SNIA SSSI | SOLID STATE STORAGE

How To Be A Part of the Real World Workload Revolution

A SNIA Solid State Storage Initiative Webcast

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Today’s Presenters

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Today's Agenda

- Real World Workloads, Comparisons to Synthetic Workloads
- Measuring and Visualizing Real World Workloads
- Real World Workload Demonstration
- Testing and Sharing
- Benefits of Joining the Program

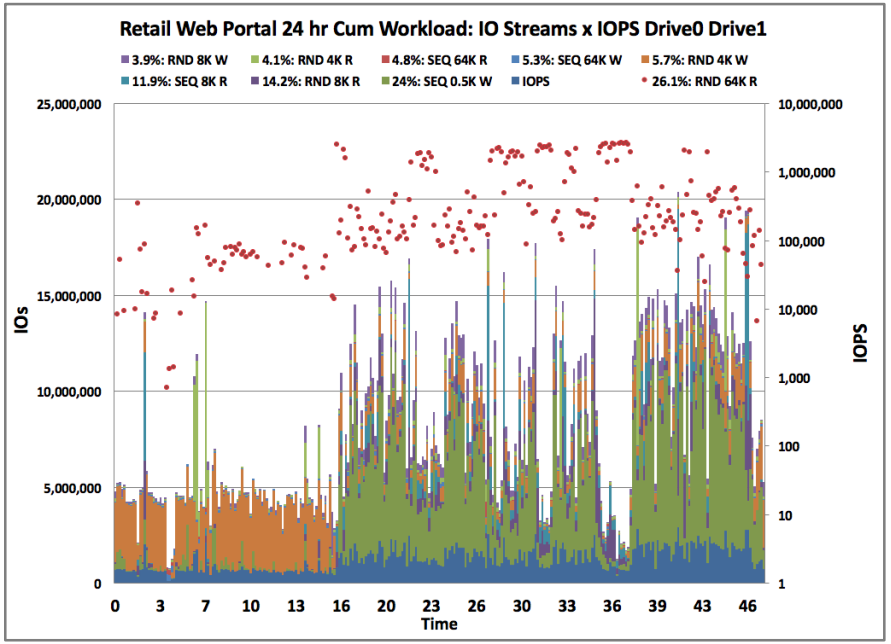
What are Real-World Workloads?

Real World Workloads are:

- A constantly changing sequence of
- IO Stream Combinations and QDs
- Captured from point A to B
- In the SW/HW Stack during actual use

Synthetic Benchmark Workloads are:

- A fixed and constant workload
- Applied to storage
- To test performance
- Outside the Range of Normal Usage



Retail Web Portal 24 Hr Workload: IO Streams & IOPS

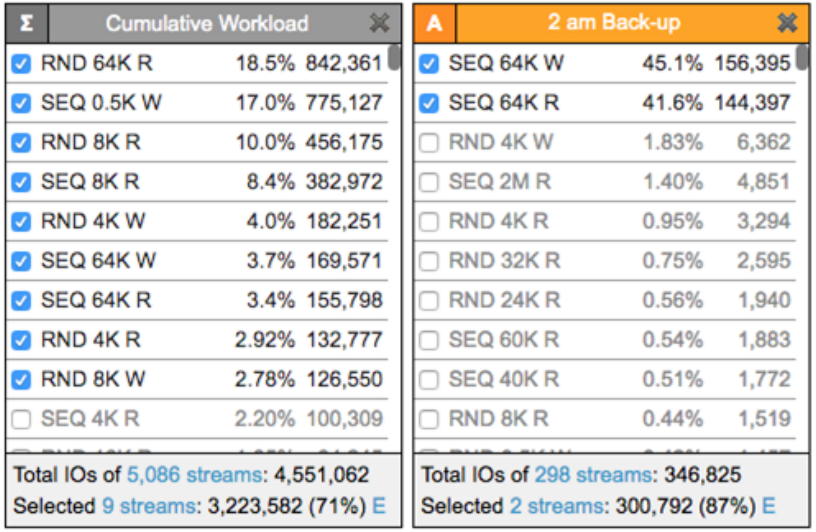
Synthetic vs. Real-World Workloads

Synthetic SQL Workload:

