Utilizing VDBench to Perform IDC AFA Testing

Michael Ault, IBM
Oracle FlashSystem Consulting Manager

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Abstract

- **Utilizing VDBench to Perform IDC AFA Testing**
  - This session will review what an all-flash-array consists of, what IDC is and what their testing involves and how to use VDBench to perform AFA testing and comparisons.

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Agenda

- What is an AFA?
- What is VDBench?
- What is the IDC and why do we care?
- What are the suggested AFA tests?
- Implementing the IDC AFA tests with VDBench

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What is an AFA?

- All-Flash-Array
- Not SSD (form-factor flash drives)
- Built from Function-designed flash modules
- Integrated control, configuration and monitoring
- S4-TWG defines AFA as a solid state storage array connected by redundant network protocols

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What is VDBench?

- Command line system
- Simulates various load scenarios including multiple hosts
- Doesn’t require an Oracle/DB install
- Scriptable
- Provided free from Oracle
- Vdbench has been tested on Solaris Sparc and x86, Windows NT, 2000, 2003, 2008, 2012, XP and Windows 7+8, HP/UX, AIX, Linux, Mac OS X, zLinux, and native VmWare
- Download from:

http://www.oracle.com/technetwork/server-storage/vdbench-downloads-1901681.html

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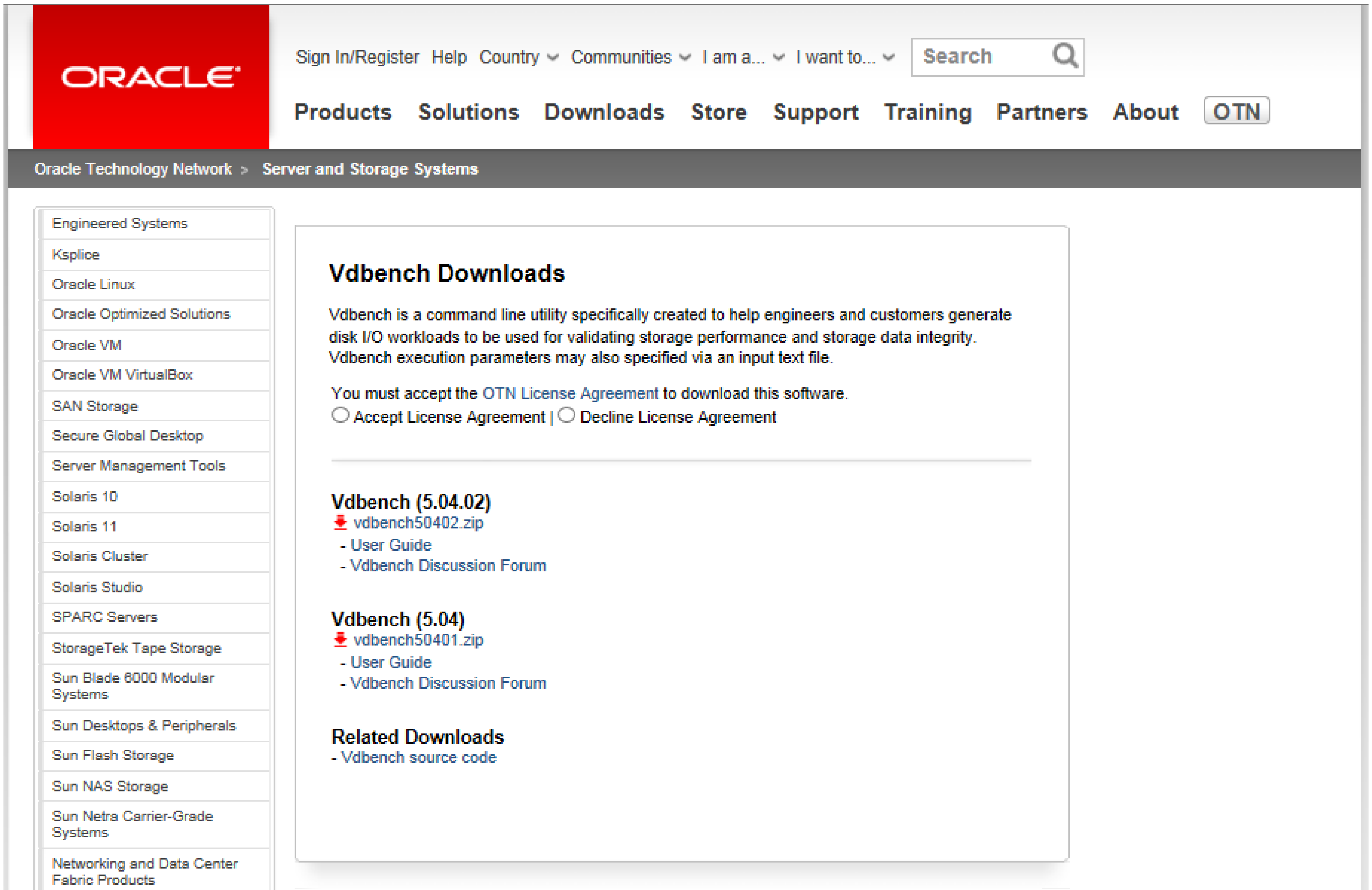
VDBench Download Page



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IDC and AFA

- IDC provides guidelines on standard tests to use in comparing computer technologies
- IDC has provided a detailed test guidelines for AFA
- Using the IDC guidelines you can easily test and compare AFAs
- The public link for the IDC testing guidelines for AFAs is:

http://idcdocserv.com/251951

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Differences Between AFA and HDD

- Preconditioning.
  - Flash-based array performance will differ significantly from FOB (fresh out of box) and after first write on every flash cell.
  - HDDs don't exhibit the FOB effect.
- Read/write asymmetries.
  - Traditional HDD overwrites data in place and does not lock data on writes.
  - Flash needs to erase before rewriting and cell locks on writes causing writes to be slower
- Endurance.
  - After a defined number of P/E cycles, flash will become read only and ultimately inoperable.

