



# Calypso Blind Survey 2010

## SSD Performance Comparison *MLC, SLC & HDD*

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Calypso Systems, Inc.  
*SSD Blind Surveys*

- CBS 2010 – 2d Annual Blind Survey
- SSD Performance Comparisons
- SNIA Solid State Storage Performance Test Specification (SSS PTS) Compliant
- SNIA Specified Reference Test Platform (RTP)
- Apples-to-Apples Device Level Comparison



# Blind Survey SSD Sample Pool

(8) MLC; (8) SLC; (1) HDD

No.	Drive Manufacturer	Drive Model No.	NAND Type & Capacity	Form Factor & Interface
1.	Imation	MAC25-12 .003	128 GB MLC Client	2.5" 3 Gb/s SATA
2.	Intel	X25M	160 GB MLC Client	2.5" 3 Gb/s SATA
3.	Micron	C 300	256 GB MLC Client	2.5" 3 Gb/s SATA
4.	SanDisk	G3	128 GB MLC Client	2.5" 3 Gb/s SATA
5.	Samsung	MZ7PA	128 GB MLC Client	2.5" 3 Gb/s SATA
6.	SandForce	SF 1000	200 GB MLC Client	2.5" 3 Gb/s SATA
7.	Smart Modular	SG9XGS	128 GB MLC Client	2.5" 3 Gb/s SATA
8.	Toshiba	N2 – 694	128 GB MLC Client	2.5" 3 Gb/s SATA
9.	Dell	MCCOE1HG	100 GB SLC Enterprise	2.5" 3 Gb/s SATA
10.	Intel	X25E	64 GB SLC Enterprise	2.5" 3 Gb/s SATA
11.	Micron	P300	100 GB SLC Enterprise	2.5" 6 Gb/sec SATA
12.	Pliant	LB150S	150 GB SLC Enterprise	2.5" 6 Gb/s SAS
13.	Pliant	LS300S	300 GB SLC Enterprise	3.5" 6 Gb/s SAS
14.	Samsung	SS805	100 GB SLC Enterprise	2.5" 3 Gb/s SATA
15.	Soligen	50	50 GB SLC Enterprise	Proprietary 3 Gb/s SATA
16.	Viking Modular	Element	200 GB SLC Enterprise	2.5" 3 Gb/s SATA
17.	Seagate	Savvio	500GB 15K RPM HDD	2.5" 3 Gb/s SAS



## Calypso Blind Surveys Test Set Up

- Calypso RTP 2.0 / CTS 6.5
- SNIA SSS PTS Compliant
- Reference Test Environment
- Performance Comparison of SAS/SATA SSDs