- Typically defined as random 8K R/W
- 65:35 R/W ratio
- Limited I/O threads to storage

Actual Real-World Workload:

- 72:28 R/W ratio
- 10% 8K Read, 2.8% 8K Write
- Over 5000 unique I/O streams
- Factors in additional workloads on the system (i.e. Backup)



Σ	Cumulative Workload		
☑	RND 64K R	18.5%	842,361
☑	SEQ 0.5K W	17.0%	775,127
☑	RND 8K R	10.0%	456,175
☑	SEQ 8K R	8.4%	382,972
☑	RND 4K W	4.0%	182,251
☑	SEQ 64K W	3.7%	169,571
☑	SEQ 64K R	3.4%	155,798
☑	RND 4K R	2.92%	132,777
☑	RND 8K W	2.78%	126,550
☐	SEQ 4K R	2.20%	100,309

Total IOs of 5,086 streams: 4,551,062
Selected 9 streams: 3,223,582 (71%) E

A	2 am Back-up		
☑	SEQ 64K W	45.1%	156,395
☑	SEQ 64K R	41.6%	144,397
☐	RND 4K W	1.83%	6,362
☐	SEQ 2M R	1.40%	4,851
☐	RND 4K R	0.95%	3,294
☐	RND 32K R	0.75%	2,595
☐	RND 24K R	0.56%	1,940
☐	SEQ 60K R	0.54%	1,883
☐	SEQ 40K R	0.51%	1,772
☐	RND 8K R	0.44%	1,519

Total IOs of 298 streams: 346,825
Selected 2 streams: 300,792 (87%) E

Why are Real World Storage Workloads (RWSWs) Important?

RWSWs are key determinants in storage performance and have a significant impact on SW and storage optimizations

- Solid State Storage Performance depends, in large part, on RWSWs
- Unlike lab test workloads, RWSWs are comprised of dynamically changing combinations of IO Streams & Demand Intensity
- IO Stream content affects Optimization, Design, Validation & Failure Analysis
- IO Streams change at each layer of software abstraction in the SW Stack

What are Real World Storage Workloads?

A collection of IO Streams seen by Storage

Generated in Application space

During Real World computer usage

Now, Let's look at some Definitions:

What is an IO Stream?

Access Pattern	RND or SEQ	Block Size	Read/Write	Queue Depth Ave/Max	% Occurrence	Quantity (IOs)
SEQ 1.5K W	SEQ	1536	W	1/111	1.34	69
SEQ 1K W	SEQ	1024	W	1/111	4.32	223
SEQ 0.5K W	SEQ	512	W	1/111	9.24	477
SEQ 4K W	SEQ	4096	W	1/111	22.31	1152
SEQ 16K W	SEQ	16384	W	1/111	14.25	736
RND 4K W	RND	4096	W	1/111	9.8	506
RND 3.5K W	RND	3584	W	1/111	0.62	32
RND 3K W	RND	3072	W	1/111	0.58	30
RND 2.5K W	RND	2560	W	1/111	0.74	38
RND 8K R	RND	8192	R	1/111	0.15	8
RND 2K W	RND	2048	W	1/111	0.93	48
RND 1.5K W	RND	1536	W	1/111	1.74	90
RND 1K W	RND	1024	W	1/111	3.21	166
RND 0.5K W	RND	512	W	1/111	1.99	103
RND 8K W	RND	8192	W	1/111	2.73	141
RND 4K R	RND	4096	R	1/111	0.91	47
RND 12K W	RND	12288	W	1/111	1.24	64
RND 16K W	RND	16384	W	1/111	15.63	807
RND 20K W	RND	20480	W	1/111	0.58	30
RND 28K W	RND	28672	W	1/111	2.03	105
RND 36K W	RND	36864	W	1/111	0.19	10