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- Data stream/data set definition.
  - The mixed virtual workloads in 3rd Platform computing are very different than traditional client/server workloads.
  - A relevant workload will exhibit
    - a variety of read/write ratios
    - wide distribution of block sizes
    - Be skewed toward random I/O
    - Have a high percentage of reducible data
- Load generation.
  - Flash-based arrays deliver 10x performance
  - Load generators have to take this into account

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Some Flash Terminology

- P/E cycles.
  - Each individual flash cell P/E cycle, the flash cell incurs a slight amount of damage known as wear.
  - A single iteration of erasing and writing to a flash cell is known as a "program/erase cycle" (P/E cycle).
- Asymmetric behavior.
  - flash delivers latencies an order of magnitude lower than HDDs,
  - read/write I/O exhibit different latencies depending on state of flash media
  - If the page has data that must be overwritten, a P/E cycle must occur

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Some Flash Terminology

- Overprovisioned capacity.
  - A set amount of capacity reserved for administrative activities associated with flash performance, endurance, or reliability.
- Wear leveling.
  - Cells have a specified wear rating.
  - Frequent use cells will wear out sooner

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Some Flash Terminology

- Free space management.
  - To write a single byte, an entire erase block must be available.
  - "garbage collection," ensures that systems always have a ready supply of clean blocks.
  - Invalidated data is not immediately overwritten but marked as "available" to be written.
- Write amplification.
  - There are two processes in most flash-based arrays that amplify the number of writes within the array: garbage collection and data protection.
  - The ratio of FTL writes to Server requests

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Some Flash Terminology

- Flash translation layer (FTL).
  - Flash storage is generally combined with an FTL (FPGA, ASIC, or software based)
  - FTL is a logical block interface for OS to access the flash media as if it were a traditional HDD.

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IDC Testing

In the universe of performance testing, there are five basic types of tests that could potentially be performed, and these are ranked in order of relevance to understanding how an array will perform on your actual production workload:

- **Class A:** Workload testing using your actual data streams, data sets, and workflows
- **Class B:** Workload testing using data streams, data sets, and workflows that are generated using application-specific testing tools like SLOB (Oracle), Jetstress (Exchange), Login VSI (VDI), and others
- **Class C:** Workload testing that uses data streams, data sets, and workflows generated by general-purpose workload generation tools like Load DynamiX, FIO, or vdbench that are capable of very accurate modeling
- **Class D:** An intelligent performance corners test using generic data sets, data streams, and workflows designed to closely model 3rd Platform computing workloads
- **Class E:** Hero testing that encompasses most classic performance corners testing

In AFA testing, IDC recommends Class D type tests

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IDC Test Plan

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AFA Test Plan Summary

Phase	Description	Tasks	Estimated Elapsed Time
1	Setup and preconditioning	2 x 85% overwrite	24 hours
	Data set preparation	2 x 5% overwrite 5 x 1% overwrite	6 hours
2	Baseline workload testing	Develop scripts	6 hours
		Thread/queue depth optimization	6 hours
		IOPS ramp testing (4 runs at 3 hours per run)	12 hours
3	Functional testing	Document workflows	6 hours
		Test workflows (4 runs at 4 hours per run)	16 hours
4	Fault injection testing	Inject failures (4 runs at 2 hours per run)	8 hours
5	Soak test	Run 4 baseline workloads consecutively(12 hours each)	48 hours
			132 hours

Source: IDC, 2014

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Testing the a 40 TiB System

- Preconditioning
  - Actual amount of flash is 65.9 TB
  - System 40 usable TiB (37.5 TB after RAID5)
  - We already have extracted the “overhead” so we will configure the 37 into 37 -1 TiB LUNS
  - Preconditioning volume of writes would be 65.9*0.85*2=112 TB
  - At 128K blocks the throughput for the 840 is 1.7 GB/s for a single Power8 server with 16 threads per LUN (592 total)
  - 67,500 seconds to do writes (~19 hours)
  - Monitor for write cliff, if not reached at end of first run, repeat

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Testing the a 40 TiB System

- Data Set Preparation and Aging
  - 2 additional runs with small random writes (4-16kb) each at 5% of 65.9 TB so 3.3 TB each run randomly spread across system (3 runs of around 1,100 GiB one at 4k, 8k and 16k)
  - 5 additional runs with small random writes (4-16kb) each at 1% of 65.9 TiB (660 GB) each run randomly spread across system (3 streams 4, 8 and 16k each doing 220 GB each) each run addressing different sets of luns.

