SPC BENCHMARK 1™

FULL DISCLOSURE REPORT

NETAPP, INC.
NETAPP® AFF A800

SPC-1 V3.6.0

SUBMISSION IDENTIFIER: A32007

SUBMITTED FOR REVIEW: JULY 5, 2018

First Edition – July 2018

THE INFORMATION CONTAINED IN THIS DOCUMENT IS DISTRIBUTED ON AN AS IS BASIS WITHOUT ANY WARRANTY EITHER EXPRESS OR IMPLIED. The use of this information or the implementation of any of these techniques is the customer's responsibility and depends on the customer's ability to evaluate and integrate them into the customer's operational environment. While each item has been reviewed by NetApp, Inc. for accuracy in a specific situation, there is no guarantee that the same or similar results will be obtained elsewhere. Customers attempting to adapt these techniques to their own environment do so at their own risk.

This publication was produced in the United States. NetApp, Inc. may not offer the products, services, or features discussed in this document in other countries, and the information is subject to change with notice. Consult your local NetApp, Inc. representative for information on products and services available in your area.

Trademarks

SPC Benchmark 1, SPC-1, SPC-1 IOPS, SPC-1 LRT and SPC-1 Price-Performance are trademarks of the Storage Performance Council.

NetApp, the NetApp logo, and the marks listed at http://www.netapp.com/TM are trademarks or registered trademarks of NetApp, Inc. in the United States and other countries. All other brands, trademarks, and product names are the property of their respective owners.

Benchmark Specification and Glossary

The official SPC Benchmark 1™ (SPC-1™) specification is available on the website of the Storage Performance Council (SPC) at www.spcresults.org.

The SPC-1™ specification contains a glossary of the SPC-1™ terms used in this publication.

Table of Contents

AUDIT CERTIFICATION

Mr. Jim Laing
NetApp, Inc.
7301 Kit Creek Road
Research Triangle Park, NC 27709

July 3, 2018

I verified the SPC Benchmark 1™ (SPC-1™ V3.6) test execution and performance results of the following Tested Storage Product:

NetApp® AFF A800

The results were:

SPC-1 IOPS™	**2,401,171**
SPC-1 Price-Performance™	**$1,154.53/SPC-1 KIOPS™**
SPC-1 IOPS™ Response Time	0.590 ms
SPC-1 Overall Response Time	0.351 ms
SPC-1 ASU Capacity	182,674 GB
SPC-1 Space Effectiveness Ratio	1.76
SPC-1 ASU Price	$15.18/GB
SPC-1 Total System Price	$2,772,201.07

In my opinion, these performance results were produced in compliance with the SPC requirements for the benchmark.

The testing was executed using the SPC-1 Toolkit Version v3.0.2-1-g823a. The audit process was conducted in accordance with the SPC Policies and met the requirements for the benchmark.

A Letter of Good Faith was issued by the Test Sponsor, stating the accuracy and completeness of the documentation and testing data provided in support of the audit of this result.

A Full Disclosure Report for this result was prepared by InfoSizing, reviewed and approved by the Test Sponsor, and can be found at www.spcresults.org under the Submission Identifier A32007.

63 Lourdes Dr. | Leominster, MA 01453 | 978-343-6562 | www.sizing.com

The independent audit process conducted by InfoSizing included the verifications of the following items:

- The physical capacity of the data repository;
- The total capacity of the Application Storage Unit (ASU);
- The accuracy of the Benchmark Configuration diagram;
- The tuning parameters used to configure the Benchmark Configuration;
- The Workload Generator commands used to execute the testing;
- The validity and integrity of the test result files;
- The compliance of the results from each performance test;
- The compliance of the results from each persistence test;
- The compliance of the submitted pricing model; and
- The differences between the tested and the priced configuration, if any.

The Full Disclosure Report for this result was prepared in accordance with the disclosure requirements set forth in the specification for the benchmark.

The following benchmark requirements, if any, were waived in accordance with the SPC Policies:

> Per SPC-1 v3.6.0 Clause 6.2.5, an exception was made by the auditor to the requirement for an uninterrupted benchmark execution sequence. The execution of the final Persistence Test did not immediately follow the Primary Metrics Test. This exception has no impact on any of the reported metrics.

Respectfully Yours,

Doug Johnson, Certified SPC Auditor

63 Lourdes Dr. | Leominster, MA 01453 | 978-343-6562 | www.sizing.com

LETTER OF GOOD FAITH

Date: June 27, 2018

From: NetApp, Inc.

