5. Collect Data

- Collect data from Steady State Measurement Window

6. Generate Reports

- Use standard report formats and include required and optional elements

Key Concepts Used in the Spec.

- A. Purge
- B. Pre-Condition
  - Workload independent
  - Workload dependent
- C. Active Range
  - Pre-conditioning
  - Test
- D. Steady State
  - Measurement window
  - Data excursion condition
  - Slope excursion condition

A: Purge

- As per the PTS V1.0 Specification, purge is defined as:

> *“ The process of returning an SSS device to a state in which subsequent writes execute, as closely as possible, as if the device had never been used and does not contain any valid data”*

- Example implementation includes: ATA Security Erase, Sanitize, SCSI Format Unit

B: Pre-Conditioning

- Pre-Conditioning is a key requirement in getting repeatable, representative results
- Goal is to put drive into "Steady State", using:
  - Workload independent *– PTS v1.0 Section 3.3*
    - Use a prescribed workload unrelated to the test loop
    - Write 2X user capacity using SEQ/128KiB blocks
  - Workload dependent *– PTS v1.0 Section 3.3*
    - Run test workload itself as pre-conditioning (self pre-conditioning)

C: Active Range

- As per the PTS V1.0 Specification, Active Range is defined as:

"… ActiveRange is the range of LBA's that may be accessed by the preconditioning and/or test code..."

- They are normally defined as % of the maximum LBA available to the user
- Note Pre-conditioning and Test can have different Active Ranges

D: Steady State Definition

- Premise is that reported data should be take only AFTER the test loop results shows the drive has reached and maintained "Steady State"
- The Measurement Window is the interval, measured in Rounds, when the test results have entered and maintained Steady State for 5 Rounds

D: Steady State Definition

- Steady State is reached only if BOTH of the following conditions are satisfied (assuming "*y*" is the variable being tracked):

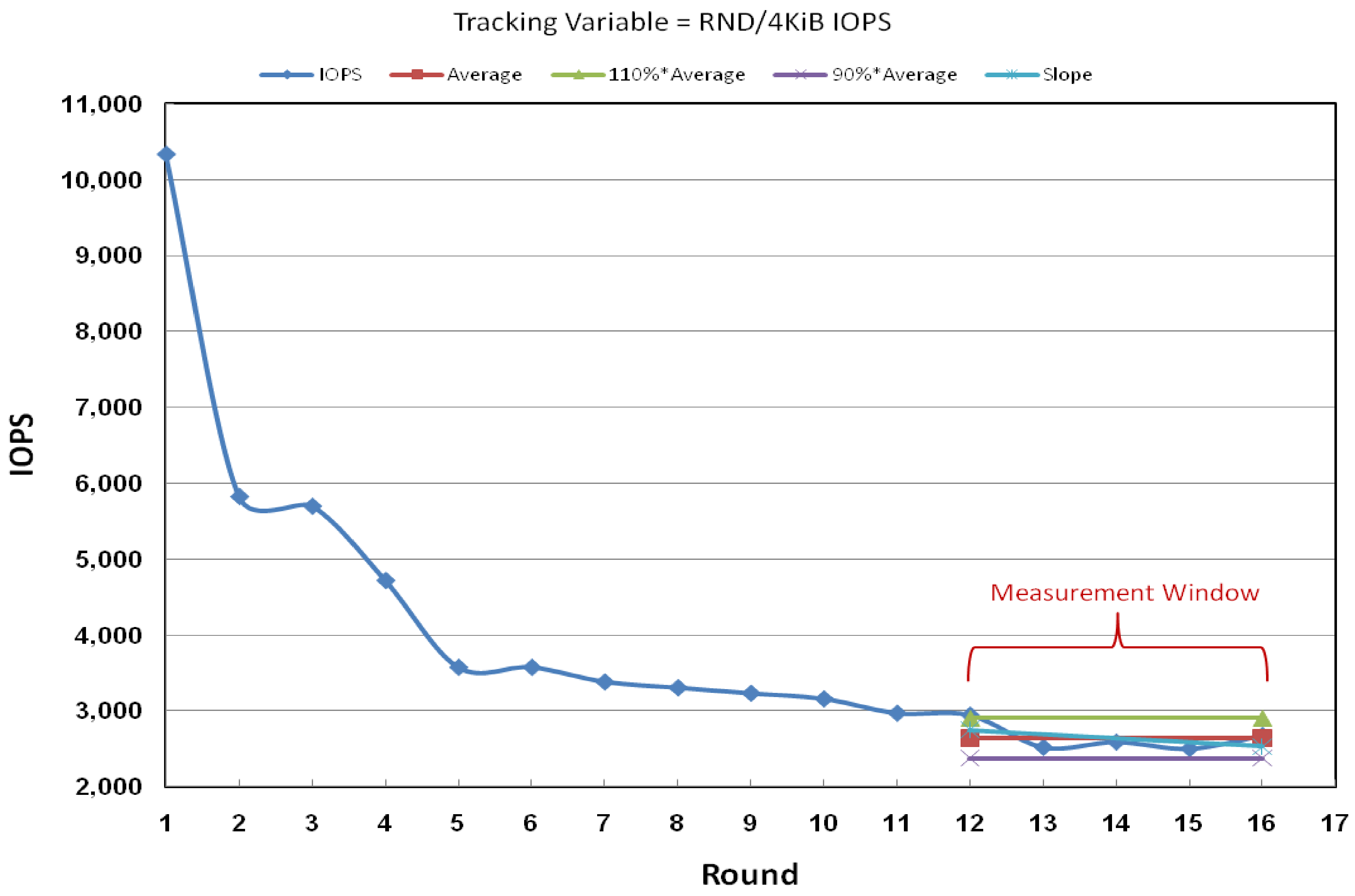
  1. Variation of *y* within the Measurement Windows is within 20% of the Average