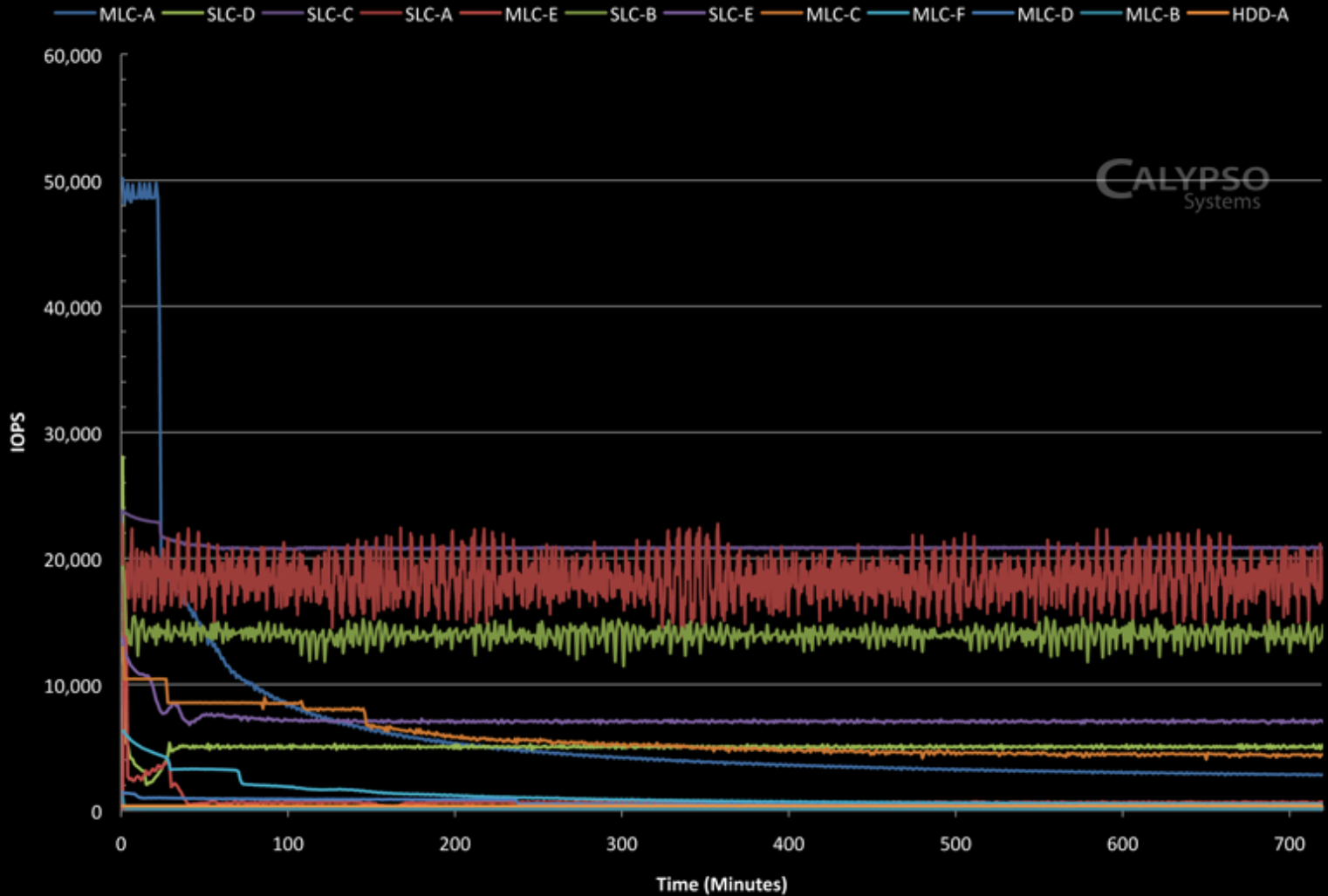




# Performance Change over Time

## WSAT - Continuous RND 4K Writes - FOB

### RND/4K Write Saturation

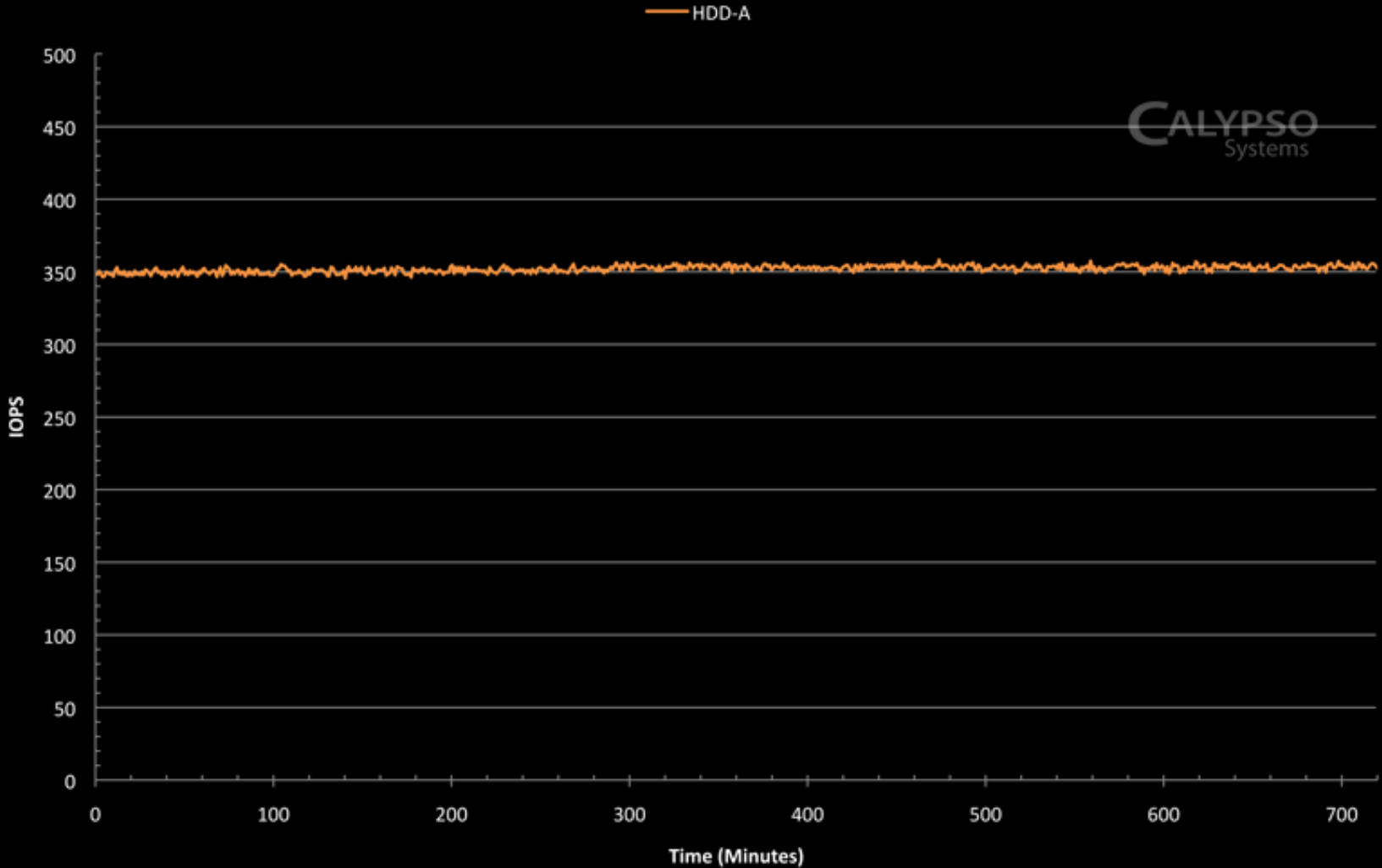




# HDDs: Stable but low IOPS – 350 IOPS

15K RPM SAS 2.5" HDD – continuous RND 4K W

### RND/4K Write Saturation

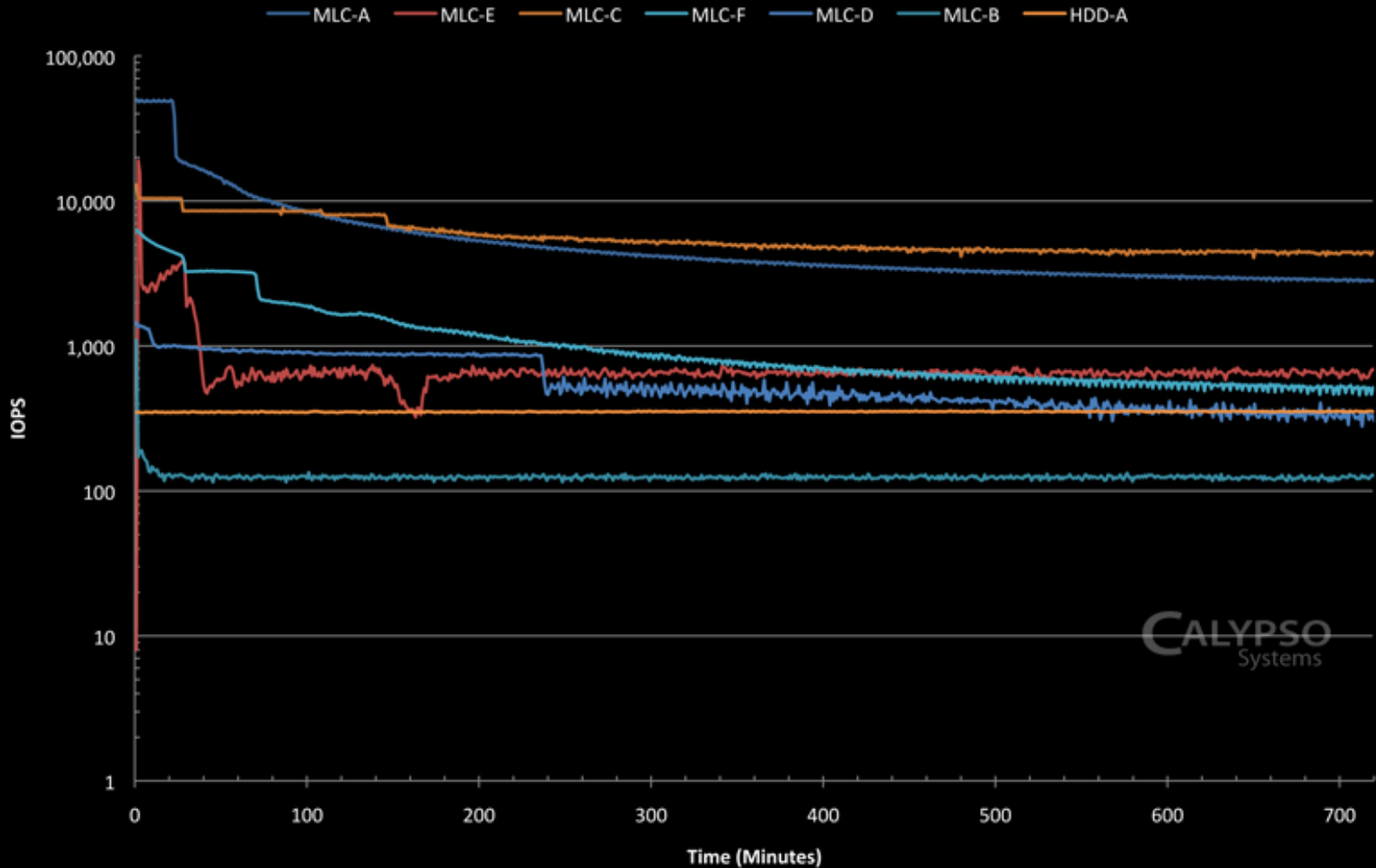




# MLC WSAT:

*FOB - Higher IOPS, Much Settling*

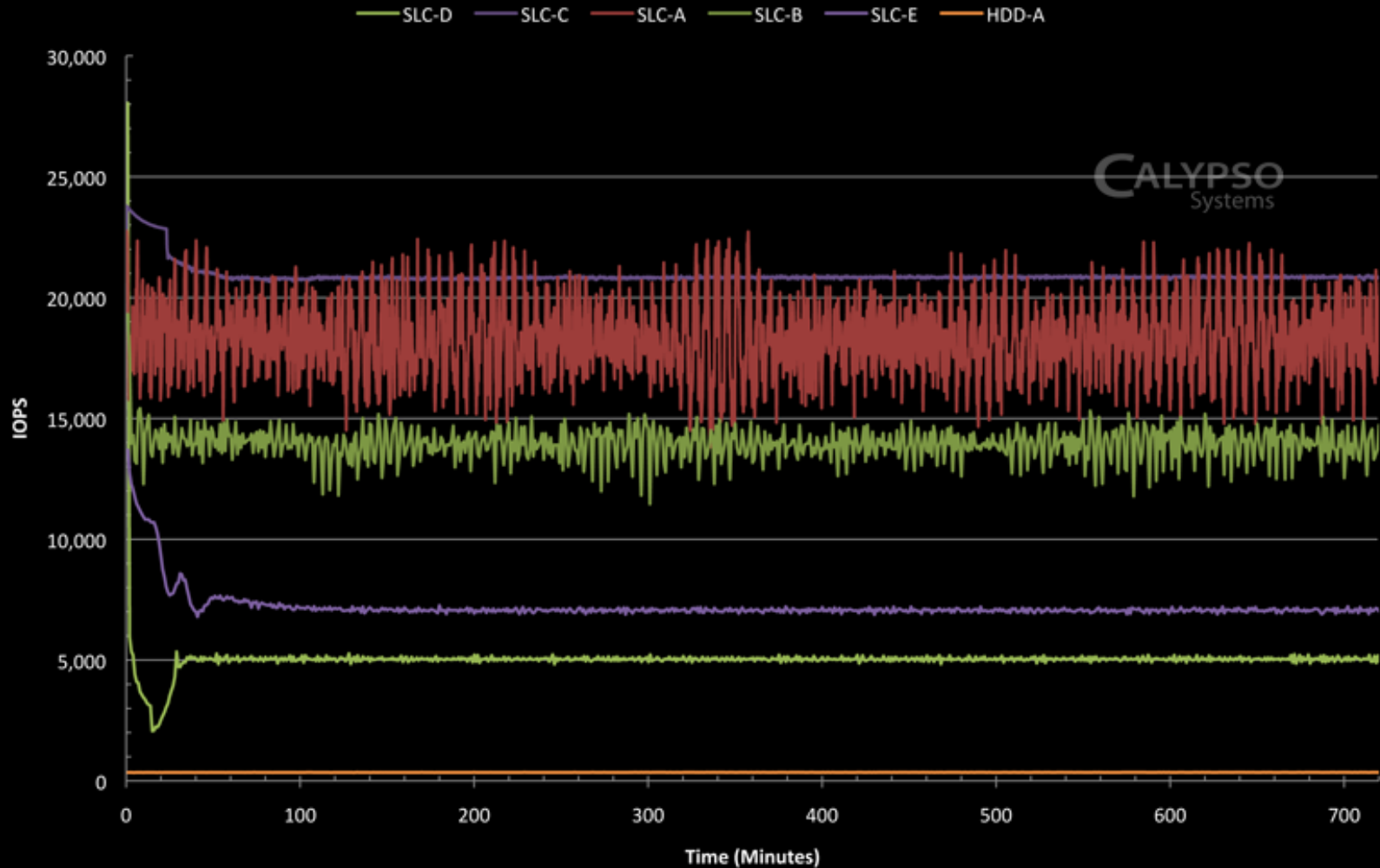
## MLC RND/4K Write Saturation





# SLC WSAT: *More Stability, More Endurance... IOPS Throttling?