SNIA Solid State Storage Performance Test Specification V0.9

Measuring the Performance of Solid State Storage Devices

- Draft V0.9 Released for Public Review -

Easen Ho

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PTS V0.9 Draft for Public Review

Public Review Period
7/12/2010 – 9/12/2010

The SSSI & SSS TWG seeks Industry Feedback

Download the spec:

www.snia.org/tech_activities/publicreview

Upload Feedback:

www.snia.org/tech_activities/feedback

Updates to Spec:

www.snia.org/forums/sssi

Solid State Storage Performance Test Specification – V0.9

SNIA
Advancing storage & information technology

Solid State Storage (SSS)
Performance Test Specification (PTS)

Version 0.9

Publication of this Working Draft for review and comment has been approved by the SSS TWG. This draft represents a "best effort" attempt by the SSS TWG to reach preliminary consensus, and it may be updated, replaced, or made obsolete at any time. This document should not be used as reference material or cited as other than a "work in progress." Suggestion for revision should be directed to http://www.snia.org/feedback/.

Working Draft

June 22, 2010

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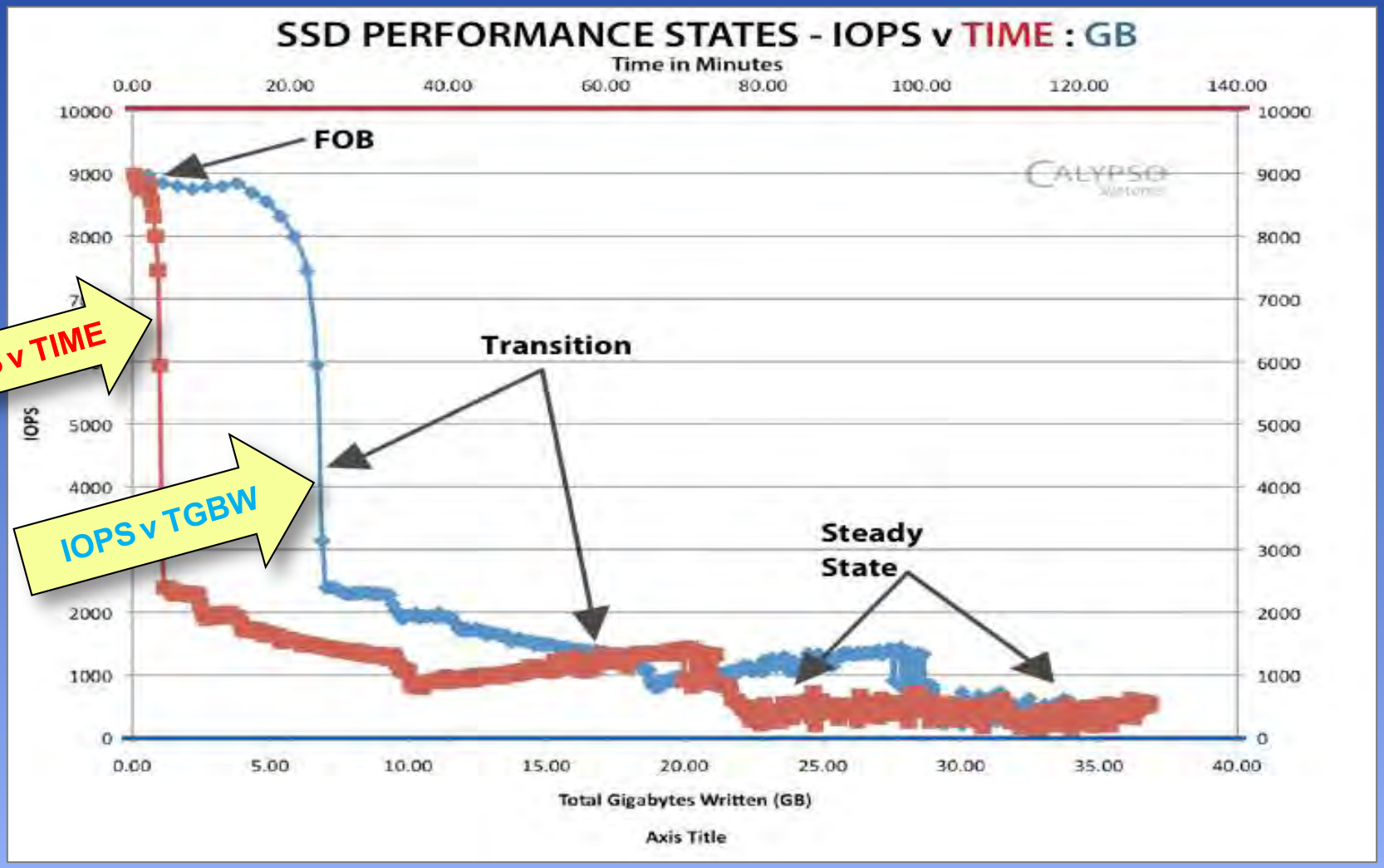
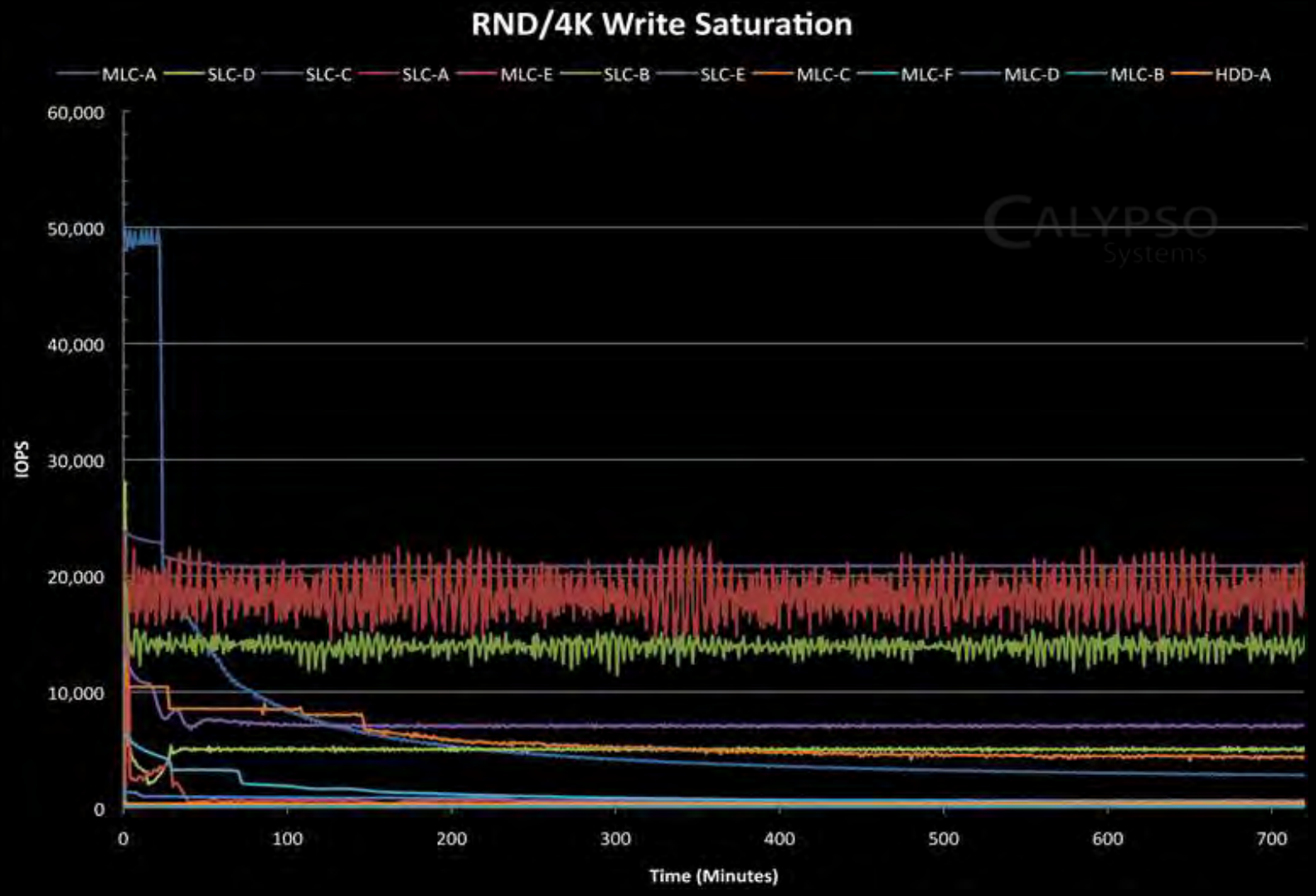
Motivation

- No Industry Standard
  - No standard methodology, common terminology, nor test environment for measuring SSS performance
- Ad Hoc Tests & Benchmarks
  - SSS makers/reviewers use different applications, OS and hardware; produces and uses selected metrics
- Market Confusion
  - Difficult to compare test results from different sources; difficult to ensure accuracy in representing SSS products to end users

SSD Performance Varies Over Time



Many Different Kinds of Behaviors



Items Impacting SSD Performance

Write History	PC Active Range	Test Active Range	Data Pattern
• What was previously written	• Where data was previously written • Trim effects	• Where data is currently written	• What is being accessed

Access Pattern	Demand Intensity	Throttling	?
• Manner in which data is being accessed	• How hard the application is driving the device	• How much data is being written	

A Solution is in Emerging

- SSS PTS
  - SNIA SSSI & TWG Solid State Storage Performance Test Specification (SSS PTS) v 0.9 – 60 Day Public Review
- Standardized Tests & Methodologies
  - Effectively measure device performance of SSS products
- Fair Comparisons
  - Using a standardize test methodology and reporting requirements, performance can be more easily compared, particularly done using a reference environment

Key Concepts

- The SSS PTS introduces key basic concepts:
  - *Common Starting Point* - start test by first placing the drive into a known, repeatable state
  - *Pre-conditioning* – from the common starting point, pre-conditioned the drive
  - *Steady State* – measurements are taken only when the drive reaches and maintains steady state condition
  - *Required Reporting* – establishes required testing conditions and results reporting

The SSS PTS

- Test Platform Agnostic – No specified test environment
- Test Tool Requirements – Sets out minimum requirements a test application and the test environment must be able to do
- Standardized Test Report Format– Draft test report format is proposed with required conditions, variables & data formats
- Reference Test Platform (RTP) – A common RTP intended to facilitate direct comparison of drive device performance

Calypso's SSD Reference Test Platform

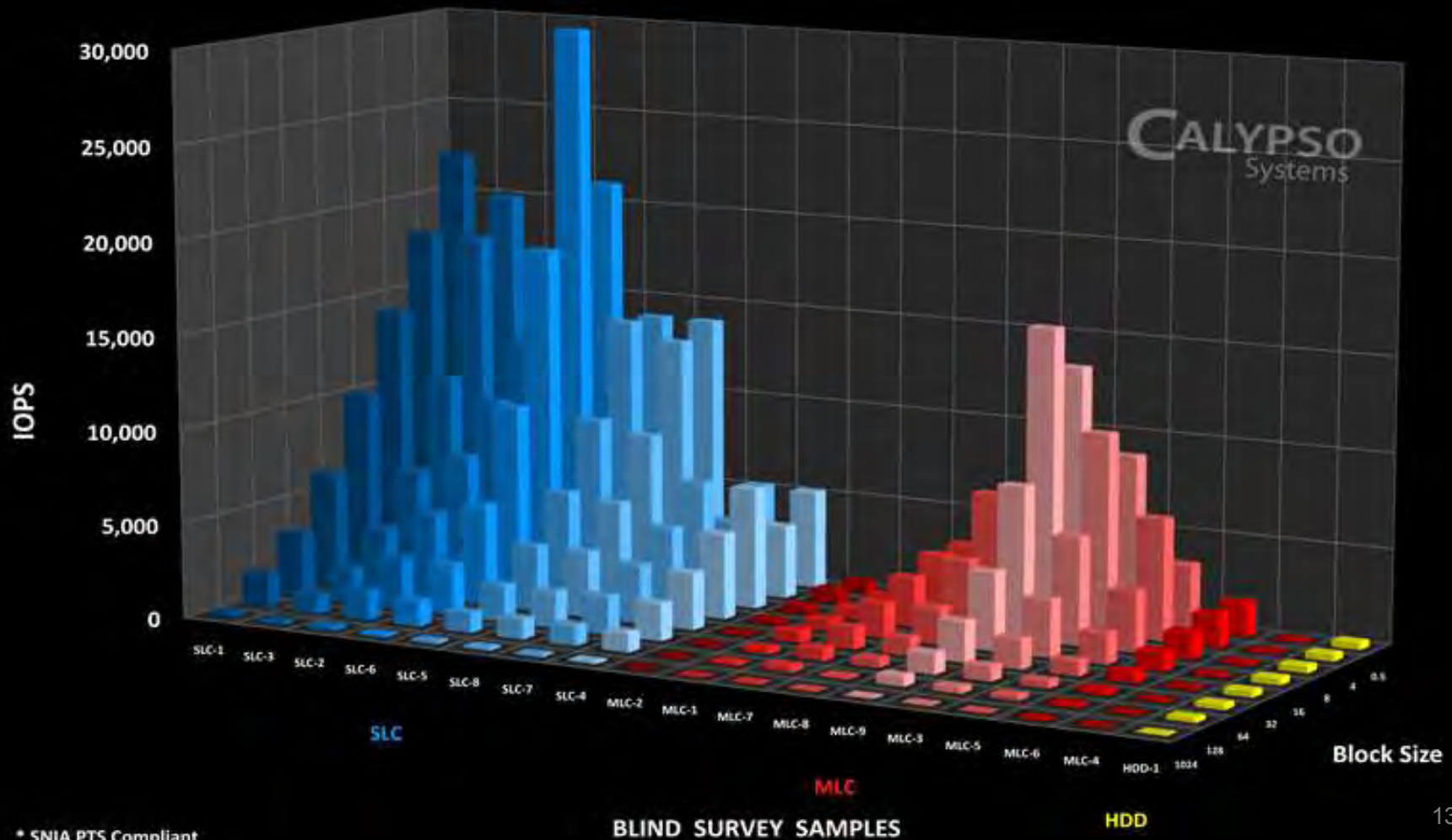
- The SNIA SSS TWG approved a "Reference Test Platform", which specified a set of hardware and options for software to allow direct comparisons
- Calypso has developed a RTP product based on this recommendation
- A significant portion of the data used as input to inform the formation of the Spec is taken on the Calypso RTP
- The Calypso RTP has been used extensively to validate the current Draft V0.9 Specification
- Calypso's RTP is fully PTS-compliant, and has been used by Calypso for 2010 Blind Survey of SAS/SATA SSDs & 3d Party Comparison Reports

Calypso's SSD 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

Data Taken on Calypso's SSD RTP R/W=65/35, Various Block Sizes



* SNIA PTS Compliant

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Purpose

"…This Specification defines a set of
device level tests
and methodologies to enable
comparative testing
of Solid State Storage (SSS) devices."

- Performance Test Specification v0.9 – Section 1.1

Test Contained In Draft V0.9 Spec.