To: Mr. Doug Johnson, Certified SPC Auditor
PerfLabs, Inc. dba InfoSizing
63 Lourdes Drive
Leominster, MA, 01453-6709

Subject: SPC-1 Letter of Good Faith for the NetApp AFF A800

NetApp, Inc. is the test sponsor for the above listed product. To the best of our knowledge and belief, the required SPC-1 results and materials we have submitted for that product are complete, accurate, and in full compliance with v3.6 of the SPC-1 benchmark specification.

In addition, we have reported any items in the Benchmark Configuration and execution of the benchmark that affected the reported results even if the items are not explicitly required to be disclosed by the SPC-1 benchmark specification.

Signed:

Octavian Tanase
Senior Vice President
ONTAP Storage and Systems Group

Date: 6/27/2018

Date of Signature

SPC BENCHMARK 1™

EXECUTIVE SUMMARY

NETAPP, INC.
NETAPP® AFF A800

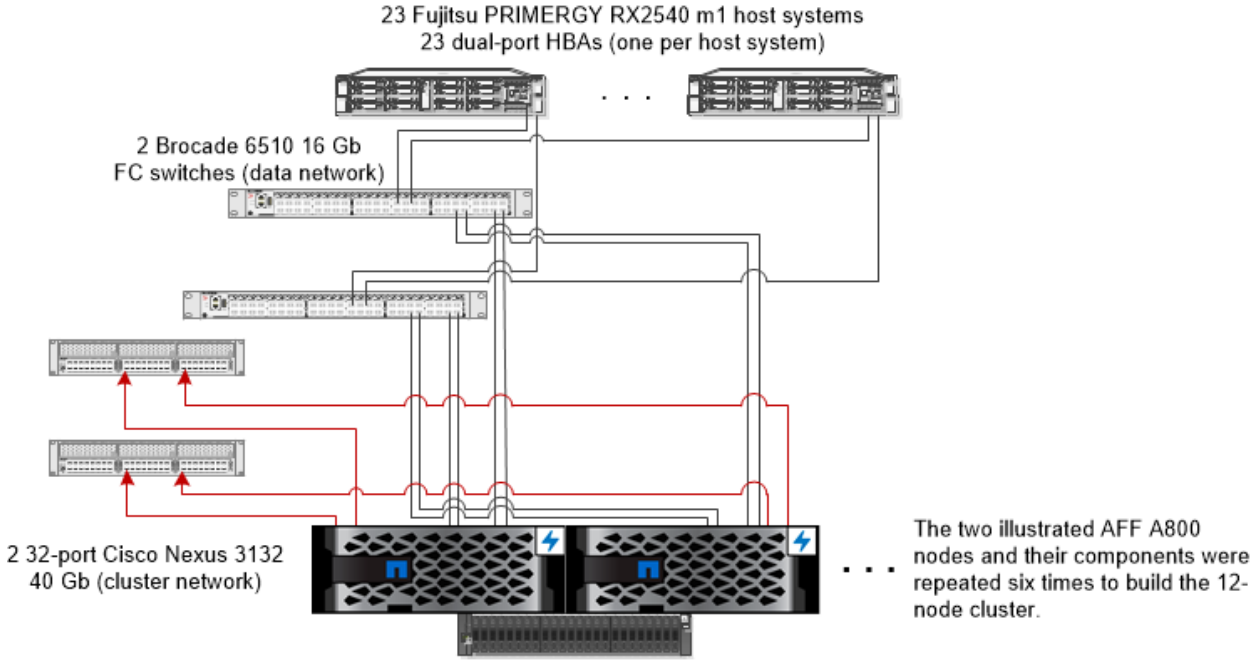
SPC-1 IOPS™	**2,401,171**
SPC-1 Price-Performance™	**$1,154.53/SPC-1 KIOPS™**
SPC-1 IOPS™ Response Time	0.590 ms
SPC-1 Overall Response Time	0.351 ms
SPC-1 ASU Capacity	182,674 GB
SPC-1 Space Effectiveness Ratio	1.76
SPC-1 ASU Price	$15.18/GB
SPC-1 Total System Price	$2,772,201.07
Data Protection Level	Protected 2 (NetApp RAID DP®)
Physical Storage Capacity	276,535 GB
Pricing Currency / Target Country	U.S. Dollars / USA

SPC-1 V3.6.0

SUBMISSION IDENTIFIER: A32007

SUBMITTED FOR REVIEW: JULY 5, 2018

Benchmark Configuration Diagram



NetApp AFF A800 storage system
6 HA controller pairs (12 storage nodes total)