*

### SLC RND/4K Write Saturation







## TAKE AWAY: *Need For DEVICE Testing at Steady State*

Comparison of FOB and Steady State RND 4KW IOPS		
Drive	FOB (WSAT) *	STEADY STATE **
HDD-1	348	340
MLC-1	1,447	305
MLC-2	19,010	221
MLC-3	50,156	2,716
SLC-1	55,677	19,561
SLC-2	28,063	1,182
SLC-3	21,581	7,556

\* Calypso CTS 6.5 Compliant

\*\* SNIA PTS 0.9 Compliant



# Pre Conditioning to Steady State

## Set Write History & Optimize Workloads

PTS v 0.9 – Steady State Measurement Process *		
Step	Activity	Purpose
<b>PURGE</b>	Security Erase/Format Unit Writing to all LBAs As if no Writes Occurred	Create a Repeatable Test Starting Point
<b>Workload Independent PC</b>	2X User Capacity SEQ 128K W	Touch all LBAs Linearize Look Up Table
<b>Workload Dependent PC</b>	Test Stimulus Access Pattern In Rounds	Repeat Workload Dependent Stimulus
<b>Steady State Convergence</b>	Plot Workload Dependent Rounds all Block Sizes	Determine when Steady State Reached
<b>Steady State Measurement Window</b>	5 Rounds within 20% Excursion of Ave & 10% Slope of Curved Fit	Establish Window from Which to take Measurements

