
# Enterprise Applications
# How to create a synthetic workload test

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# Abstract

- Test Engineers & Marketing Managers responsible for SSD test, deployment and qualification.
  - This session will appeal to Data Center Managers, Development Managers, and those that are seeking a fundamental understanding of the SNIA's Solid State Storage Performance Test Specification (PTS).
  - The session will investigate Demand Intensity / Outstanding IOs, Confidence Level Plots / Response Time Histograms, and Synthetic Application Workloads.
  - The audience learn how to evaluate IOPS and Response Time Saturation, how to conduct a Response Time Confidence Level Sensitivity Analysis, and how to build a test template for synthetic workloads.
  - A case study will be presented using a synthetic database OLTP workload.

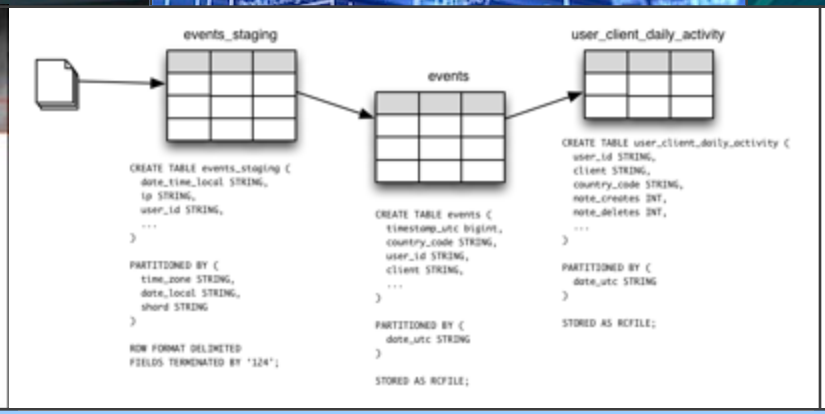

# Synthetic Enterprise Application Workloads

- What are they?
- Why are they used?
- How do I use them?
- What are some examples?
- Case Study
  - *Two 2014 released SATA Enterprise class SSDs*
  - *OLTP workload tested to saturation*
  - *Examination of IOPS and Response Times*

# Learning Objectives

- What are:
  - Demand Intensity Levels & Outstanding IOs
  - Confidence Level Plots & Response Time Histograms
  - Synthetic Application workloads
- How to:
  - Evaluate IOPS and Response Time Saturation
  - Do a Sensitivity Analysis of Confidence Levels
  - Build a test template for synthetic workloads

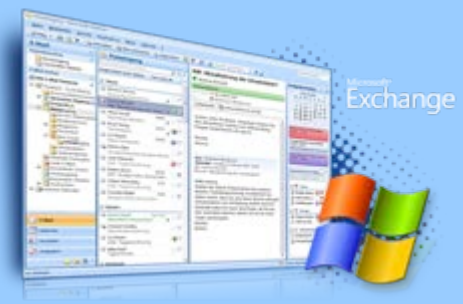




Synthetic Enterprise Application Workloads

# WHAT ARE THEY?




# Enterprise Applications

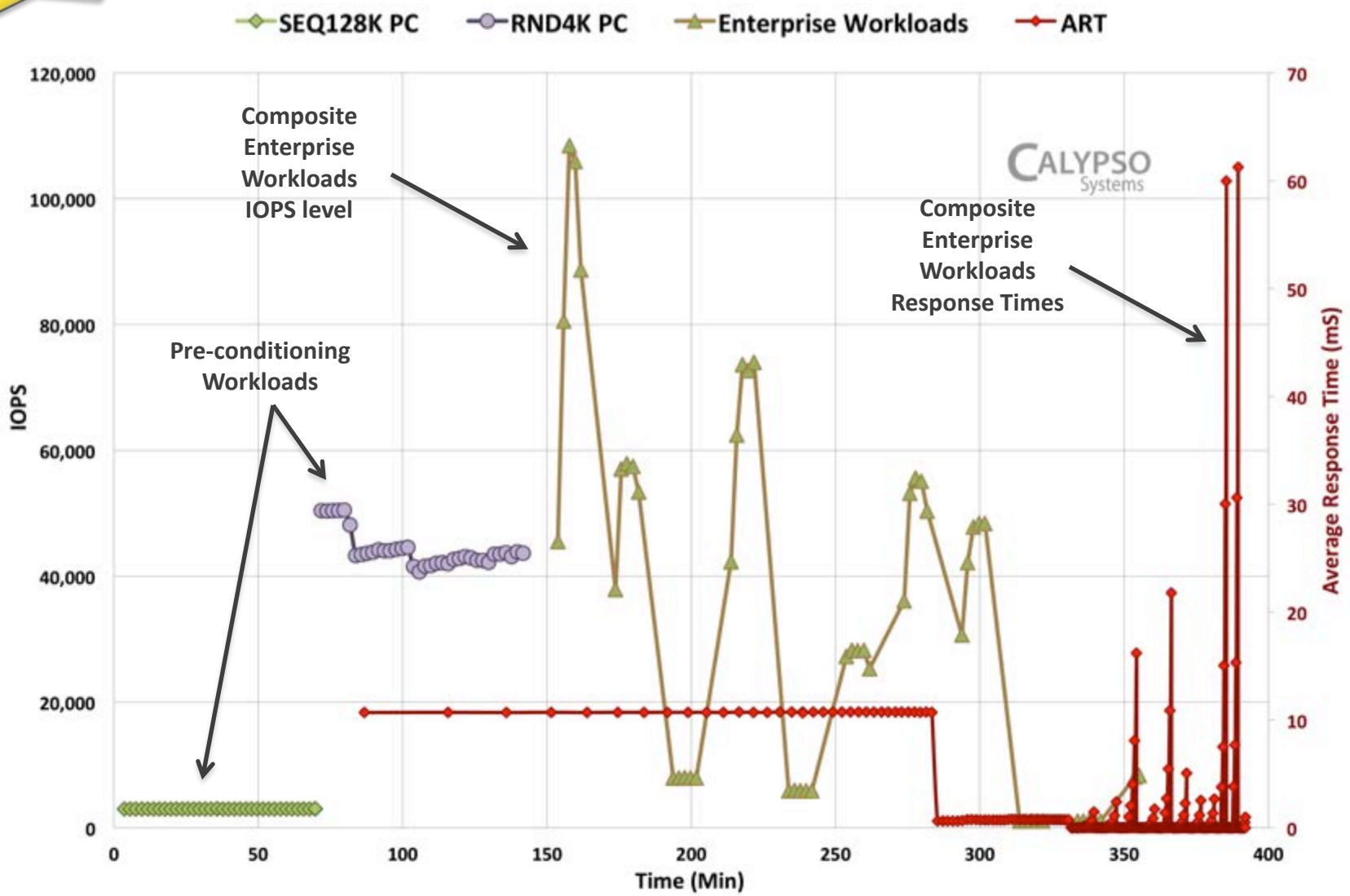
Applications common in the Enterprise include:

- OLTP (On Line Transaction Processing)
- OLAP (On Line Analytical Processing)
- VOD (Video on demand)
- OS Paging
- Webserver / Exchange mail
- Logging (web server, SQL server logs)
- DSS (Decision Support Systems)
- Medical Imaging

TAKE AWAY
Different workloads apply different access patterns to the SSD.

# Enterprise Application Workloads are Different

*Test Profile – IOPS & RT levels of different synthetic workloads*



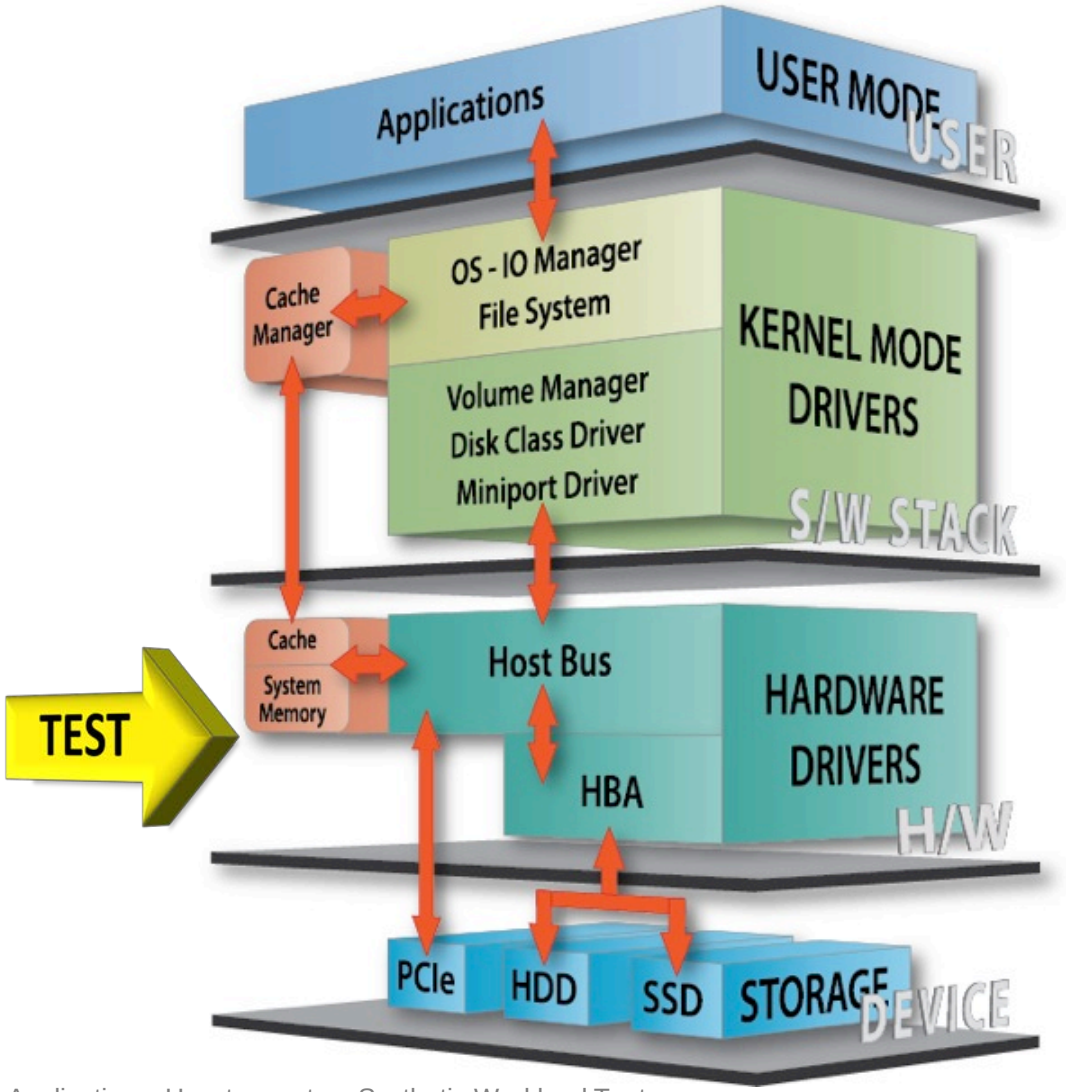
TAKE AWAY
HW/SW stack affects IOs – use standardized test platform to isolate SSD Device Performance.