- The V0.9 Specification encompasses:
  - A suite of basic SSS performance tests
    - IOPS
    - Throughput
    - Latency
  - Preconditioning requirements
  - Standard test procedures
  - Standard test reporting requirements

What Is NOT Covered In the Spec

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

- Performance Test Specification v0.9 – Section 1.3.1

The SNIA PTS Draft V0.9

Client 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

Client TP

- **Sequential Access**
- **R/W:**
  - 100/0, 0/100
- **BS:**
  - 1024K

Client Latency

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

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

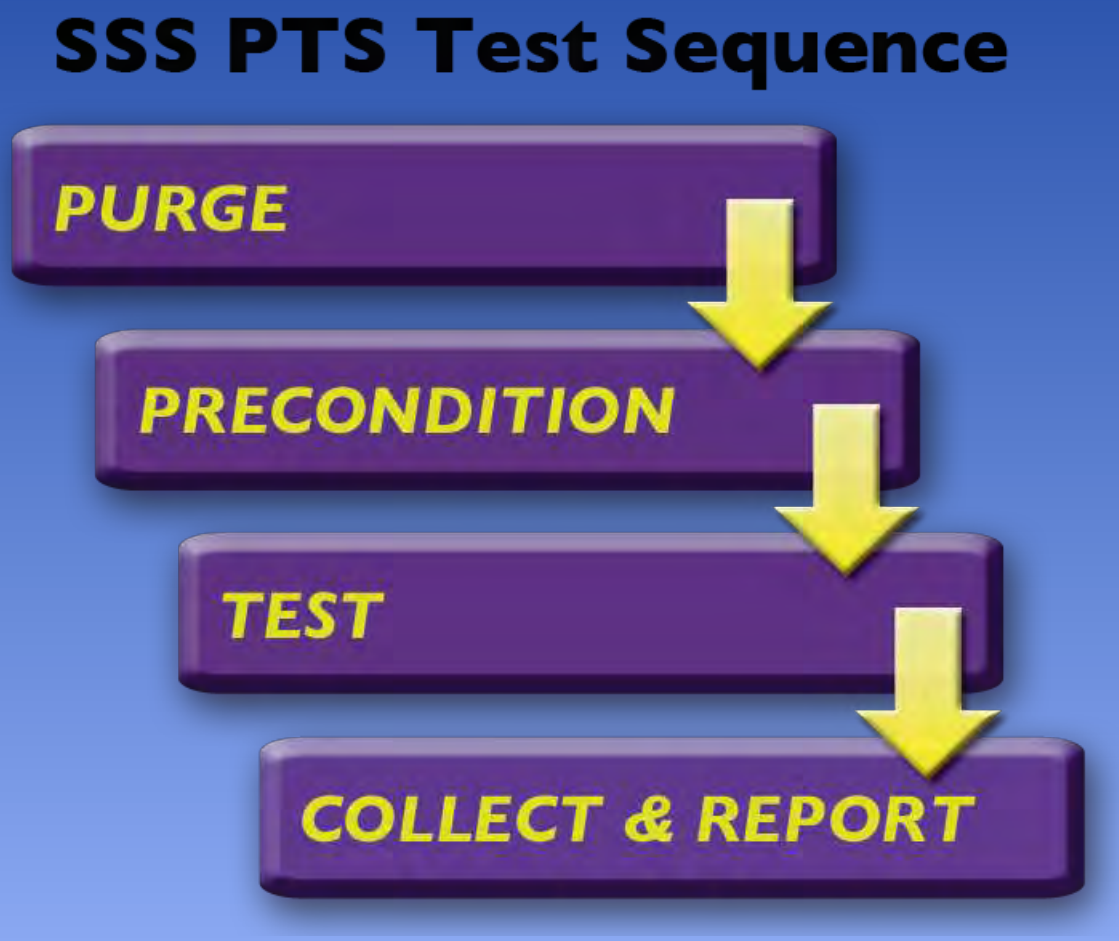
Enterprise Latency

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

Basic Test Flow

1. Purge	• Security Erase, Sanitize, Format Unit, other proprietary methods
2. Set Conditions	• Set user selectable test parameters, such as Active Range, Data Pattern, Demand Intensity
3. Pre-Condition	• Workload independent • Workload dependent
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

Basic Test Flow



Key Concepts Used in the Spec.

- Purge
- Pre-Condition
  - Workload independent
  - Workload dependent
- Active Range
  - Pre-conditioning
  - Test
- Steady State
  - Measurement window
  - Data excursion condition
  - Slope excursion condition

Purge

- As per the PTS V0.9 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

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 v0.9 Section 2.1.19*
    - Use a prescribed workload unrelated to the test loop
    - Write 2X user capacity using SEQ/128KiB blocks
  - Workload dependent *– PTS v0.9 Section 2.1.20*
    - Run test workload itself as pre-conditioning (self-pre-conditioning)

Active Range

- As per the PTS V0.9 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

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

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. "*

Illustration: Steady State Measurement Window

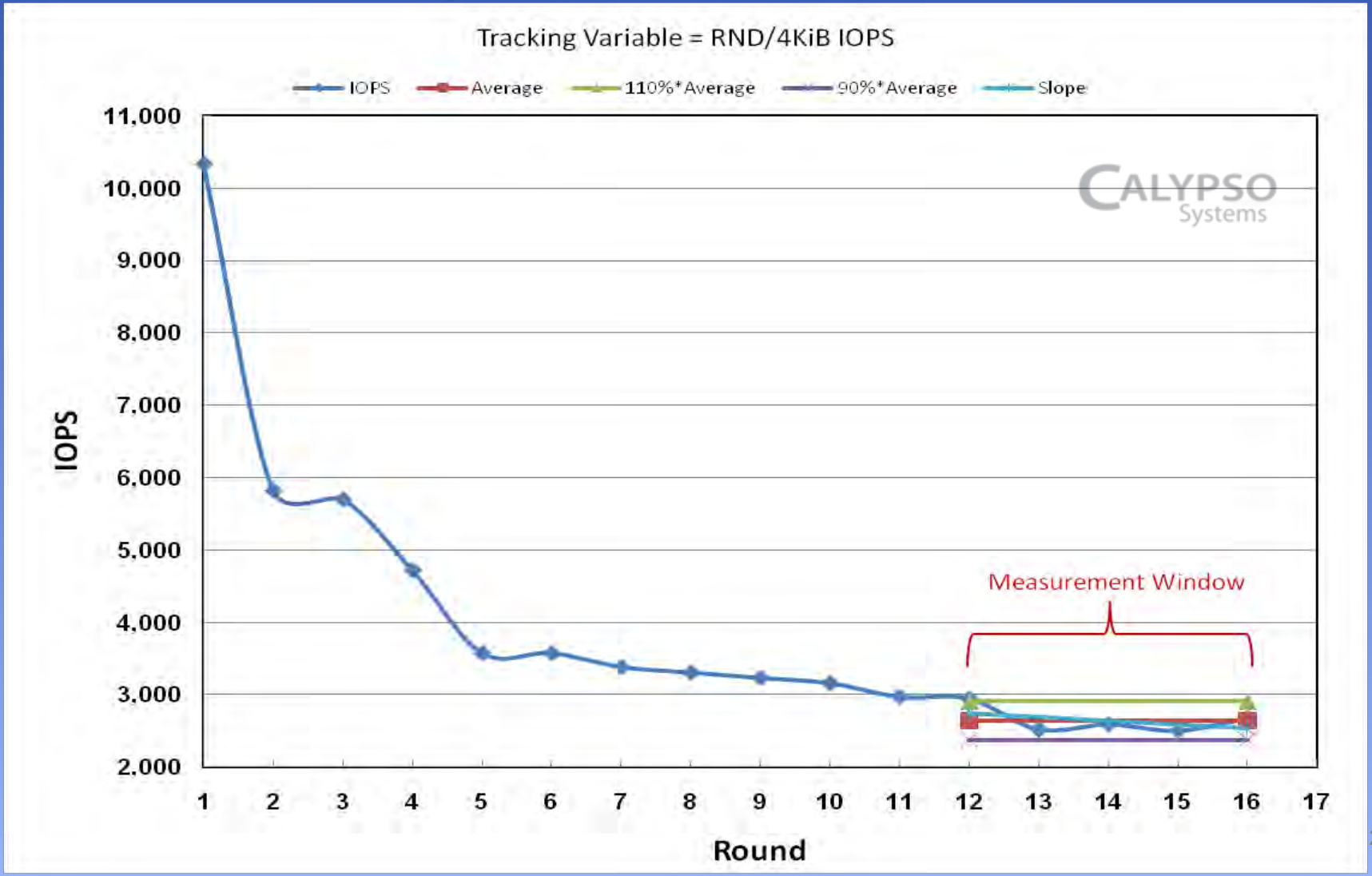
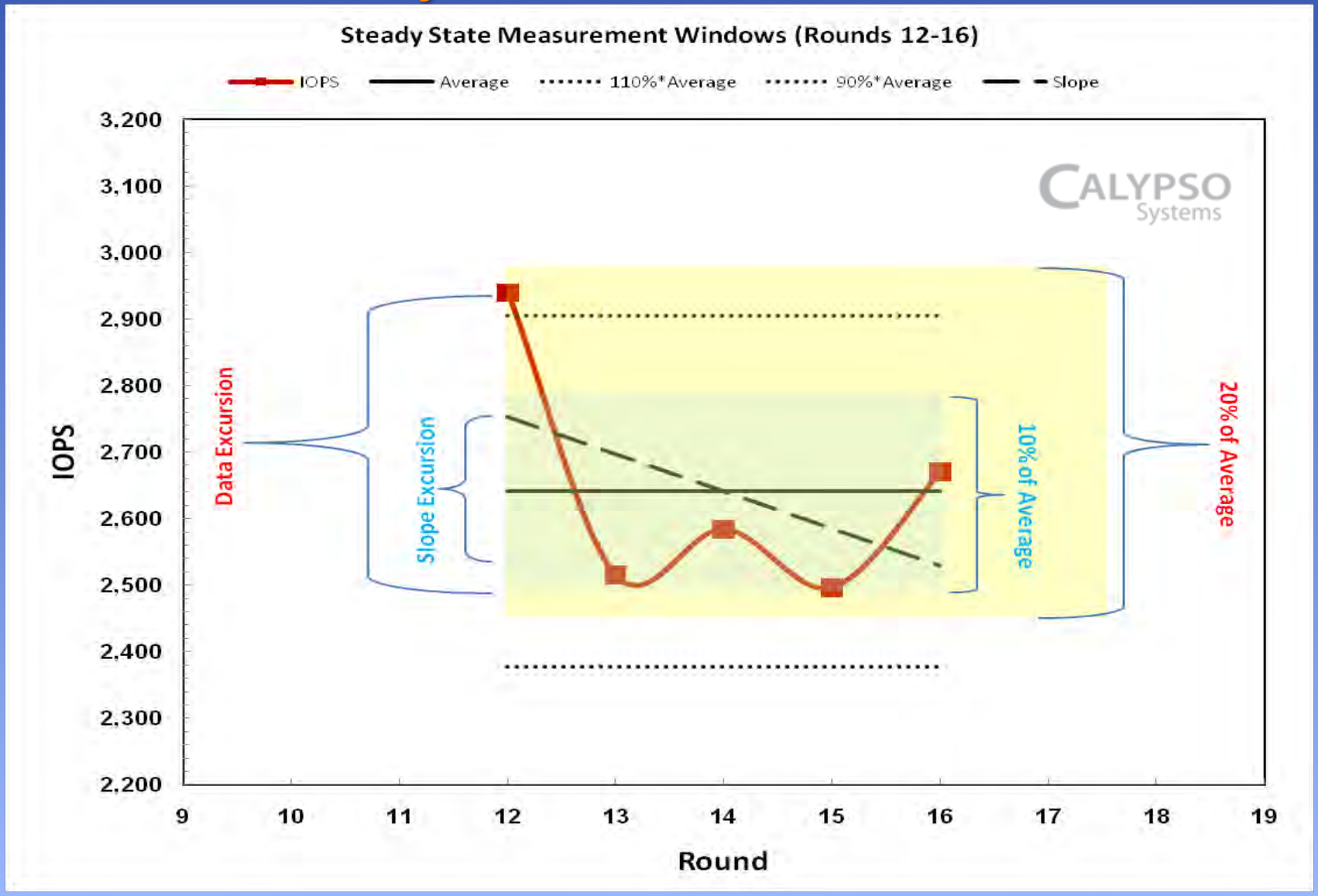


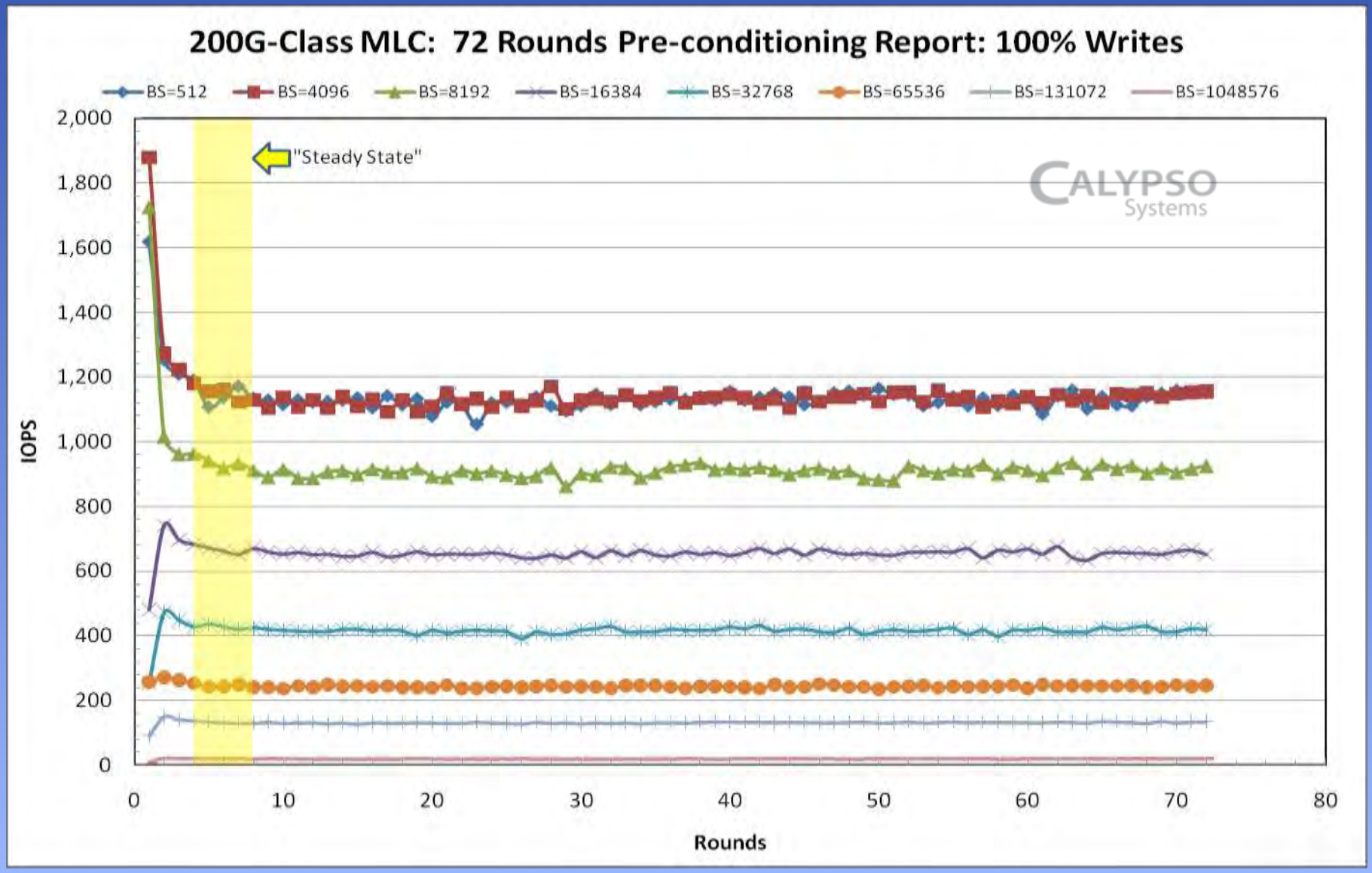
Illustration: Steady State Measurement Window



