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Examining Latency of NVMe™ SSDs for Time-critical Applications Using Exceedance Analysis

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Flash Memory Summit

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The Data Propulsion Labs (DPL)

The mission of the DPL is to design, develop, deploy, and document compelling solutions using Western Digital®, SanDisk®, and HGST-brand products

- SQL Server™ and Oracle® Testing
  - Many world records for database benchmarks have been set using Western Digital products and these test are often done with key partners
- Application Testing
  - Multiple application benchmark suites are used, including HammerDB, Aerospike®, and various other performance test suites
- Software-Defined Storage Solutions
  - Much effort goes into understanding SDS and demonstrating its benefits, including all key players
- Ad Hoc Testing
  - New solutions are routinely tested, including Storage Class Memory, Memory Extension Technology, simulation of future devices, new data base designs, etc.
- Block Device Testing
  - The Block Performance Suite tests peak & sustained performance as well as Quality of Service

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Goals

1. Overview of Exceedance Charts and Exceedance Analysis
2. The problem statement and an answer (Exceedance Charts)
3. Several example Exceedance Charts
4. The easiest path to Exceedance Charts
5. One final issue…

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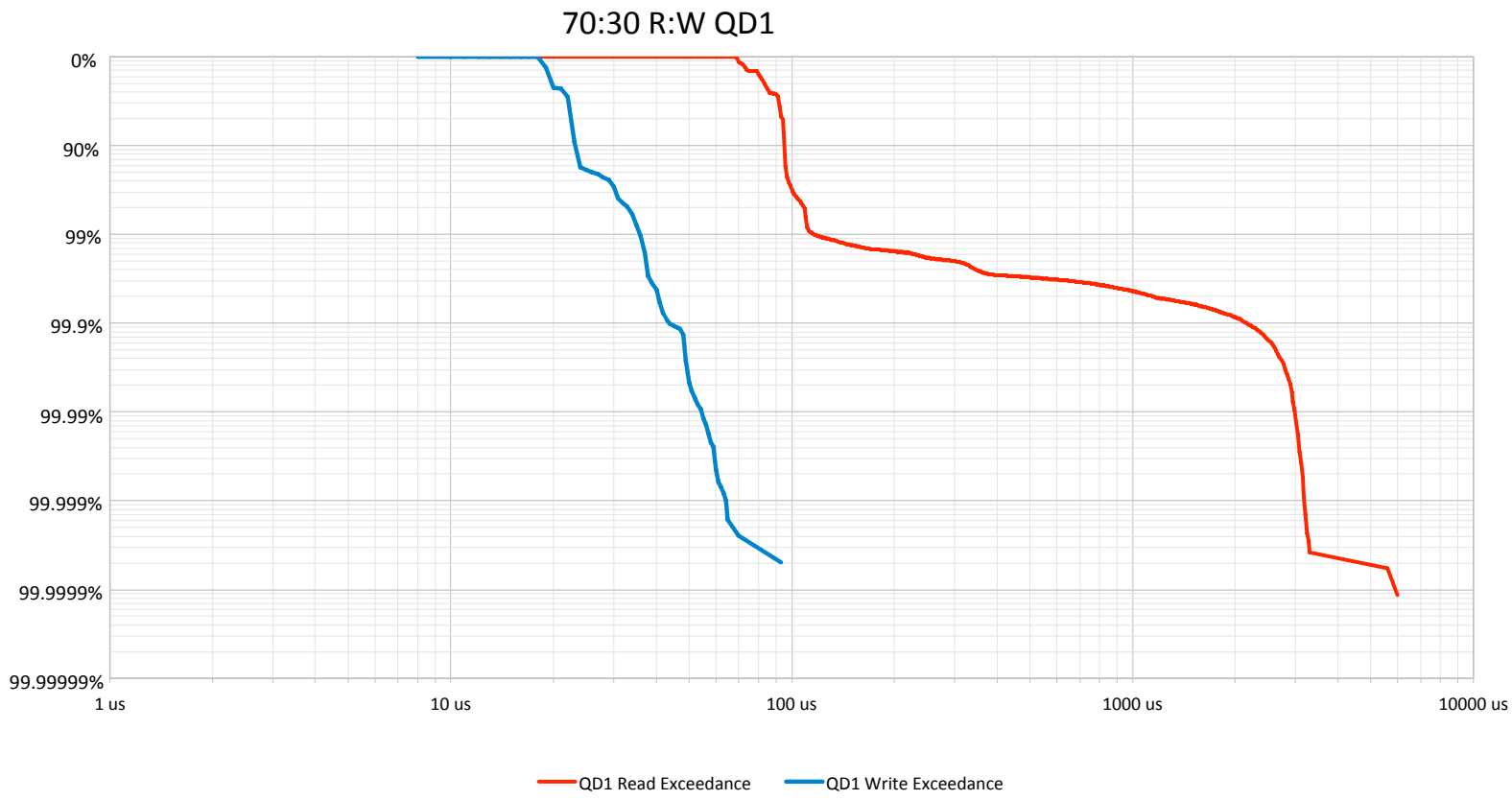
This is an Exceedance Chart…