# Workloads are affected by the IO Stack

Application Workloads are generated in user space and traverse the IO stack to the SSD

Testing wants to measure workloads as close to the SSD as possible

(Block IO level)



# Workloads are described by Access Patterns

| Degree of Randomness | Data Transfer Size | Read Write Ratio |
|---|---|---|
| Random or Sequential | Block Size | Read/Write Mix |
| Workloads are a series of Access Patterns over an observation period | | |
| **Examples of Access Patterns for different workloads:** | | |
| RND | 4KiB | RW0 |
| RND | 8KiB | RW65 |
| SEQ | 128KiB | RW90 |
| SR75 | 64KiB | RW95 |
| SR25 | 128KiB | RW05 |

Workloads can be:

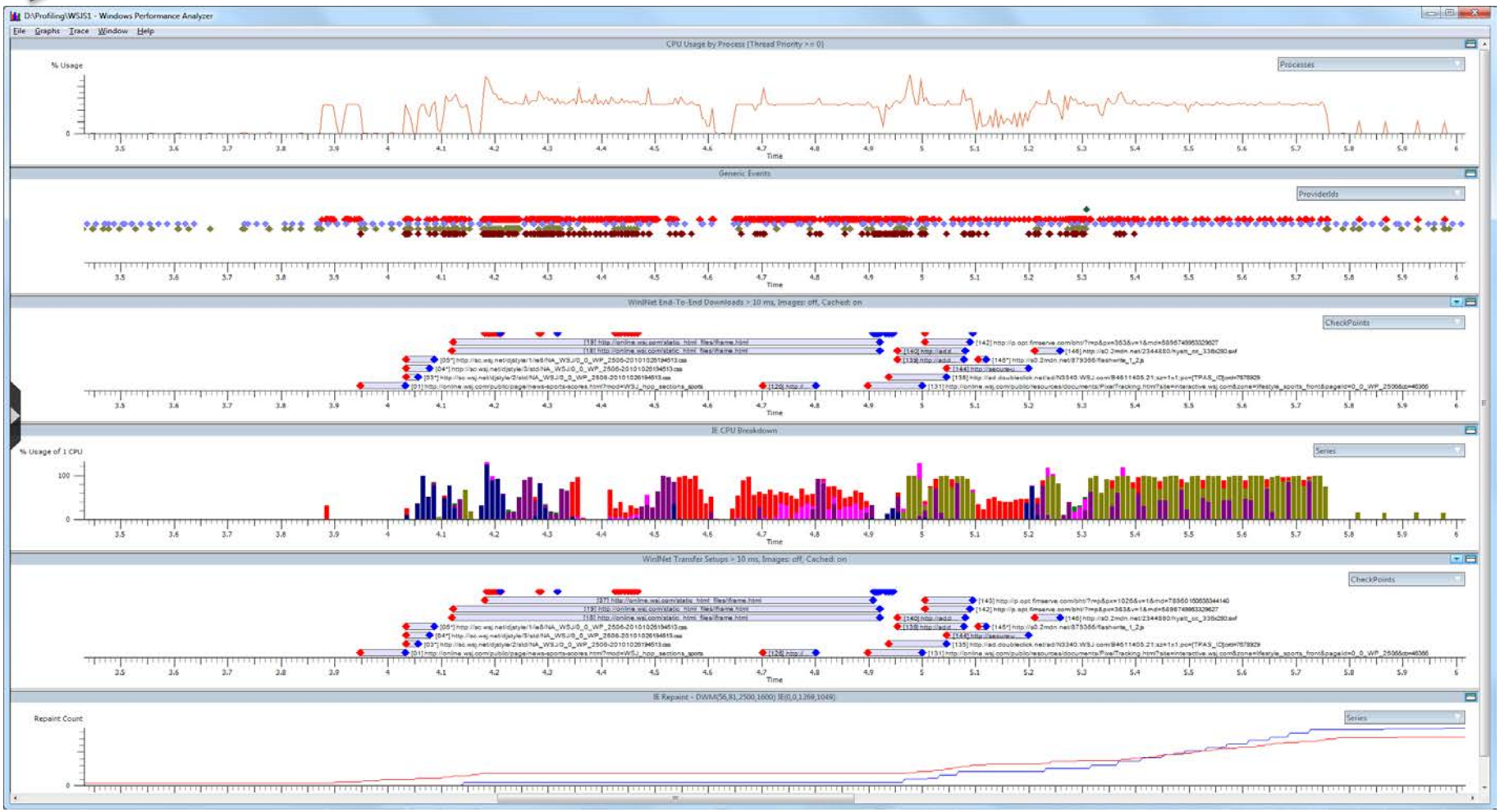
*Monotonic or Composite stream of Accesses*
*Synthetic or Real World workloads*

TAKE AWAY
IO Traces captures are specific to the system HW and drive tested.

# Real-world Workloads

IO Trace Captures are specific to the system

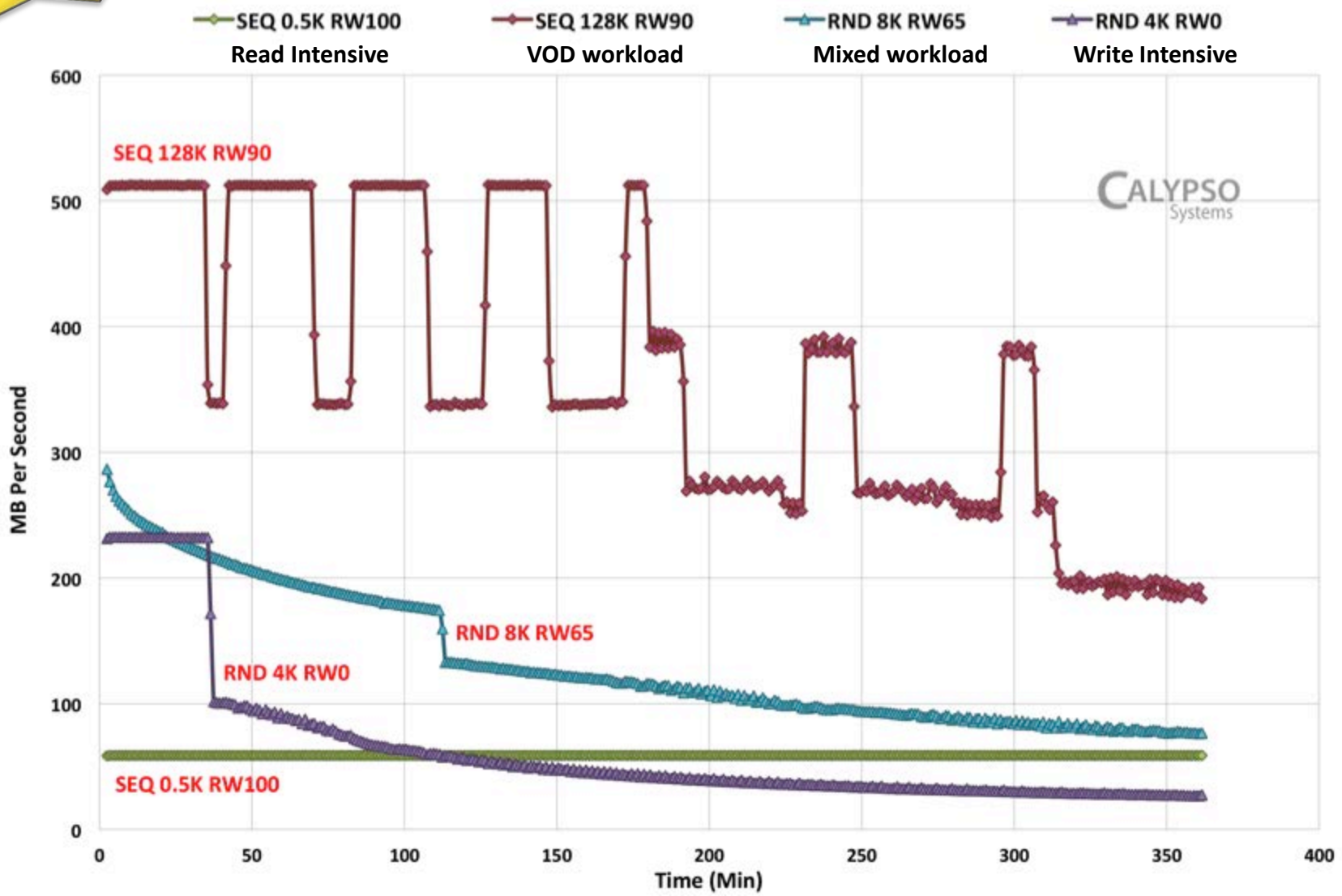
Contain many many streams of different access patterns

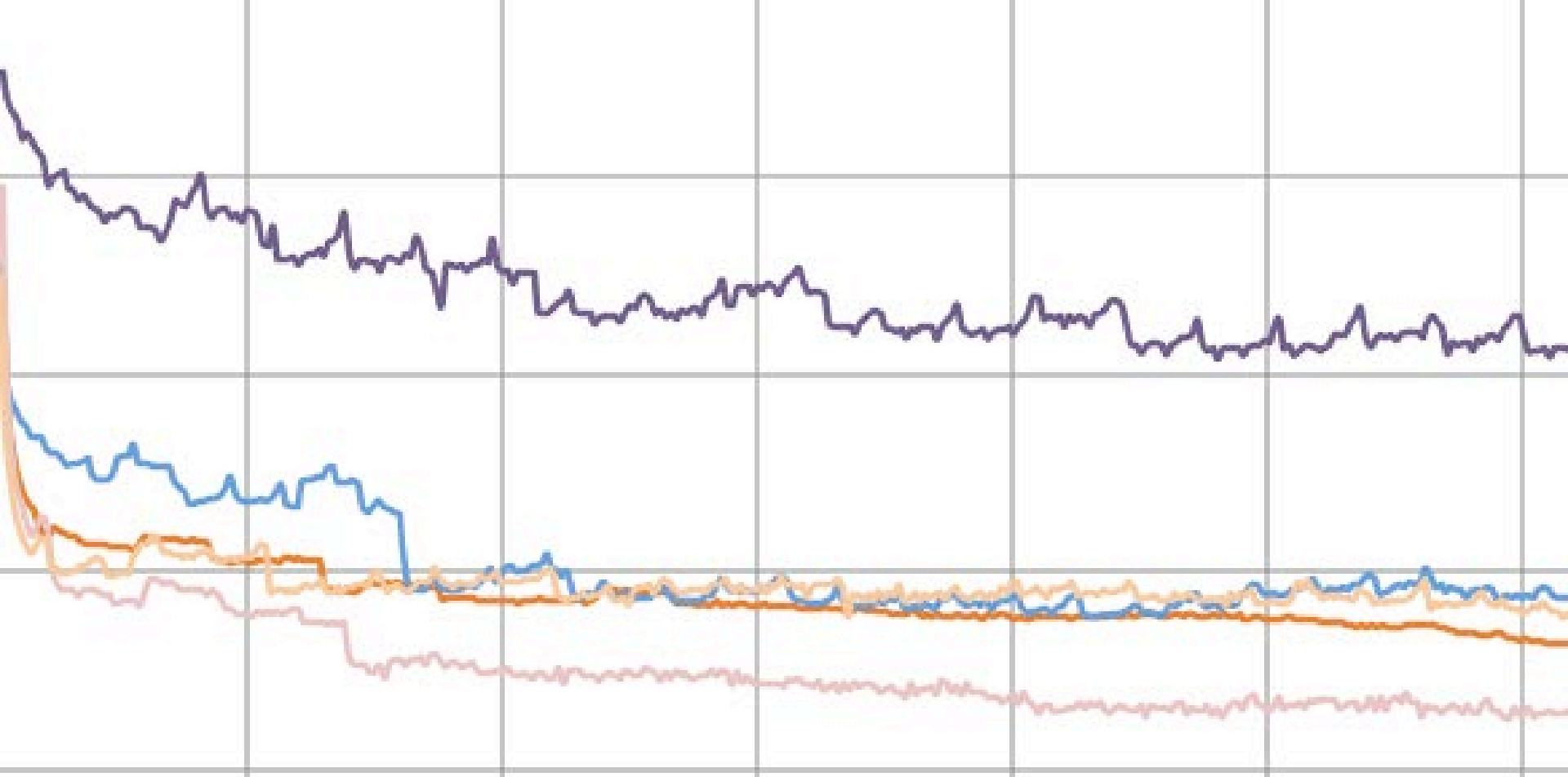


TAKE AWAY
Standard synthetic workloads can be used with all testers and applied to all SSDs.