\* SNIA PTS 0.9 Compliant



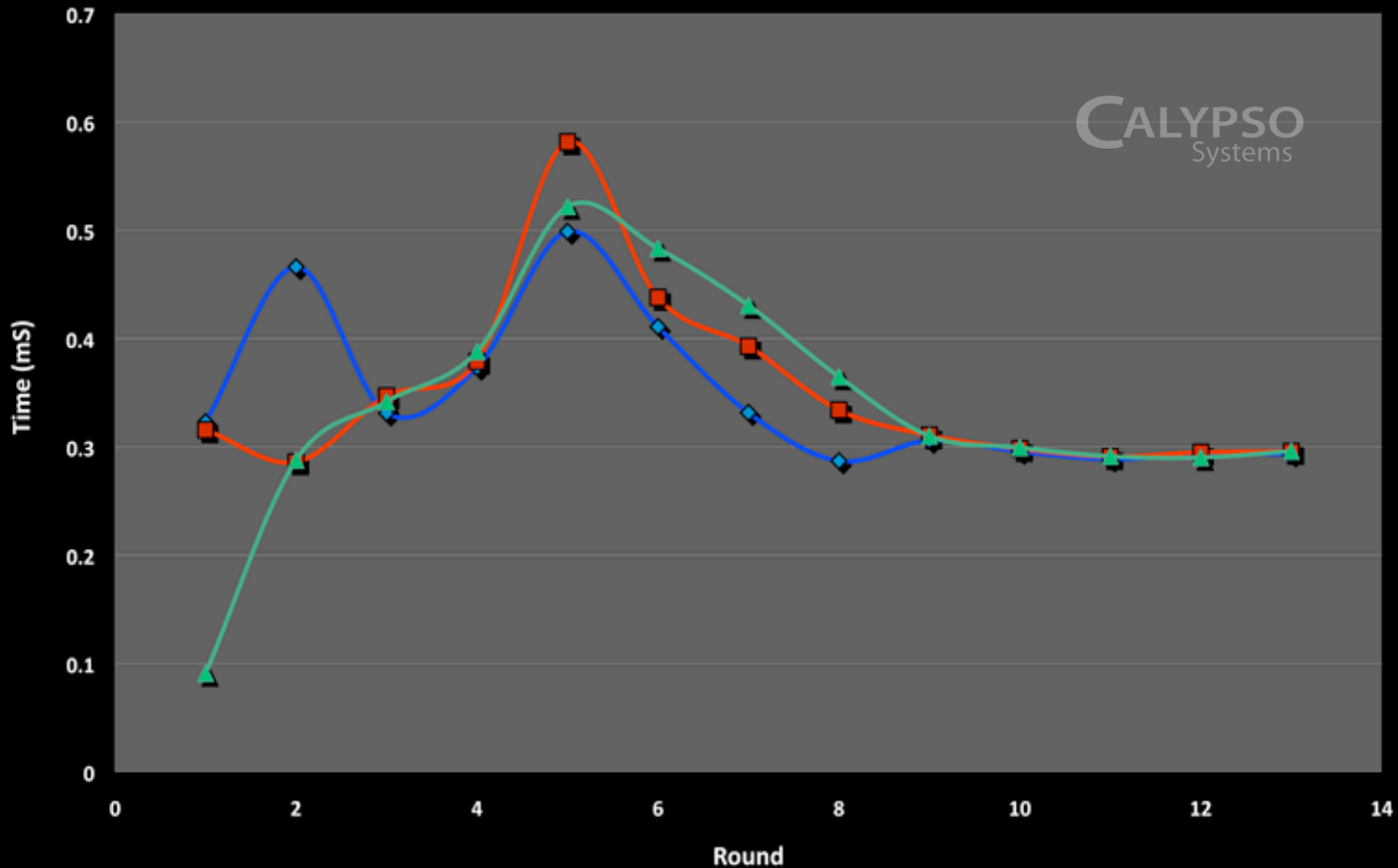
# FOB to STEADY STATE

After 2X SEQ PC, SS Convergence – All Block Sizes

## LATENCY Pre Conditioning Convergence Report

100% Write Convergence - 3 Block Sizes For All Rounds

— RW=0, BS=0.5K    — RW=0, BS=4K    — RW=0, BS=8K

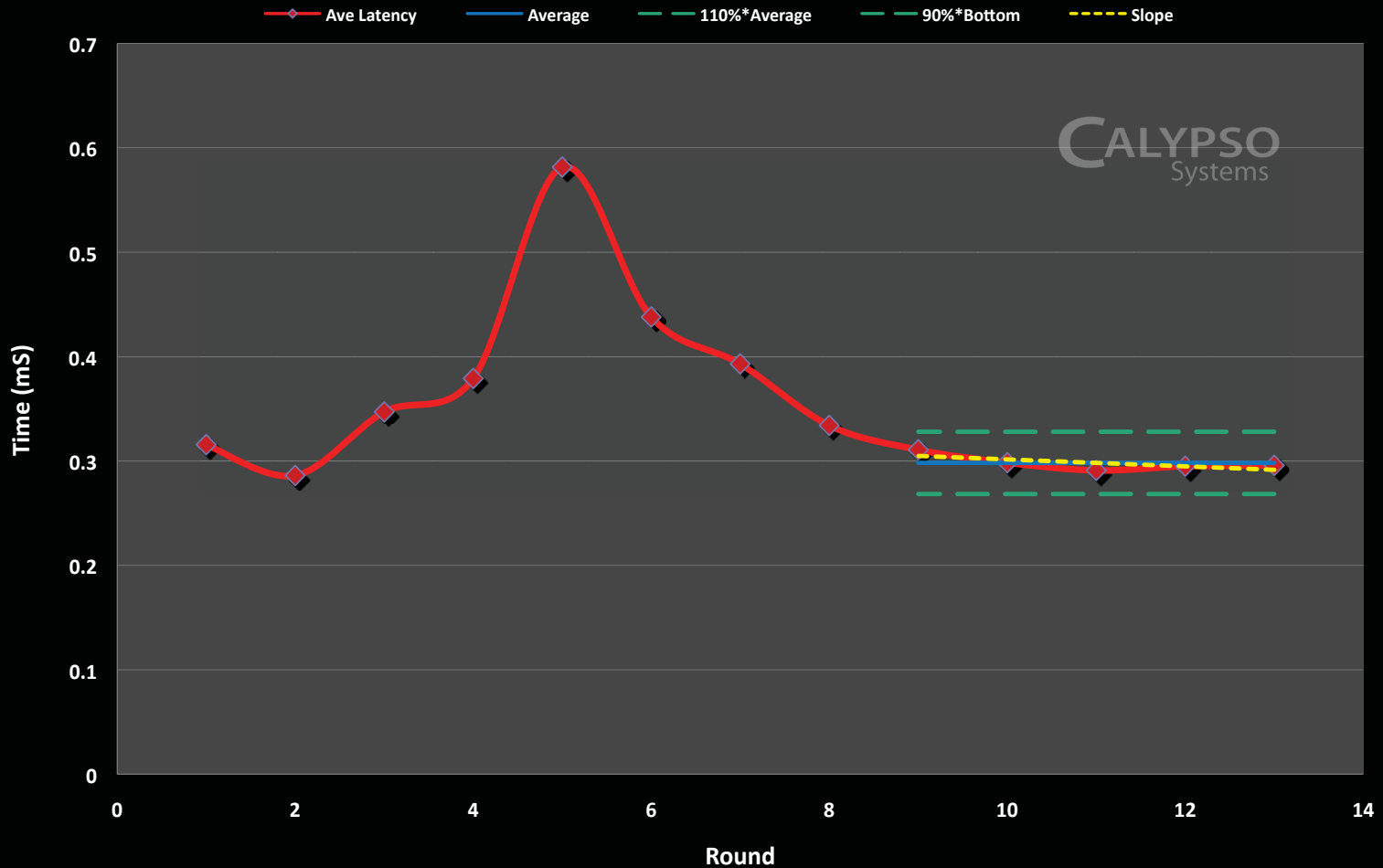




# Convergence to Steady State

## SS Measurement Rounds – Tracking Block Size 4KiB AVE

Steady State Measurement Window  
4KB W Average Latency - SS Rounds 9 - 14





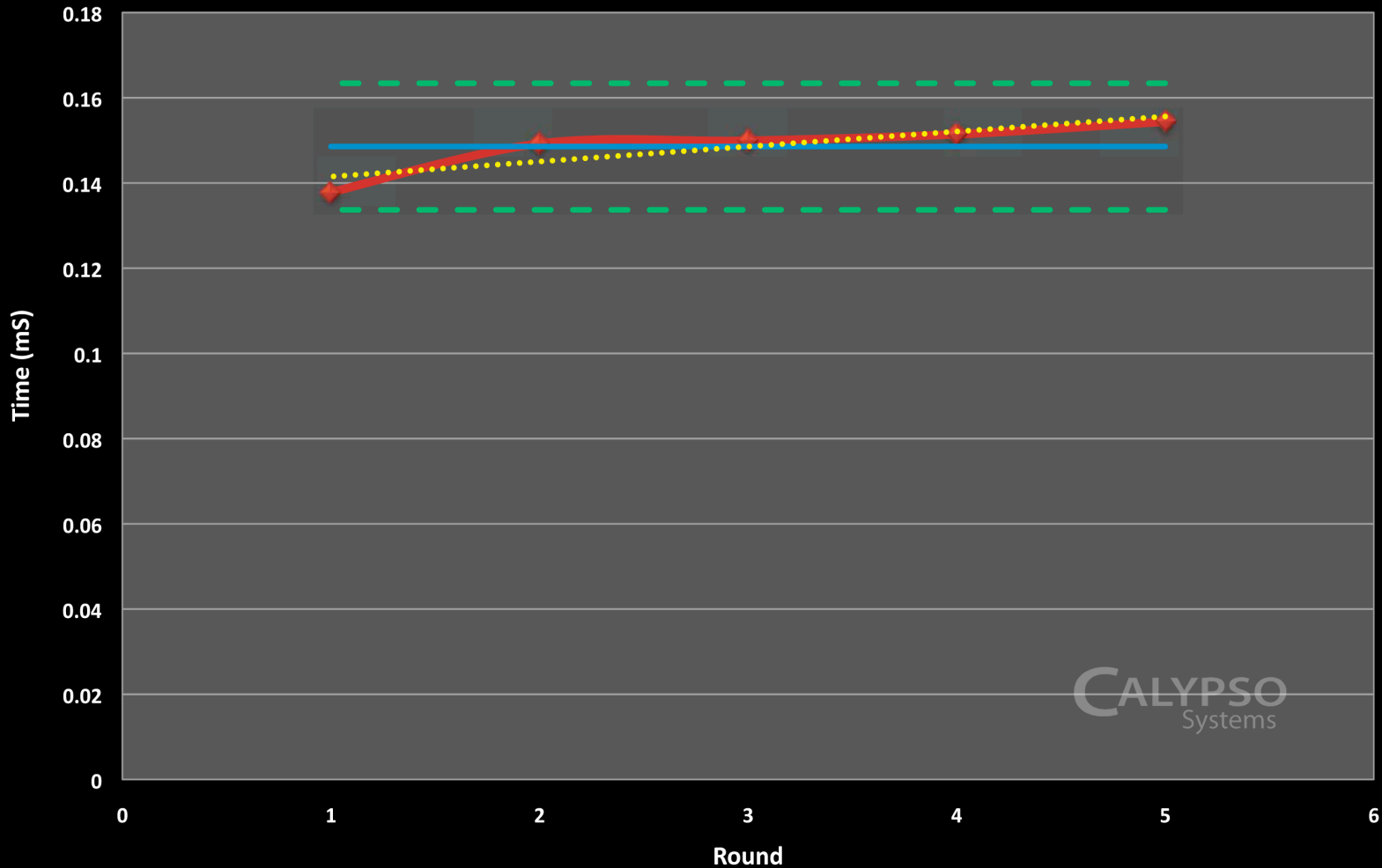
# STEADY STATE Measurement Window

5 Rounds: w/in 20% Excursion Band **AND** 10% Slope

## Steady State Measurement Window

4KB W Average Latency - SS Window

—◆— Ave Latency    — Average    - - - Top    - - - Bottom    ..... Slope





# Calypso Blind Survey 2010

## *Test Plan: Level I & Level II*

- **Sample Pool:** 8 MLC, 8 SLC, 1 HDD
- **Level I Tests:** Standard CTS & PTS Tests
  - WSAT (Write Saturation) & Latency Histogram
  - IOPS, Throughput, Latency (Client & Enterprise)
- **Level II Tests:** CTS 6.5 Tests
  - Non RND Data Pattern Tests
  - Limited Active Range (LBA Hot Zones)
  - Cross Stimulus Recovery (RND-SEQ-RND) (SEQ-RND-SEQ)
- **Test Set Up:** 6 Gb/s SAS/SATA HBA; Calypso RTP 2.0 / CTS 6.5
- **Report Date:**
  - Part I: AUG 2010
  - Part II: OCT 2010