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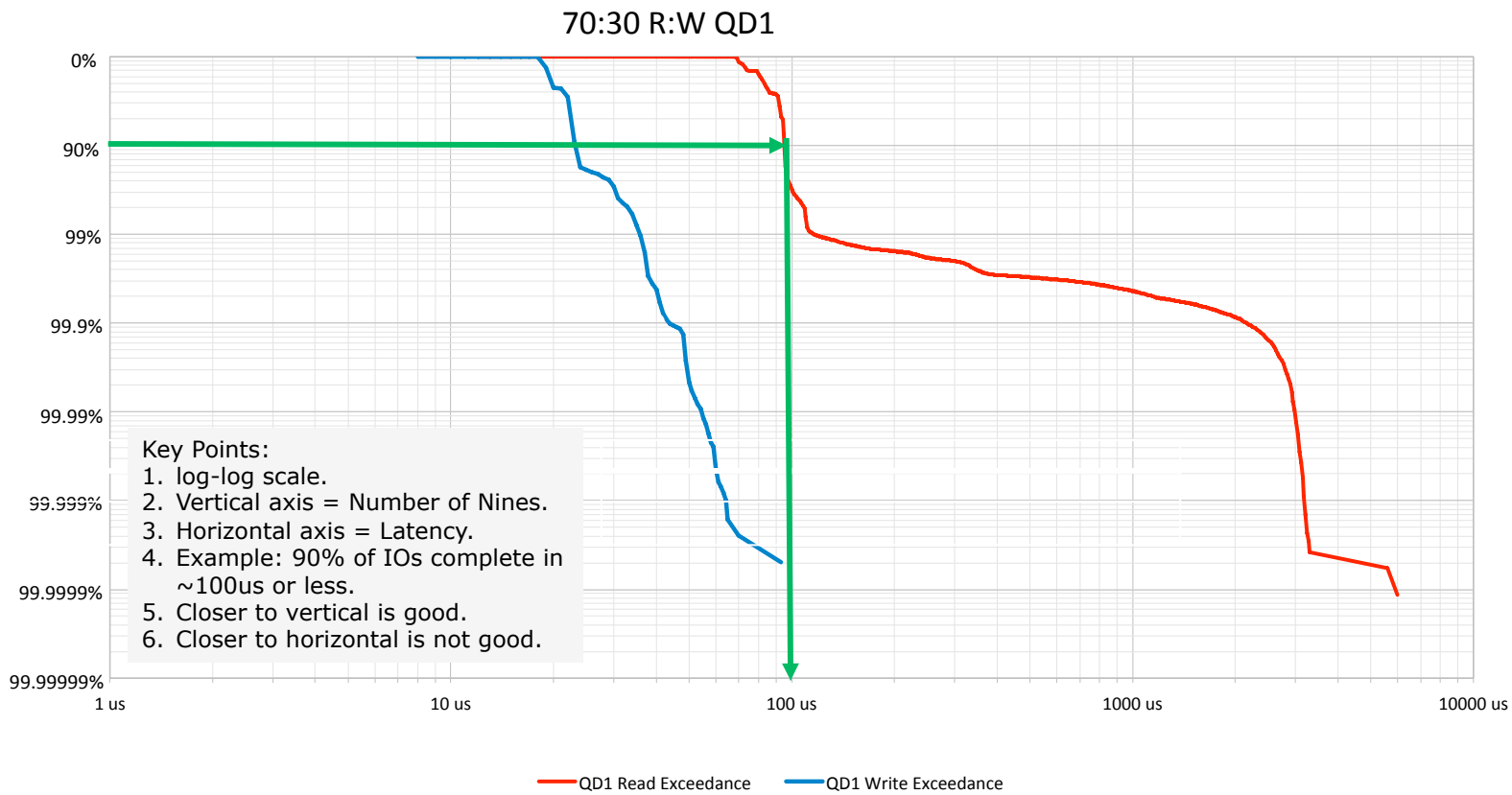
This is an Exceedance Chart…



Key Points:
1. log-log scale.
2. Vertical axis = Number of Nines.
3. Horizontal axis = Latency.
4. Example: 90% of IOs complete in ~100us or less.
5. Closer to vertical is good.
6. Closer to horizontal is not good.

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Problem Statement and an Answer

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Problem Statement and an Answer

- **The Problem**
  - How to specify Quality of Service Requirements for high performance storage devices?
  - How to compare high performance storage devices?
  - How to diagnose performance problems in these devices?
- **The Outliers**
  - It is all about outliers, which can destroy QoS and make a device unusable for a given purpose.
  - Many ignore outliers, but the National Bureau of Standards says: Realistic performance parameters require the acceptance of all data that cannot be rejected for cause.
- **An Answer**
  - Exceedance Charts present QoS data in a very compact and understandable format that can be used for:
    - Product selection purposes
    - Comparative purposes
    - Diagnostic and performance monitoring purposes