# Synthetic Workloads – Known & Repeatable Stimulus for Standardized Test

*Four "corner case" workloads applied to a single SSD - Bandwidth*





Synthetic Enterprise Application Workloads

# WHY ARE THEY USED?

TAKE AWAY
Synthetic Workloads select representative accesses for SSD Performance Comparison.

# Synthetic workloads provide a reasonable basis for SSD Comparison

## Real World (Trace based / IO based) Workloads:

- Are specific only to the system on which it was captured (***Apples to Oranges***)
- Difficult to account for "idle times"
- Have a large number of streams (can be 50 or more discrete access patterns)

## Synthetic Workloads:

- Are repeatable and of known content (***Apples to Apples***)
- Can be standardized for testing on a few known patterns
- ***Provide a basis for SSD Performance comparison***

| | | | |
|---|---|---|---|
| Webserver 8K | 8 KiB | 75:25 | 95:5 |
| Webserver 64K | 64 KiB | 75:25 | 95:5 |
| Exchange Mail 4K | 4 KiB | 100:0 | 67:33 |
| Exchange Mail 64K | 64 KiB | 100:0 | 67:33 |
| Web Server Logs | 8 KiB | 0:100 | 0:100 |
| File Servers | 8 KiB | 75:25 | 90:10 |
| DB OLTP | 8 KiB | 100:0 | 70:30 |
| SQL Logs | 64 KiB | 0:100 | 0:100 |
| Media Streaming | 64 KiB | 0:100 | 98:2 |
| Archive | 2048 KiB | 95:5 | 55:45 |

Synthetic Enterprise Application Workloads

# WHAT ARE SOME EXAMPLES?

# Examples of Common Synthetic Enterprise Application Workloads

| Application Name | General Description | Example Access Pattern |
|---|---|---|
| OLTP<br>VDI | Small Block Mixed RND Workload | RND 4KiB RW65<br>RND 8KiB RW67<br>RND 8KiB RW70 |
| VOD | Video Edge Server large block SEQ | SEQ 128KiB RW90<br>RND 128KiB RW90 |
| Webserver/<br>MS Exchange Mail | Application page sizes of 64K | SEQ25 64KiB RW95<br>RND 64KiB RW0 |
| Webserver Logs | Logging workloads for RDBMS | SEQ 8KiB RW0 |
| Decision Support Service (DSS) | Heavily Indexed large table structures for real time access | RND 64KiB RW100 |
| OS Paging<br>Media Streaming<br>Medical Imaging | OS data requests from storage in medium block SEQ transfers | SEQ 64KiB RW90<br>SEQ 64KiB RW98<br>SEQ 1,024KiB RW05 |

Workloads can be a single access pattern or a composite of many different access patterns

Synthetic Enterprise Application Workloads

# CASE STUDY

## Building a synthetic workload test

# Objectives

- Define a procedure to test and measure ***Synthetic application workloads***
- Use ***SNIA PTS test methodologies*** for Pre-conditioning & Steady State
- ***Isolate variables*** for IOPS & RT Confidence measurement
- ***Create a template*** to modify / substitute synthetic workloads of interest

# Test Plan


1. Define a synthetic OLTP database workload
2. Run the OLTP workload to steady state
3. Run Demand Intensity (DI) Sensitivity workload loops
4. Measure IOPS, ART & MRT at each QD for each loop
5. Plot Confidence Level Histograms for each OIO point
6. Determine IOPS & Response Time Saturation point(s)
7. Compare OIO “sweet spots” for different DI workload loops

# Test Set Up

## Hardware Platform – PTS RTP 3.0

- PTS 1.1 Reference Test Platform
- OS: CentOS 6.5
- Test Software: CTS BE ver 1.9.184
- Motherboard: Intel Gen3 E5
- CPUs: Dual S2697W 3.1Ghz 8 core
- HBA: 12Gb/s LSI 9300

## Software Platform – CTS 6.5

- Test Software: CTS FE ver 1.18.11
- OS: Windows 7 Pro


*Reference Test Platform for the SSS PTS specification*
*RTP/CTS used to develop and validate the PTS*
*Certified SNIA SSSI PTS test labs RTP*

# Test Flow

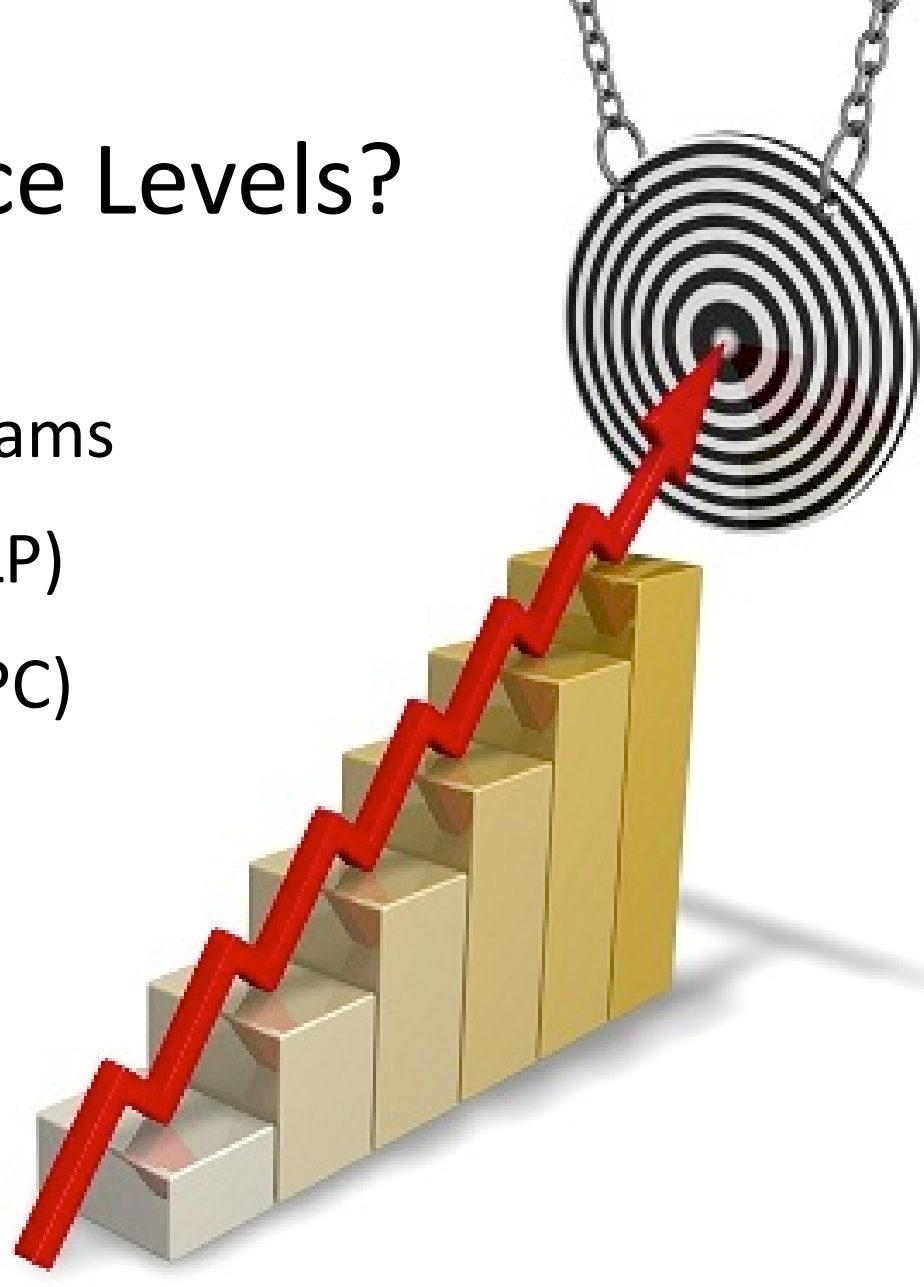
1. **PURGE** (Security Erase)
2. **Settings**: Data Pattern=RND; LBA Range=(0,100)
3. **Pre-condition** – WIPC 2x user capacity SEQ 128KiB RW0; T1Q32
4. **Run Workload Dependent PC** – RND 8KiB RW65; T4Q8
5. **Run to Steady State**
   - 5 consecutive one minute Rounds
   - Each Round separated by 29 min of WDPC pre-writes
   - Least squares linear fit no greater than 20% data excursion nor exceeding a 10% slope
6. **Set Restricted LBA zones**
   - 50% of the IOs to the first 5% of the LBAs
   - 30% of the IOs to the next 15% of the LBAs
   - 20% of the IOs to the last 80% of the LBAs
7. **Run Workload Segment loops** w/ varying OIO:
   - Thee TC loops per drive: T2, T4, T8 or T4, T8, T16
   - Step QD 2,4,8,16,32
8. **Plot IOPS, ART, MRT** at each OIO
9. **Plot Confidence Level Histogram & RT Ceiling** for each OIO
10. **Compare Optimal OIO** sweet spots between different TC workload segment loops

# What are Confidence Levels?

Response Time (RT) Histograms

Confidence Level Plots (CLP)

CLP Comparison Plots (CLPC)