IO Stream Table: 2 Minute Capture Step showing IO Stream Statistics

An IO Stream[1] is an Input/Output Operation (IO) that has a unique:

- Random or Sequential Access
- Block Size or Data Transfer Size
- Read or Write IO
- Queue Depth (QD)

A single IO Stream can occur many times during an IO Capture Step

Other Secondary Metrics can be associated with IO Streams

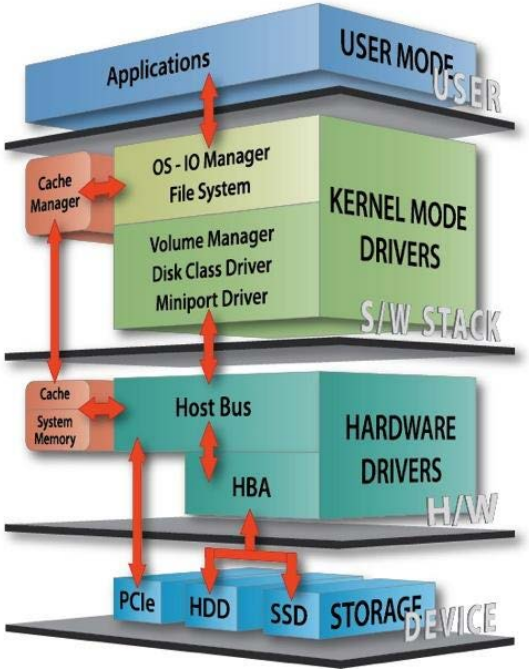
[1] Workload IO Stream definitions used here differ from SSD Endurance Streams where similar write operations are associated with a group of associated data

What is an IO Capture?

An IO Capture is the tabulation of statistics on IO Streams that are observed during a capture period

- IO Capture Tools gather statistics and metrics on IO Streams
- An IO Capture is NOT an IO Trace
- No data or private information is collected
- Only binary numeric tables are gathered

What is the Software Stack?

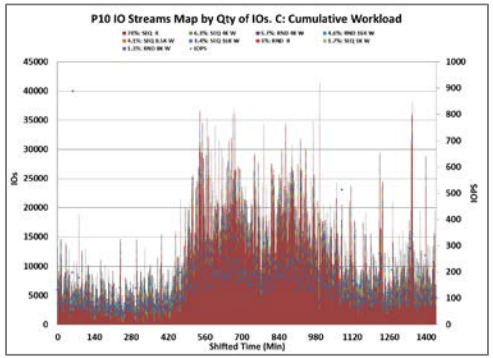


Windows Software Stack

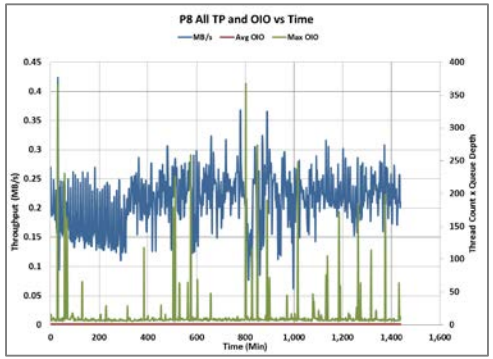
The Software (SW) Stack refers to the layers of software (OS, APIs, programs, drivers and abstractions) that exist between User space and storage

- IO Streams are generated in User space by software applications, run everywhere
- IO Streams traverse the SW State back and forth to storage
- IO Stream composition is different at different levels of the SW Stack

Why do RWSWs Affect Performance?