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Annotated Exceedance Charts

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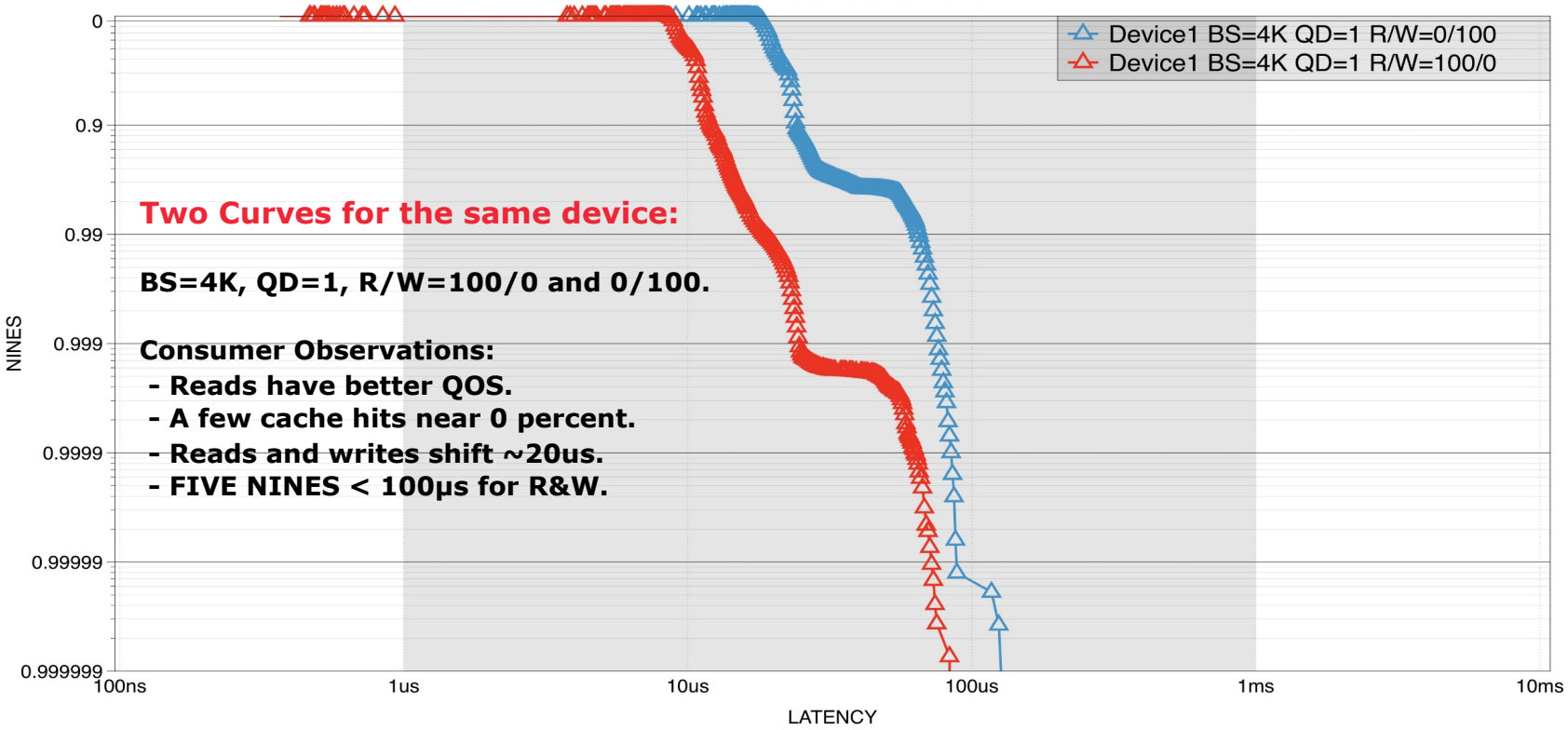
Exceedance Chart 1



Two Curves for the same device:

BS=4K, QD=1, R/W=100/0 and 0/100.

Consumer Observations:

- **Reads have better QOS.**
- **A few cache hits near 0 percent.**
- **Reads and writes shift ~20us.**
- **FIVE NINES < 100µs for R&W.**

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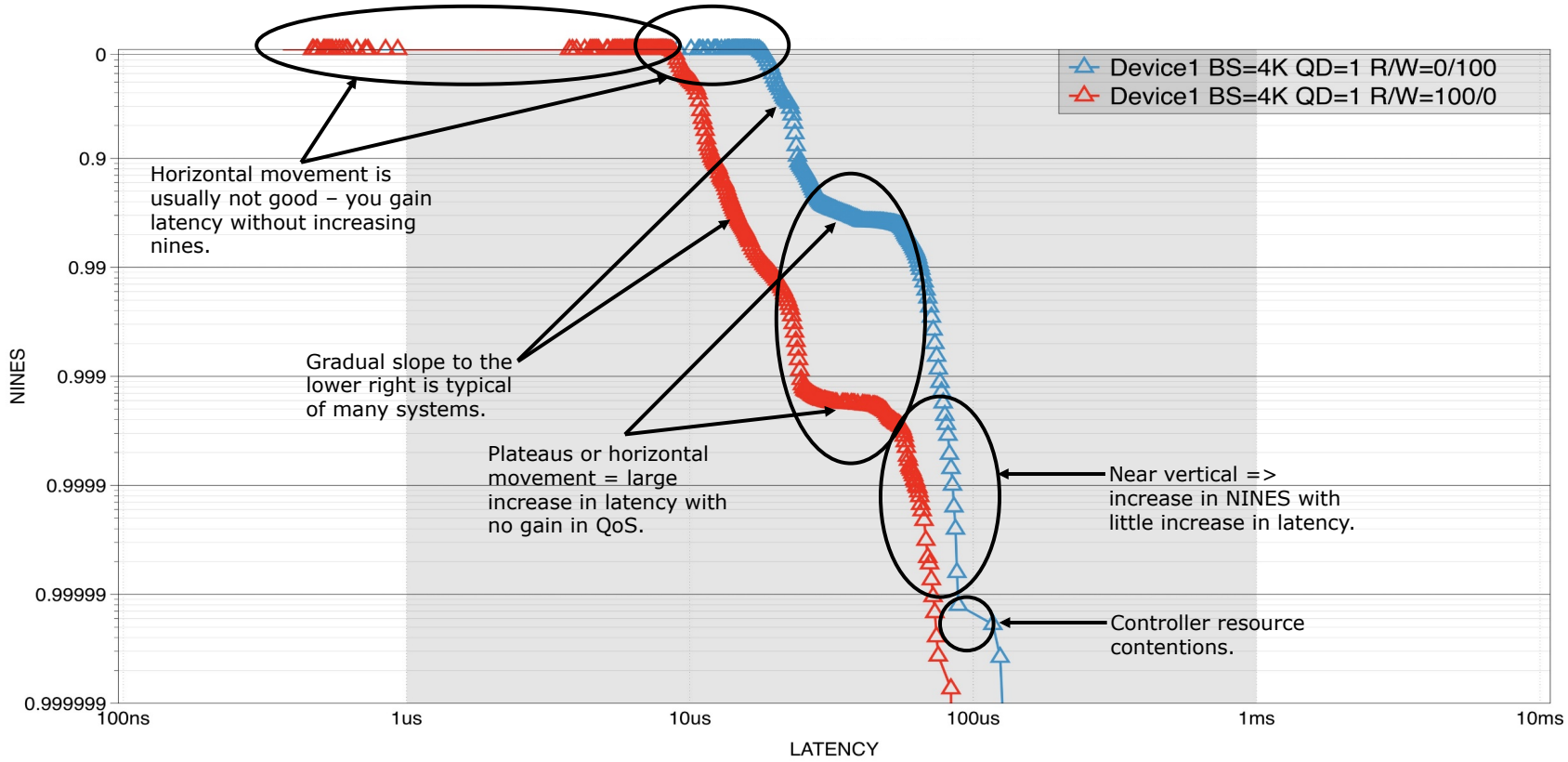
Exceedance Chart 2