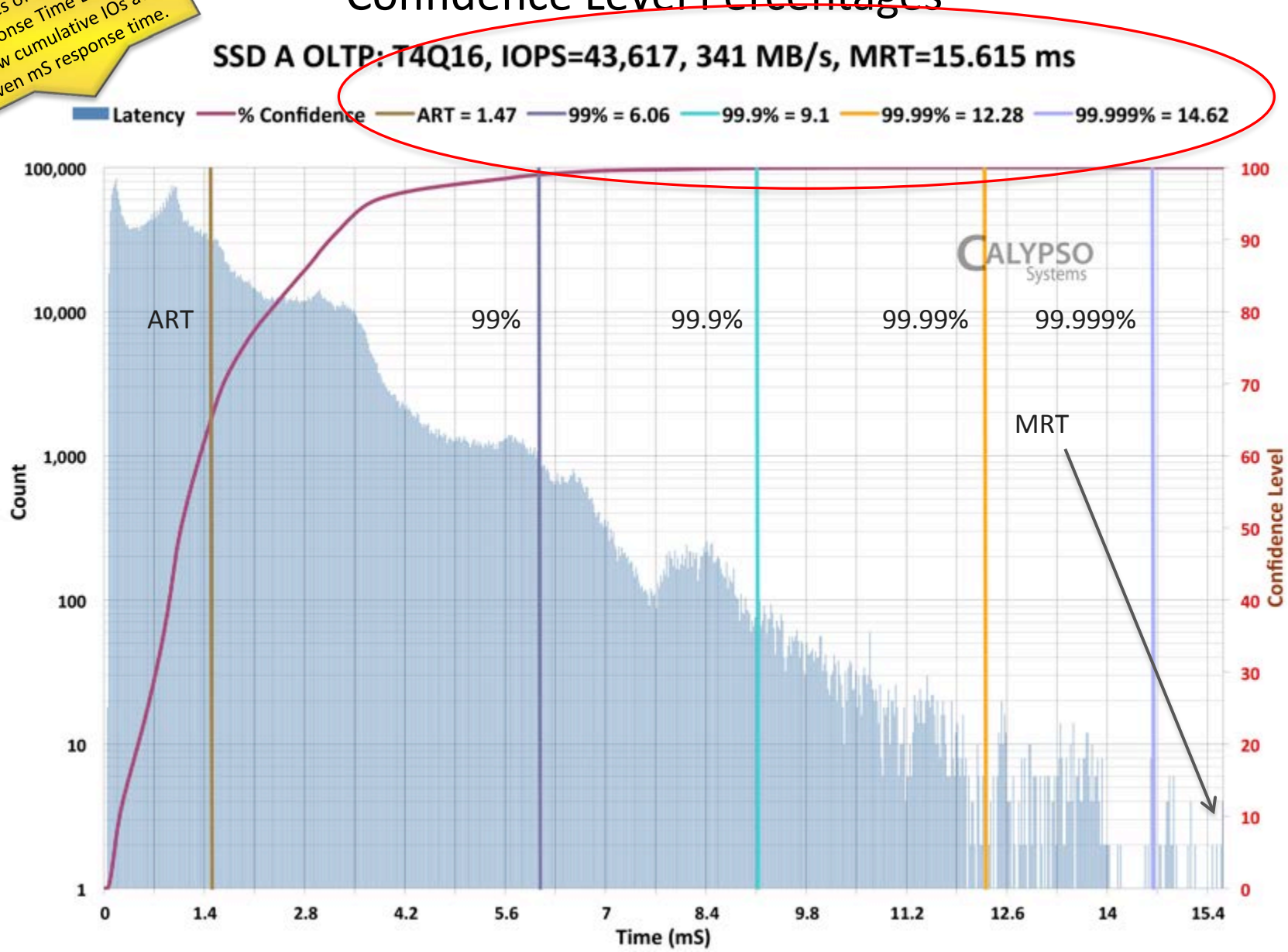
# Confidence Levels – Quality of Service ("Q o S")

| IO Rate Per Sec | Measurement Period | Total IOs | % Confidence Level | Q o S No. "9's" | No. of Dropped IOs |
|---|---|---|---|---|---|
| One Minute Measurement Period | | | | | |
| 10,000 | One Minute | 600,000 | 99.999% | 5 9's | 6 |
| 10,000 | One Minute | 600,000 | 99.99% | 4 9's | 60 |
| 10,000 | One Minute | 600,000 | 99.9% | 3 9's | 600 |
| Ten Minute Measurement Period | | | | | |
| 10,000 | Ten Minutes | 6,000,000 | 99.999% | 5 9's | 60 |
| 10,000 | Ten Minutes | 6,000,000 | 99.99% | 4 9's | 600 |
| 10,000 | Ten Minutes | 6,000,000 | 99.9% | 3 9's | 6,000 |

*"Five 9's" = 99.999% or 99,999 of 100,000 events*

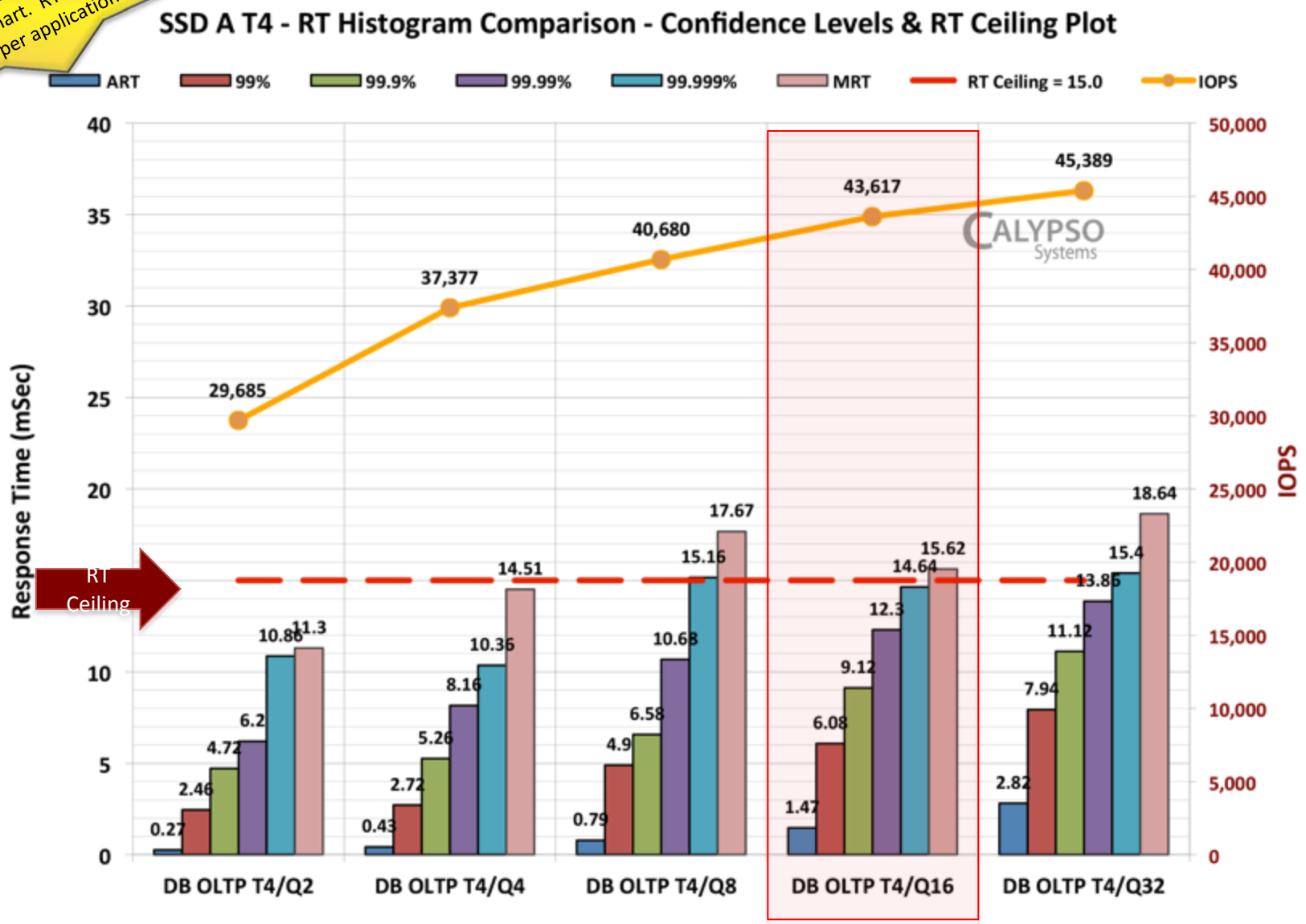
# Response Time Histogram with Confidence Level Percentages

**TAKE AWAY**
Figures of Merit are the Response Time Bars that show cumulative IOs at a given mS response time.



TAKE AWAY
Histogram data can be plotted and compared on a Bar chart. RT Ceiling is set per application.