# Calypso CBS 2010 Blind Survey

## *Select Data Presentation*

- Level I: **Standard Tests** – AUG 2010
  - **RND 4 KB** - 100% R 100% W
  - **65% 35% R/W Mix** – RND 4K IOPS
  - **1 MB SEQ Throughput** – 100% R 100% W
  
- Level II: **Custom Tests** – OCT 2010
  - **Data Pattern** – Non Random File as Stimulus
  - **Active Range** – Limited Active Range for Pre Conditioning & Workload
  - **Cross Stimulus Recovery** – RND-SEQ-RND and SEQ-RND-SEQ



# RND 4KB W

*Steady State 100% R 100% W \**

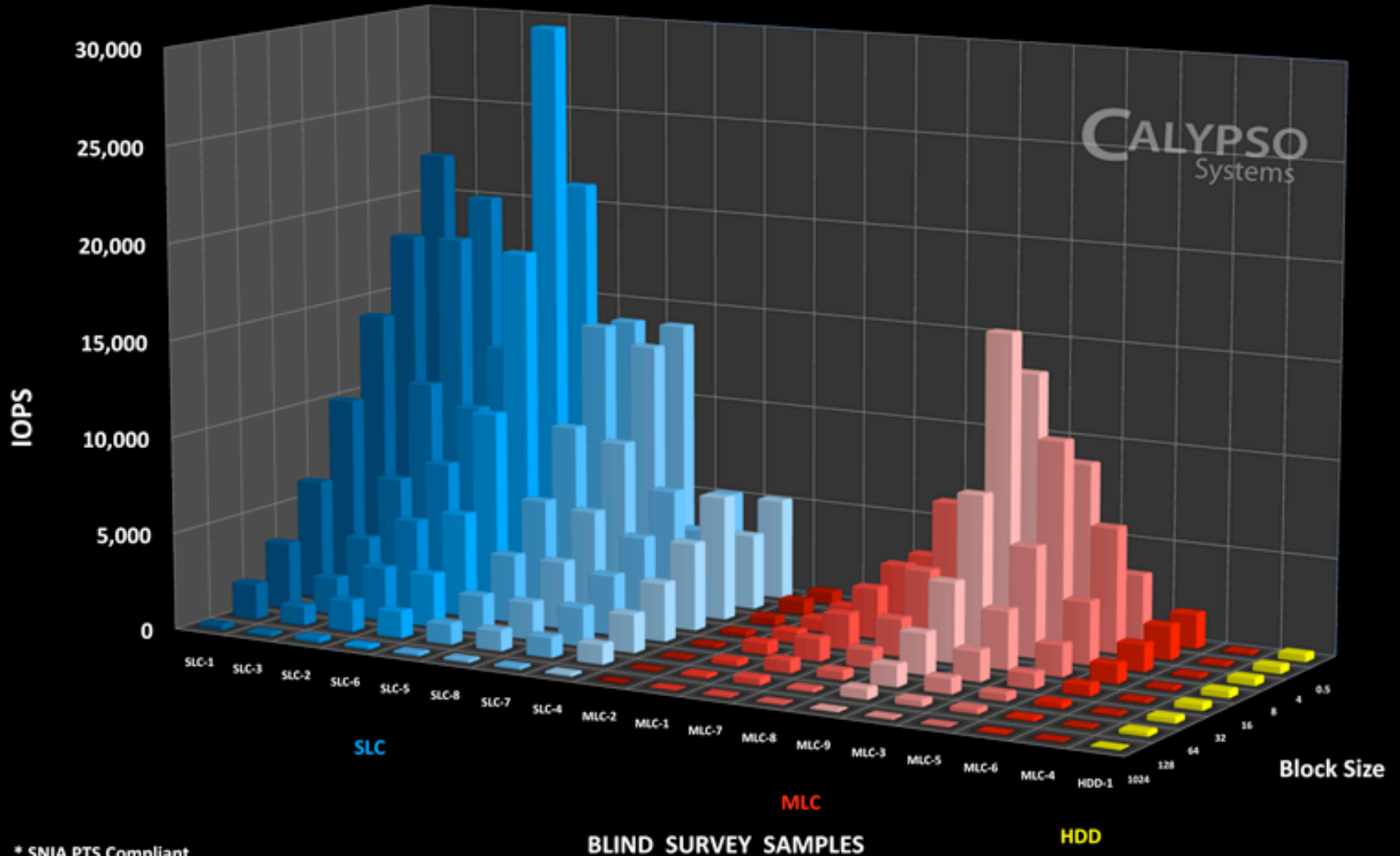
Selected <b>Steady State</b> RND 4K W IOPS *		
Drive	Steady State <b>READS</b>	Steady State <b>WRITES</b>
HDD-1	402	340
MLC-A	2,495	305
MLC-B	60,988	2,717
MLC-C	25,819	4,502
SLC-A	37,091	1,182
SLC-B	24,273	20,312
SLC-C	46,365	19,561