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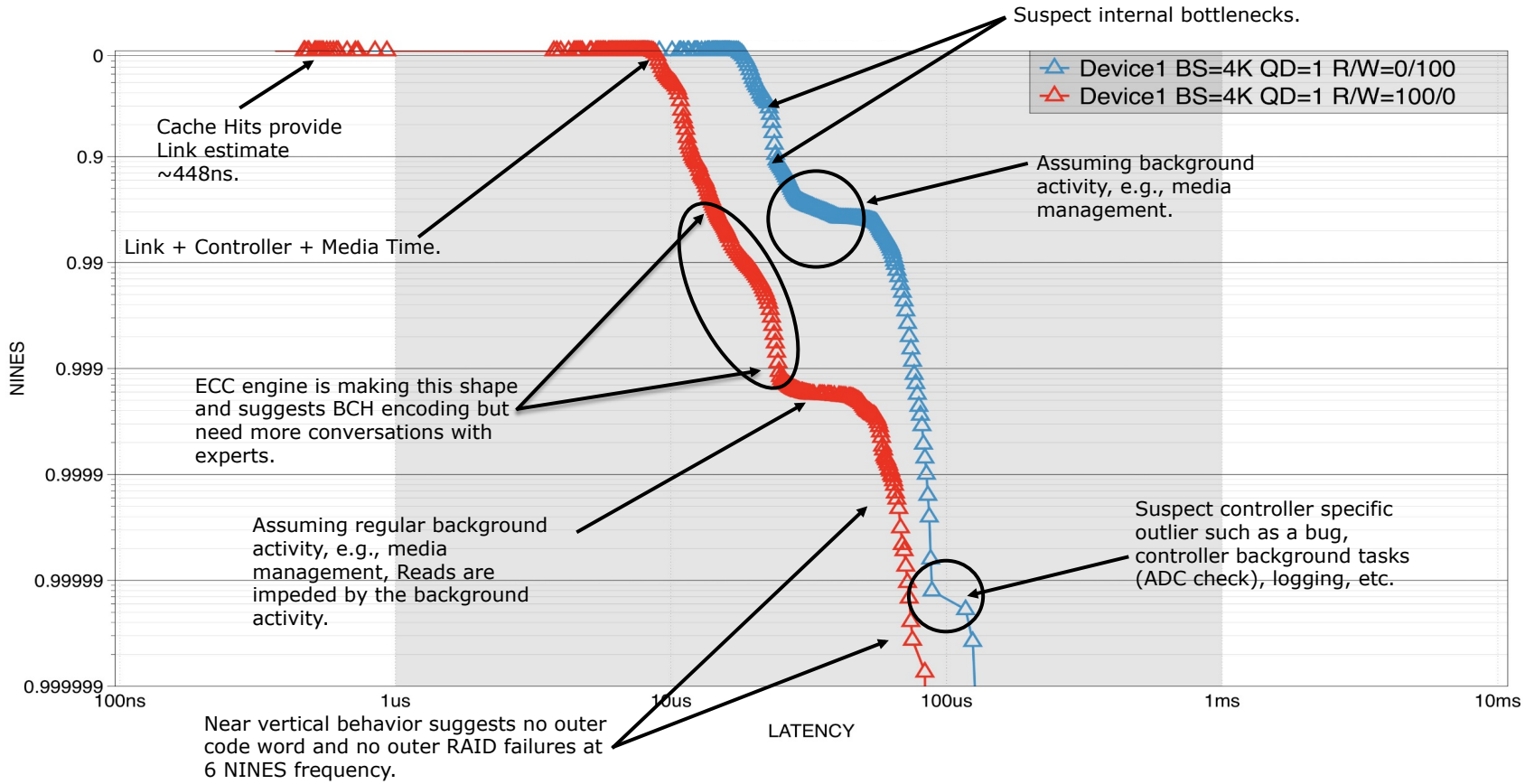
Exceedance Chart 3