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VDBench Scripting

- Utilizes tags for each script section
- SD for drive/storage designations
- WD for workload definitions
- RD for run definitions

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Preconditioning Script

Create several luns, do 37-1.0 TiB size that used most of the 37.5 TiB.

Contents of precondition.cfg:

```
sd=default, openflags=o_direct
sd=sd1,lun=\\.\PhysicalDrive1
sd=sd2,lun=\\.\PhysicalDrive2
sd=sd3,lun=\\.\PhysicalDrive3
…
sd=sd37,lun=\\.\PhysicalDrive37


wd=fill,sd=sd*,rdpct=0,xfersize=128k,seekpct=-1
rd=precondition,wd=fill,iorate=max,elapsed=67500,interval=30,
threads=16
```


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Running the Script

- Use the command line
- Specify output location if you want a specific location for the output HTML files

\vdbench\vdbench -f precondition.cfg –m 37 –o \vdbench\output\precon

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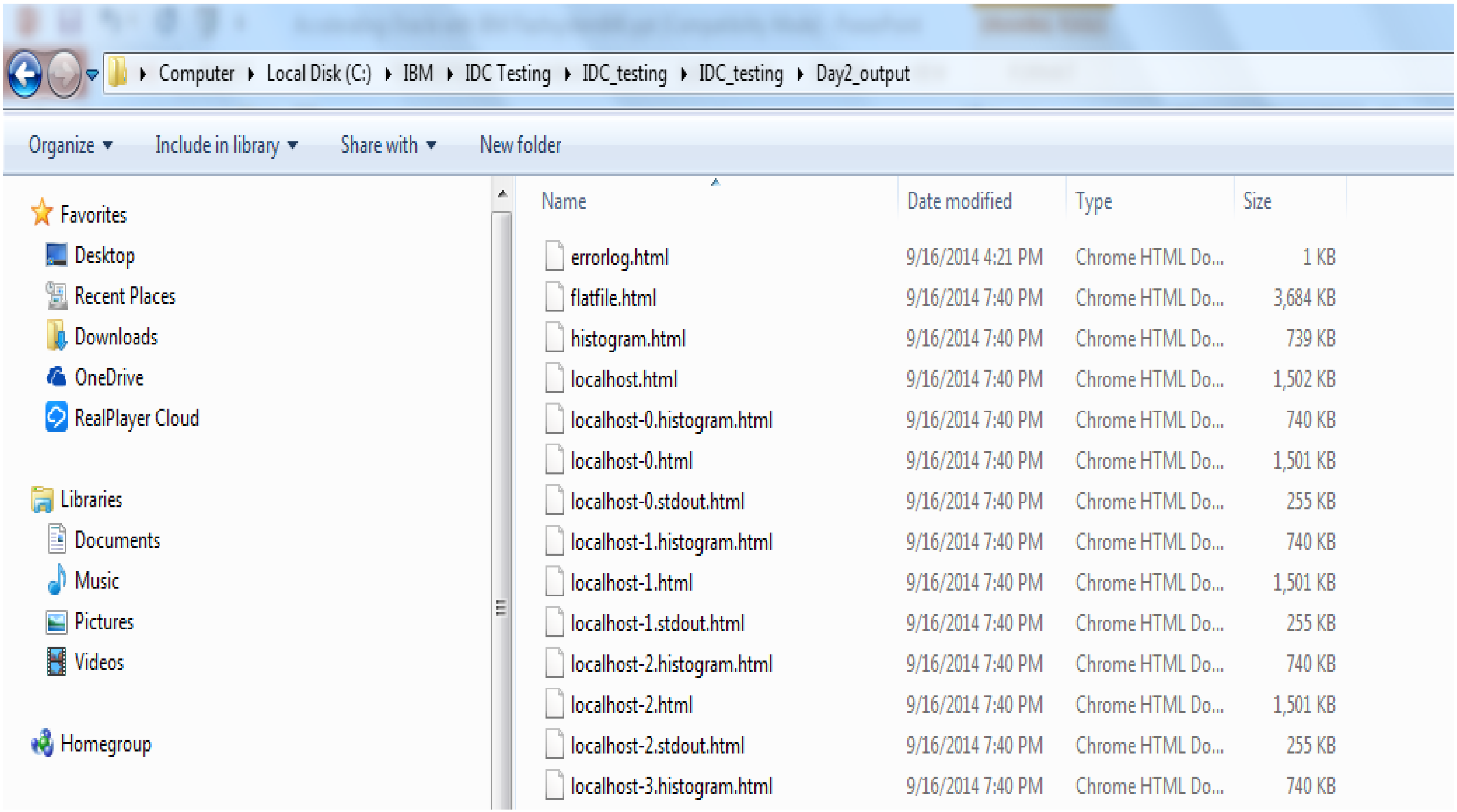
Example Output Files



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File Contents (Summary file)