# Histogram Compare Plot with RT Ceiling



# OLTP Saturation Test with Demand Intensity (DI) Sensitivity Analysis

Workload loops with Varying Demand Intensity

SSD A: T4, T8, T16

SSD B: T2, T4, T8

*Find your operating Sweet Spot!*

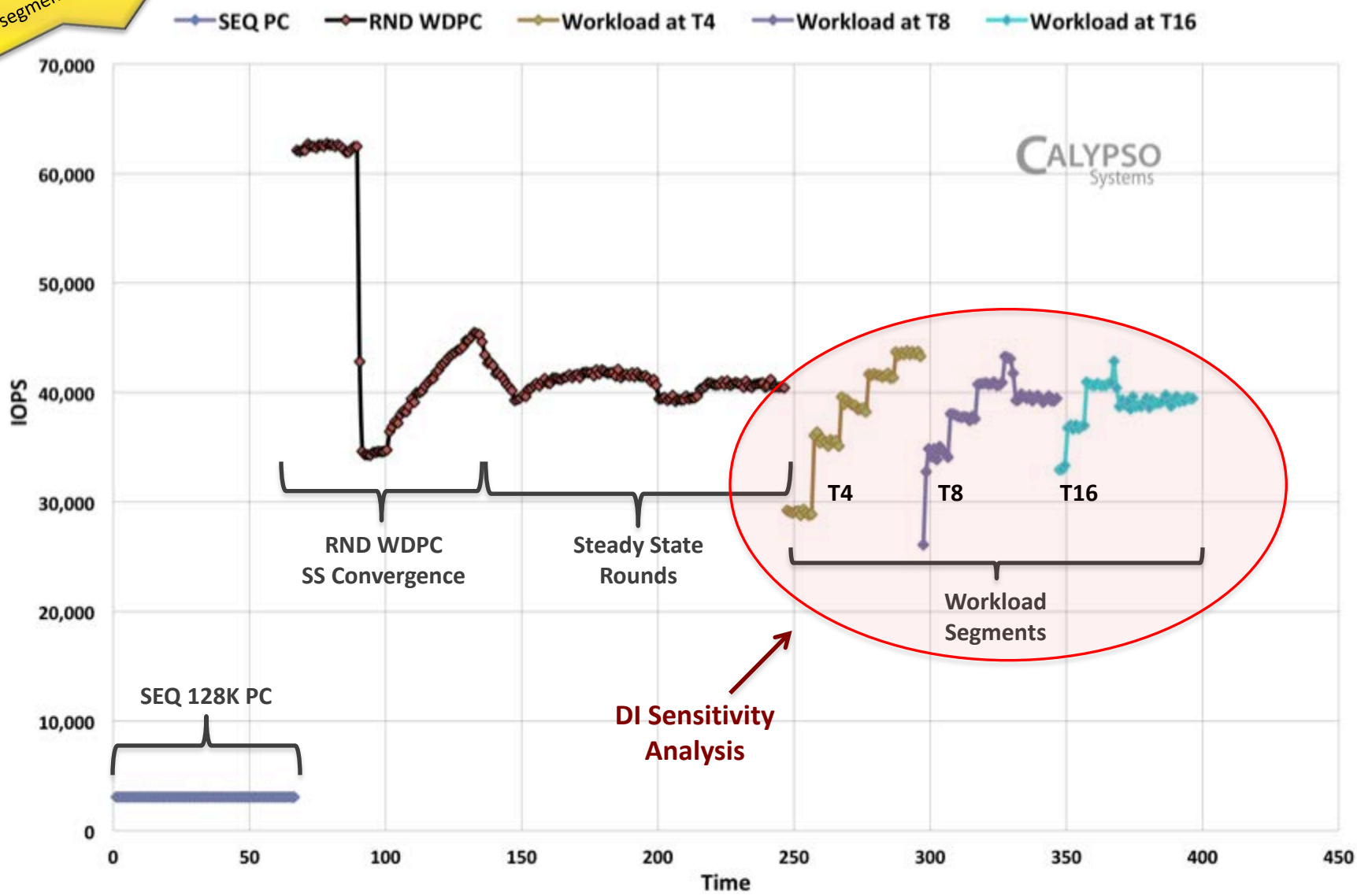

800 GB Enterprise class 2.5” SATA

# SSD A

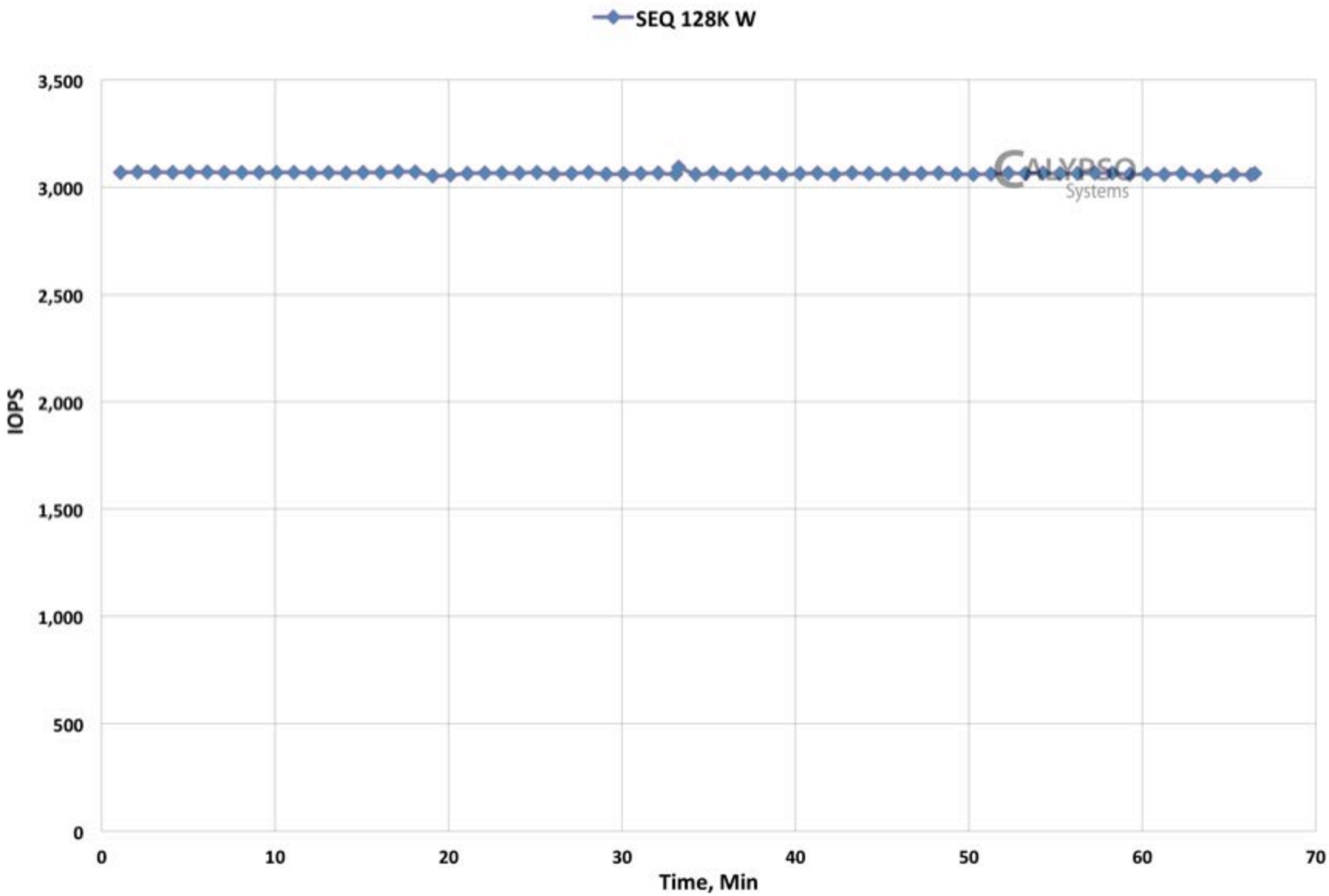
TAKE AWAY
DI Sensitivity test measures workload segments at increasing TC