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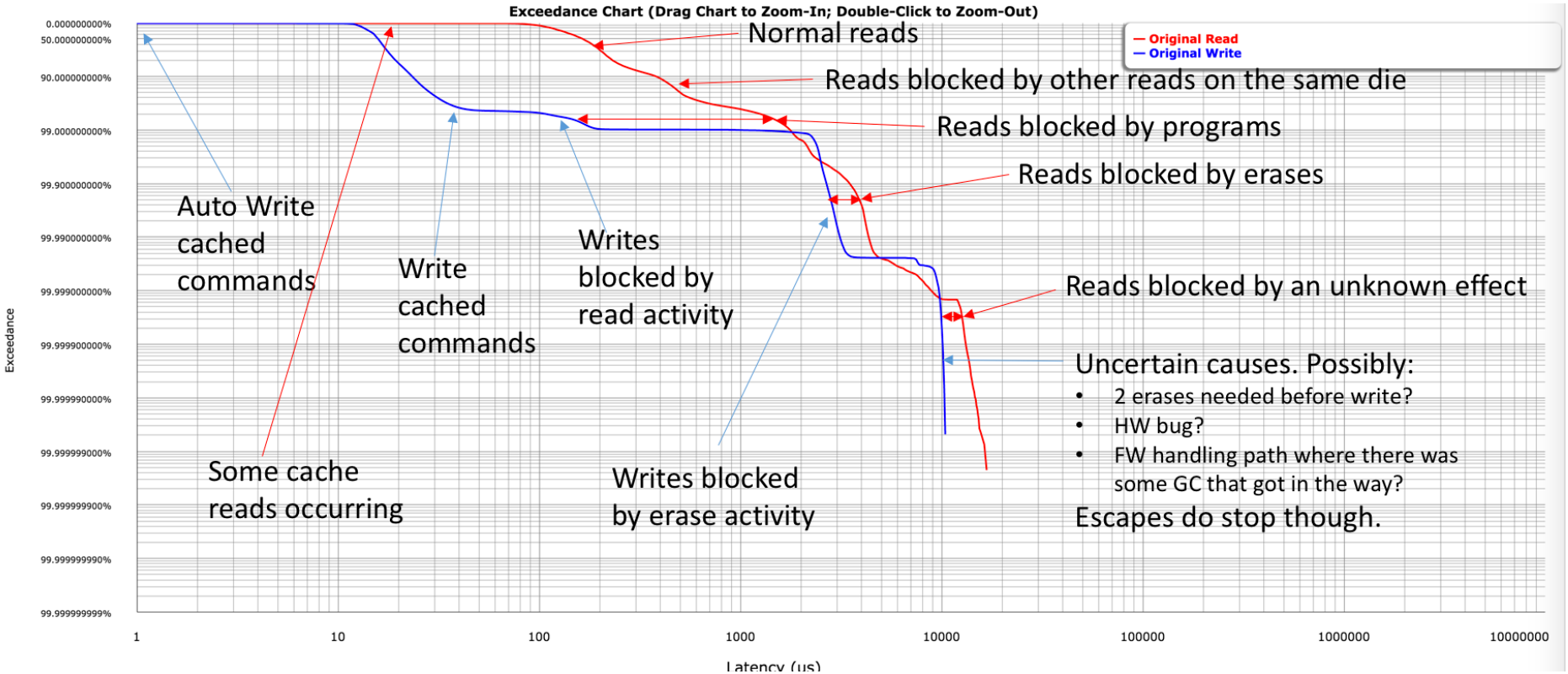
Exceedance Analysis Can Provide…

Rich detail and insights for storage devices



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Methods and Procedures: The Easy Button = ezfio

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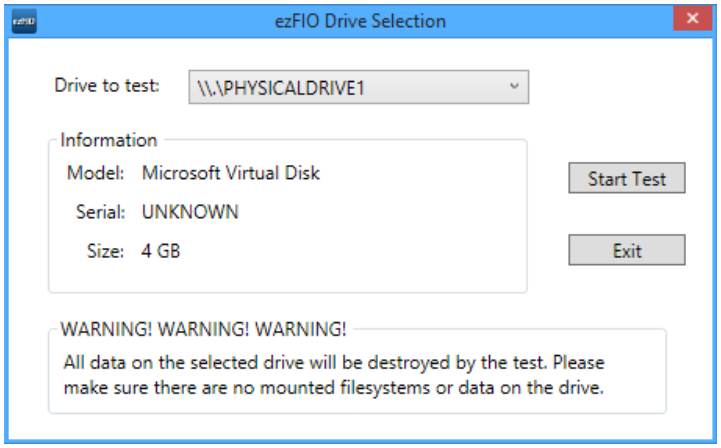
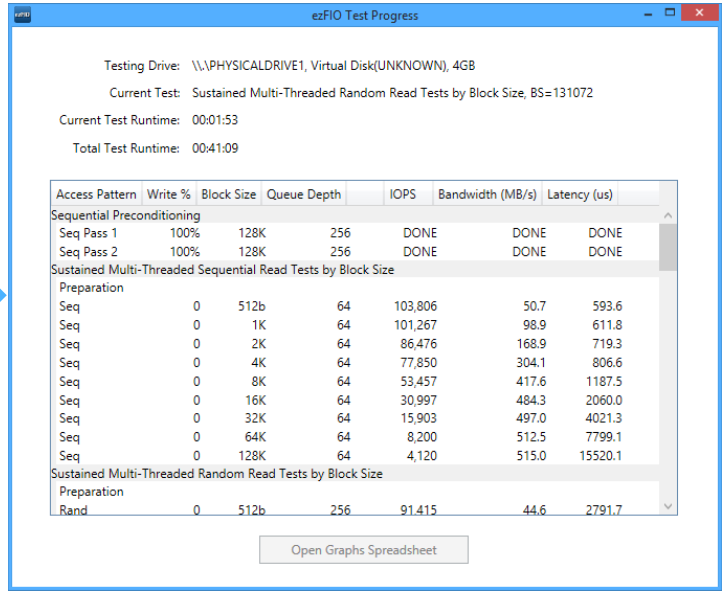
Easy Exceedance Charts with ezfio



Select Drive for fio#



Access Pattern	Write %	Block Size	Queue Depth	IOPS	Bandwidth (MB/s)	Latency (us)
Sequential Preconditioning						
Seq Pass 1	100%	128K	256	DONE	DONE	DONE
Seq Pass 2	100%	128K	256	DONE	DONE	DONE
Sustained Multi-Threaded Sequential Read Tests by Block Size						
Preparation						
Seq	0	512b	64	103,806	50.7	593.6
Seq	0	1K	64	101,267	98.9	611.8
Seq	0	2K	64	86,476	168.9	719.3
Seq	0	4K	64	77,850	304.1	806.6
Seq	0	8K	64	53,457	417.6	1187.5
Seq	0	16K	64	30,997	484.3	2060.0
Seq	0	32K	64	15,903	497.0	4021.3
Seq	0	64K	64	8,200	512.5	7799.1
Seq	0	128K	64	4,120	515.0	15520.1
Sustained Multi-Threaded Random Read Tests by Block Size						
Preparation						
Rand	0	512b	256	91,415	44.6	2791.7