     " Max(y)-Min(y) within the Measurement Window is no more than 20% of the Ave(y) within the Measurement Window; and "

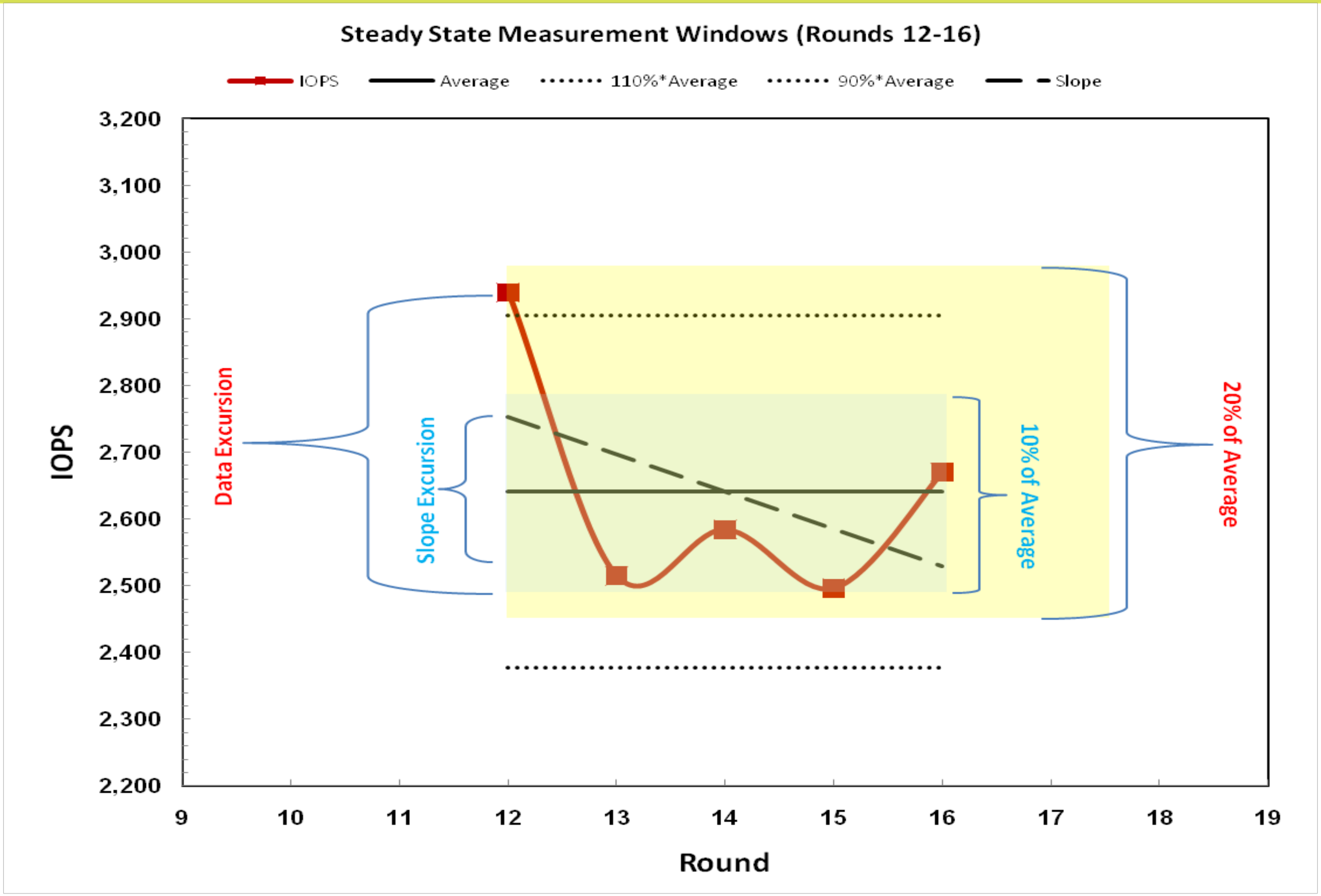
  2. Trending of *y* within the Measurement Windows is within 10% of the Average

     " [Max(y) as defined by the linear curve fit of the data within the Measurement Window] – [Min(y) as defined by the best linear curve fit of the data within the Measurement Window] is within 10% of Ave(y) within the Measurement Window. "