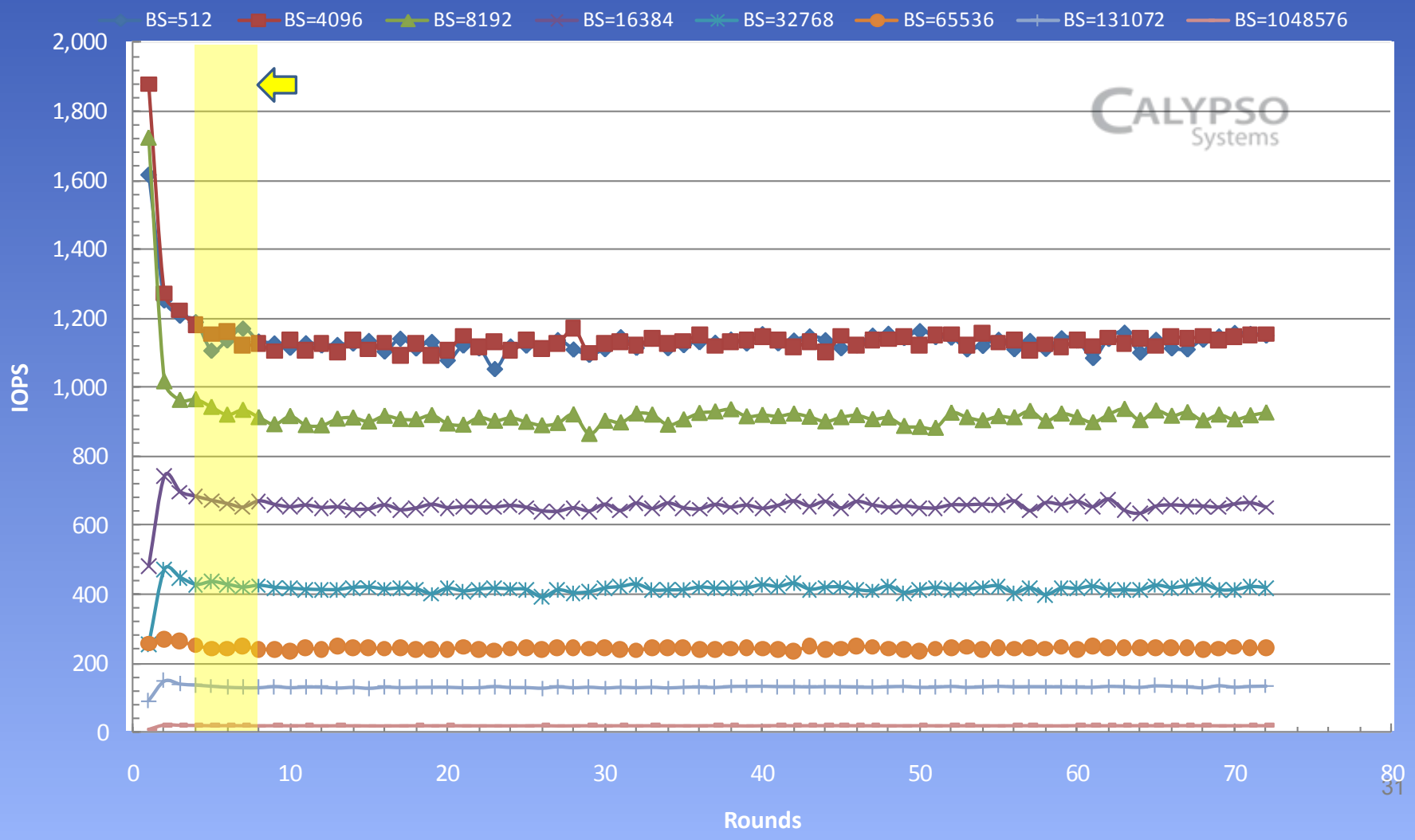
Steady State

- 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

How “good” is the “Steady State”



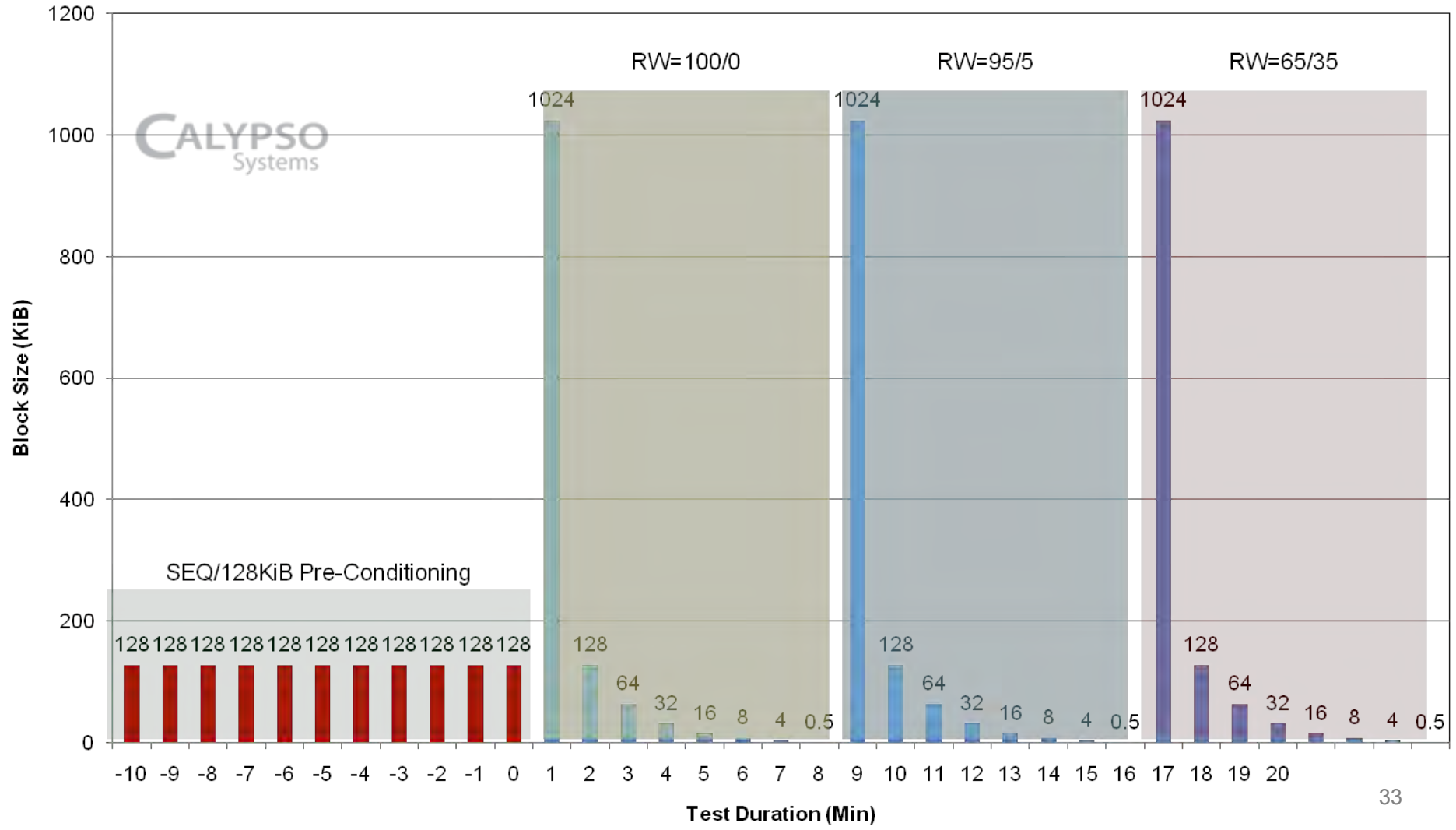
How "good" is the "Steady State"



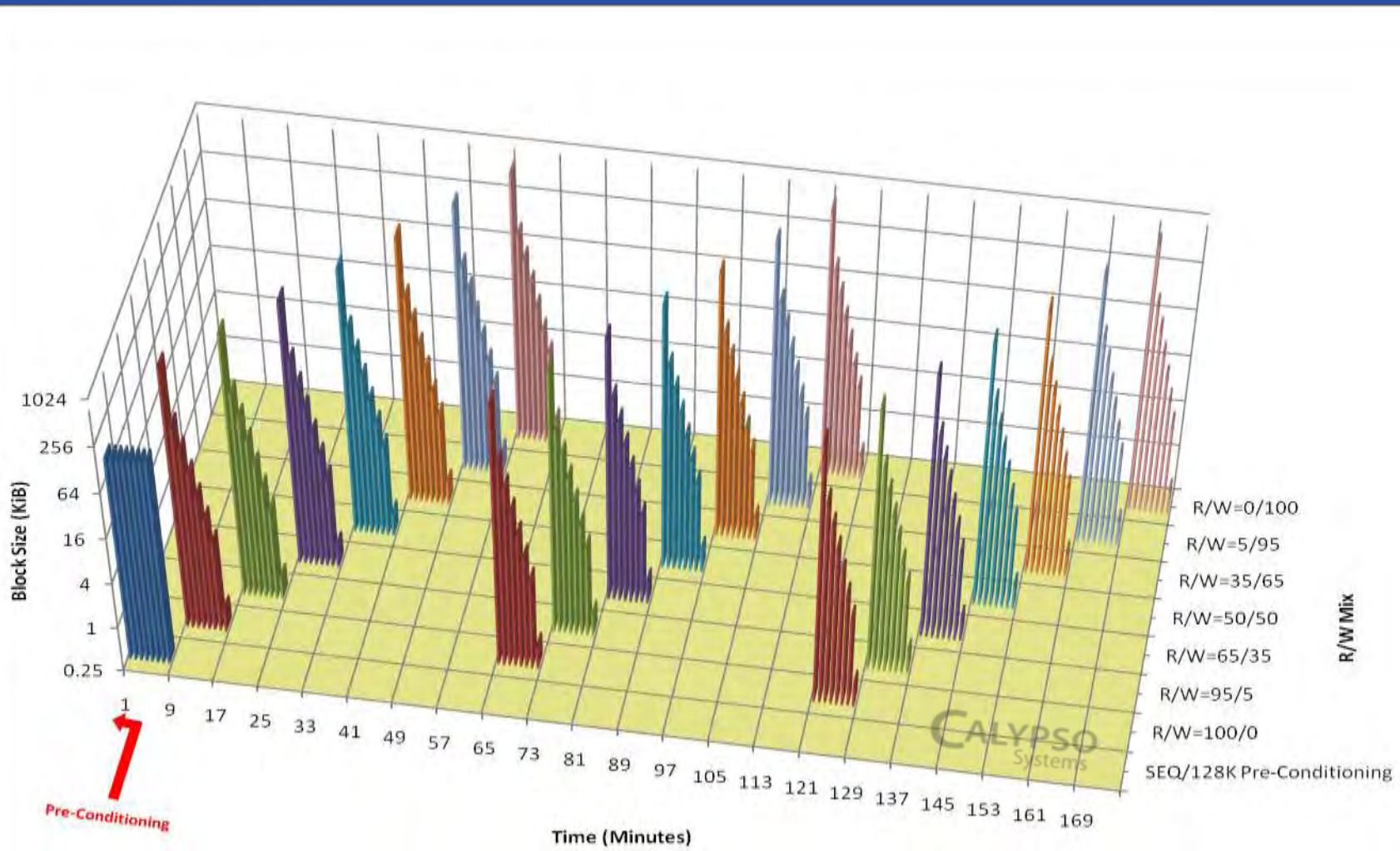
Test Drive: Client/Enterprise IOPS

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

Test Drive: Client/Enterprise IOPS Block Size Sequence



Test Drive: Client/Enterprise IOPS Block Size Sequence



Test Drive: Client/Enterprise IOPS Draft Formatted Report, 1/6

Test Run Date:	07/10/2010 11:35 AM	Report Run Date:	08/15/2010 04:17 PM

Client IOPS (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)				Rev.	0.8
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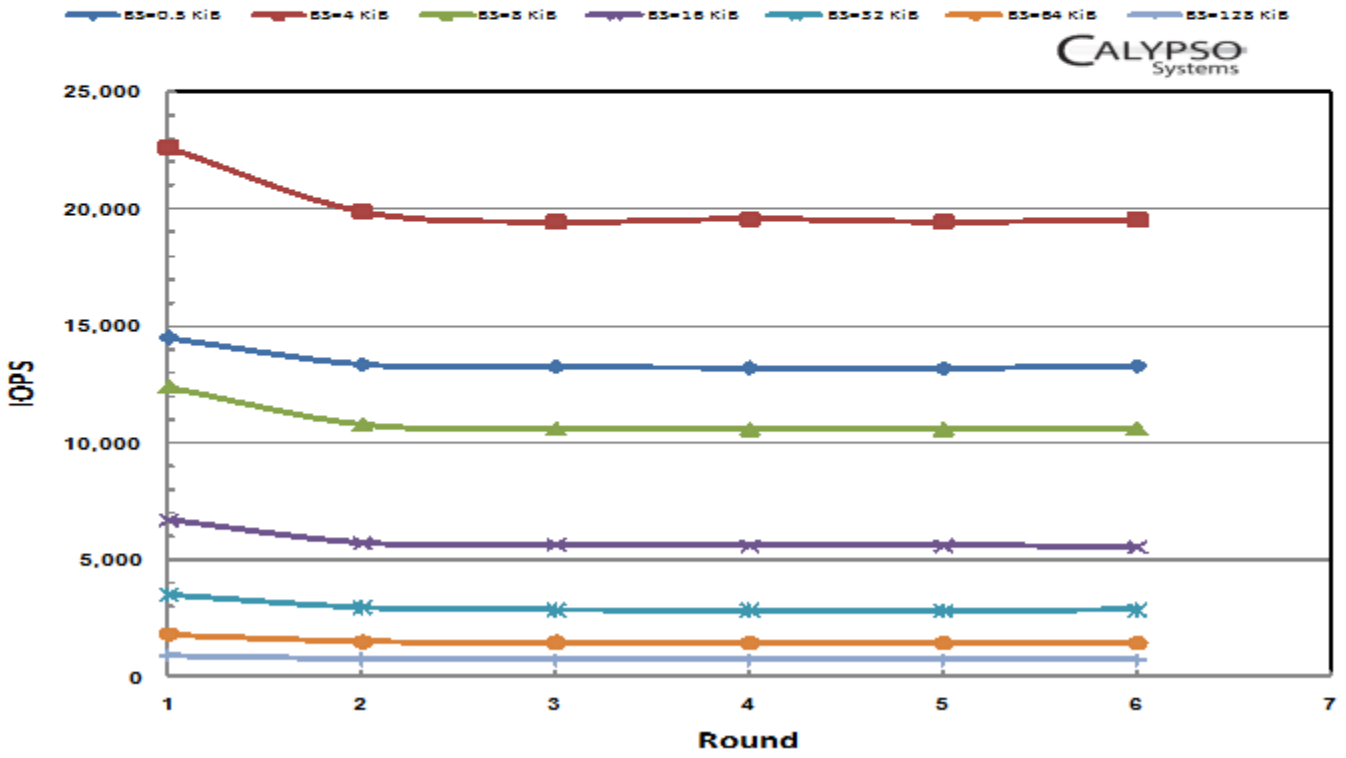
Device Under Test (DUT)		Vendor	8.1 Client IOPS Test – REQUIRED	Calypso Systems Test	Calypso Systems
/dev/sdd		DUT Preparation		Test Loop Parameters	Steady State
S/N: /dev/sdd		Purge	Security Erase	REQUIRED:	Convergence: YES
DUT I/F	SATA 6Gb/s	Pre-Conditioning		Data Pattern: RND	Rounds: 2-6
SYS I/F	LSI 9212-4e4i Int. SAS	Workload Independent	2X SEQ/128 KiB	Tester's Choice:	Active Range
Test HW	Calypso RTP			OIO/Thread: 16	REQ: 100%
Test SW	CTSv6.5	Workload Dep.	Full IOPS Loop	Thread Count: 2	OPT: N/A