Real-Time Status

#fio: https://github.com/axboe/fio

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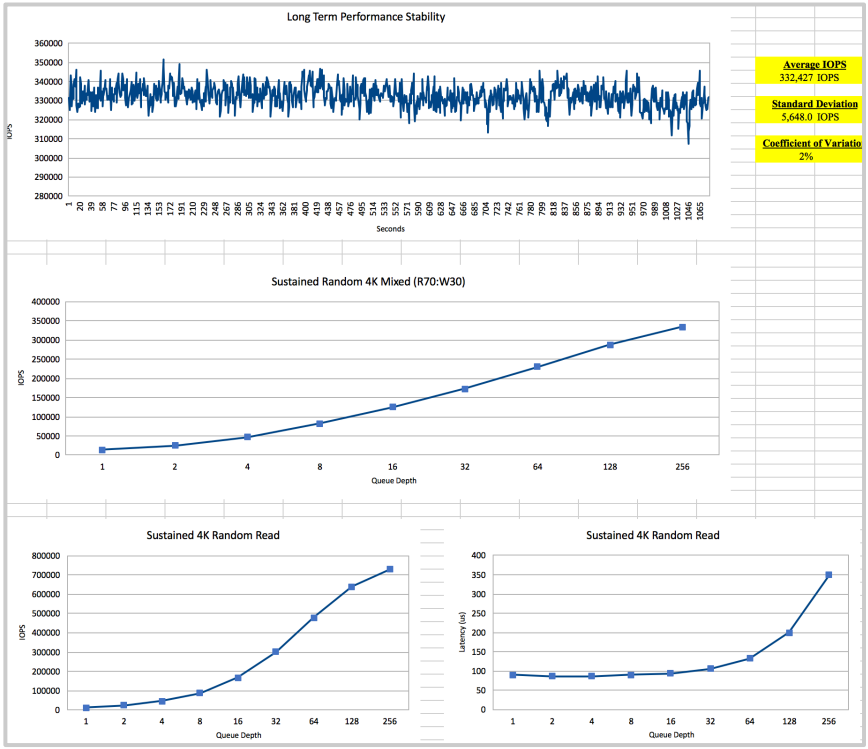
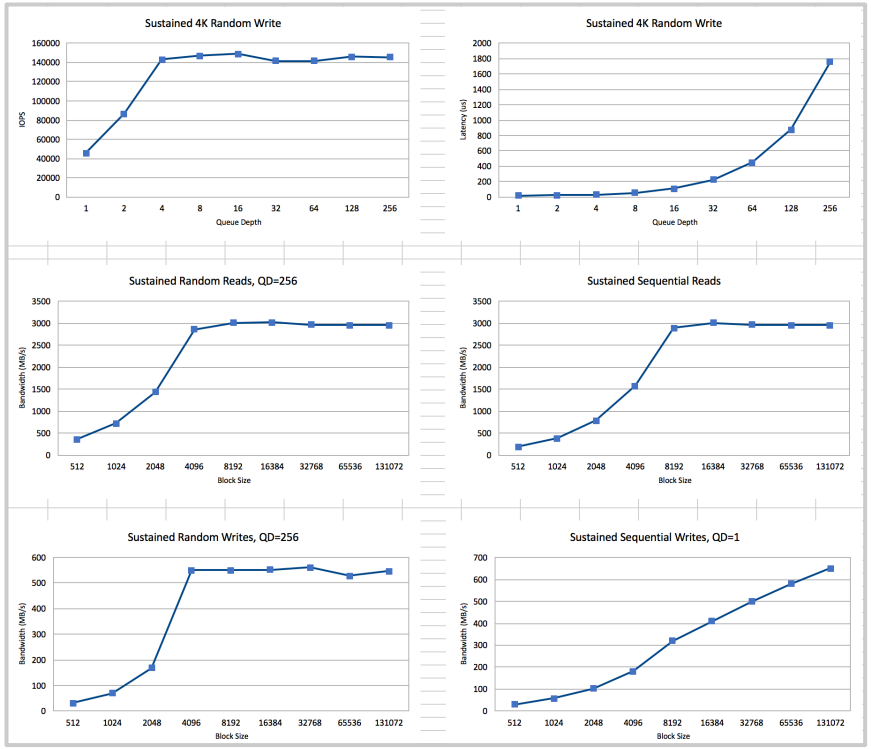
ezfio produces the usual charts – IOPs, Lat & BW