D: SS Measurement Window



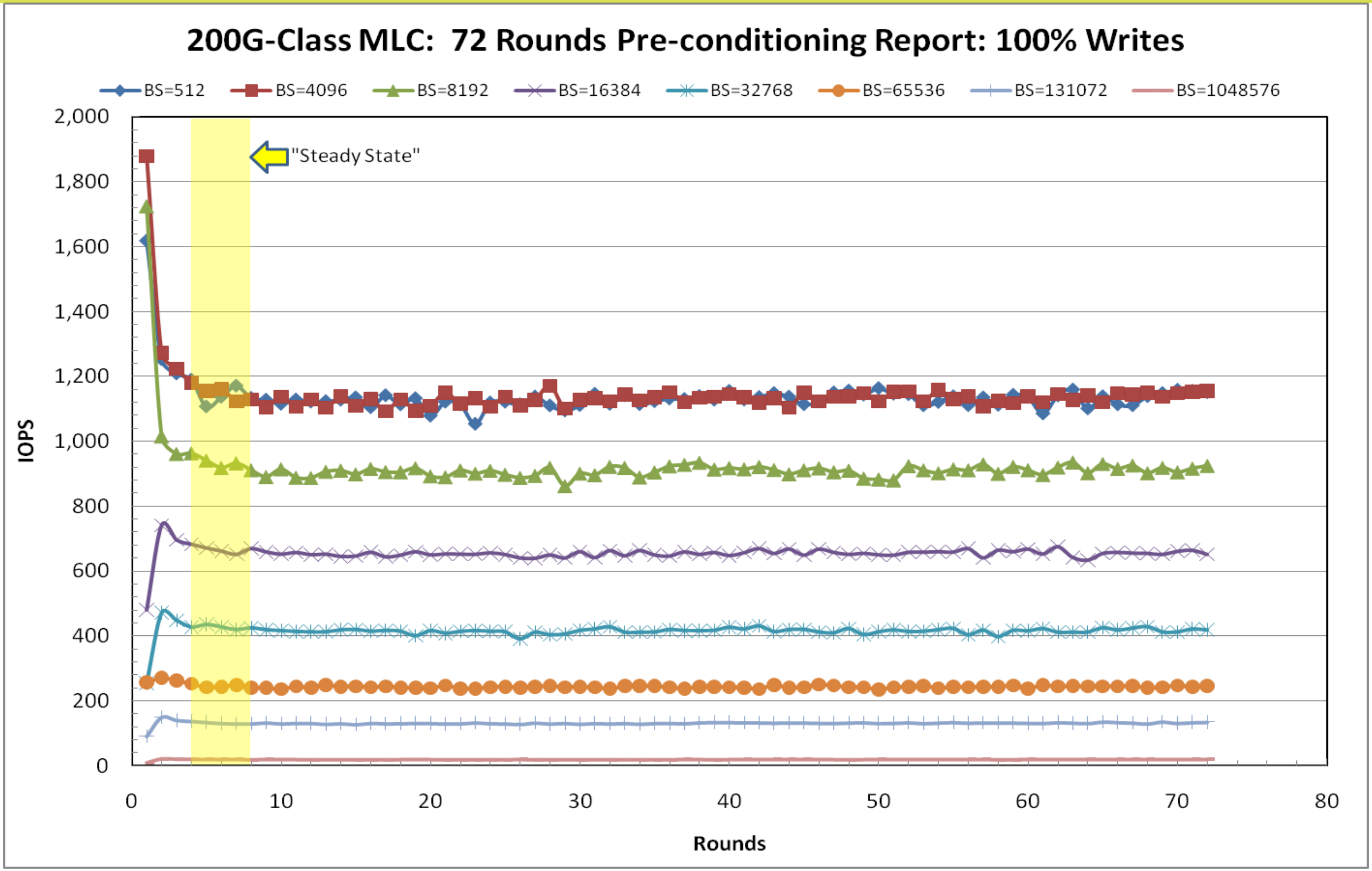
D: SS Measurement Window



D: Steady State Definition

- Compare
  - [Data Excursion] with [20% of Average]
  - [Slope Excursion] with [10% of Average]
- Note
  - This method is slightly more tolerant than +10% and – 10% data excursion method and +5% and – 5% slope excursion method