Sep 16, 2014	interval	i/o rate	MB/sec 1024**2	bytes i/o	read pct	resp time	read resp	write resp	resp max	resp stddev	queue depth	cpu% sys+u	cpu% sys
16:19:08.058	1	74950.00	36.60	512	10.04	0.341	0.541	0.318	426.042	1.776	25.5	0.0	4.3
16:19:09.018	2	103950.00	50.76	512	10.01	0.258	0.437	0.238	6.256	0.257	26.8	8.2	6.4
16:19:10.016	3	118267.00	57.75	512	10.13	0.233	0.464	0.207	46.793	0.540	27.5	13.6	7.6
16:19:11.030	4	121366.00	59.26	512	9.88	0.230	0.471	0.204	195.091	0.932	27.9	12.1	8.2
16:19:12.020	5	110907.00	54.15	512	9.93	0.245	0.425	0.225	6.435	0.258	27.2	5.1	5.8
16:19:13.017	6	105364.00	51.45	512	9.99	0.261	0.427	0.243	7.380	0.248	27.5	8.3	5.4
16:19:14.016	7	125217.00	61.14	512	9.95	0.220	0.474	0.192	29.523	0.637	27.5	10.2	8.2
16:19:15.030	8	116730.00	57.00	512	10.10	0.239	0.486	0.212	149.333	0.830	27.9	12.5	7.8
16:19:16.018	9	117267.00	57.26	512	10.09	0.232	0.423	0.210	11.671	0.265	27.2	8.0	7.1
16:19:17.016	10	126531.00	61.78	512	10.01	0.218	0.462	0.190	16.961	0.605	27.5	10.4	7.5
16:19:18.002	11	111330.00	54.36	512	10.04	0.247	0.426	0.227	11.312	0.261	27.5	9.5	7.5
16:19:19.016	12	125546.00	61.30	512	10.15	0.219	0.471	0.191	62.544	0.619	27.5	12.8	8.6
16:19:20.017	13	108123.00	52.79	512	10.06	0.255	0.437	0.234	13.263	0.272	27.5	6.6	4.7
16:19:21.016	14	118485.00	57.85	512	10.03	0.233	0.459	0.207	16.959	0.565	27.6	10.2	7.4
16:19:22.030	15	127885.00	62.44	512	9.98	0.218	0.460	0.192	31.209	0.660	27.9	12.0	9.9
16:19:23.018	16	108483.00	52.97	512	9.99	0.251	0.449	0.229	301.127	0.958	27.2	7.7	5.8
16:19:24.016	17	108807.00	53.13	512	9.77	0.253	0.494	0.227	78.131	0.903	27.6	10.8	6.3
16:19:25.018	18	114688.00	56.00	512	9.96	0.240	0.423	0.220	9.425	0.248	27.5	9.0	6.7
16:19:26.016	19	116589.00	56.93	512	10.01	0.236	0.486	0.208	31.922	0.648	27.5	8.1	6.7
16:19:27.017	20	109109.00	53.28	512	9.98	0.252	0.429	0.233	13.926	0.265	27.5	11.8	6.0
16:19:28.016	21	123767.00	60.43	512	9.99	0.222	0.448	0.197	15.685	0.566	27.5	8.4	8.5
16:19:29.030	22	124040.00	60.57	512	9.90	0.225	0.479	0.197	112.039	0.749	27.9	13.2	8.7
16:19:30.018	23	113921.00	55.63	512	9.94	0.238	0.414	0.219	12.076	0.254	27.2	8.4	7.9

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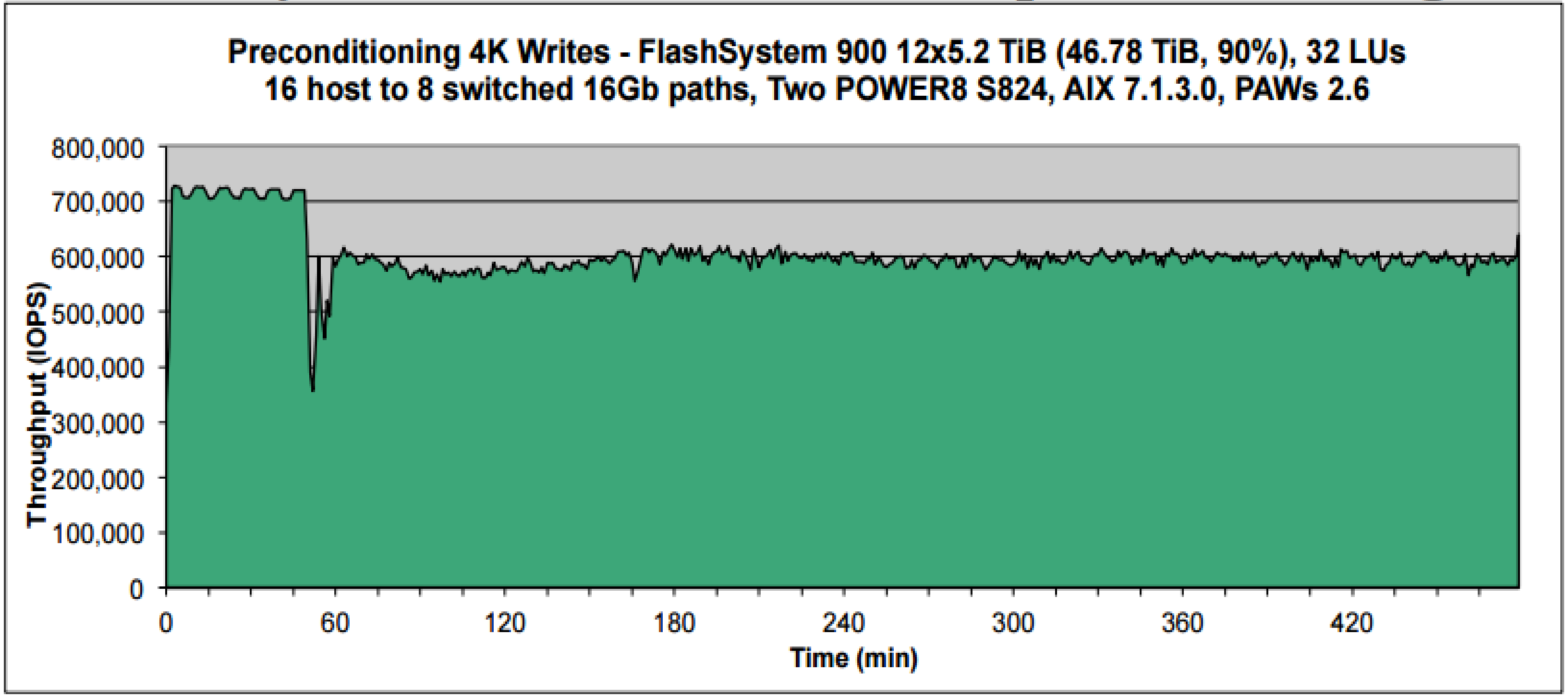
Write Cliff (Preconditioning is over)