\* SNIA PTS COMPLIANT





65% 35% Read Write Mix  
*RND 4KB Steady State Performance\**

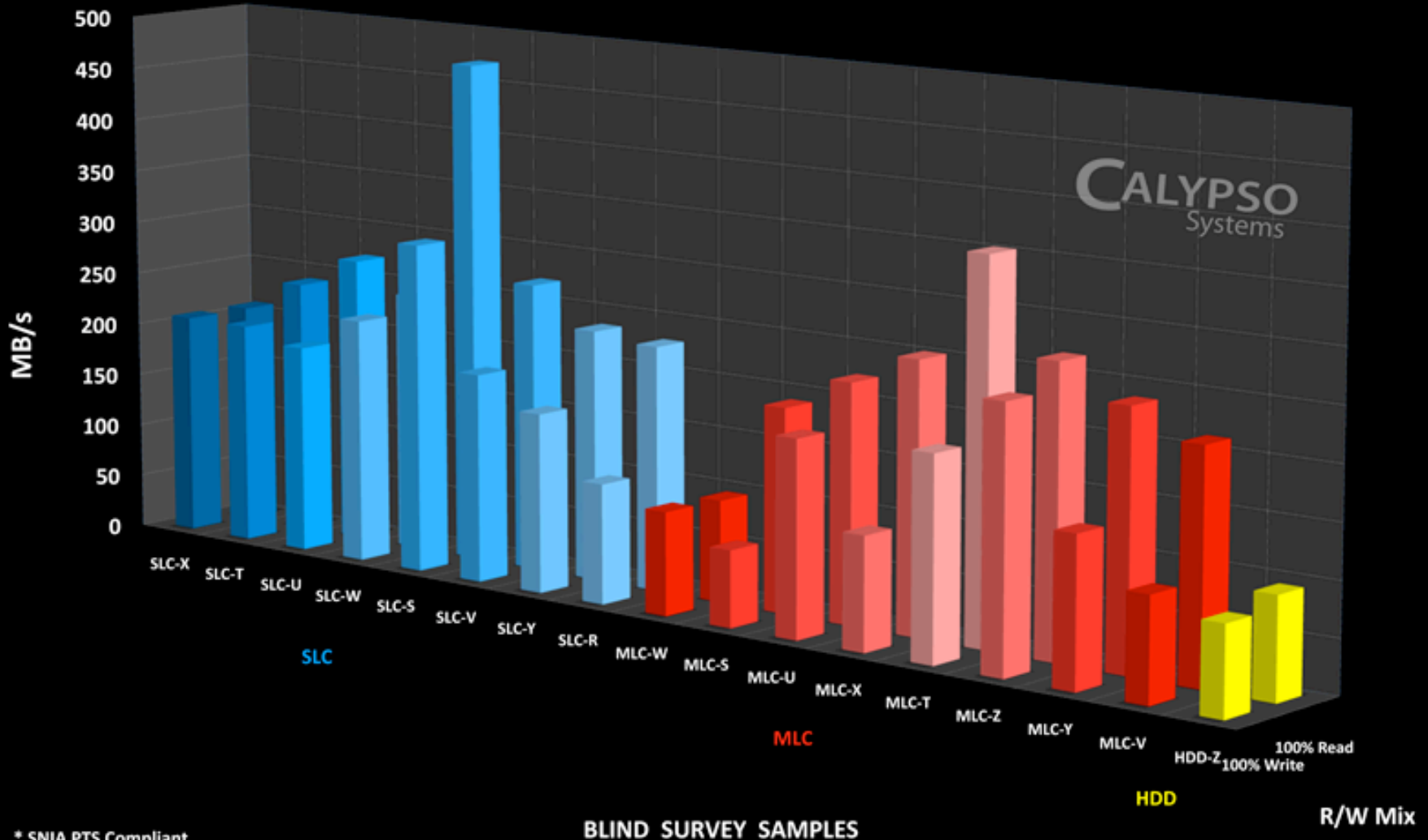


\* SNIA PTS Compliant



# SEQ 1MB THROUGHPUT

100% R 100% W - Steady State\*



\* SNIA PTS Compliant

BLIND SURVEY SAMPLES

R/W Mix



## CBS 2010 Blind Survey: *Performance Issues - Take Aways*

- *Performance Changes over Time; SSDs have Limited Life*
- *Performance is Write History & Workload Dependent*
- *SSD Performance States Evolve:*
  - *FOB Transient Enhanced*
  - *Pre Conditioning – Workload Ind. & Dependent*
  - *Convergence to Steady State(s)*
- *Steady State Measurement Window*
- *Asymmetric Performance – Fast Reads, Slower Writes*



## CBS 2010 Blind Survey: SSD Industry - Take Aways

- *New Standardized Metrics & Methodologies*
- *SNIA PTS Specified Tests & Testers*
- *SLC & MLC SSDs are Maturing*
- *Controllers & NAND Flash are Improving*
- *Device Level Test is key for Ordinal Ranking & Comparison*
- *Synthetic Workloads are being Characterized*
- *SSDs are being Integrated to Mass Storage Ecosystem*



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*Professionals in Solid State Storage Test & Measurement*

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