D: How Good is the Steady State



Workload Schematics

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Write Saturation

- Random Access
- R/W: 100% Writes
- BS: 4K

Enterprise IOPS

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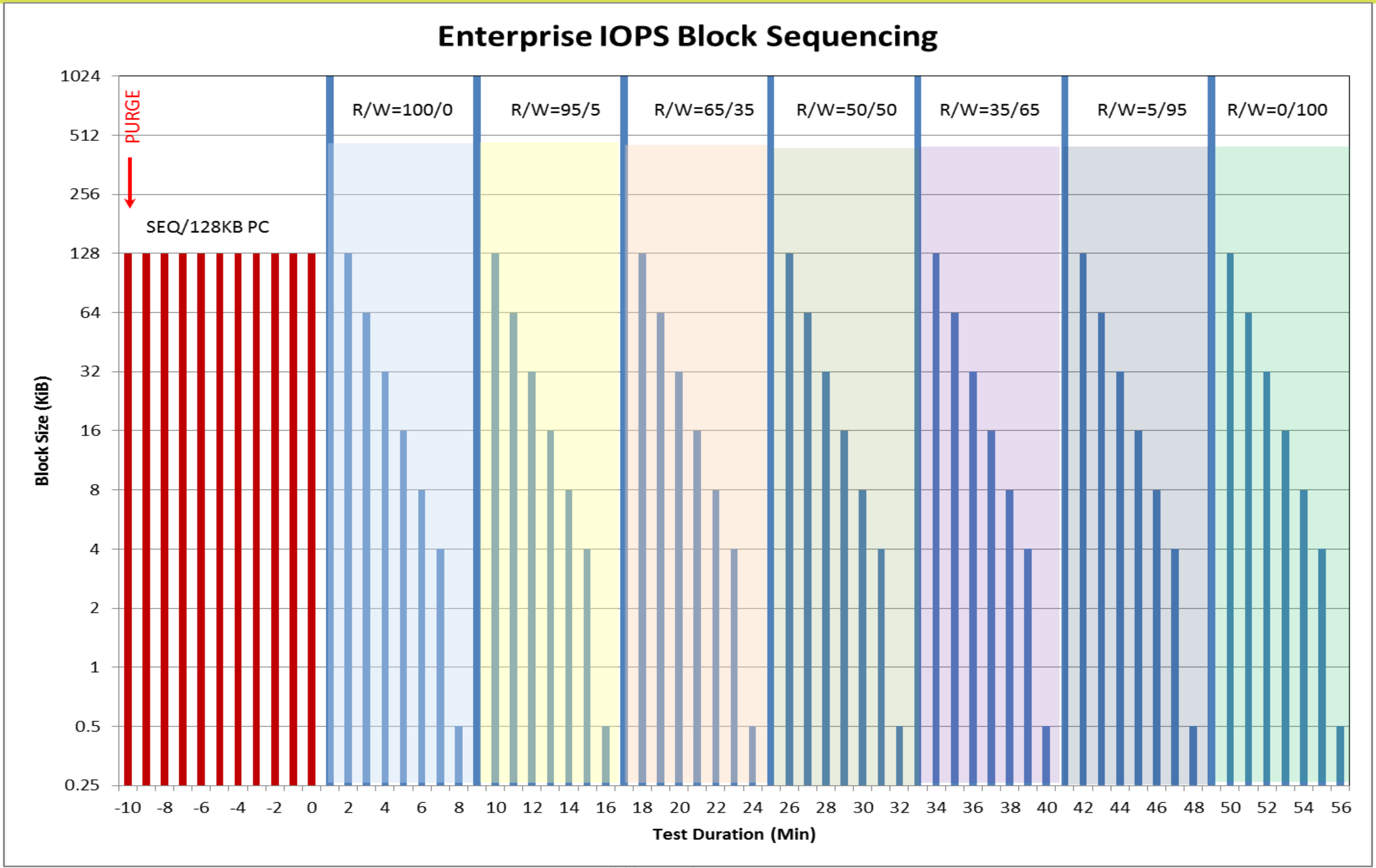
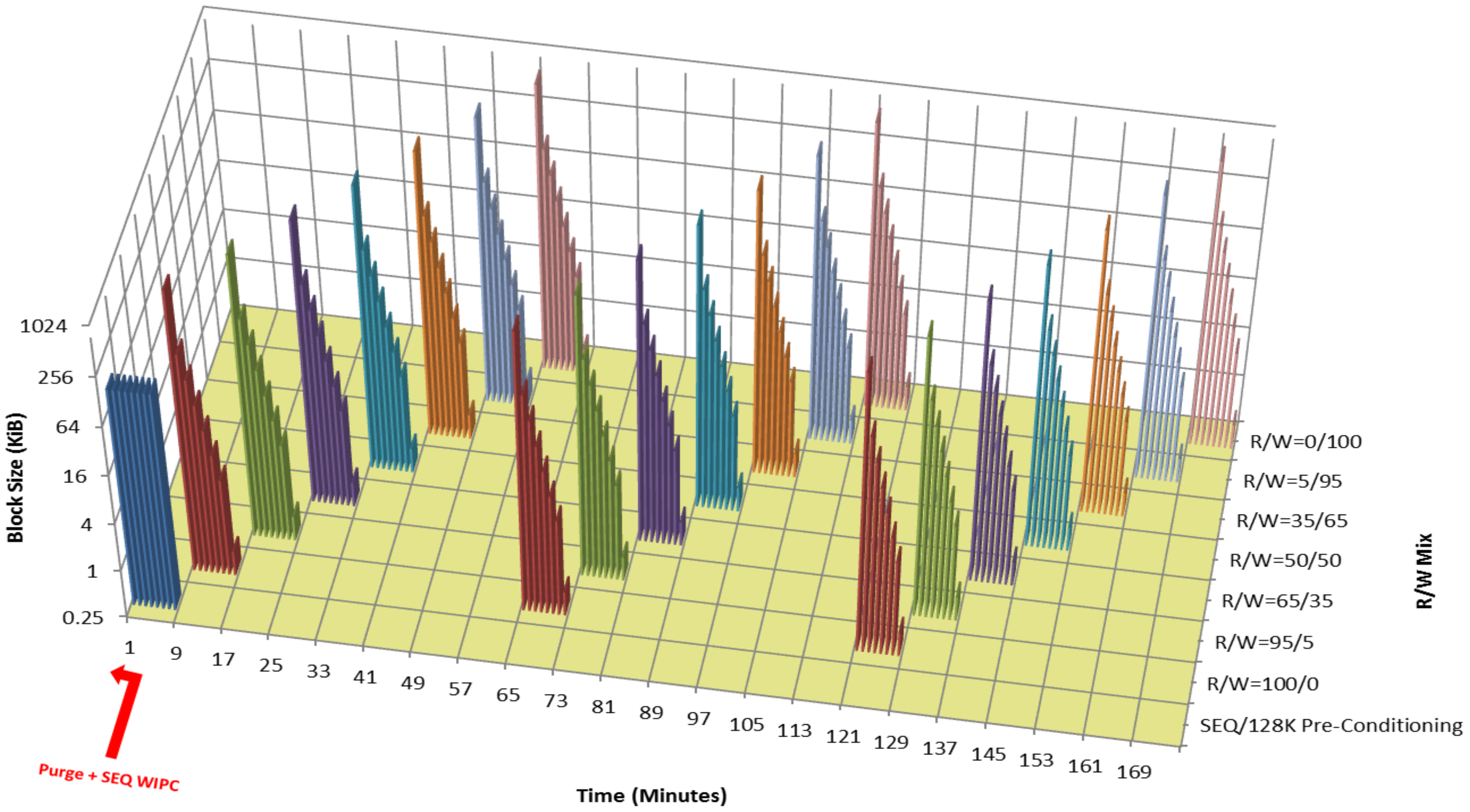
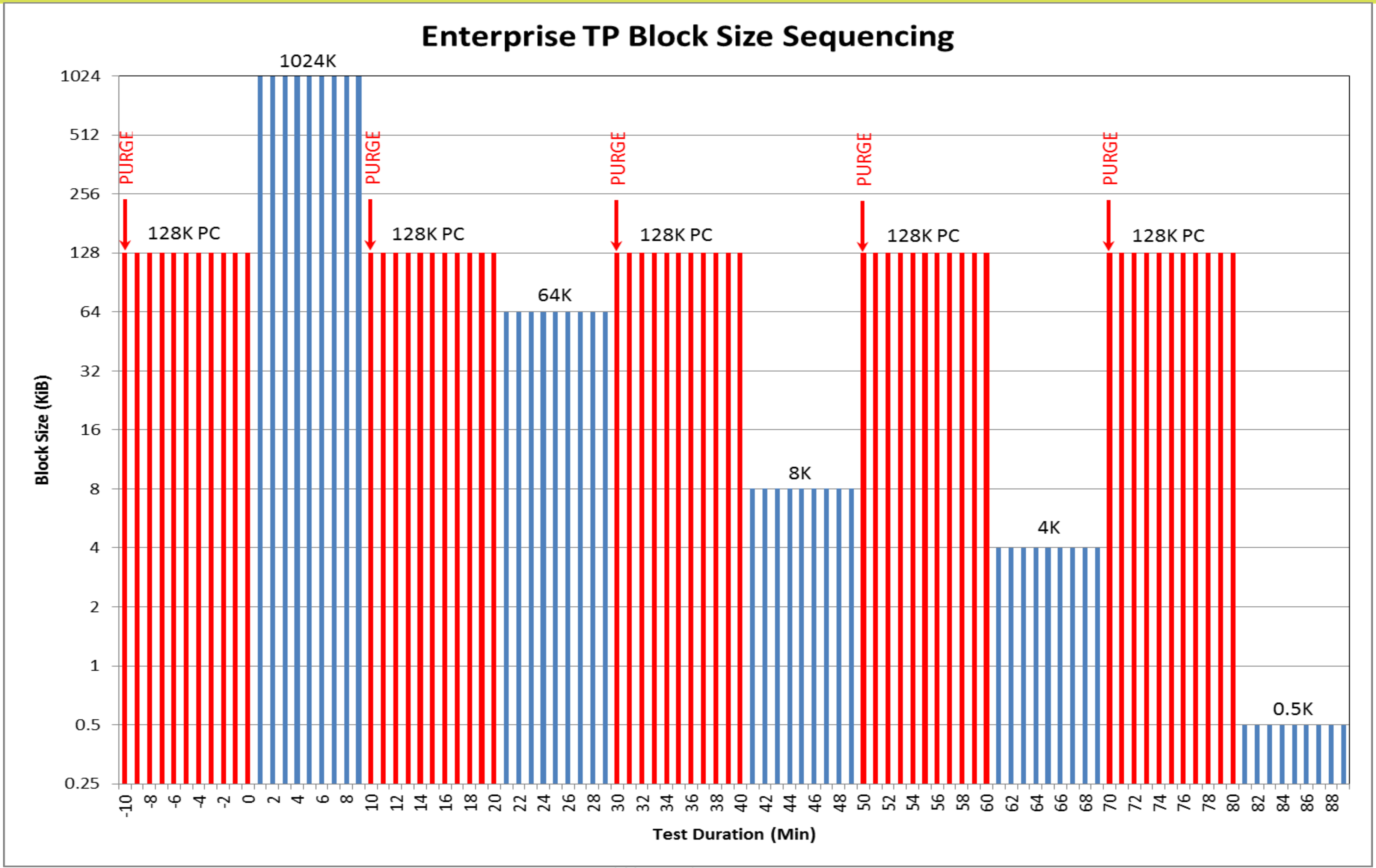
IOPS RW/BS Sequence