FlashSystem 900: Random Write preconditioning



Max write IOPS = 700+ K IOPS (sustained over 45 mins)
Long-term write IOPS is about 600 K IOPS
Note that this long-term IO rate is consistent with the 100% 4KB write response time curve in later pages

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Phase 1: Data Conditioning and Aging

- Conditioning is 2 passes:
  - 5:1 reducible (compressible)
  - Sequential small writes randomized in size around average expected I/O size
  - 5% of data volume
- Aging is 5 passes:
  - 5:1 reducible (compressible)
  - Random small writes randomized in size around average expected I/O size
  - 1% of data volume

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Data Conditioning Script

```
compratio=5
*SD:
sd=default, openflags=o_direct
sd=sd1,lun=\\.\PhysicalDrive1
sd=sd2,lun=\\.\PhysicalDrive2
sd=sd3,lun=\\.\PhysicalDrive3
…
sd=sd37,lun=\\.\PhysicalDrive37

*WD:       Workload Definitions
wd=wd1,sd=sd*,seekpct=sequential

*RD:       Run Definitions
*Will run 1 test  IO size with random (4k, 8k, 16k) for approximately 3300 GB
rd=rd1,wd=wd1,iorate=max,elapsed=1950,interval=5,rdpct=0,xfersize=(4k,128k,4k),threads=(
16)
```

Run this 2 runs, the sequential IO specification localizes the data placement across 5% of the system, the 3200 elapsed is based on the IOPS for 16K size divided into the 3.3 GB (5%).

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Data Aging Script

compratio=5
*SD:
sd=default, openflags=o_direct
sd=sd1,lun=\\.\PhysicalDrive1
sd=sd2,lun=\\.\PhysicalDrive2
sd=sd3,lun=\\.\PhysicalDrive3
…
sd=sd37,lun=\\.\PhysicalDrive37

*WD: Workload Definitions
wd=wd1,sd=sd*,seekpct=random

*RD: Run Definitions
*Will run 1 test IO size with random (4k, 128k, 16k) for approximately 660 GB
rd=rd1,wd=wd1,iorate=max, elapsed=390, interval=1, rdpct=0, xfersize=(4k,128k,16k), threads=(16)

Run this 5 runs, the sequential IO specification localizes the data placement across 5% of the system, the 382 elapsed is based on the IOPS for 16K size divided into the 660 GB (1%).

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Phase 2: Baseline Workload Tests

- Once the AFA is brought to a state that is considered a start point, actual testing can start
- The next test is the baseline workload
  - 20/80 read/write ratio, all sequential, mixed block sizes matching your actual distribution, data that exhibits a 5:1 data reduction ratio, and displays some I/O banding with drift
  - 65/35 read/write ratio, all random, mixed block sizes matching your actual distribution, data that exhibits a 5:1 data reduction ratio, and displays some I/O banding with drift
  - 35/65 read/write ratio, all random, mixed block sizes matching your actual distribution, data that exhibits a 5:1 data reduction ratio, and displays some I/O banding with drift
  - 80/20 read/write ratio, all sequential, mixed block sizes matching your actual distribution, data that exhibits a 5:1 data reduction ratio, and displays some I/O banding with drift

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Banding and Drift

- Also known as spatial and temporal data
- Spatial is sequential data
- Temporal is data that is accessed near the same time
- Buffering/caching usually deals best with temporal data

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Writes in AFA

- Usually large writes will be broken up
- 4-8K write shards are common
- A large write that would be written sequentially to HDD will be “shot gunned” to all available free blocks across several flash modules due to wear leveling