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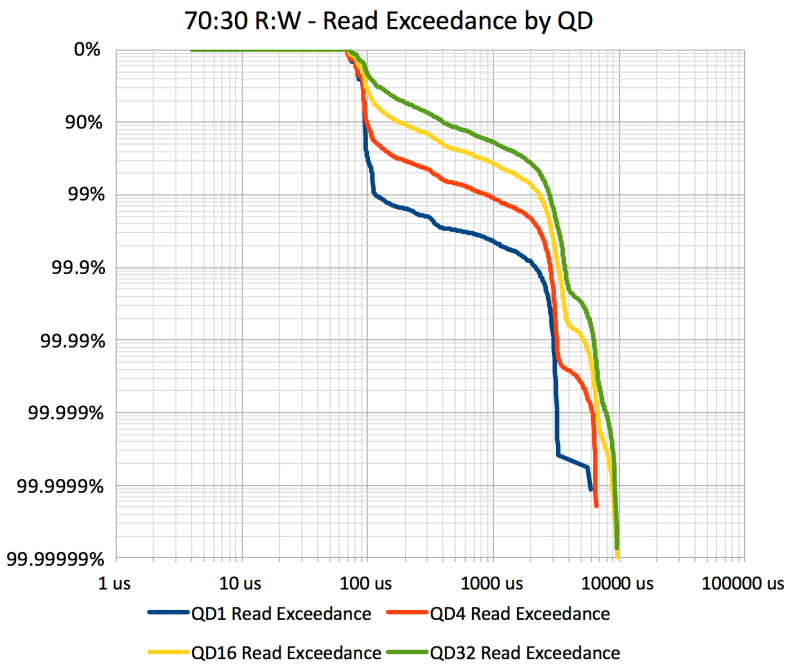
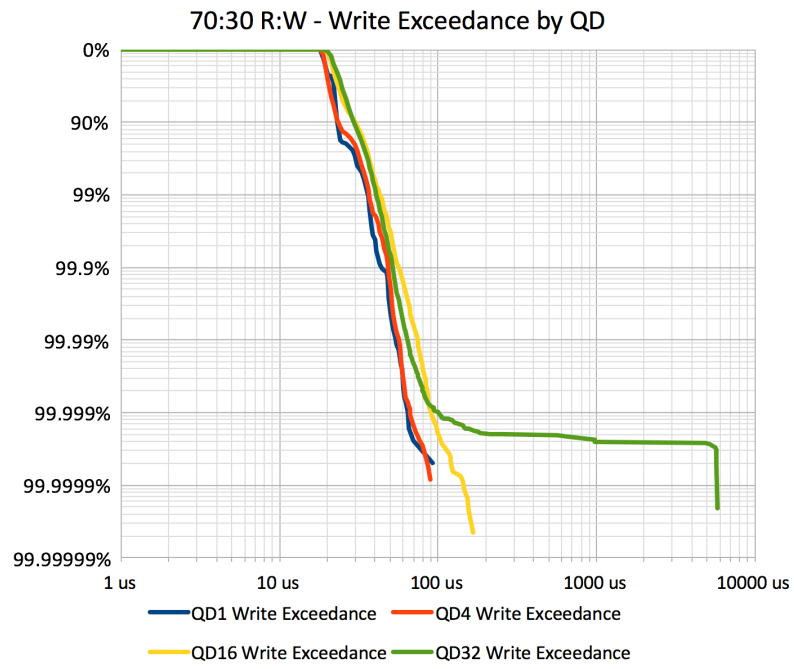
ezfio produces well-formed Exceedance Charts





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Contributors to the Current State of the Art

- **Earle Philhower III**, Western Digital
  - https://github.com/earlephilhower/ezfio A complete performance assessment tool including graphics of time series data, the standard performance description charts, and exceedance charts.
  - www.nvmexpress.org/ezfio-powerful-simple-nvme-ssd-benchmark-tool An article about using ezfio.
- **Vincent Fu**, Western Digital, https://github.com/vincentkfu
  - https://github.com/vincentkfu/fio-nanosecond-128-bit Modification of fio to support nanosecond resolution needed by today's faster devices. This enhance reveals performance below the 1-microsecond floor.
  - A steady state detector extension to fio: http://fio.readthedocs.io/en/latest/fio_doc.html#steady-state.
  - Contributed to the implementation of exceedance charts in TAU, a test harness, this was foundational to the general availability of exceedance chart building blocks in fio.
- **Rebecca Cran**, Western Digital
  - Creator and overseer of the Windows port of fio: http://bluestop.org/fio/
- **Dan Helmick,** Western Digital
  - Provided significant advice and technical assistance as we implemented Exceedance Charts.

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One final issue …

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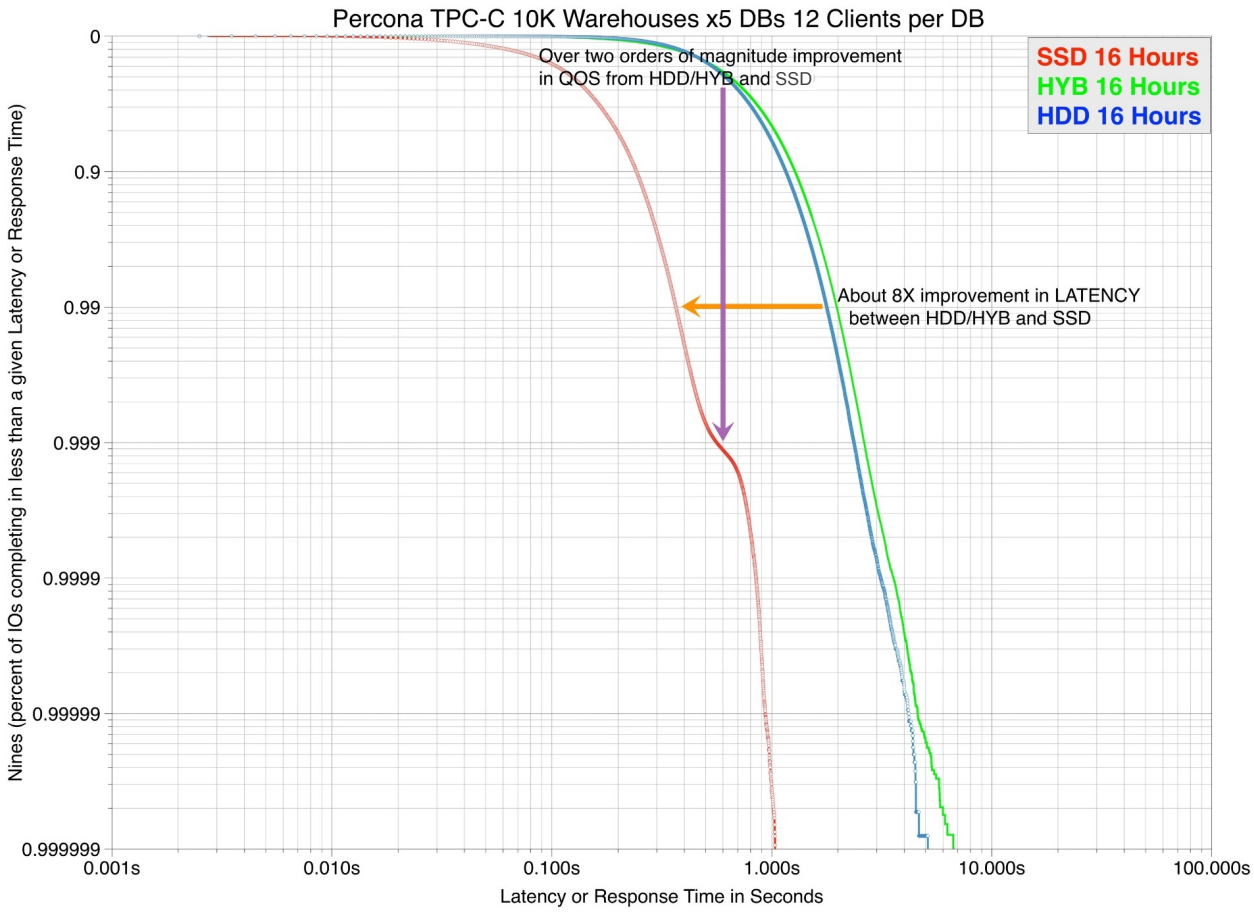
One Final Issue:

Exceedance Analysis is not a standalone figure of merit

- Here is a sample Exceedance Chart for TPC-C-like Transactions
- What's missing?



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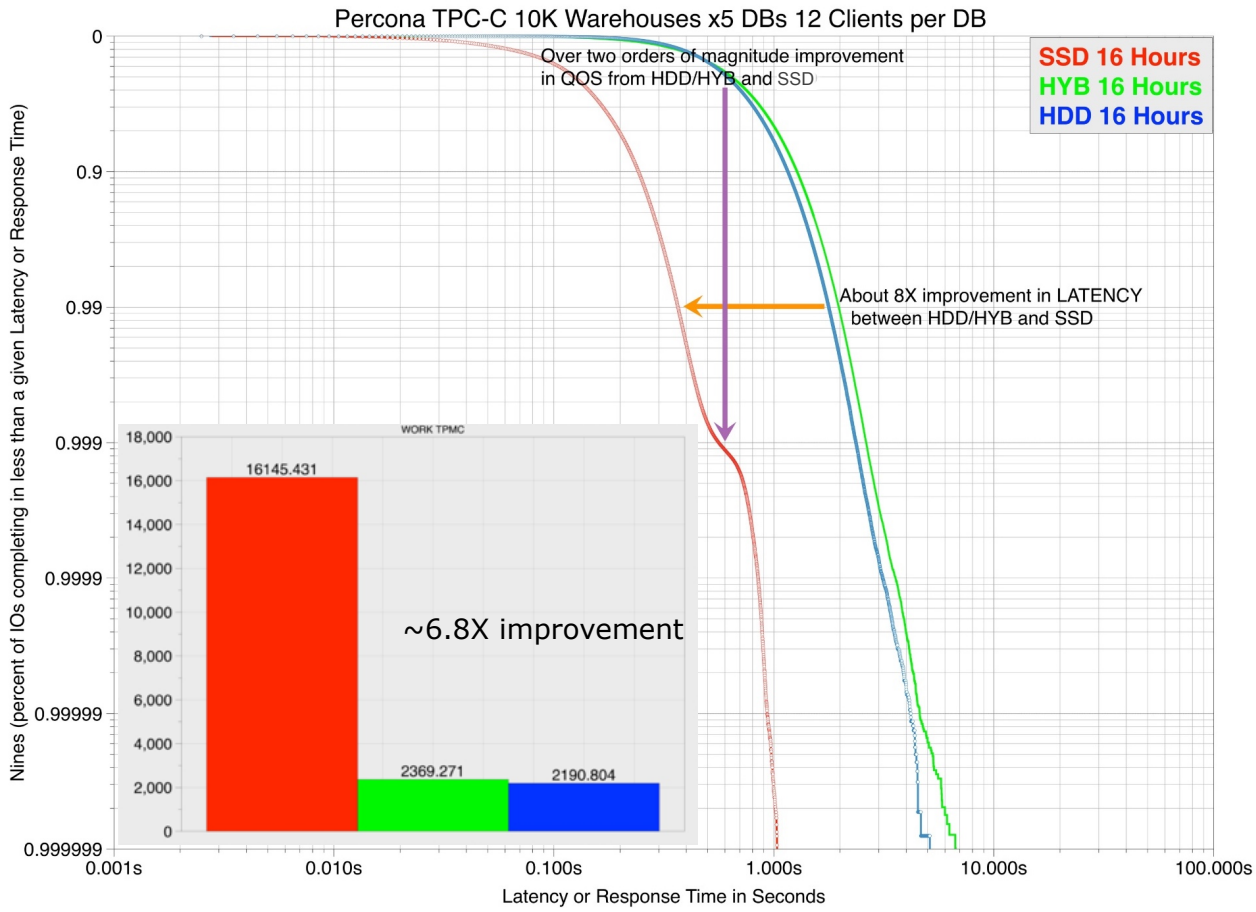
One Final Issue:

Exceedance Analysis is not a standalone figure of merit

- Here is an Exceedance Chart for TPC-C-like transactions
- The sub chart in the lower left shows the performance of the three configurations
- The QOS and the performance, here in TPM units, provide a pretty complete picture of the alternative configurations



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Questions, comments, discussion?

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This is the end.
And, Thank You!

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