8.1.1 Steady State Convergence Plot – All Block Sizes



Test Drive: Client/Enterprise IOPS Draft Formatted Report, 2/6

Test Run Date:	07/10/2010 11:35 AM	Report Run Date:	08/15/2010 04:17 PM

Client IOPS (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)	Rev.	0.8
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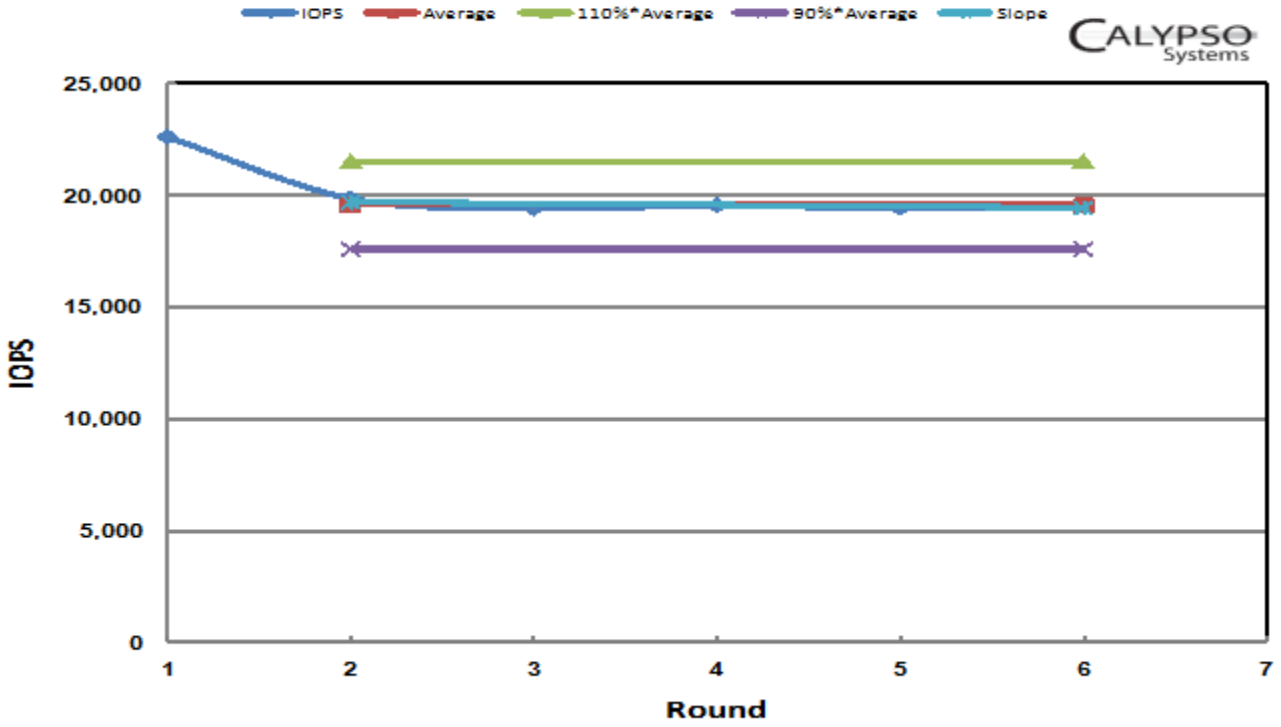
Device Under Test (DUT)		Vendor	8.1 Client IOPS Test – REQUIRED	Calypso Systems Inc.	
/dev/sdd		DUT Preparation		Test Loop Parameters	
S/N: /dev/sdd		Purge	Security Erase	REQUIRED:	
DUT I/F	SATA 6Gb/s	Pre-Conditioning		Data Pattern	RND
SYS I/F	LSI 9212-4e4i Int. SAS	Workload Independent	2X SEQ/128 KiB	Tester's Choice:	
Test HW	Calypso RTP			OIO/Thread	16
Test SW	CTSv6.5	Workload Dep.	Full IOPS Loop	Thread Count	2

Steady State	
Convergence	YES
Rounds	2-6
Active Range	
REQ:	100%
OPT:	N/A

8.1.2 Steady State Measurement Window



Test Drive: Client/Enterprise IOPS Draft Formatted Report, 3/6

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Client IOPS (REQUIRED) - Report Page

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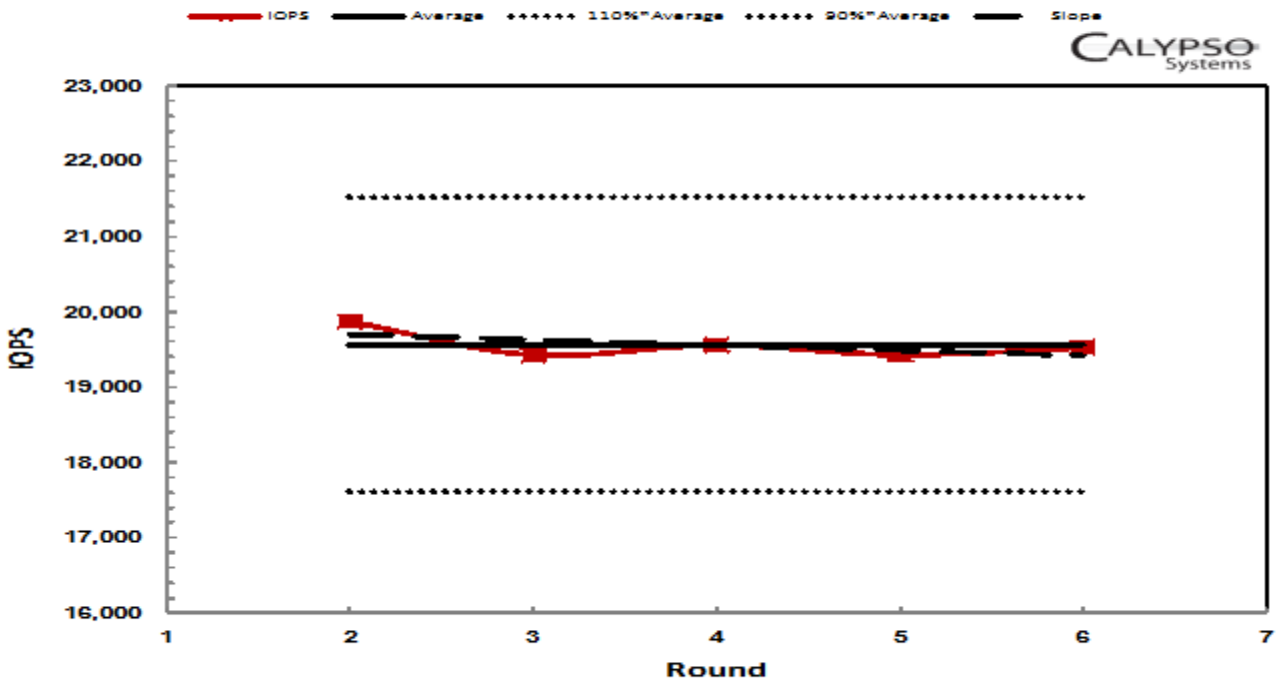
Device Under Test (DUT)		Vendor	8.1 Client IOPS Test – REQUIRED	Calypso Systems Inc.
/dev/sdd		DUT Preparation		
S/N: /dev/sdd		Purge	Security Erase	
DUT I/F	SATA 6Gb/s	Pre-Conditioning		
SYS I/F	LSI 9213-8e6i (rev. B0)	Workload Independent	2X SEQ/128 KiB	
Test HW	Calypso RTP	Workload Dep.	Full IOPS Loop	
Test SW	CTSv6.5			

Test Loop Parameters	
REQUIRED:	
Data Pattern	RND
Tester's Choice:	
OIO/Thread	16
Thread Count	2

Steady State	
Convergence	YES
Rounds	2-6
Active Range	
REQ:	100%
OPT:	N/A

8.1.3 Steady State Measurement Window – RND/4KiB



Steady State Determination Data

Average IOPS:			19360.6
Allowed Maximum Data Excursion	2012.1	Measured Maximum Data Excursion	205.6
Allowed Maximum Slope Excursion	1050.1	Measured Maximum Slope Excursion	125.2
Least Squares Linear Fit Formula:			$-60.122 * R + 19765.000$

Test Drive: Client/Enterprise IOPS Draft Formatted Report, 4/6

Test Run Date:	07/10/2010 11:35 AM	Report Run Date:	08/15/2010 04:17 PM

Client IOPS (REQUIRED) - Report Page

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Device Under Test (DUT)		Vendor	8.1 Client IOPS Test - REQUIRED	Calypso Systems Inc	CALYPSO Systems
/dev/sdd		DUT Preparation		Test Loop Parameters	Steady State
S/N: /dev/sdd		Purge	Security Erase	REQUIRED:	Convergence: YES
DUT I/F	SATA 6Gb/s	Pre-Conditioning		Data Pattern: RND	Rounds: 2-6
SYS I/F	LSI 9212-4e4i Int. SAS	Workload Independent	2X SEQ/128 KiB	Tester's Choice:	Active Range
Test HW	Calypso RTP			OIO/Thread: 16	REQ: 100%
Test SW	CTSv6.5	Workload Dep.	Full IOPS Loop	Thread Count: 2	OPT: N/A

8.1.4 Client IOPS - ALL RW Mix & BS – Tabular Data

Block Size (KiB)	Read / Write Mix %						
	0/100	5/95	65/35	50/50	35/65	95/5	100/0
0.5	13,255.7	13,581.2	15,581.3	18,393.7	21,115.5	40,004.8	43,368.3
4	19,560.6	20,238.4	23,886.3	26,641.2	29,827.0	41,460.1	46,365.3
8	10,630.3	11,033.1	13,806.4	15,780.9	18,244.6	27,803.9	32,259.3
16	5,620.5	5,824.9	7,451.9	8,651.6	10,174.7	15,772.3	18,309.1
32	2,872.2	3,002.7	3,862.5	4,513.2	5,377.6	8,337.0	9,472.3
64	1,461.8	1,515.4	1,962.1	2,293.9	2,751.4	4,304.9	4,829.3
128	735.7	763.7	987.4	1,148.8	1,389.0	2,187.9	2,439.4
1024	92.5	95.9	124.1	144.6	173.1	277.2	307.6

Test Drive: Client/Enterprise IOPS Draft Formatted Report, 5/6

Test Run Date:	07/10/2010 11:35 AM	Report Run Date:	08/15/2010 04:17 PM

Client IOPS (REQUIRED) - Report Page

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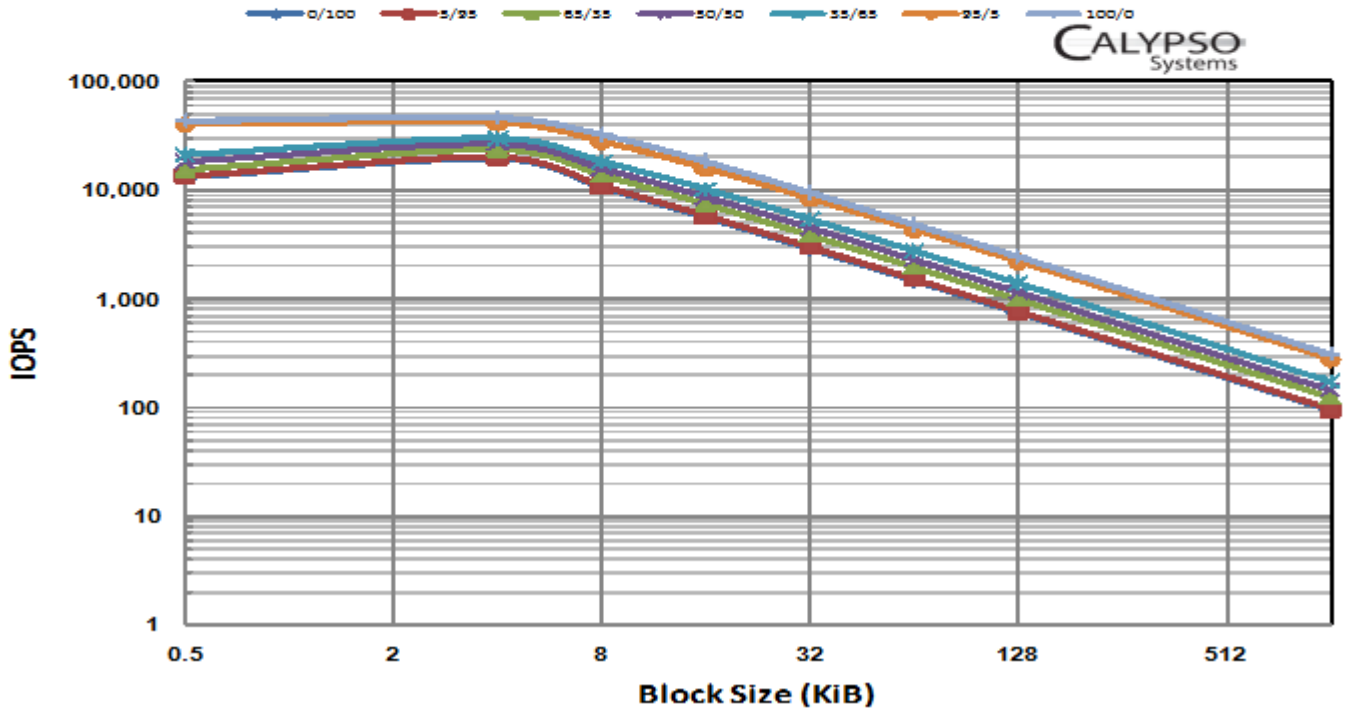
Device Under Test (DUT)		Vendor	8.1 Client IOPS Test - REQUIRED	Calypso Systems Inc.	CALYPSO Systems
/dev/sdd		DUT Preparation		Test Loop Parameters	Steady State
S/N: /dev/sdd		Purge	Security Erase	REQUIRED:	Convergence: YES
DUT I/F	SATA 6Gb/s	Pre-Conditioning		Data Pattern: RND	Rounds: 2-6
SYS I/F	LSI 9212-4e4i Int. SAS	Workload Independent	2X SEQ/128 KiB	Tester's Choice:	Active Range
Test HW	Calypso RTP			OIO/Thread: 16	REQ: 100%
Test SW	CTSv6.5	Workload Dep.	Full IOPS Loop	Thread Count: 2	OPT: N/A