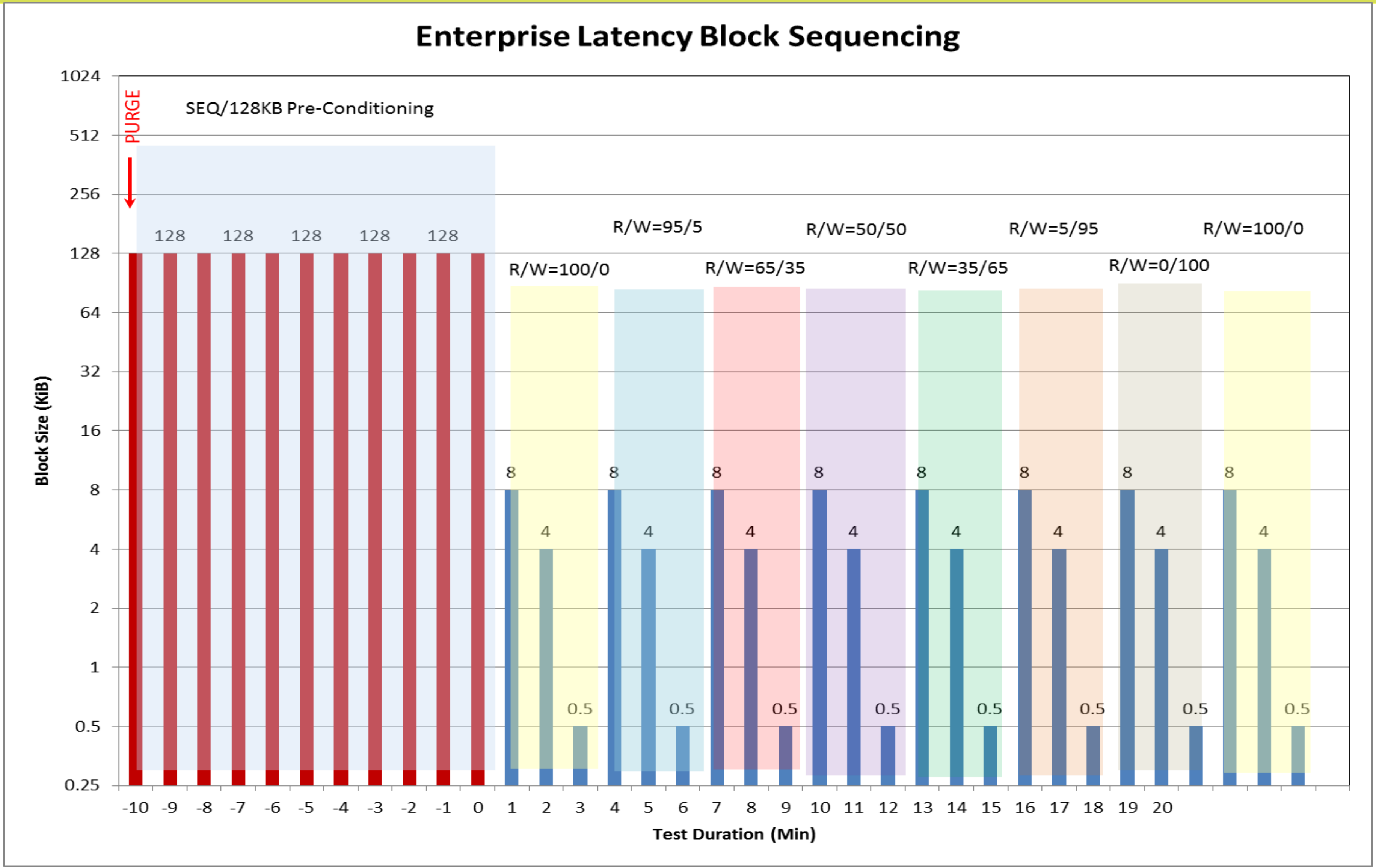
Enterprise IOPS RW/BS Sequence



TP RW/BS Sequence



Enterprise Latency RW/BS Sequence



Example: Enterprise IOPS

- DUT:
  - 100GB-Class Enterprise SLC drive
- Test Parameters:
  - Active Range = [0,100%]
  - Thread Count=2
  - Queue Depth (Outstanding IO/Thread)=16
  - DP=RND

Enterprise IOPS Draft Formatted Report, 1/6

Enterprise IOPS Draft Formatted Report, 2/6

Enterprise IOPS Draft Formatted Report, 3/6

Enterprise IOPS Draft Formatted Report, 4/6

Enterprise IOPS Draft Formatted Report, 5/6

Enterprise IOPS Draft Formatted Report, 6/6

PTS Follow-On Work (PTS-E 1.1)

Idle Recovery	• See how the drive responds to host idle time amidst continuous access
Cross Stimulus Recovery	• See how drive handles switching between sustained access patterns
Demand Intensity	• See how drive responds to increasing host demands
Response Time Histogram	• Get detailed response time statistics during specific stimulus
IOPS/W	• Measures power efficiency of the device
Trace-Based Workloads	• Captures or uses captured workloads traces and provide a consistent way to playback such traces
Enterprise Composite Synthetic Workload	• Synthetic composite workload for Enterprise environments similar to JEDEC workload for endurance testing

Q&A / Feedback

- Please send any questions or comments on this presentation to SNIA: tracksolidstate@snia.org

Many thanks to the following individuals for their contributions to this tutorial.

- SNIA Education Committee

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