RWSW – IOPS & Changing Combinations of IO Streams

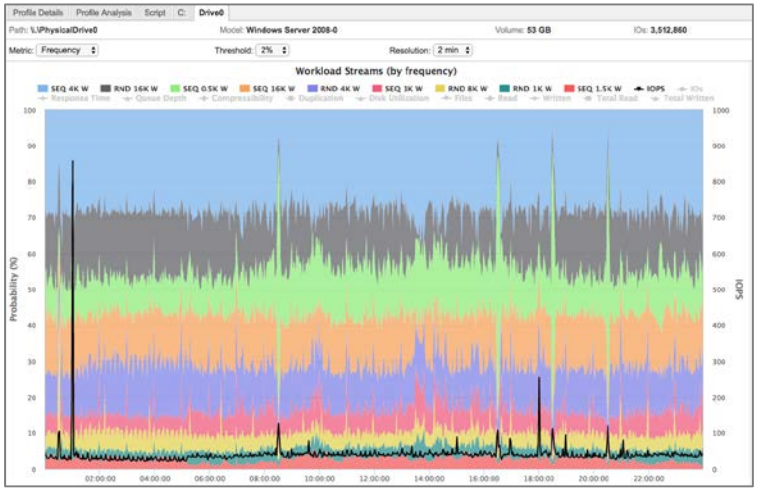


RWSW - Throughput & Changing Queue Depths

Solid State Storage Performance depends on how well storage responds to constantly changing combinations of IO Streams and Demand Intensity

- RWSWs are constantly changing combinations of IO Streams and QDs; Synthetic Lab tests are a fixed and constant
- IO Streamsvary by Block Size, Accesses and R/W IOs
- Solid State Storage responds differently to the type of access (RND/SEQ), Block Size, and whether the IO is a Read/Write
- The type and combination of RWSW IO Streams and the Demand Intensity determines, in large part, the storage performance that is provided

What do RWSWs Look Like?

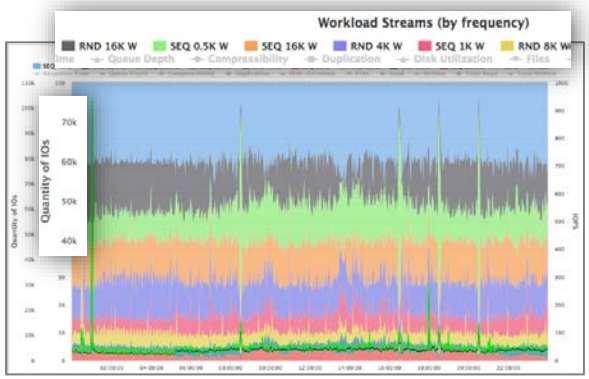


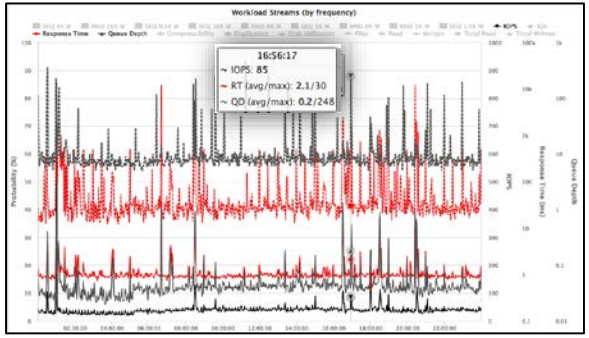
IO Stream Map: 24-hour Block IO Level (Drive0) Capture showing IOPS & IO Streams

RWSW can be visualized by creating an IO Stream Map that shows the changing combinations of IOs and metrics over Time

- IO Stream % probability of occurrence - different color data series
- IOPS - dominant black line
- Time - X-axis: 24-hour capture at 2 minute steps
- Secondary metrics captured by the Capture tool can be displayed