# SSD A – Test Profile: IOPS v Time

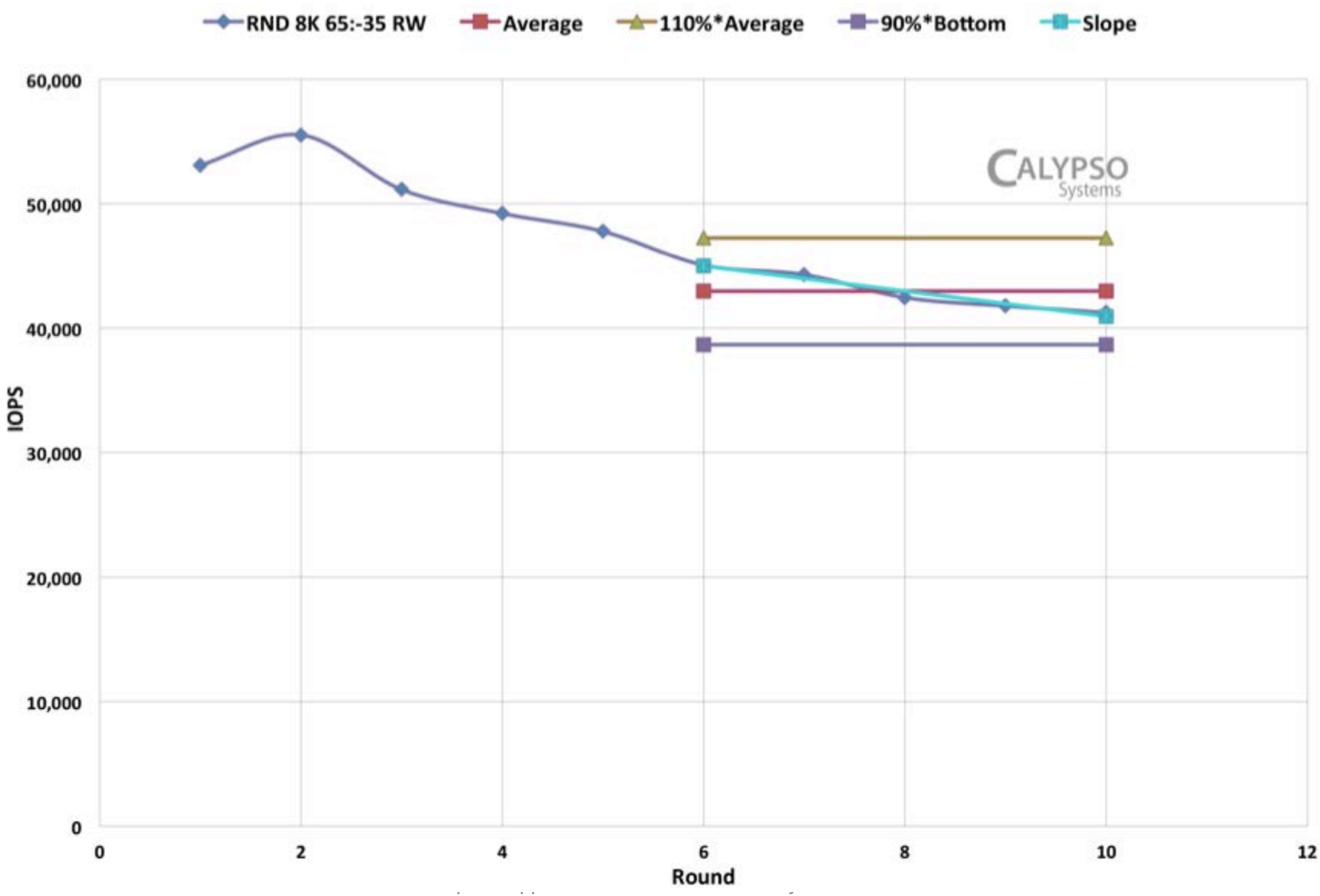
## Workload Segments T4, T8, T16



# SSD A: SEQ128K PC

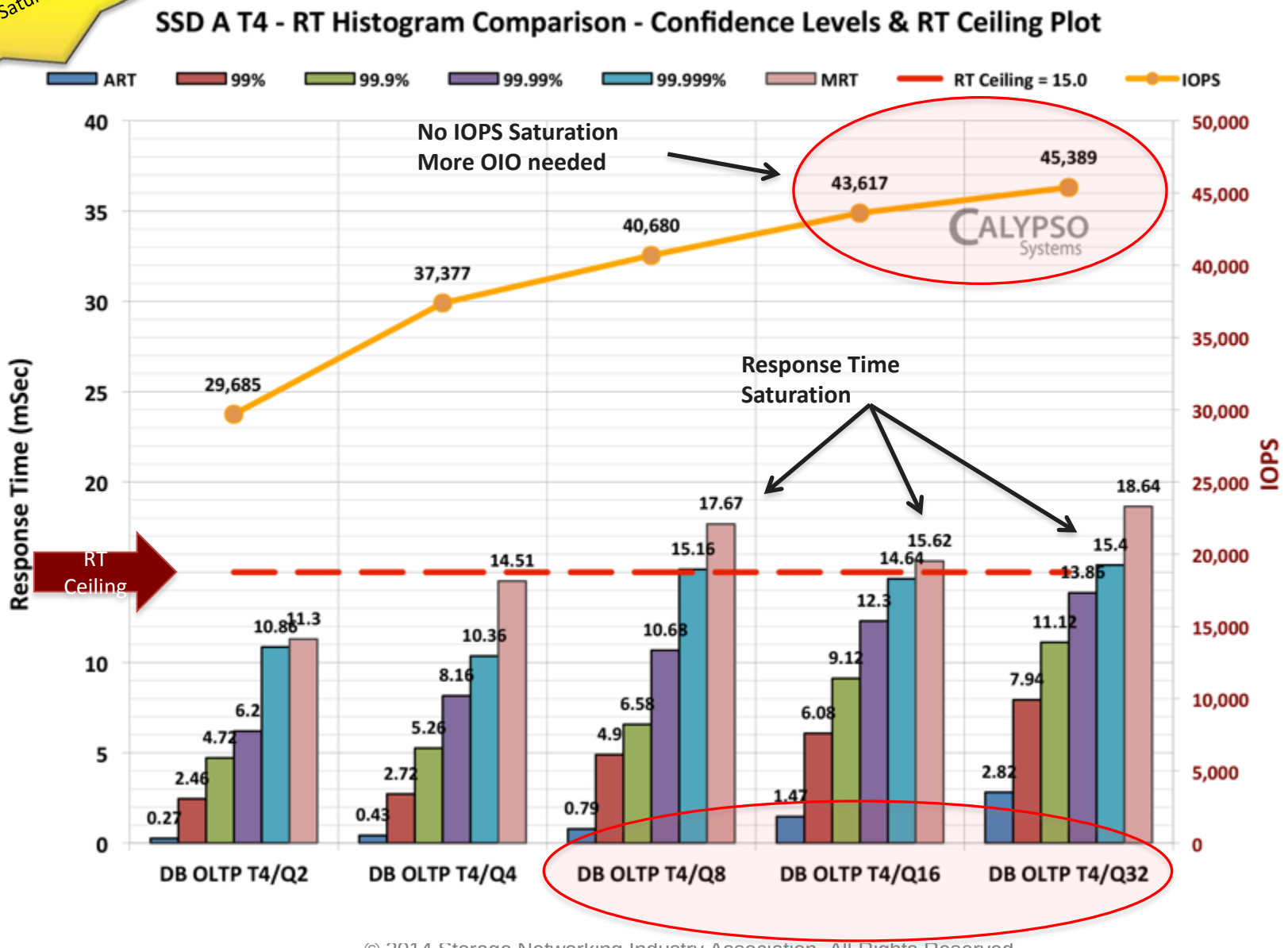


# SSD A: WDPC & Steady State



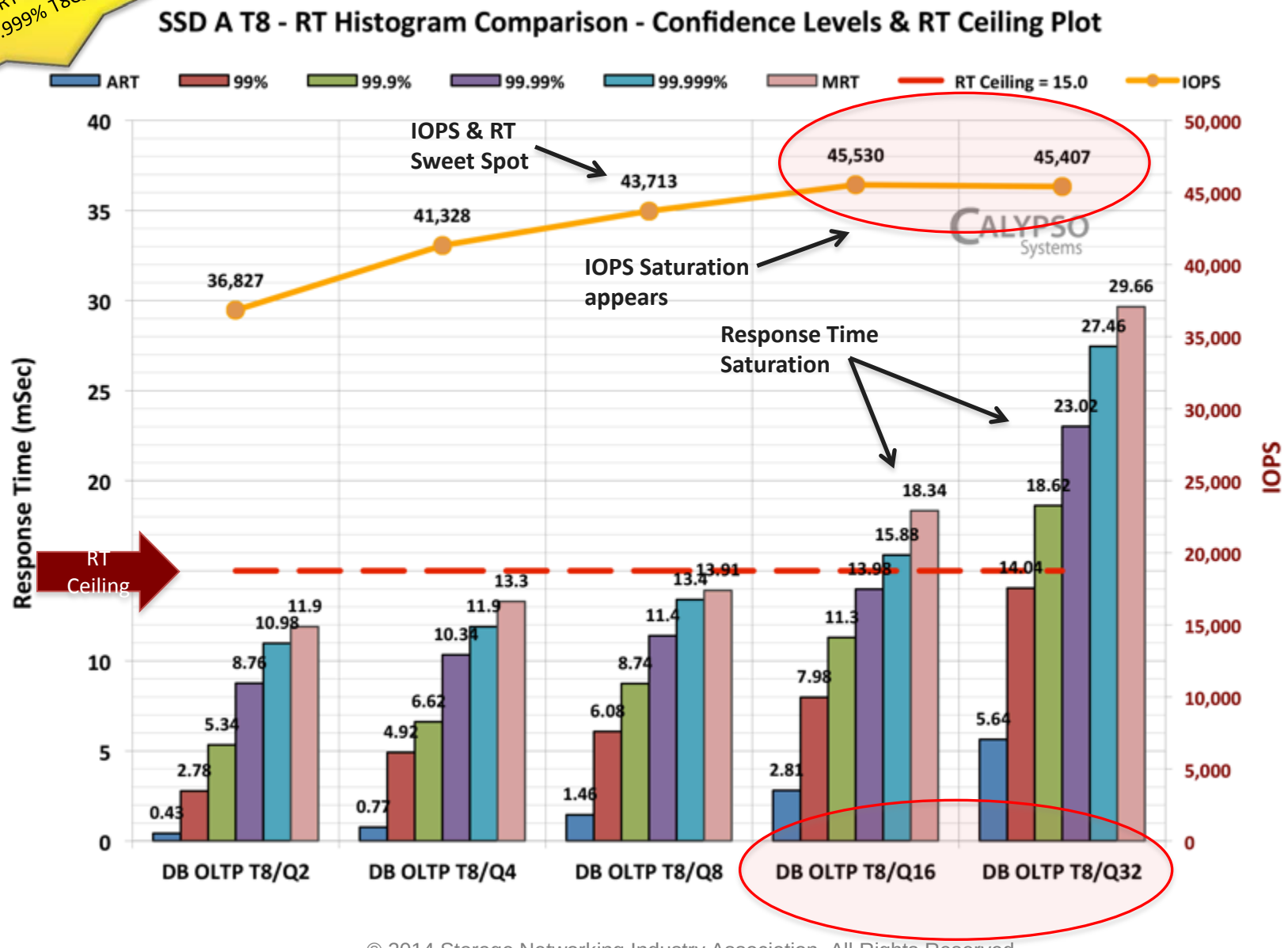
TAKE AWAY
T4 is not enough OIO to Saturate.

# SSD A T4: QD Histogram Compare



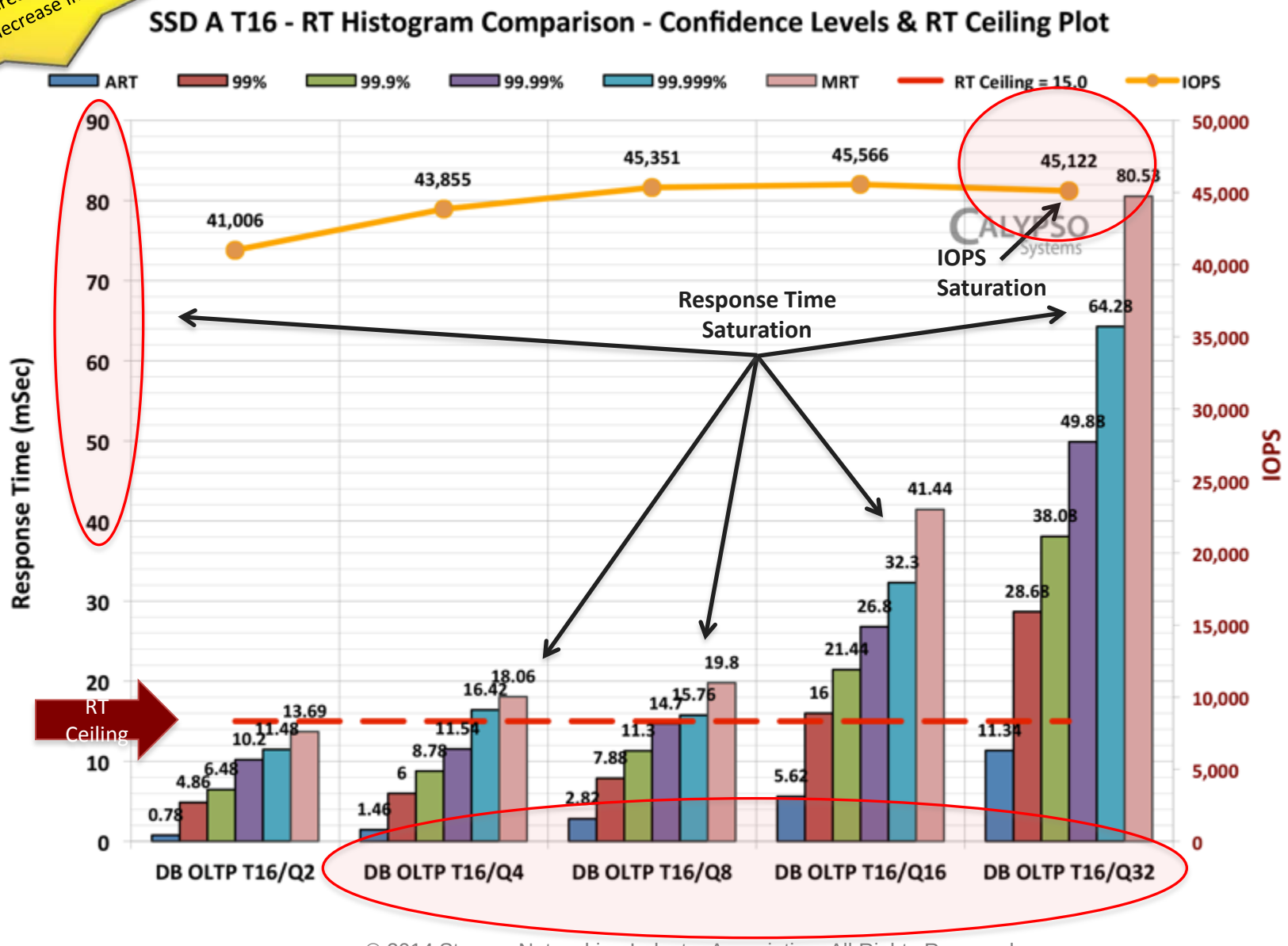
TAKE AWAY
IOPS Saturation begins at T8Q16 RT Saturation at 99.999% T8Q32.

# SSD A T8: QD Histogram Compare



TAKE AWAY
SSD at T16 fully Saturates.
Note increase in RT scale and decrease in IOPS.