8.1.5 Client IOPS - ALL RW Mix & BS - 2D Plot



Test Drive: Client/Enterprise IOPS Draft Formatted Report, 6/6

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Client IOPS (REQUIRED) - Report Page						
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)					Rev.	0.8
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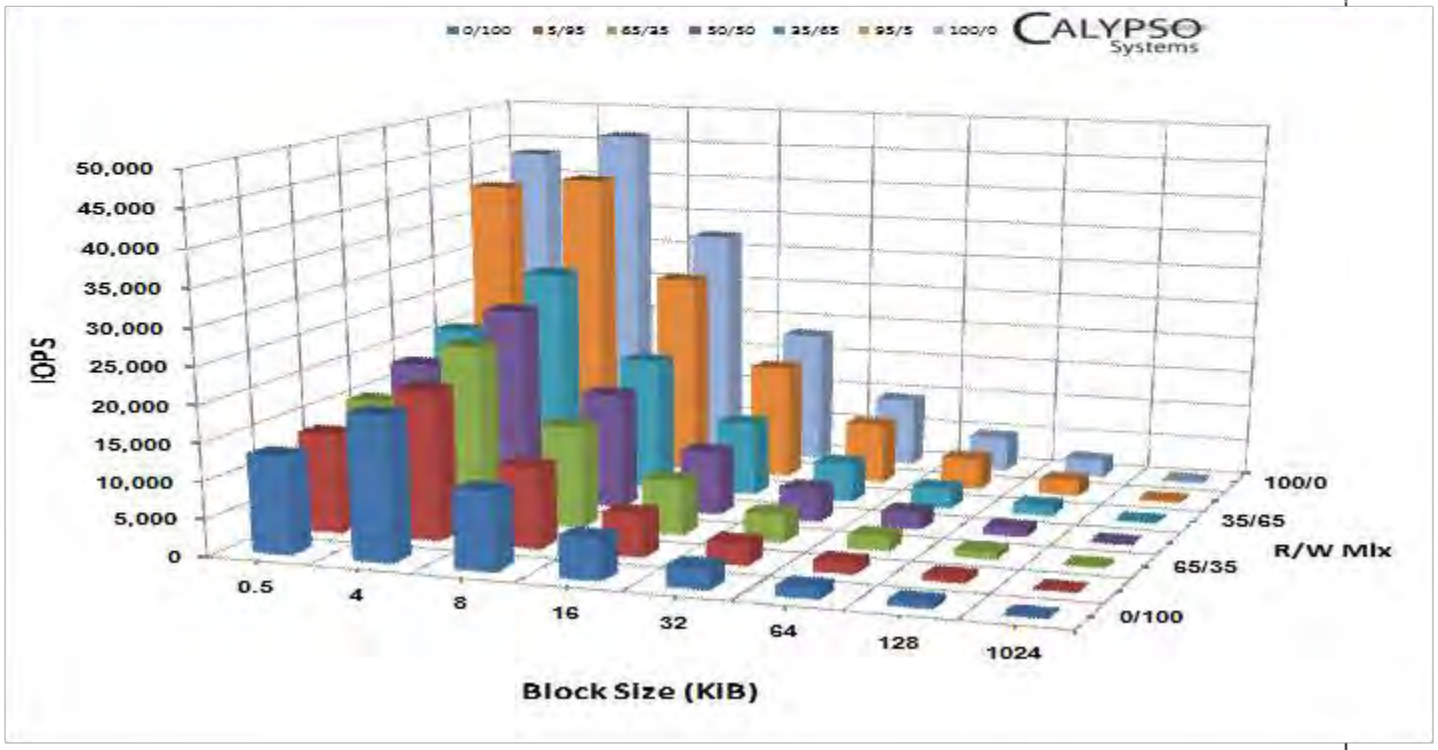
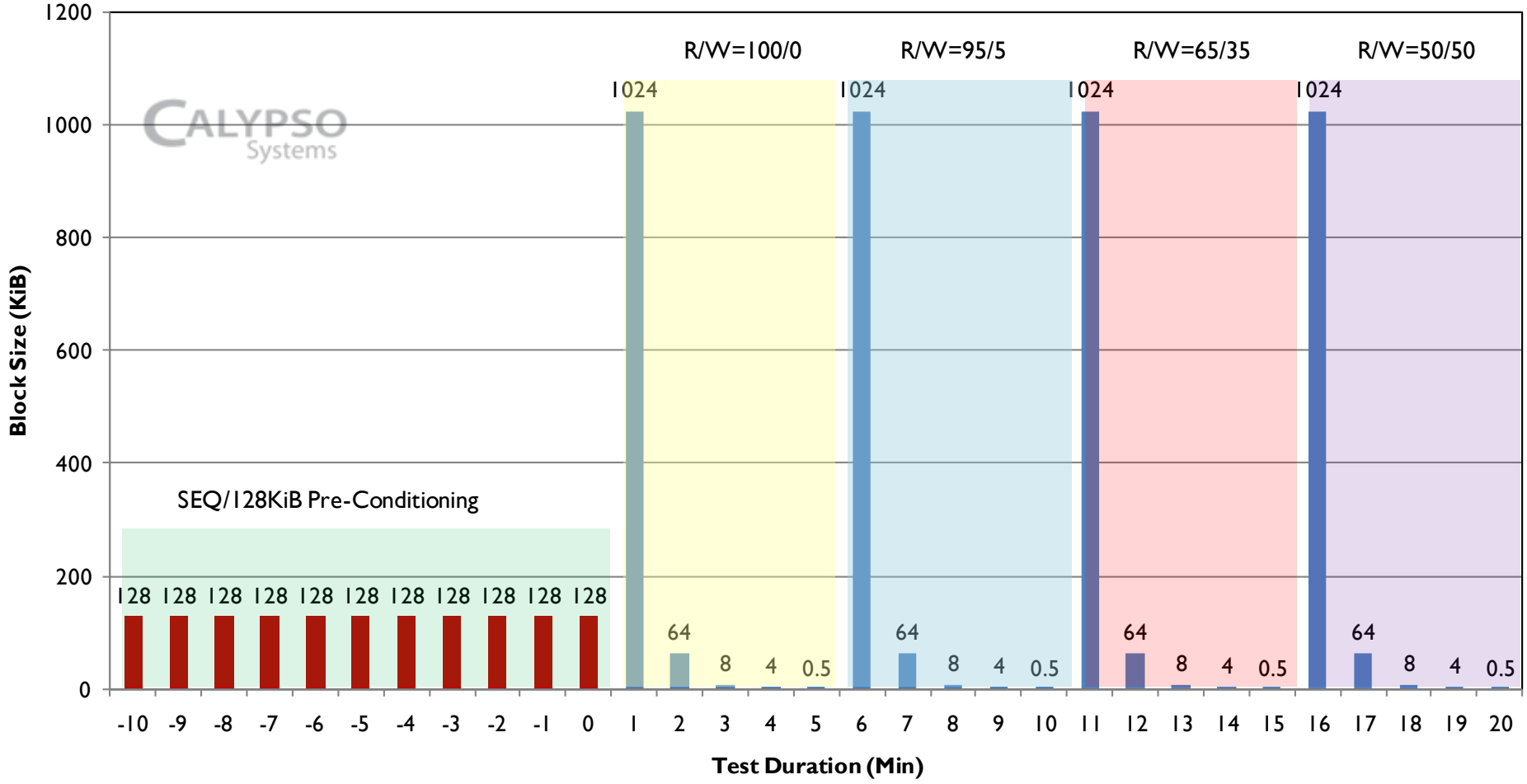
Device Under Test (DUT)	Vendor	8.1 Client IOPS Test – REQUIRED		Calypso Systems Inc.	CALYPSO Systems	
/dev/sdd	DUT Preparation		Test Loop Parameters		Steady State	
S/N: /dev/sdd	Purge	Security Erase	REQUIRED:		Convergence	YES
DUT I/F SATA 6Gb/s	Pre-Conditioning		Data Pattern	RND	Rounds	2-6
SYS I/F	Workload Independent	2X SEQ/128 KiB	Tester's Choice:		Active Range	
Test HW Calypso RTP			OIO/Thread	16	REQ:	100%
Test SW CTSv6.5	Workload Dep.	Full IOPS Loop	Thread Count	2	OPT:	N/A
8.1.6 Client IOPS – ALL RW Mix & BS – 3D Columns						



Test Drive: Enterprise TP

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

Enterprise TP Block Size Sequence



Test Drive: Enterprise TP Draft Formatted Report 1/6

Test Run Date:	04/29/2010 06:08 PM		Report Run Date:	08/15/2010 11:24 PM		
Enterprise ThroughPut Test (REQUIRED) - Report Page						
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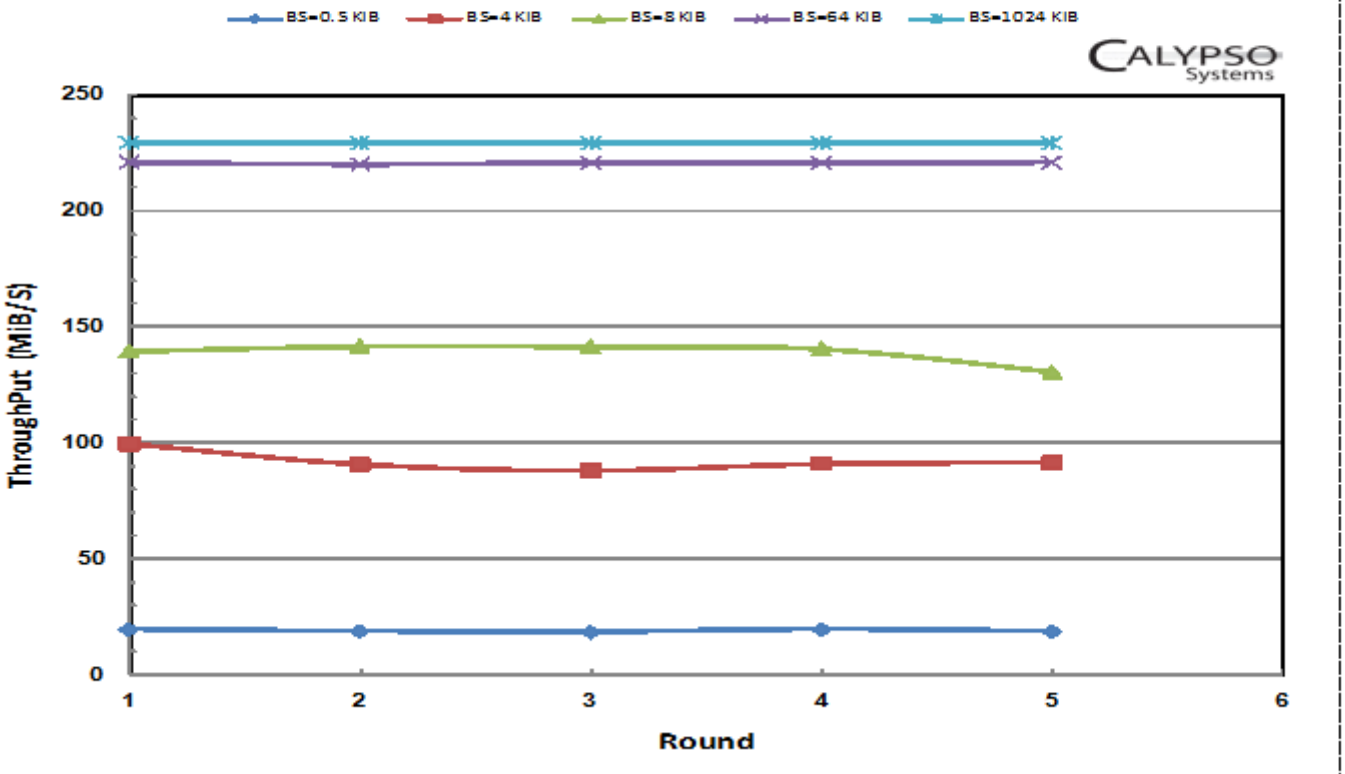
Device Under Test (DUT)	-	Enterprise TP Test – REQUIRED		Calypso Systems Inc.	CALYPSO Systems	
Key Set Up Data		DUT Preparation		Test Loop Parameters		Steady State
-		Purge	Format Unit	REQUIRED:		Convergence: YES
DUT I/F	SAS 6Gb/s	Pre-Conditioning		Data Pattern	RND	Rounds: 1-5
SYS I/F	[illegible]	Workload Independant	2X SEQ/128 KiB	Tester's Choice:		Active Range
Test HW	Calypso RTP			OIO/Thread	16	REQ: 100%
Test SW	CTSv6.5	Workload Dep.	Full Enterprise TP Loop	Thread Count	2	OPT: N/A

Enterprise TP Test - SS Convergence - Write TP



Test Drive: Enterprise TP Draft Formatted Report 2/6

Test Run Date:	04/29/2010 06:08 PM		Report Run Date:	08/15/2010 11:24 PM		
Enterprise ThroughPut Test (REQUIRED) - Report Page						
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)					Rev.	0.8
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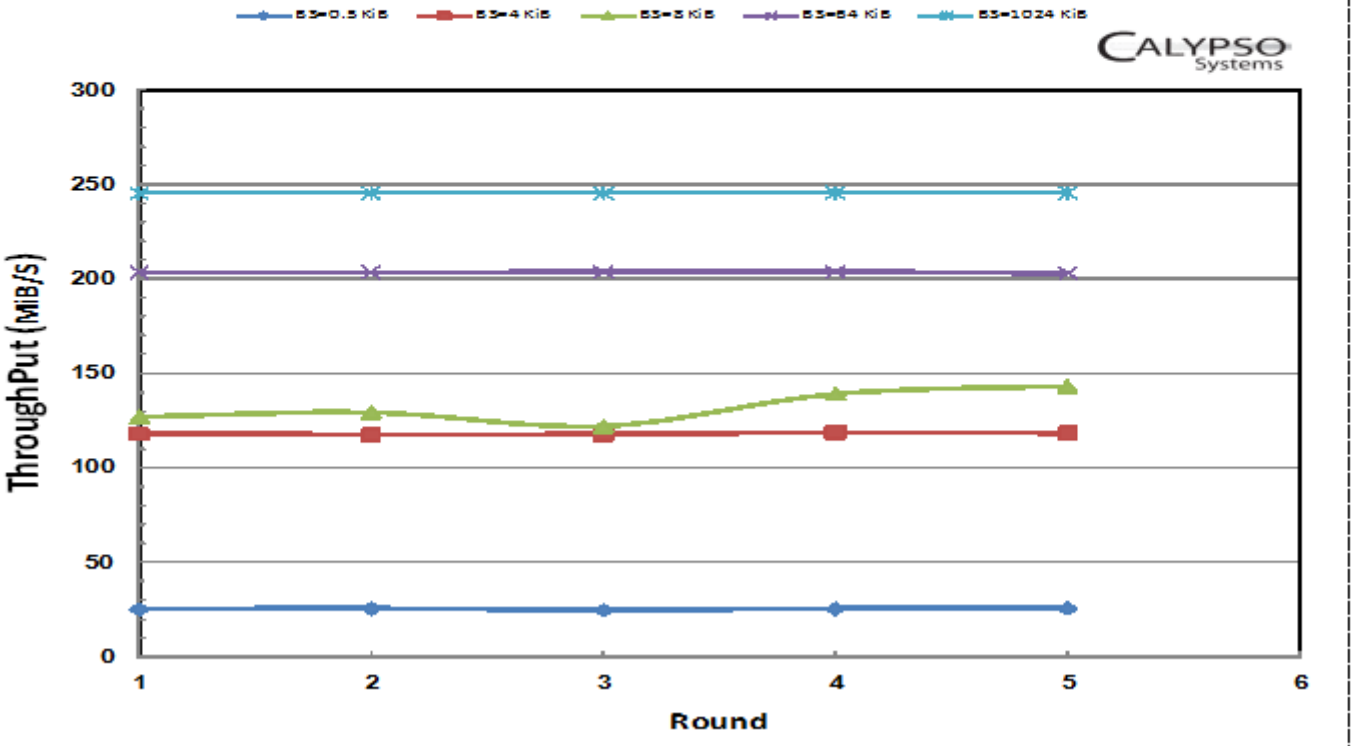
Device Under Test (DUT)	-	Enterprise TP Test – REQUIRED		Calypso Systems Inc.		
Key Set Up Data		DUT Preparation		Test Loop Parameters		Steady State
-		Purge	Format Unit	REQUIRED:		Convergence: YES
DUT I/F	SAS 6Gb/s	Pre-Conditioning		Data Pattern	RND	Rounds: 1-5
SYS I/F	[illegible]	Workload Independant	2X SEQ/128 KiB	Tester's Choice:		Active Range
Test HW	Calypso RTP			OIO/Thread	16	REQ: 100%
Test SW	CTSv6.5	Workload Dep.	Full Enterprise TP Loop	Thread Count	2	OPT: N/A

Enterprise TP Test - SS Convergence - Read TP



Test Drive: Enterprise TP Draft Formatted Report 3/6

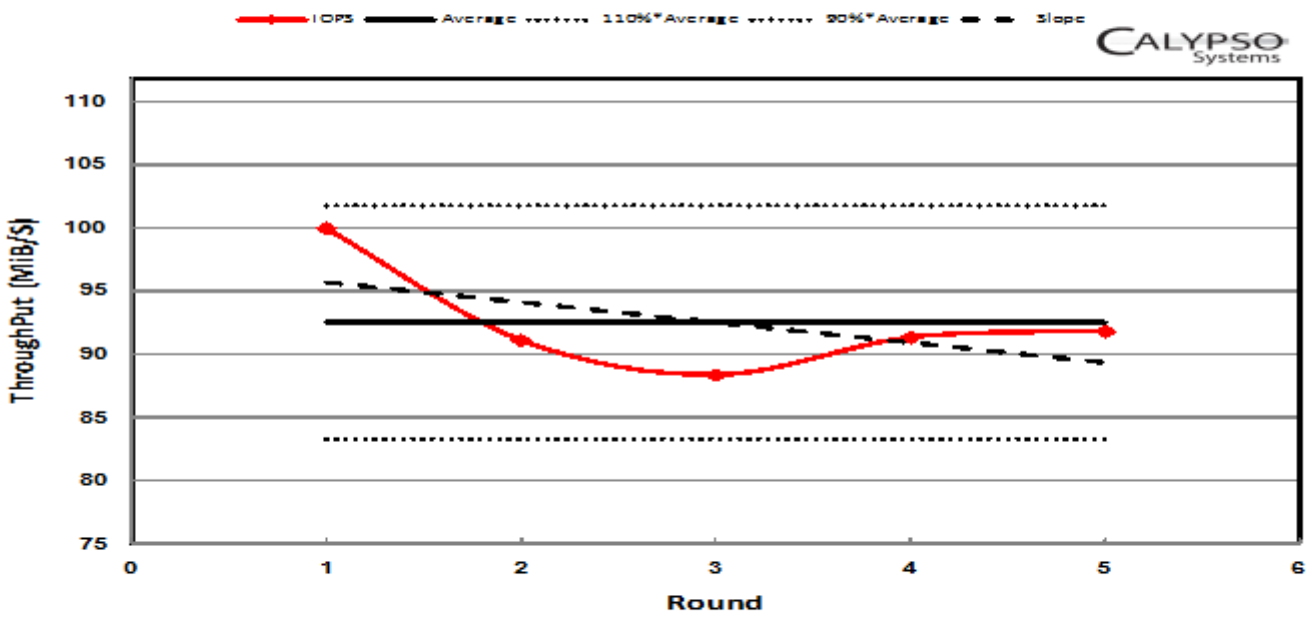
Test Run Date:	04/29/2010 06:08 PM	Report Run Date:	08/15/2010 11:24 PM

Enterprise ThroughPut Test (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)				Rev.	0.8
				Page	3 of 6
Device Under Test (DUT)	-	Enterprise TP Test – REQUIRED	Calypso Systems Inc.	CALYPSO Systems	

Key Set Up Data		DUT Preparation		Test Loop Parameters		Steady State	
-		Purge	Format Unit	REQUIRED:		Convergence	YES
DUT I/F	SAS 6Gb/s	Pre-Conditioning		Data Pattern	RND	Rounds	1-5
SYS I/F	[illegible]	Workload Independent	2X SEQ/128 KiB	Tester's Choice:		Active Range	
Test HW	Calypso RTP			OIO/Thread	16	REQ:	100%
Test SW	CTSv6.5	Workload Dep.	Full Enterprise TP Loop	Thread Count	2	OPT:	N/A