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20/80 and 80/20 Read Percent Sequential Workloads

```
*SD:     Storage Definitions
sd=default, openflags=o_direct
sd=sd1,lun=\\.\PhysicalDrive1
sd=sd2,lun=\\.\PhysicalDrive2
sd=sd3,lun=\\.\PhysicalDrive3
…
sd=sd37,lun=\\.\PhysicalDrive37

*WD:     Workload Definitions
wd=wd1,sd=sd*,seekpct=sequential

*RD:     Run Definitions
*Will run 40 tests (10 for 8k, 10 for 16k, 10 for 32k, 10 for 128k) for 120 seconds each
rd=rd1,wd=wd1,iorate=max,elapsed=300,interval=1,pause=5,forrdpct=(20,80),forxfersize=(8k,16k, 32k,128k),forthreads=(1,16,d)
```


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35/65 and 65/35 Read Percent Random Workloads

```
*SD:     Storage Definitions
sd=default, openflags=o_direct
sd=sd1,lun=\\.\PhysicalDrive1
sd=sd2,lun=\\.\PhysicalDrive2
sd=sd3,lun=\\.\PhysicalDrive3
…
sd=sd37,lun=\\.\PhysicalDrive37

*WD:     Workload Definitions
wd=wd1,sd=sd*,seekpct=random

*RD:     Run Definitions
*Will run 40 tests (10 for 8k, 10 for 16k, 10 for 32k, 10 for 128k) for 120 seconds each
rd=rd1,wd=wd1,iorate=max,elapsed=300,interval=1,pause=5,forrdpct=(35,65),forxfersize=(8k,16k, 32k,128k),forthreads=(1,16,d)
```


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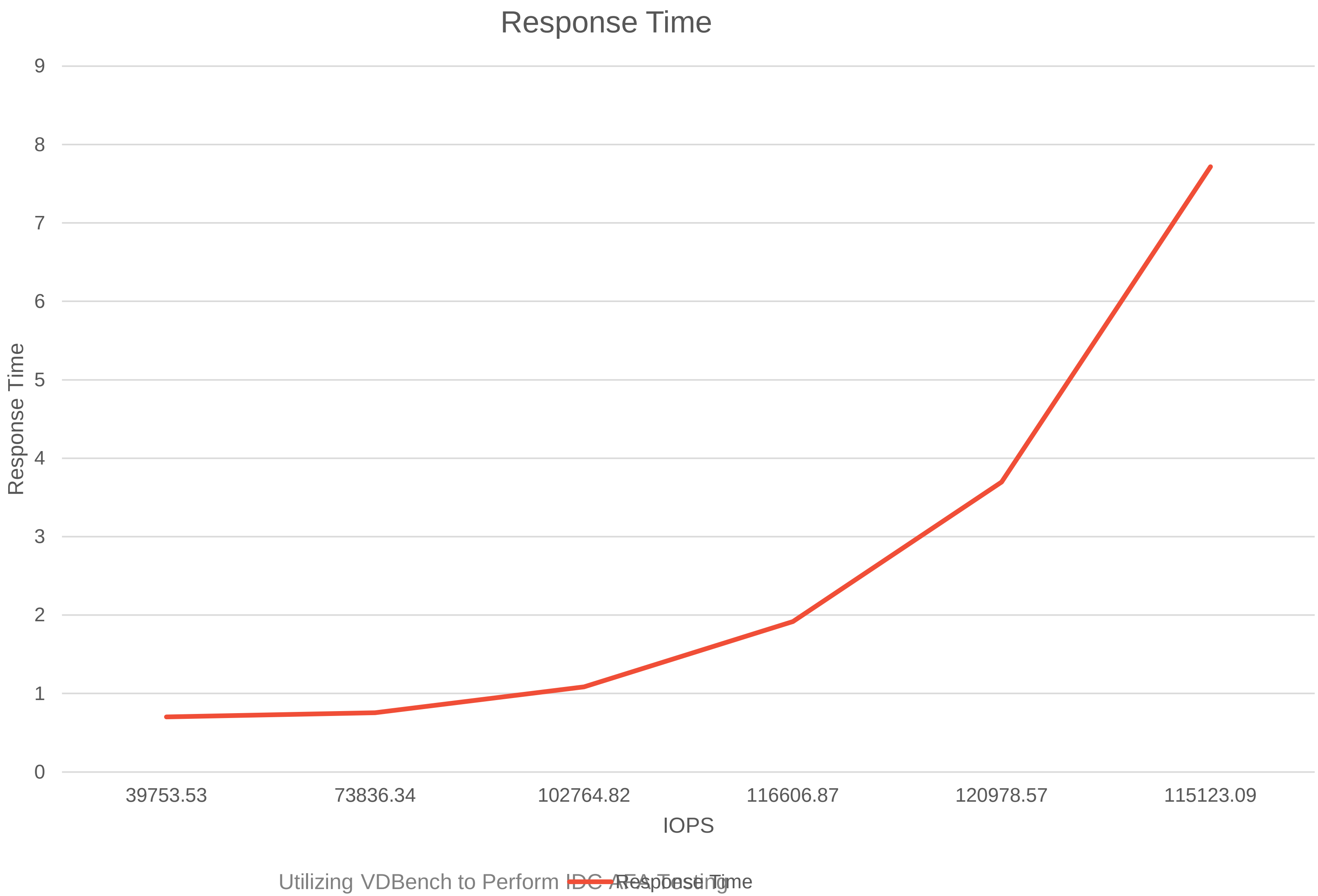
Determine the Inflection Point