# SSD A T16: QD Histogram Compare



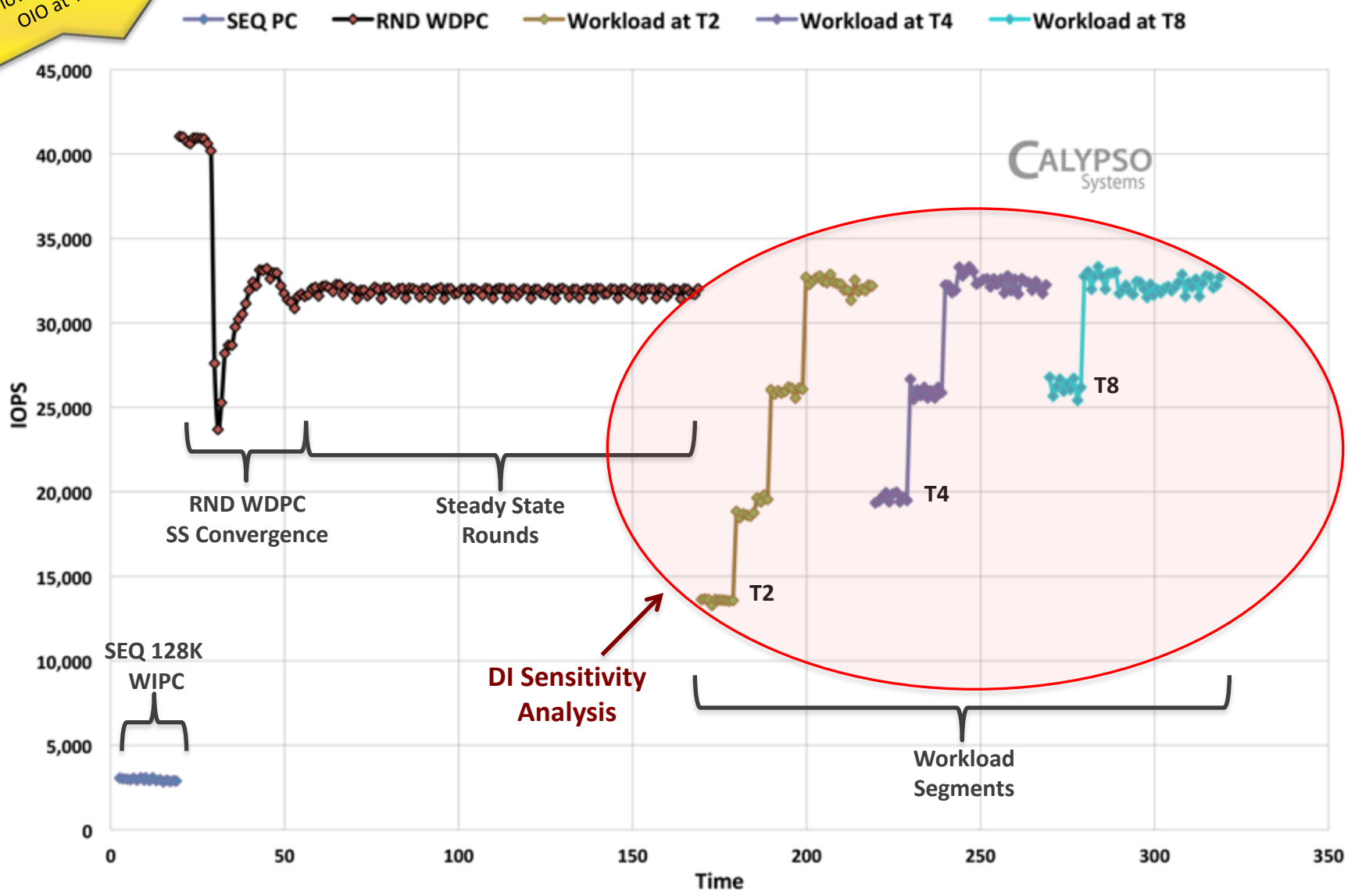

200 GB Enterprise class 2.5” SATA

# SSD B

TAKE AWAY
SSD B DI Sensitivity is lower and tests will set OIO at T2, T4 and T8.

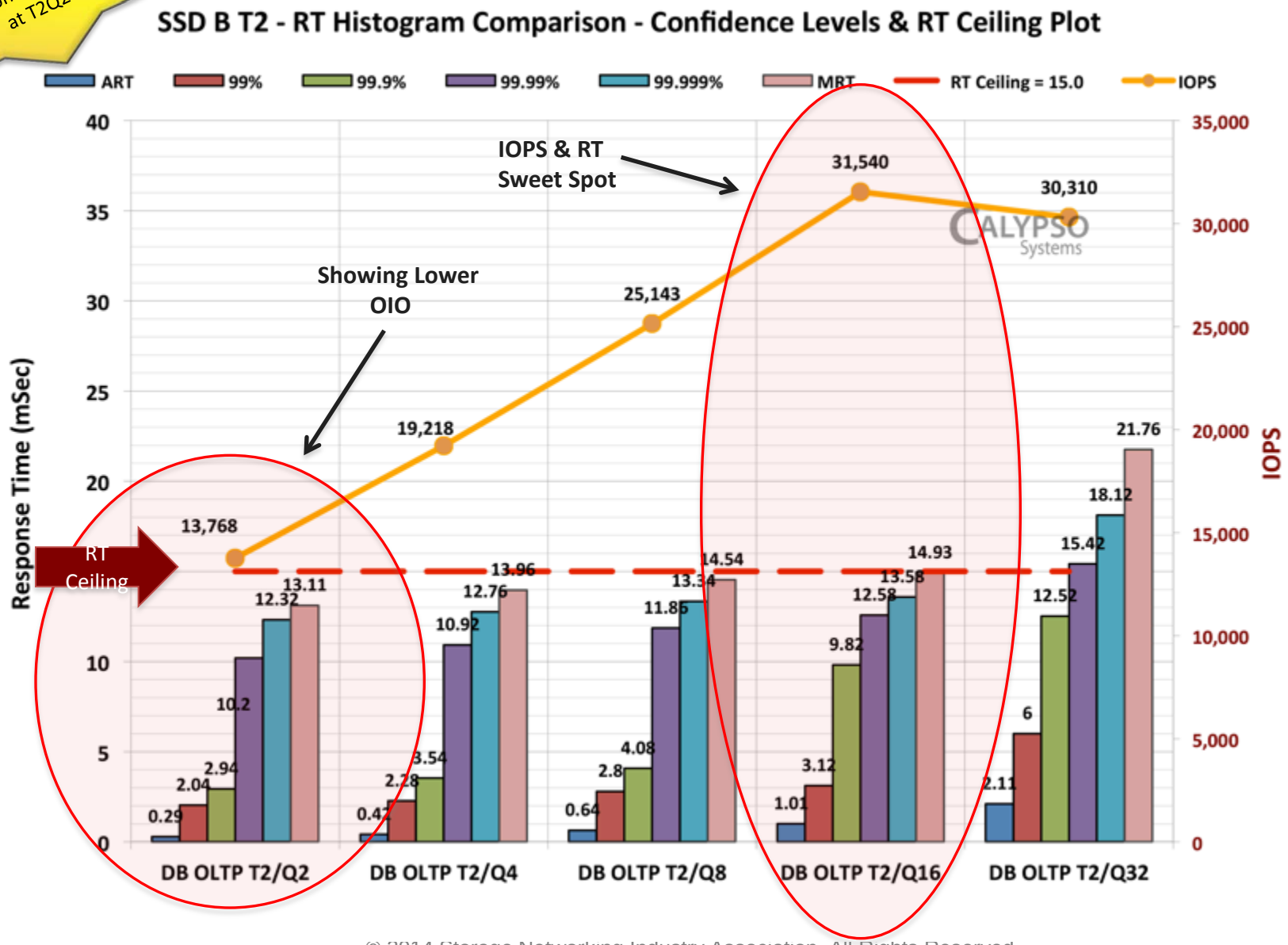
# SSD B – Test Profile: IOPS v Time

## Workload Segments T2, T4, T8



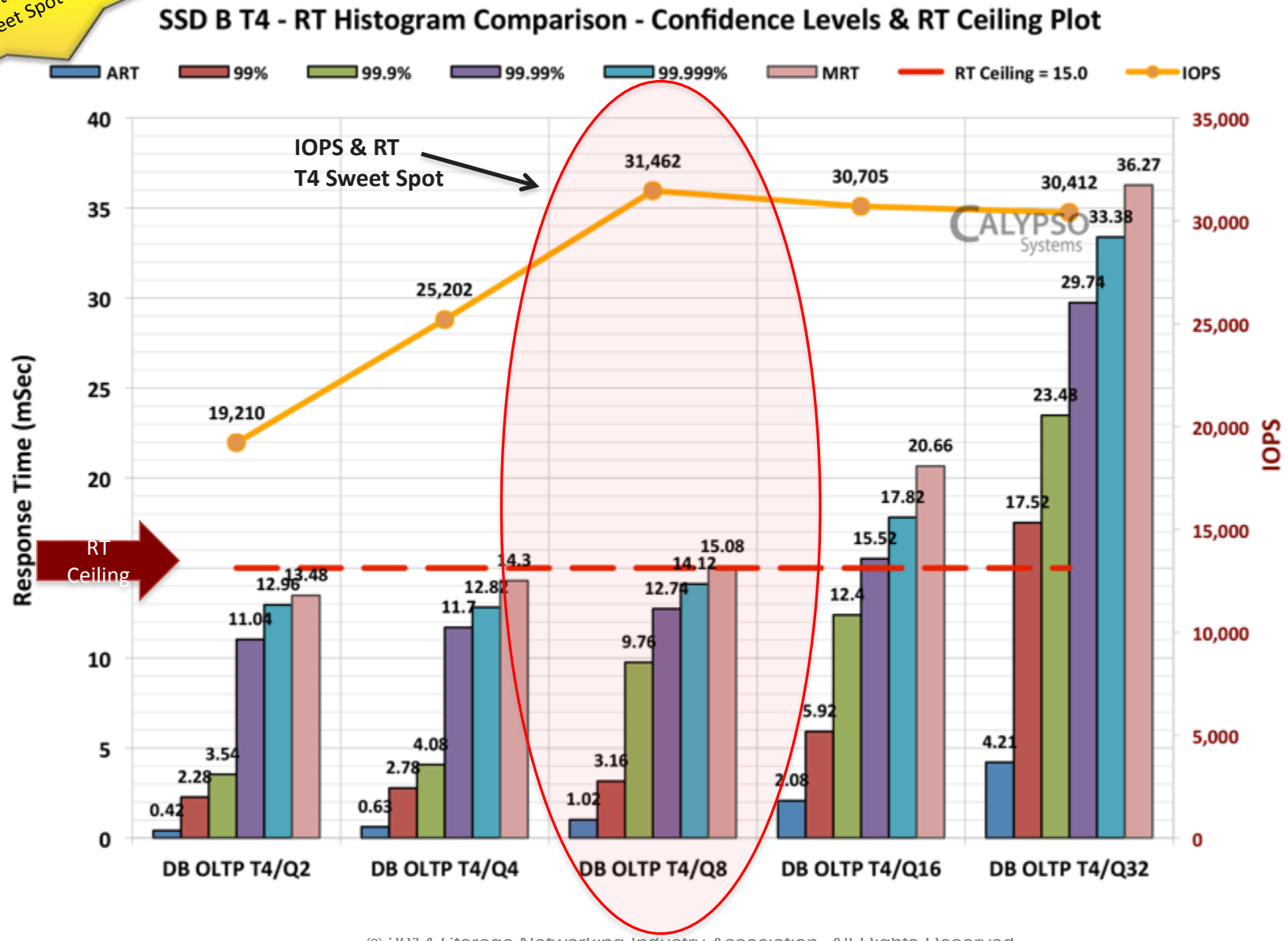
TAKE AWAY
SSD B OIO T2 shows Saturation. Note low OIO at T2Q2.