Steady State Measurement Window – SEQ/4KiB



Steady State Determination Data

Average ThroughPut:			92.1
Allowed Maximum Data Excursion:	15.4	Measured Maximum Data Excursion:	7.4
Allowed Maximum Slope Excursion:	0.2	Measured Maximum Slope Excursion:	2.2
Least Squares Linear Fit Formula:			$-1.601 * R + 98.667$

Test Drive: Enterprise TP Draft Formatted Report 4/6

Test Run Date:	04/29/2010 06:08 PM	Report Run Date:	08/15/2010 11:24 PM

Enterprise ThroughPut Test (REQUIRED) - Report Page

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Device Under Test (DUT)	-	Enterprise TP Test - REQUIRED	Calypso Systems Inc	CALYPSO Systems

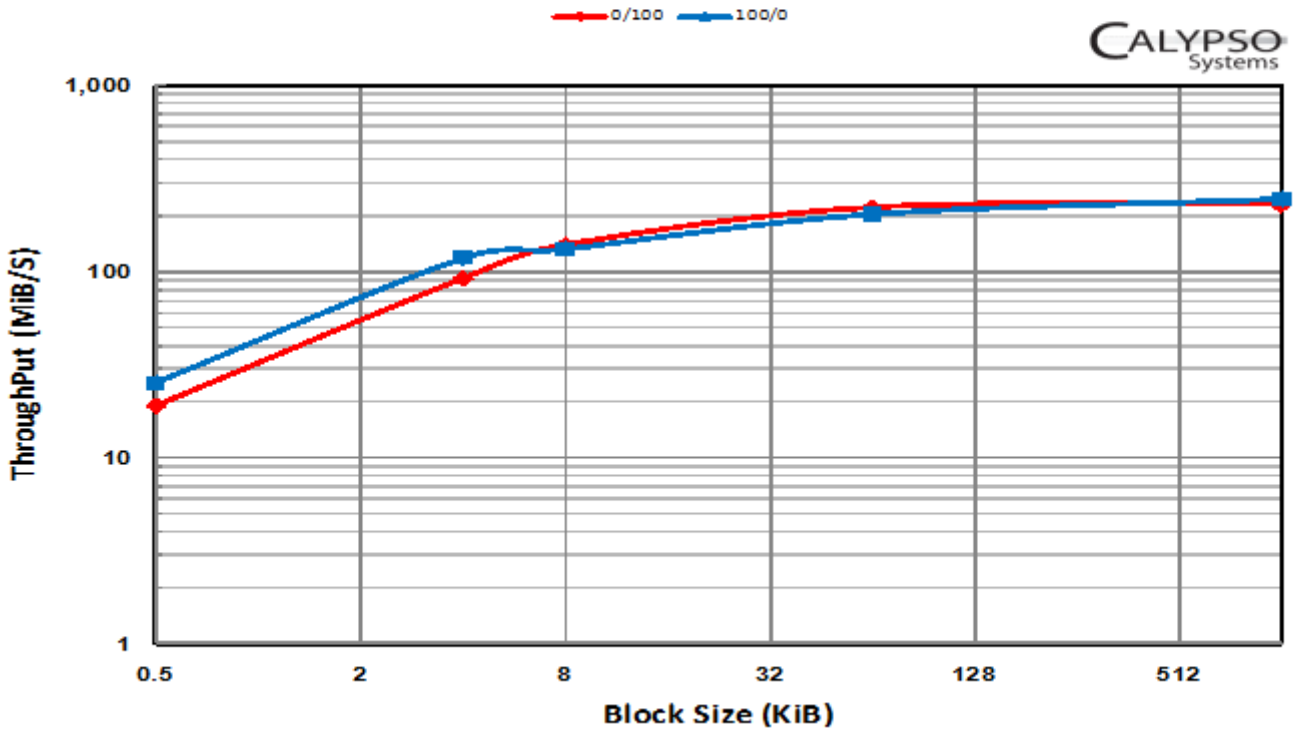
Key Set Up Data		DUT Preparation		Test Loop Parameters		Steady State	
-		Purge	Format Unit	REQUIRED:		Convergence	YES
DUT I/F	SAS 6Gb/s	Pre-Conditioning		Data Pattern	RND	Rounds	1-5
SYS I/F	LSI 9211-4e4i Int., SAS	Workload Independent	2X SEQ/128 KiB	Tester's Choice:		Active Range	
Test HW	Calypso RTP			OIO/Thread	16	REQ:	100%
Test SW	CTSv6.5	Workload Dep.	Full Enterprise TP Loop	Thread Count	2	OPT:	N/A

Enterprise ThroughPut - ALL RW Mix & BS - Tabular Data

Block Size (KiB)	Read / Write Mix %	
	0/100	100/0
0.5	19.1	25.2
4	92.1	118.0
8	138.7	132.0
64	220.6	203.4
1024	229.2	245.2

Test Drive: Enterprise TP Draft Formatted Report 5/6

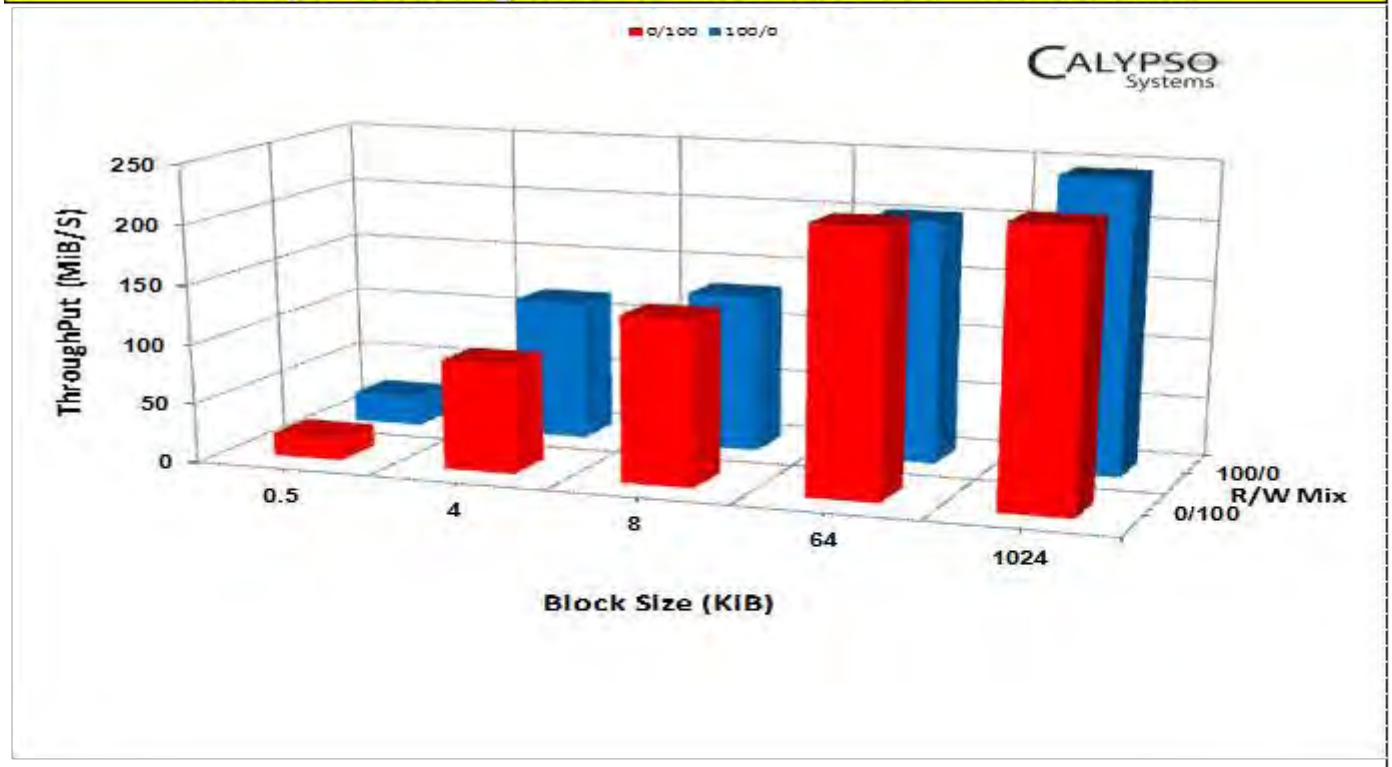
Test Run Date:	04/29/2010 06:08 PM			Report Run Date:	08/15/2010 11:24 PM		
Enterprise ThroughPut Test (REQUIRED) - Report Page							
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)						Rev.	0.8
						Page	5 of 6
Device Under Test (DUT)	-	Enterprise TP Test - REQUIRED		Calypso Systems			
Key Set Up Data		DUT Preparation		Test Loop Parameters		Steady State	
-		Purge	Format Unit	REQUIRED:		Convergence	YES
DUT I/F	SAS 6Gb/s	Pre-Conditioning		Data Pattern	RND	Rounds	1-5
SYS I/F	LSI 9212-4e4i Int. SAS	Workload Independent	2X SEQ/128 KiB	Tester's Choice:		Active Range	
Test HW	Calypso RTP			OIO/Thread	16	REQ:	100%
Test SW	CTSv6.5	Workload Dep.	Full Enterprise TP Loop	Thread Count	2	OPT:	N/A
Enterprise ThroughPut - ALL RW Mix & BS - 2D Plot							



Test Drive: Enterprise TP Draft Formatted Report 6/6

Test Run Date:	04/29/2010 06:08 PM		Report Run Date:	08/15/2010 11:24 PM		
Enterprise ThroughPut Test (REQUIRED) - Report Page						
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)					Rev.	0.8
					Page	6 of 6
Device Under Test (DUT)	-	Enterprise TP Test - REQUIRED		Calypso Systems Inc	CALYPSO Systems	
Key Set Up Data		DUT Preparation		Test Loop Parameters		Steady State
-		Purge	Format Unit	REQUIRED:		Convergence: YES
DUT I/F	SAS 6Gb/s	Pre-Conditioning		Data Pattern	RND	Rounds: 1-5
SYS I/F	[redacted]	Workload Independent	2X SEQ/128 KiB	Tester's Choice:		Active Range
Test HW	Calypso RTP			OIO/Thread	16	REQ: 100%
Test SW	CTSv6.5	Workload Dep.	Full Enterprise TP Loop	Thread Count	2	OPT: N/A

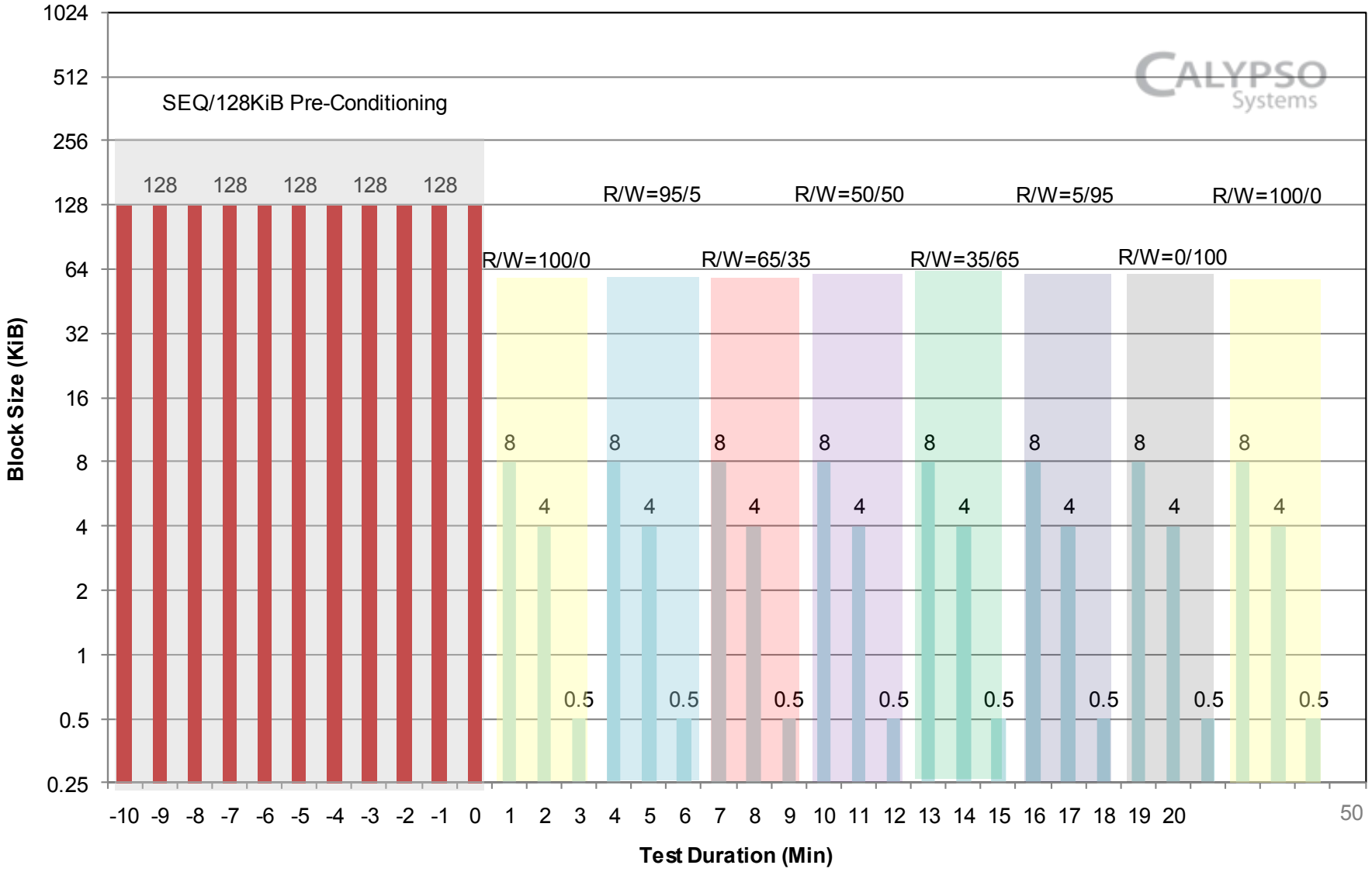
Enterprise ThroughPut - ALL RW Mix & BS - 3D Columns



Test Drive: Client/Enterprise Latency

- DUT:
  - 100GB-Class SLC drive
- Test Parameters:
  - Active Range = [0,100%]
  - Thread Count=1
  - Queue Depth (Outstanding IO/Thread)=1
  - DP=RND