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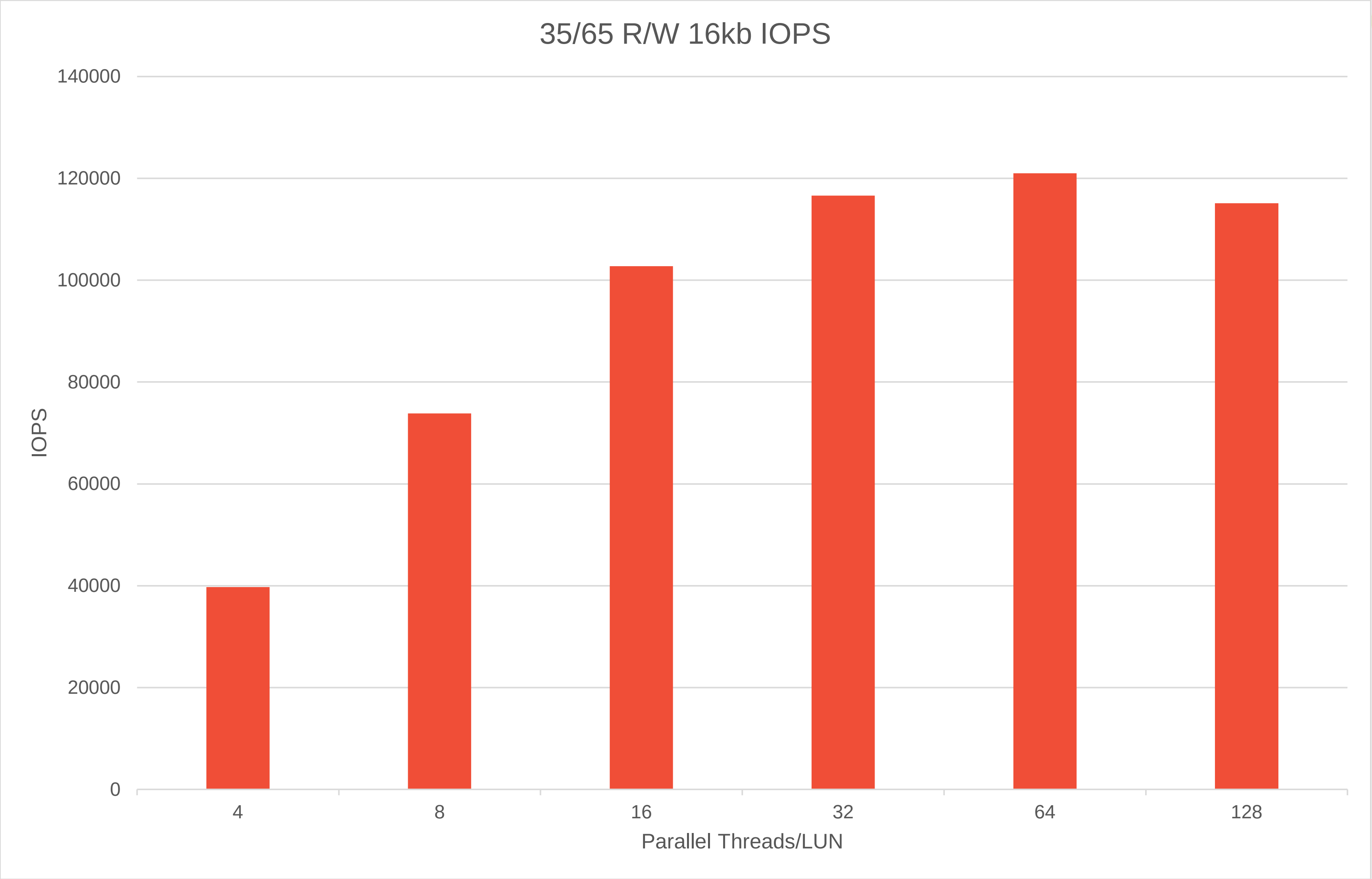
A Better Method May be IOPS



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Phase 3: Functional Testing

- Applies to full SAN type models
- Will be dependent on functions available
  - Thin provisioning
  - Snapshots
  - Replication
  - Encryption – All 840s do this transparently
  - Copy
  - Backup
  - Etc.
- Not covered in this presentation since it is array specific

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Phase 4: Fault Injection Testing

- Determine failure scenarios to test
- Establish base line, steady state mixed workload
- Test Scenarios
- Example Scenarios
  - Fail a path
  - Fail a drive (or flash module)
  - If the array claims to support it, fail two drives (or flash modules) in the same RAID group simultaneously
  - Fail a controller
  - Fail a power supply (and fail a fan separately if the array supports that)
  - Perform a controller firmware upgrade
  - Expand capacity by adding a shelf online