Viewing Secondary IO Metrics

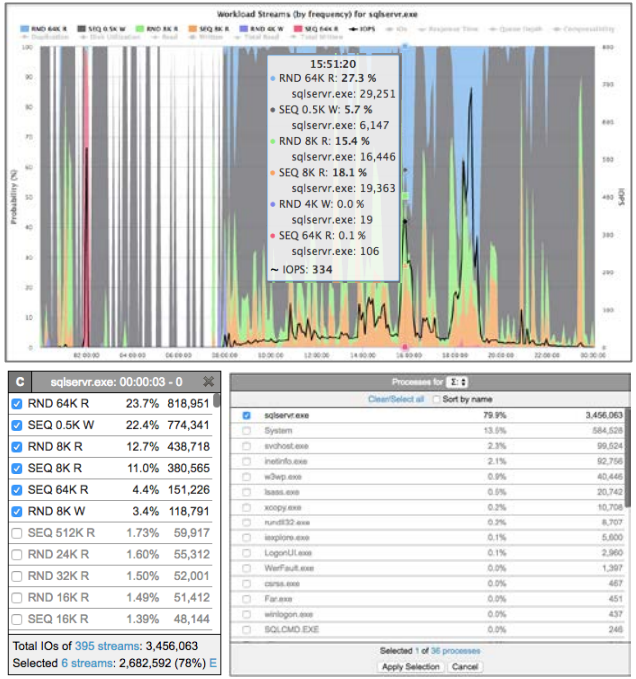




Secondary IO Metrics captured by the IO Capture tool can be viewed on an IO Stream Map

- IO Capture tools can capture various Secondary Metrics
- IO Streams can be listed by RND/SEQ access, Block Size, R/W IO
- Average and Maximum Response Times and QDs are shown to the left
- Several additional IO Metrics can be shown

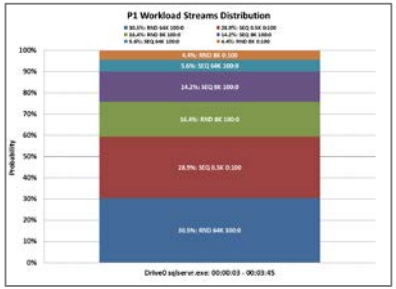
Viewing IO Streams by a Specific Application



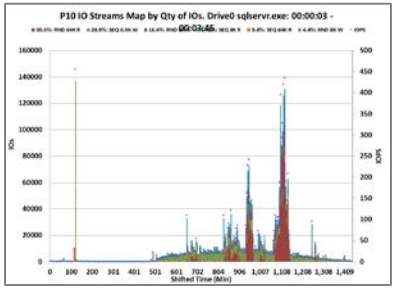
IO Streams can be filtered, extracted or presented by specific Application IOs

- Here we extract only the sqlservr.exe IOs
- sqlservr.exe IOs that occur > 3% of the time over the 24-hours
  - The Cumulative workload - 395 Streams & 36 separate Processes
  - sqlservr.exe – 6 IO Streams are 78% of the Total IO Streams
  - sqlservr.exe application IOs - 79.9% of the Total IO Streams

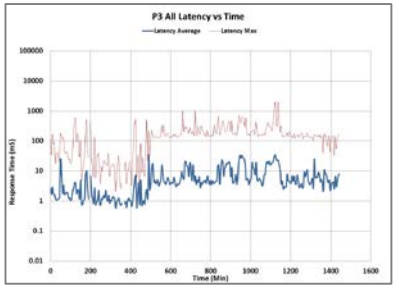
What can RWSWs Tell Us?



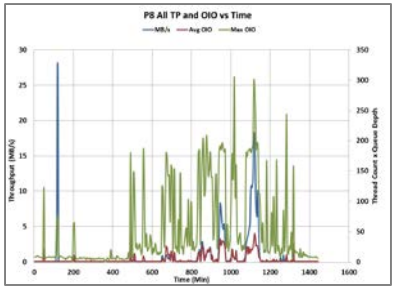
IO Stream Composition of Selected Processes



Changing Combinations of IO Streams



Application Process Response Times



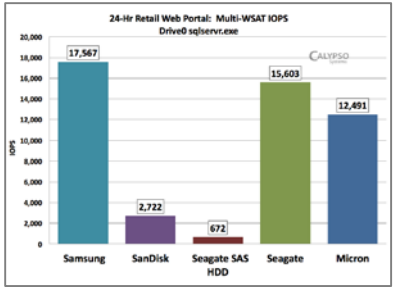
Throughput and Queue Depths v Time

RWSWs let us extract specific application IOs to analyze the IO Composition, Metrics and Performance that occur on the target server during the IO Capture. We can see:

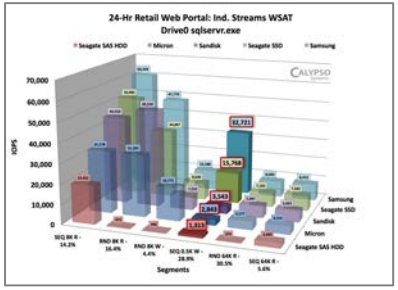
- IO Stream Distribution of the selected Process(es)
- Changing combinations of IO Streams over time
- IO Process Average & Maximum Response Times
- IO Process Throughput and Avg/Max Queue Depth
- Secondary IO Metrics

Demonstration

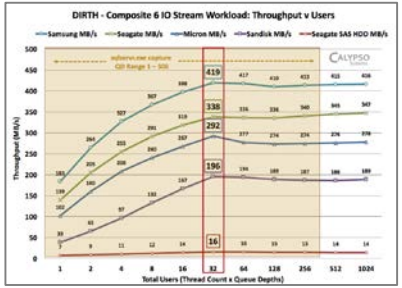
RWSW Test Examples



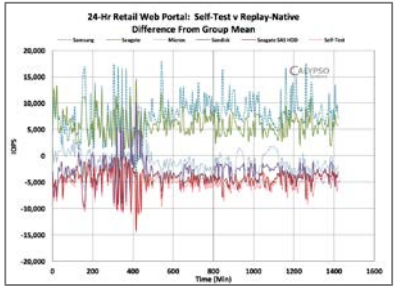
Multi-WSAT



Individual Streams-WSAT



DIRTH



Replay-Native

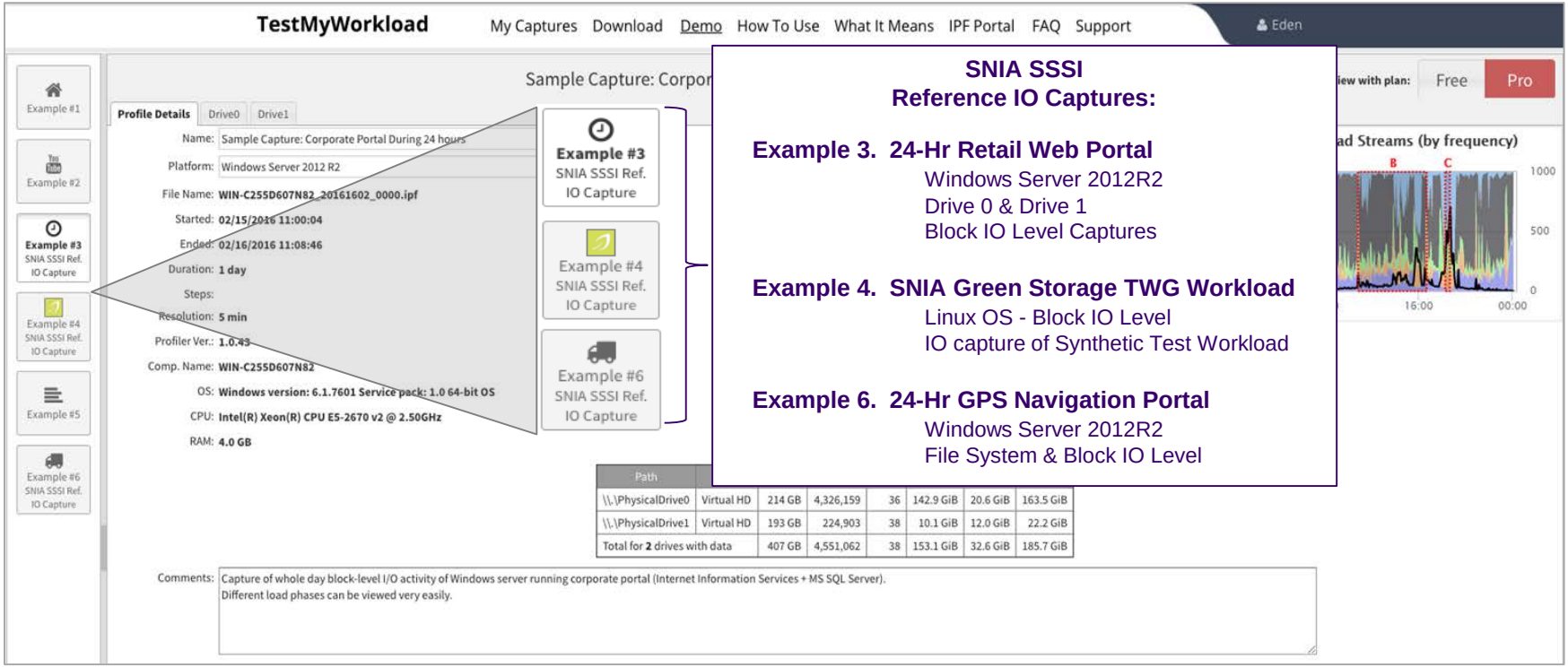
1. **Multi-WSAT** – applies fixed 6 IO Stream composite workload for each test step to Steady State.