Client Latency Block Size Sequence



Test Drive: Client/Enterprise Latency Draft Formatted Report 1/6

Test Run Date:	7/15/2010	Report Run Date:	8/10/2010

Client Latency (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)	Rev.	0.8
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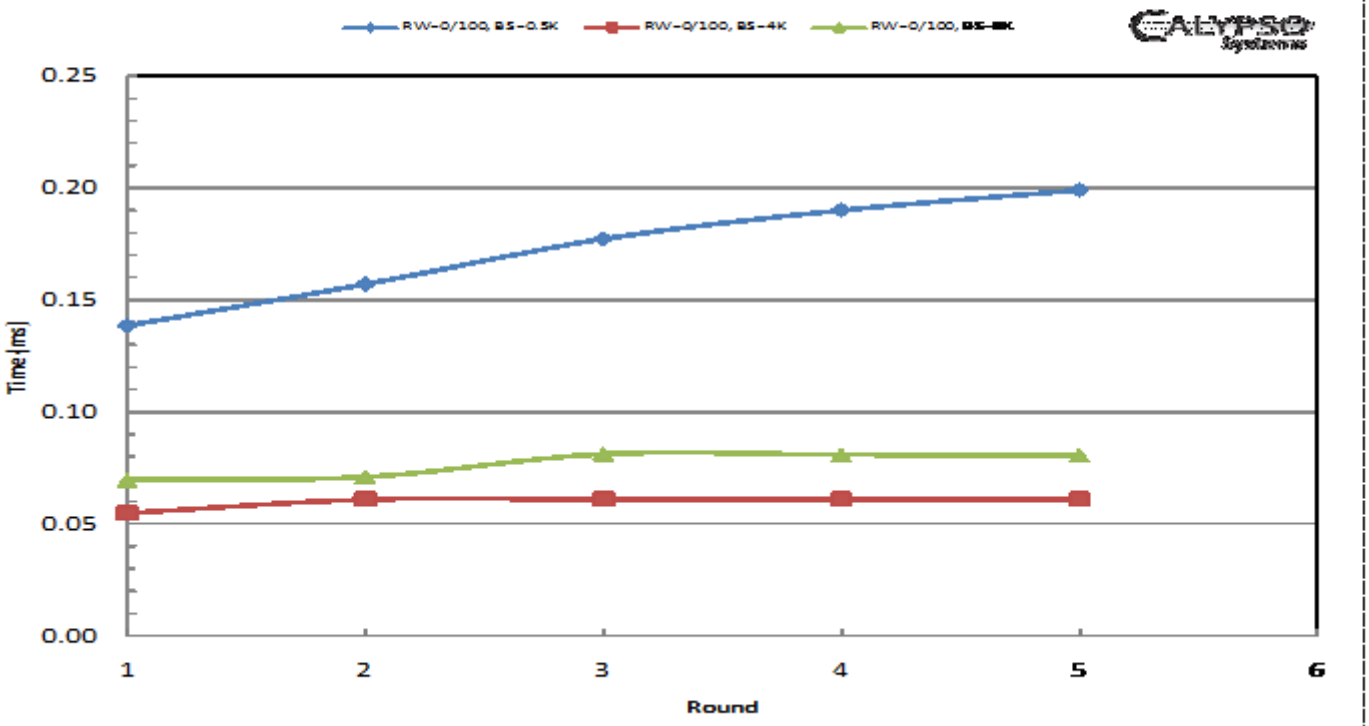
Key Set Up Data		DUT Preparation		Test Loop Parameters			Steady State	
-		Purge	Security Erase					
Serial#	-	Pre-Conditioning		REQUIRED:			Convergence	YES
DUT I/F	SATA 6Gb/s	Workload Independent	2X SEQ/128KiB	Data Pattern		RND	Rounds	1-5
SYS I/F	LSI 9212-4e4i Int. SAS			Tester's Choice:			Active Range	
Test HW	Calypso RTP	Workload Dep.	Full Latency Loop	OIO/Thread		1	REQ:	100%
Test SW	CTSv6.5			Thread Count		1	OPT:	N/A

Steady State Convergence Plot – Average Latency - 100% Writes



Test Drive: Client/Enterprise Latency Draft Formatted Report 2/6

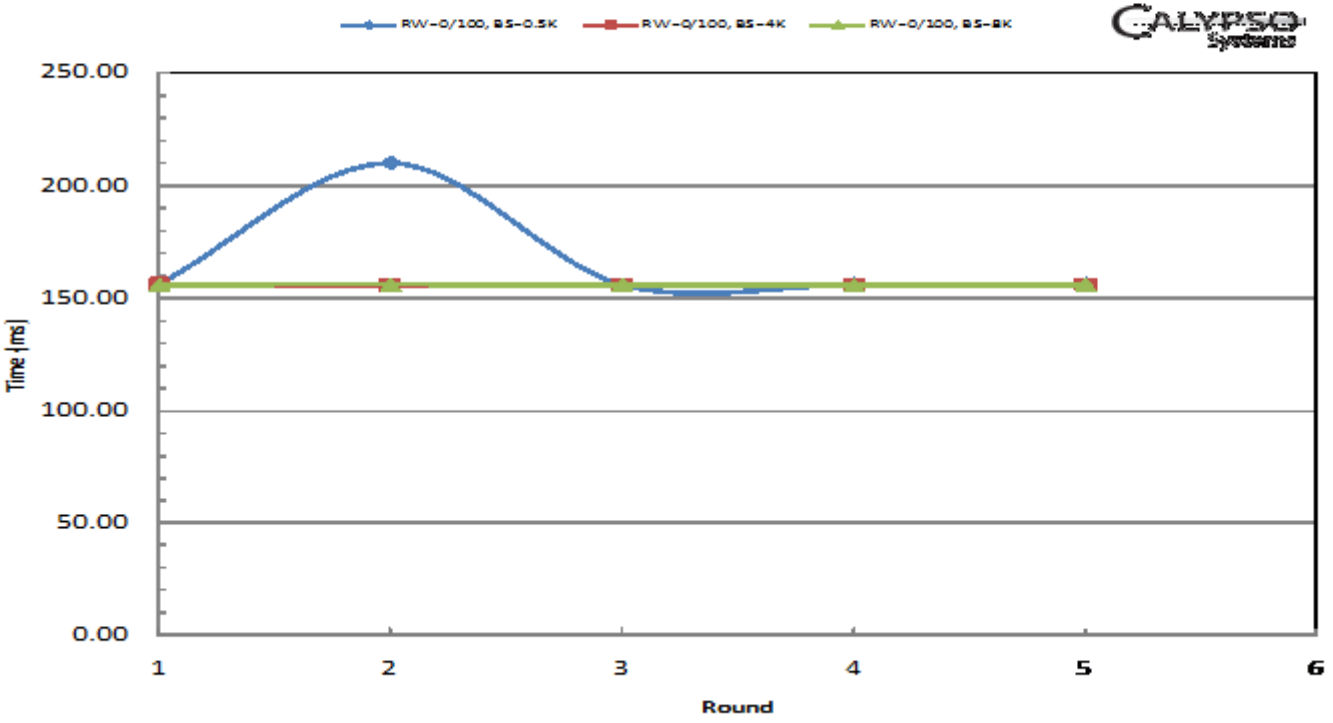
Test Run Date:	7/15/2010	Report Run Date:	8/10/2010

Client Latency (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. 0.8 — Page 2 of 6

Key Set Up Data		DUT Preparation		Test Loop Parameters			Steady State	
-		Purge	Security Erase					
Serial#	-	Pre-Conditioning		REQUIRED:			Convergence	YES
DUT I/F	SATA 6Gb/s	Workload Independant	2X SEQ/128KiB	Data Pattern		RND	Rounds	1-5
SYS I/F	LSI 9212-4e4i Int. SAS			Tester's Choice:			Active Range	
Test HW	Calypso RTP	Workload Dep.	Full Latency Loop	OIO/Thread		1	REQ:	100%
Test SW	CTSv6.5			Thread Count		1	OPT:	N/A

Steady State Convergence Plot – Maximum Latency - 100% Writes



Test Drive: Client/Enterprise Latency Draft Formatted Report 3/6

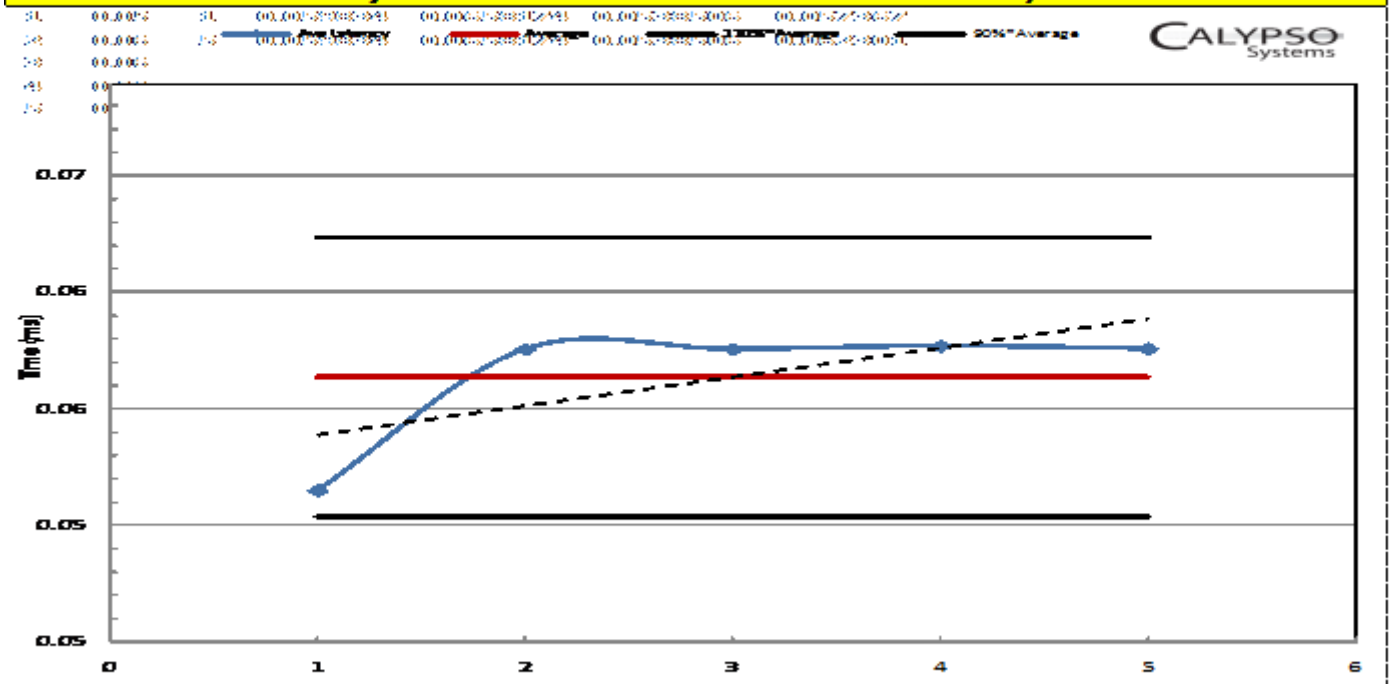
Test Run Date:	7/15/2010	Report Run Date:	8/10/2010

Client Latency (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS) — Rev. 0.8 — Page 3 of 6

Key Set Up Data		DUT Preparation		Test Loop Parameters		
-		Purge	Security Erase			Steady State
Serial#	-	Pre-Conditioning		REQUIRED:		Convergence: YES
DUT I/F	SATA 6Gb/s	Workload Independent	2X SEQ/128KiB	Data Pattern	RND	Rounds: 1-5
SYS I/F	LSI 9212-4e4i Int. SAS			Tester's Choice:		Active Range
Test HW	Calypso RTP	Workload Dep.	Full Latency Loop	OIO/Thread	1	REQ: 100%
Test SW	CTSv6.5			Thread Count	1	OPT: N/A

Steady State Measurement Window – RND/4KiB



Steady State Determination Data

Average Latency (ms):			0.060
Allowed Maximum Data Excursion:	0.012	Measured Maximum Data Excursion:	0.005
Allowed Maximum Slope Excursion:	0.006	Measured Maximum Slope Excursion:	0.002
Least Squares Linear Fit Formula:			0.001 * R + 0.056

Test Drive: Client/Enterprise Latency Draft Formatted Report 4/6

Test Run Date:				Report Run Date:		8/10/2010	
Client Latency (REQUIRED) - Report Page							
SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)						Rev.	0.8
						Page	4 of 6
Key Set Up Data		DUT Preparation		Test Loop Parameters		Calypso Systems	
-		Purge	Security Erase			Steady State	
Serial#	-	Pre-Conditioning		REQUIRED:		Convergence	YES
DUT I/F	SATA 6Gb/s	Workload Independent	2X SEQ/128KiB	Data Pattern	RND	Rounds	1-5
SYS I/F	LSI 9212-4e4i int. SAS			Tester's Choice:		Active Range	
Test HW	Calypso RTP	Workload Dep.	Full Latency Loop	OIO/Thread	1	REQ:	100%
Test SW	CTSv6.5			Thread Count	1	OPT:	N/A
Average and Maximum Response Time - ALL RW Mix & BS – Tabular Data							

Average Response Time (ms)			
	Read / Write Mix %		
Block Size (KiB)	0/100	65/35	100/0
0.5	0.1723	0.1452	0.1252
4	0.0598	0.1224	0.1337
8	0.0767	0.1450	0.1619

Maximum Response Time (ms)			
	Read / Write Mix %		
Block Size (KiB)	0/100	65/35	100/0
0.5	166.7	155.8	155.9
4	155.8	155.9	155.8
8	155.8	155.8	156.5

Test Drive: Client/Enterprise Latency Draft Formatted Report 5/6

Test Run Date:	7/15/2010	Report Run Date:	8/10/2010

Client Latency (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)						Rev.	0.8
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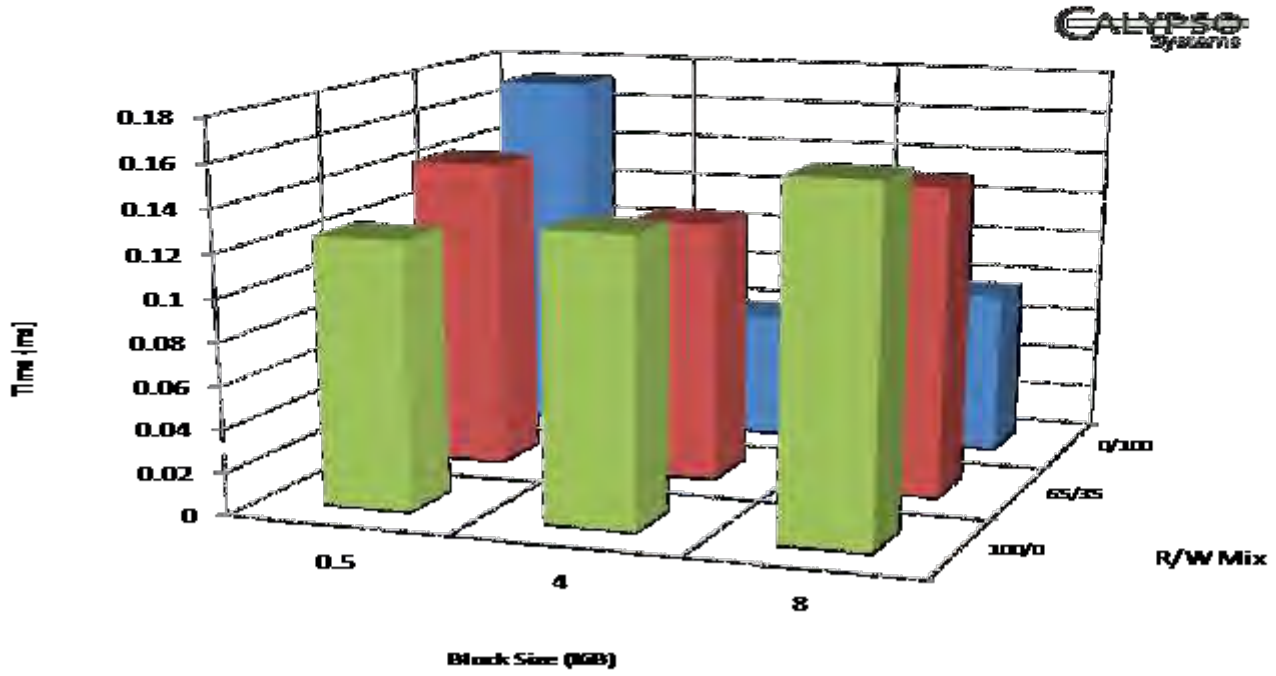
Key Set Up Data		DUT Preparation		Test Loop Parameters			Steady State	
-		Purge	Security Erase					
Serial#	-	Pre-Conditioning		REQUIRED:			Convergence	YES
DUT I/F	SATA 6Gb/s	Workload Independent	2X SEQ/128KiB	Data Pattern		RND	Rounds	1-5
SYS I/F	LSI 9212-4e4i Int. SAS			Tester's Choice:			Active Range	
Test HW	Calypso RTP	Workload Dep.	Full Latency Loop	OIO/Thread		1	REQ:	100%
Test SW	CTSv6.5			Thread Count		1	OPT:	N/A

Average Latency vs BS and R/W Mix - 3D Plot



Test Drive: Client/Enterprise Latency Draft Formatted Report 6/6

Test Run Date:	7/15/2010	Report Run Date:	8/10/2010

Client Latency (REQUIRED) - Report Page

SNIA SSS TWG: Solid State Storage Performance Test Specification (PTS)						Rev.	0.8
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Key Set Up Data		DUT Preparation		Test Loop Parameters			Steady State	
-		Purge	Security Erase					
Serial#	-	Pre-Conditioning		REQUIRED:			Convergence	YES
DUT I/F	SATA 6Gb/s	Workload Independent	2X SEQ/128KiB	Data Pattern		RND	Rounds	1-5
SYS I/F	LSI 9212-4e4i Int. SAS			Tester's Choice:			Active Range	
Test HW	Calypso RTP	Workload Dep.	Full Latency Loop	OIO/Thread		1	REQ:	100%
Test SW	CTSv6.5			Thread Count		1	OPT:	N/A