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4KB 20/80 load

4kb_20_80_seq.cfg

```
*SD:        Storage Definitions
sd=default, openflags=o_direct
sd=sd1,lun=\\.\PhysicalDrive1
sd=sd2,lun=\\.\PhysicalDrive2
sd=sd3,lun=\\.\PhysicalDrive3
sd=sd4,lun=\\.\PhysicalDrive4
sd=sd5,lun=\\.\PhysicalDrive5
sd=sd6,lun=\\.\PhysicalDrive6
sd=sd7,lun=\\.\PhysicalDrive7
sd=sd8,lun=\\.\PhysicalDrive8
sd=sd9,lun=\\.\PhysicalDrive9
sd=sd10,lun=\\.\PhysicalDrive10

*WD:        Workload Definitions
wd=wd1,sd=sd*,seekpct=sequential

*RD:        Run Definitions
*Will run 1 test 4kb sequential 2 hours long
rd=rd1,wd=wd1,iorate=max,elapsed=7200,interval=1,forrdpct=(20),forxfersize=(4k),
forthreads=(32)
```


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8KB 65/35 Load

8kb_65_35_ran.cfg

```
*SD:	Storage Definitions
sd=default, openflags=o_direct
sd=sd11,lun=\\.\PhysicalDrive11
sd=sd12,lun=\\.\PhysicalDrive12
sd=sd13,lun=\\.\PhysicalDrive13
sd=sd14,lun=\\.\PhysicalDrive14
sd=sd15,lun=\\.\PhysicalDrive15
sd=sd16,lun=\\.\PhysicalDrive16
sd=sd17,lun=\\.\PhysicalDrive17
sd=sd18,lun=\\.\PhysicalDrive18
sd=sd19,lun=\\.\PhysicalDrive19
sd=sd20,lun=\\.\PhysicalDrive20

*WD:	Workload Definitions
wd=wd1,sd=sd*,seekpct=random

*RD:	Run Definitions
*Will run 1 test 8kb random 2 hours long
rd=rd1,wd=wd1,iorate=max,elapsed=7200,interval=1,forrdpct=(65),forxfersize=(8k),forthreads
=(16)
```


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64 KB 65/35 Load

64kb_65_35_ran.cfg

```
 *SD:        Storage Definitions
sd=default, openflags=o_direct
sd=sd21,lun=\\.\PhysicalDrive21
sd=sd22,lun=\\.\PhysicalDrive22
sd=sd23,lun=\\.\PhysicalDrive23
sd=sd24,lun=\\.\PhysicalDrive24
sd=sd25,lun=\\.\PhysicalDrive25
sd=sd26,lun=\\.\PhysicalDrive26
sd=sd27,lun=\\.\PhysicalDrive27
sd=sd28,lun=\\.\PhysicalDrive28
sd=sd29,lun=\\.\PhysicalDrive29
sd=sd30,lun=\\.\PhysicalDrive30

*WD:        Workload Definitions
wd=wd1,sd=sd*,seekpct=random

*RD:        Run Definitions
*Will run 1 test 64kb 2 hours long
rd=rd1,wd=wd1,iorate=max,elapsed=7200,interval=1,forrdpct=(65),forxfersize=(64k),forthreads=(8)
```


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128 KB 80/20 Load

128kb_80_20_seq.cfg

```
*SD:        Storage Definitions
sd=default, openflags=o_direct
sd=sd31,lun=\\.\PhysicalDrive31
sd=sd32,lun=\\.\PhysicalDrive32
sd=sd33,lun=\\.\PhysicalDrive33
sd=sd34,lun=\\.\PhysicalDrive34
sd=sd35,lun=\\.\PhysicalDrive35
sd=sd36,lun=\\.\PhysicalDrive36
sd=sd37,lun=\\.\PhysicalDrive37
sd=sd38,lun=\\.\PhysicalDrive38
sd=sd39,lun=\\.\PhysicalDrive39

*WD:        Workload Definitions
wd=wd1,sd=sd*,seekpct=sequential

*RD:        Run Definitions
*Will run 1 test 128kb 2 hours long
rd=rd1,wd=wd1,iorate=max,elapsed=7200,interval=1,forrdpct=(80),forxfersize=(128k),forthreads=(4)
```


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Run Loads

Capture outputs to C:\vdbench\output as follows:

Use 4 different sessions and run one of the following commands in each:

c:\vdbench\vdbench -f 4kb_20_80_seq.cfg -o c:\vdbench\output\day_three_4kb –m 10

c:\vdbench\vdbench -f 8kb_65_35_ran.cfg -o c:\vdbench\output\day_three_8kb –m 10

c:\vdbench\vdbench -f 64kb_65_35_ran.cfg -o c:\vdbench\output\day_three_64kb –m 10

c:\vdbench\vdbench -f 128kb_80_20_seq.cfg -o c:\vdbench\output\day_three_128kb –m 9

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Do Failures

For our testing we did the following:

- Fail a path
- Reboot a controller
- Fail a controller (unrack controller)
- Fail a module
- We found the test only required 1.5 hour so we did these additional tests:
- Fail a PSU (pull out cord)
- Fail a battery (pull out battery module)

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Phase 5: Soak Test

- Use the 4 loads from phase 2
- Run each for 12 hours (48 consecutive hours)
- Review results for performance anomalies

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Summary

- Testing and comparing systems can be difficult
- Utilizing IDC guidelines testing is made more consistent
- Using tools like VDBench provides a repeatable and consistent test framework

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Attribution & Feedback

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

Authorship History

Michael Ault, IBM:

Updates:
Incorporated comments 7/22/2015

Additional Contributors

Joseph White
Thomas Rivera

Please send any questions or comments regarding this SNIA Tutorial to ***tracktutorials@snia.org***

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