2. **Individual Streams-WSAT** – tests each individual IO Stream as a separate Steady State item

3. **DIRTH** (Demand Intensity Response time Histogram) - applies fixed 6 IO Stream composite workload across a range of 1 to 1,024 Users to measure IOPS & Response Time saturation.

4. **Replay-Native** - reproduces each capture step combination of IO Streams, Queue Depths and Idle Times for storage comparison to the original IO Capture server storage

SNIA SSSI Reference IO Capture Workloads



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Reference IO Captures:

Example 3. 24-Hr Retail Web Portal
- Windows Server 2012R2
- Drive 0 & Drive 1
- Block IO Level Captures

Example 4. SNIA Green Storage TWG Workload
- Linux OS - Block IO Level
- IO capture of Synthetic Test Workload

Example 6. 24-Hr GPS Navigation Portal
- Windows Server 2012R2
- File System & Block IO Level

Benefits Across the Industry

Hardware Manufacturers

- Build/utilize an expanse of tests
- Characterize true needs of Solid State Storage/Memory
- Tune driver development

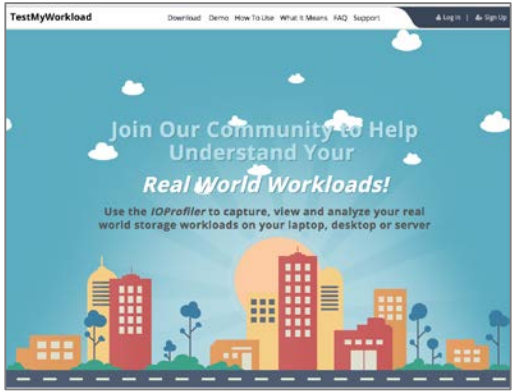
Software Developers

- Provide workloads to get hardware tuned for your performance
- Provide tools for purchasing decision makers
- Find race conditions and test new hardware more quickly

IT Organizations

- Provide your workload to get better results for your work
- Make the right choices in hardware/system specifications

Conclusions



- Understanding ***Your*** RWSW is ***critical*** for Datacenter, Storage Server and SSD Design and Optimization
- Know what you are optimizing (IO Streams & SW Stack levels)
- Find out what IO Streams are presented to Storage
- Try Demos, Free Captures & Analysis at TestMyWorkload.com
- See SNIA Reference Captures at TestMyWorkload.com
- View the SNIA Whitepaper and Calypso Whitepaper
- www.TestMyWorkload.com

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