Maximum Latency vs BS and R/W Mix - 3D Plot

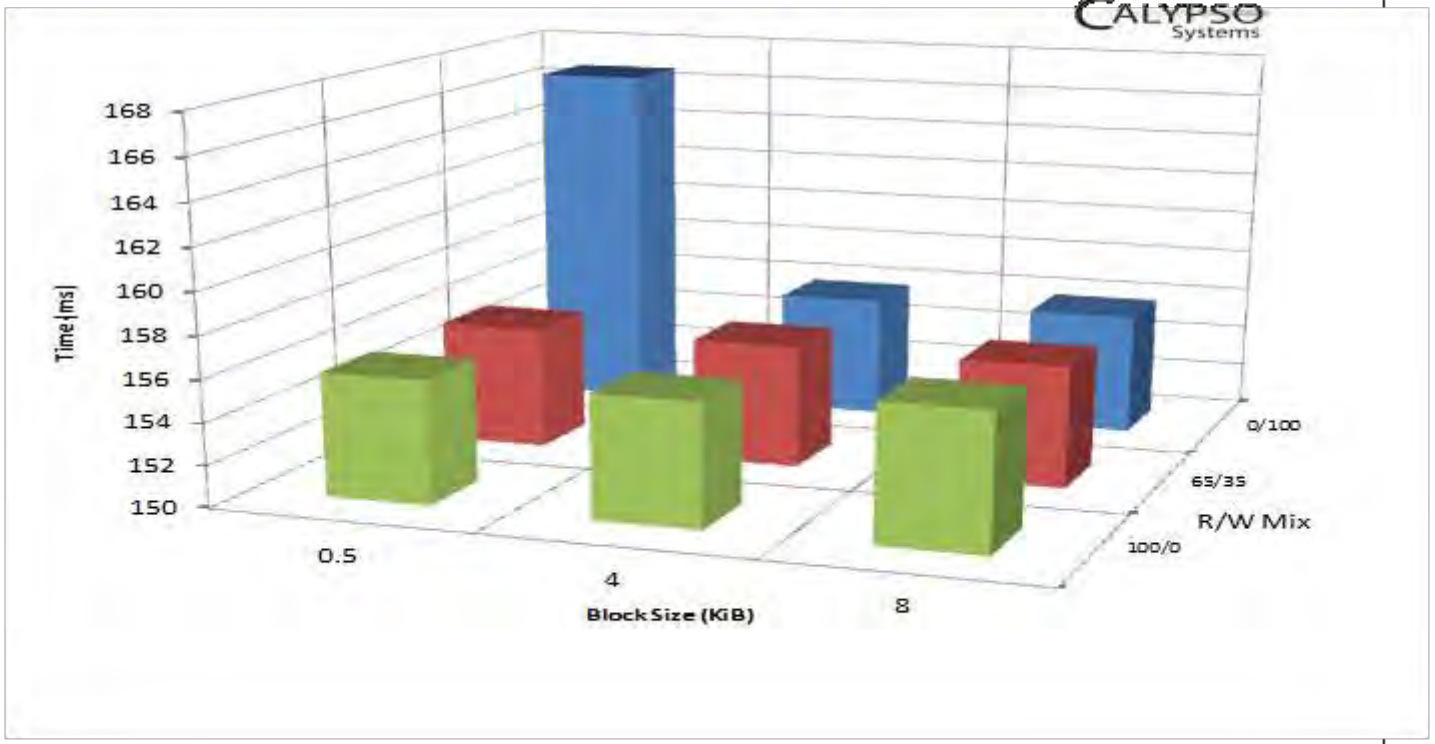

Table of Contents

SNIA SSSI PTS Follow-On Work

RND/4K Write Saturation	• Application of continuous RND/4K writes to a FOB or purged device • Observe IOPS performance evolution in time and total amount of data written
IOPS/W	• Measure total W used over a period of time, and deriving the number of IOPS that can be achieved at a given block size and access pattern with unit power • Measure the power efficiency of the device
Client Active Range Restriction	• Perform PC or Test in a restricted LBA range or ranges • To better simulate the environment of client usage
Cross Stimulus Recovery	• Measure performance metrics when changing between RND/SEQ and small block/large block stimulus • To see how drive handles switching between sustained access patterns
Demand Intensity	• Measure performance metrics with various outstanding IOS from the test application • understand the trade-off between achieving maximum IOPS vs acceptable maximum response time criteria

SNIA SSSI PTS Follow-On Work

Response Time Histogram	• Get detailed response time statistics during specific stimulus • to provide better insight into a drive's response time performance beyond a single average response time number
Task-Based Synth. Workloads	• Synthetic approximation to IO Trace playback based on understanding of access characteristics of specific tasks, such as video streaming, office productivity, etc. • Build a library of well-studied synthetic stimulus that can be used to form more complex user cases
SSD Figure of Merit	• Derive simplified metric(s) from data resulting from various PTS tests • To allow simply comparison between drives to aid marketing
Industry Requests?	• ?
?	• ?

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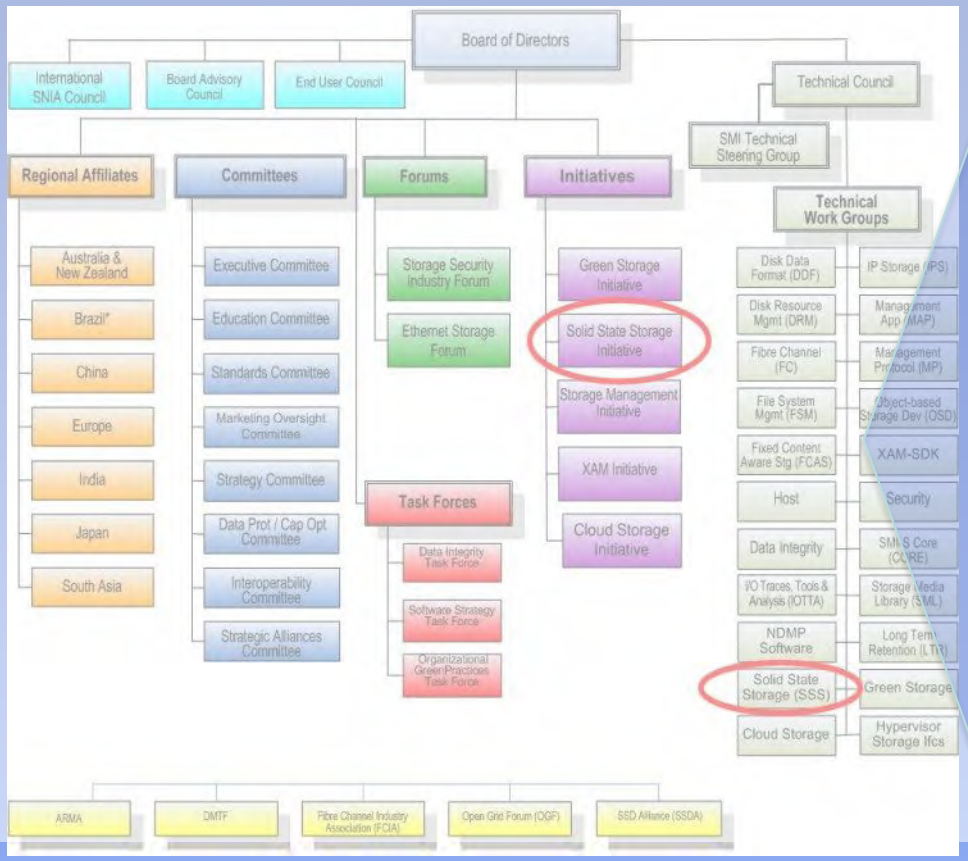
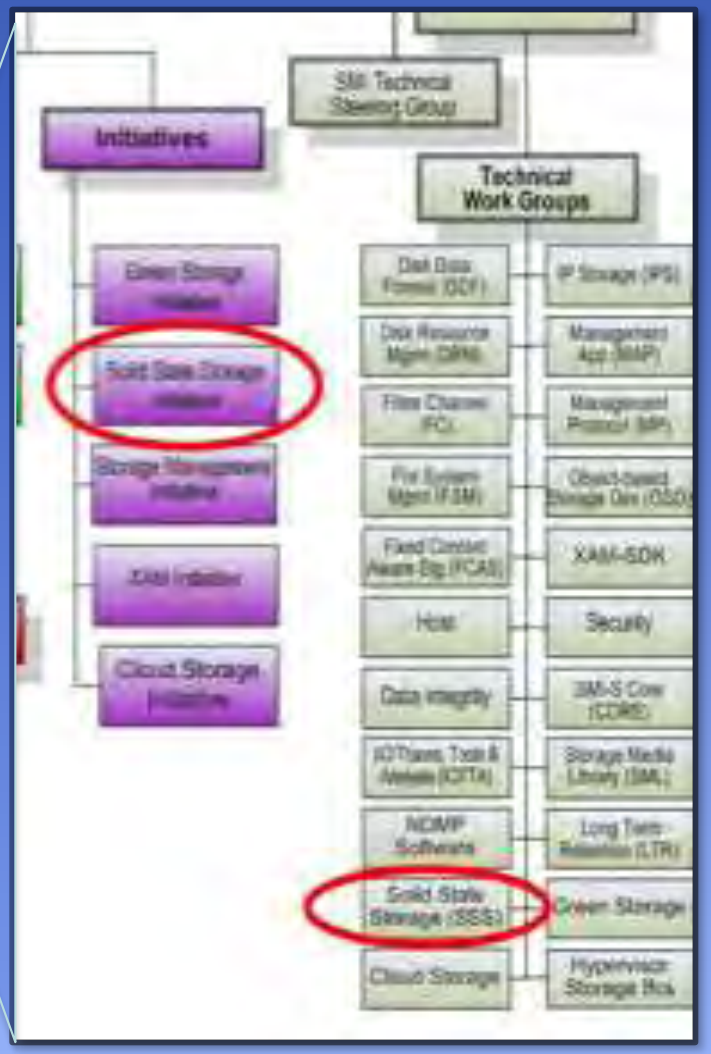
SNIA – Organization Chart





Charter & Mission Statements

SNIA – *Storage Networking Industry Association*

"Lead Industry Standards for information storage management"

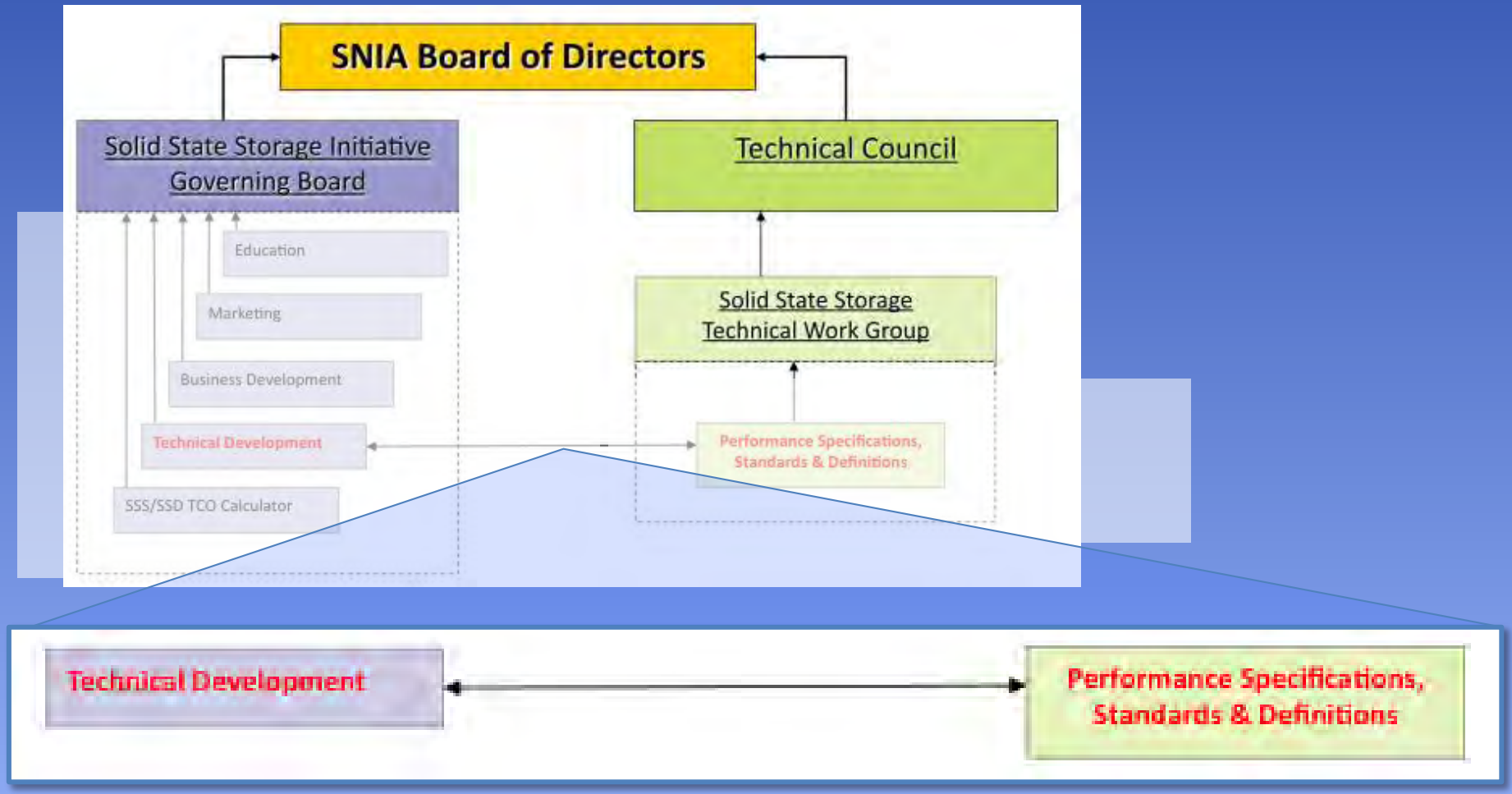
SSSI – *Solid State Storage Initiative*

"Foster the success of Enterprise & Client SSS markets"

SSS TWG – *Solid State Storage Technical Working Group*

"Develop SNIA Technical Specifications & Standards"

SSSI & The TWG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Technical Council
Education
Marketing
Business Development
Technical Development
SSS/SSD TCO Calculator
Solid State Storage Technical Work Group
Performance Specifications, Standards & Definitions
Technical Development
Performance Specifications, Standards & Definitions

SSSI – 33 Members

(as of 06/21/2010)

1) AmerNet
2) ATTO
3) BiTMICRO Networks
4) Calypso Systems
5) Coughlin Associates
6) Dell
7) EMC
8) Fusion-io
9) Hitachi GST
10) HP
11) IBM
12) Intel
13) LSI
14) Marvell
15) Micron
16) Microsoft
17) NetApp
18) Objective-Analysis
19) Patni Computer Systems
20) Pliant Technology
21) PMC-Sierra
22) Samsung
23) SanDisk
24) Seagate
25) Silverton Consulting
26) Smart Modular
27) Sun Microsystems
28) Texas Memory Systems
29) Toshiba
30) Violin Memory
31) Webfeet Int'l
32) Western Digital
33) Xiotech

TWG – 56 Members

(as of 06/21/2010)

1) AmerNet
2) ATTO
3) Avere Systems
4) BiTMICRO Networks
5) Calypso Systems
6) Compellent
7) Coughlin Associates
8) Data Mobility Group
9) Dataram
10) Data Storage Institute
11) Dell
12) EMC
13) Exar Corp.
14) Florida State Univ.
15) Fusion-io
16) George Washington Univ.
17) Harvey Mudd College
18) HCL Technologies
19) HDS
20) Hitachi GST
21) Hauwei
22) HP
23) IBM
24) Intel
25) LSI
26) Marvell Semiconductor
27) Micron
28) Microsoft
29) Mtron
30) NetApp
31) Objective-Analysis
32) Olocity
33) Oracle
34) Patni Computer Systems
35) Pillar Data Systems
36) Pliant Technology
37) PMC-Sierra
38) Samsung
39) SandForce
40) SanDisk
41) Seagate
42) Silverton Consulting
43) Smart Modular
44) Storspeed
45) Sun Microsystems
46) Tata Consultancy
47) Texas Memory Systems
48) *Toshiba (in process)*
49) Univ. of Minnesota
50) Violin Memory
51) Vmware
52) Webfeet Int'l
53) Western Digital
54) Wipro Technologies
55) Xiotech
56) Xyratex

Feedback & Involvement

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Thank You

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