# SSD B T2: QD Histogram Compare



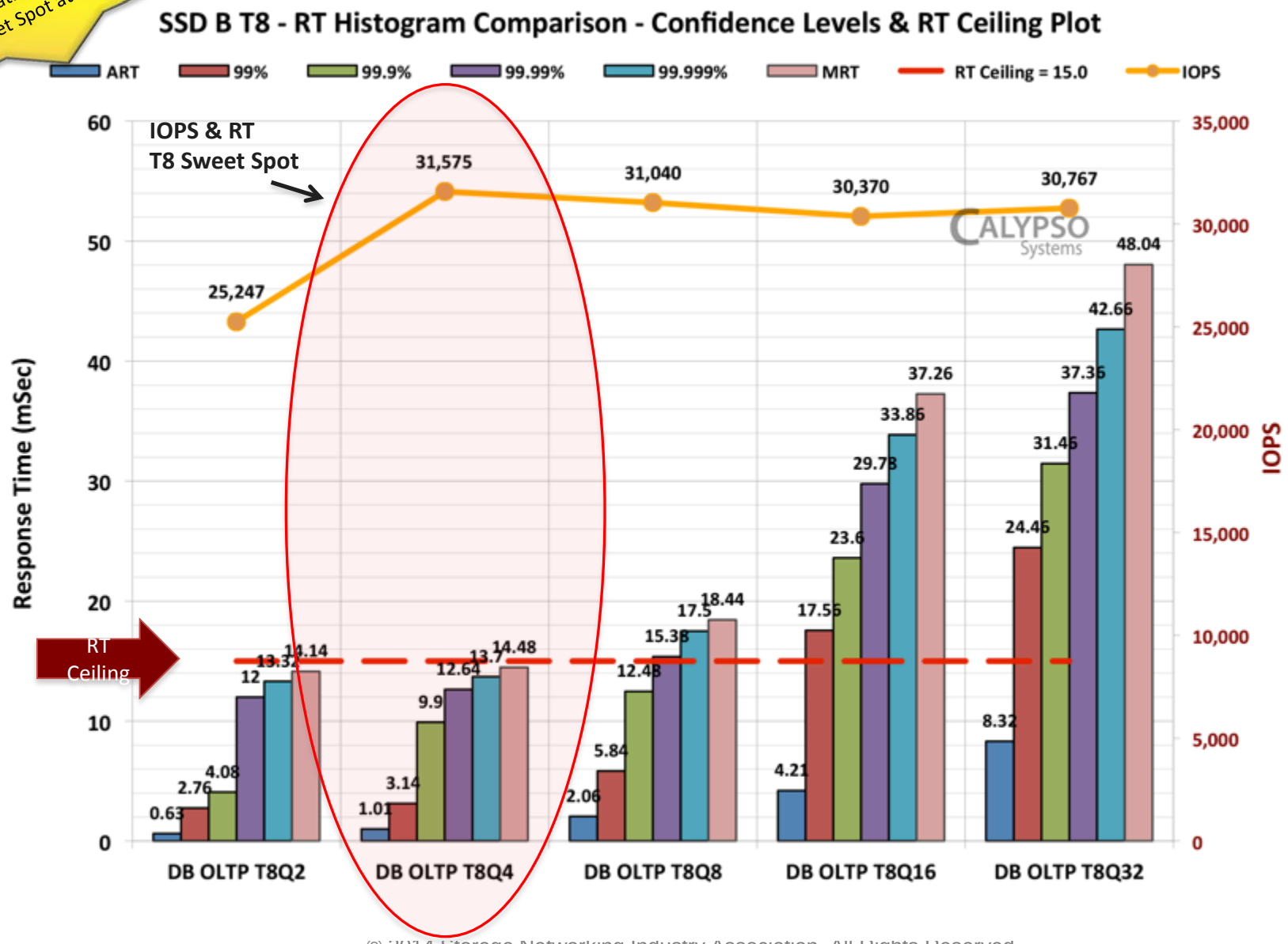
TAKE AWAY
SSD B at T4 shows Saturation. Note OIO Sweet Spot T4Q8.

# SSD B T4: QD Histogram Compare



TAKE AWAY
SSD B at T8 verifies Saturation. Note T8 Sweet Spot at T8Q4.

# SSD B T8: QD Histogram Compare

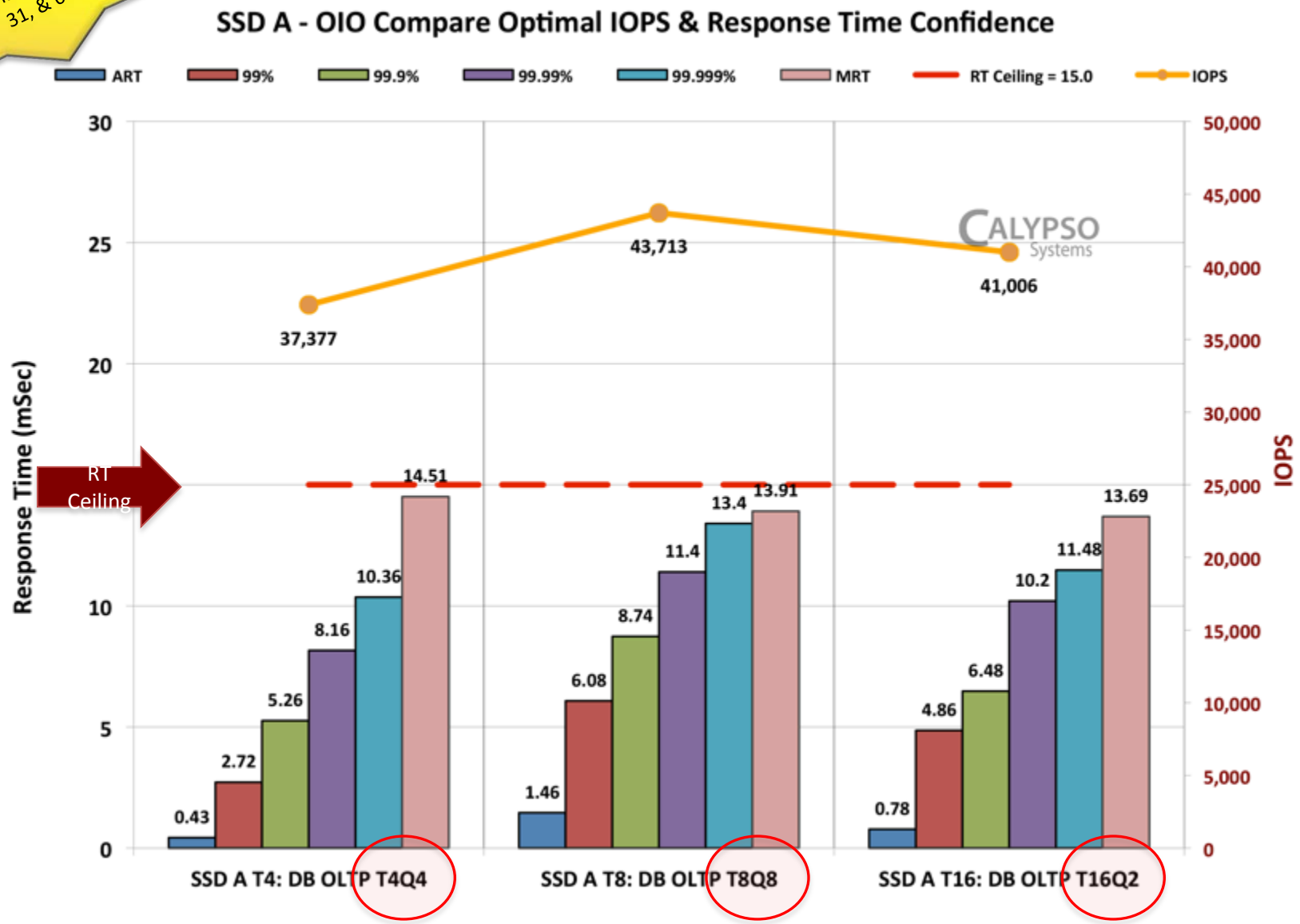


# Findings

What are the optimal operating point(s)?

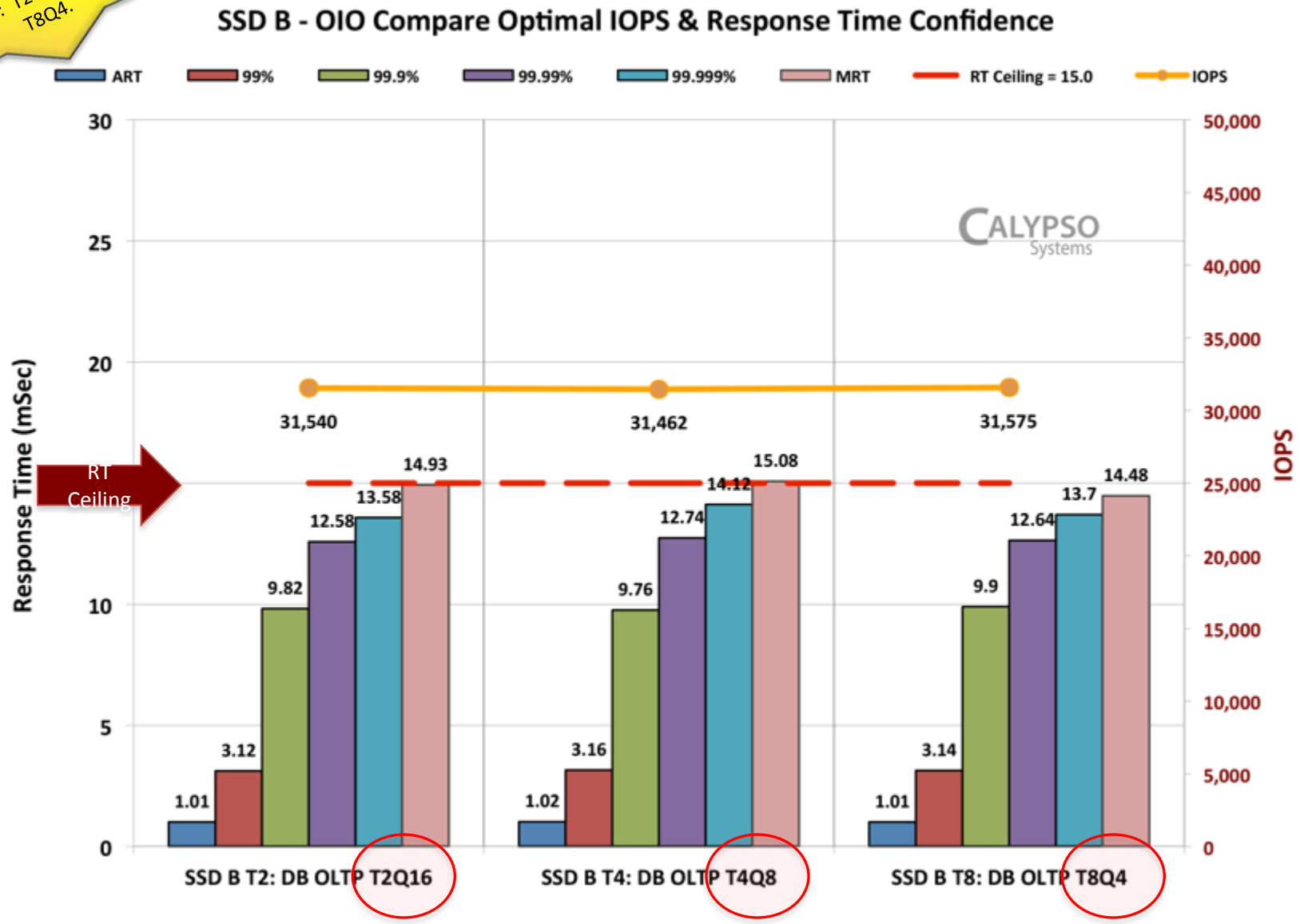
TAKE AWAY
SSD A 800 GB shows good performance at OIO 16, 31, & 64.

# SSD A: Histogram Compare T4 T8 T16



TAKE AWAY
SSD B 200 GB optimal OIO at any combination of OIO=32: T2Q16, T4Q8 or T8Q4.

# SSD B: Histogram Compare T2 T4 T8



# Conclusion

- Application(s) may require low or high OIO
- Drive Design may emphasize low or high OIO
- Drives may be designed for specific (different) workloads

*Understanding your SSD's deterministic behavior helps SSD & system design optimization.*

*Know the "cost" of more IOPS in terms of Response Times.*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# Attribution & Feedback

The SNIA Education Committee thanks the following individuals for their contributions to this Tutorial.

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