This cluster includes:
1 TB memory/cache per HA pair
24 x 1.9 TB internal NVMe SSDs per HA pair (144 total)
2 QLogic 2672 16 Gb HBA Initiators per server (23 total)
2 Emulex LPe32004 32 Gb HBA Targets per HA pair (12 total)
2 Cisco Nexus 3132 40 Gb 32-port switches (cluster network)
2 Brocade 6510 16 Gb FC 48-port switches (data network)

Tested Storage Product Description

As an end-to-end NVMe-based all-flash array, the AFF A800 system delivers industry-leading performance, density, scalability, security, and network connectivity in a 4U chassis. By combining low-latency NVMe solid-state drives (SSDs) with NVMe over Fibre Channel (NVMe/FC) host connectivity, the AFF A800 delivers extremely low latency and massive throughput in a scaled-out cluster configuration. This all-flash array is built on a unified scale-out architecture extending enterprise-grade flash to the most demanding workloads such as AI and deep learning.

Priced Storage Configuration Components

23 x QLogic 2672 dual-port, 16 Gb host bus adapter (HBA)
NetApp AFF A800 6 HA Controller Pairs (12 nodes total), each pair with: 1 TB cache (6 TB total) 8 x 32 Gbps FC ports (48 ports total) Internal NVMe drive connections (no cards, no cables) 144 x 1.92 TB NVMe SSDs (12 per node, 24 per HA pair)
2 x Brocade 6510 16 Gb FC Switches (Data Network) 2 x Cisco Nexus 3132 32-Port 40Gb (Cluster Network)

Storage Configuration Pricing

Part No.	Description	Source	Qty	Unit Price	Ext. Price	Disc.	Disc. Price
Hardware & Software							
AFF-A800-100-	AFF A800,HA,CTL,AC PS,100G,-C	1	6	250,120.00	1,500,720.00	50%	750,360.00
X4001A-12-C	Drive Pack,12X1.9TB,NVMe,SSD,-C	1	12	44,460.00	533,520.00	50%	266,760.00
SW-FLASH-02-C	ONTAP,Per-0.1TB,Flash-C (BASE BNDL: OS + Protocols)	1	2,736	1,095.00	2,995,920.00	50%	1,497,960.00
X-6510-48-16G-	Switch,Brocade 6510 48-Pt FF Ent 16G SWL SFPs	1	2	17,179.00	34,358.00	50%	17,179.00
X190001	Switch, Cisco Nexus 3132Q-X, 32 QSFP+ ports, low	1	2	13,000.00	26,000.00	50%	13,000.00
X66100-1	Cable,Direct Attach CU SFP+,40Gb,1m	1	2	50.00	100.00	50%	50.00
FXE10-10M2y	Cable,Cntlr-Switch,2m,Pair,LC/LC,Op	2	48	33.56	1,610.88	0%	1,610.88
FXE10-10M10y	Cable,Host-Switch,10m,Pair,LC/LC,Op	2	46	43.88	2,018.48	0%	2,018.48
Qlogic 2672	HBA Initiator,Qlogic 16Gig 2port	3	23	989.99	22,769.77	0%	22,769.77
X1135A-C	HBA Target,Emulex LPe32004,4-port FCP Targt-Init	1	12	6,790.00	81,480.00	50%	40,740.00
X66100-5	Cable,Direct Attach CU SFP+,40Gb,5m	1	24	75.00	1,800.00	50%	900.00
X8712C-EN-R6-	PDU, 1-Phase, 24 Outlet, 30A, NEMA, -C, R6	1	2	115.80	231.60	50%	115.80
X870E-EN-R6-C	Cab,Lighted,Empty,No PDU,No Rails,EN,-C	1	1	1,947.71	1,947.71	50%	973.86
X8778-R6-C	Mounting Bracket, Tie-Down, 32X0, -C, R6	1	12	21.38	256.56	50%	128.28
					Hardware & Software Subtotal		**2,614,566.07**
Support & Maintenance							
CS-O2-4HR-VA	SupportEdge Premium 4hr Onsite,VA	1	6	52,545.00	315,270.00	50%	157,635.00
					Support & Maintenance Subtotal		**157,635.00**
SPC-1 Total System Price							**2,772,201.07**
SPC-1 IOPS™							2,401,171
SPC-1 Price-Performance™ ($/SPC-1 KIOPS™)							**1,154.53**
SPC-1 ASU Capacity (GB)							182,674
SPC-1 ASU Price ($/GB)							**15.18**

Pricing Details: The following key lists the price sources used above.

1. NetApp, Inc.
2. Rexel USA
3. Serverpartdeals.com

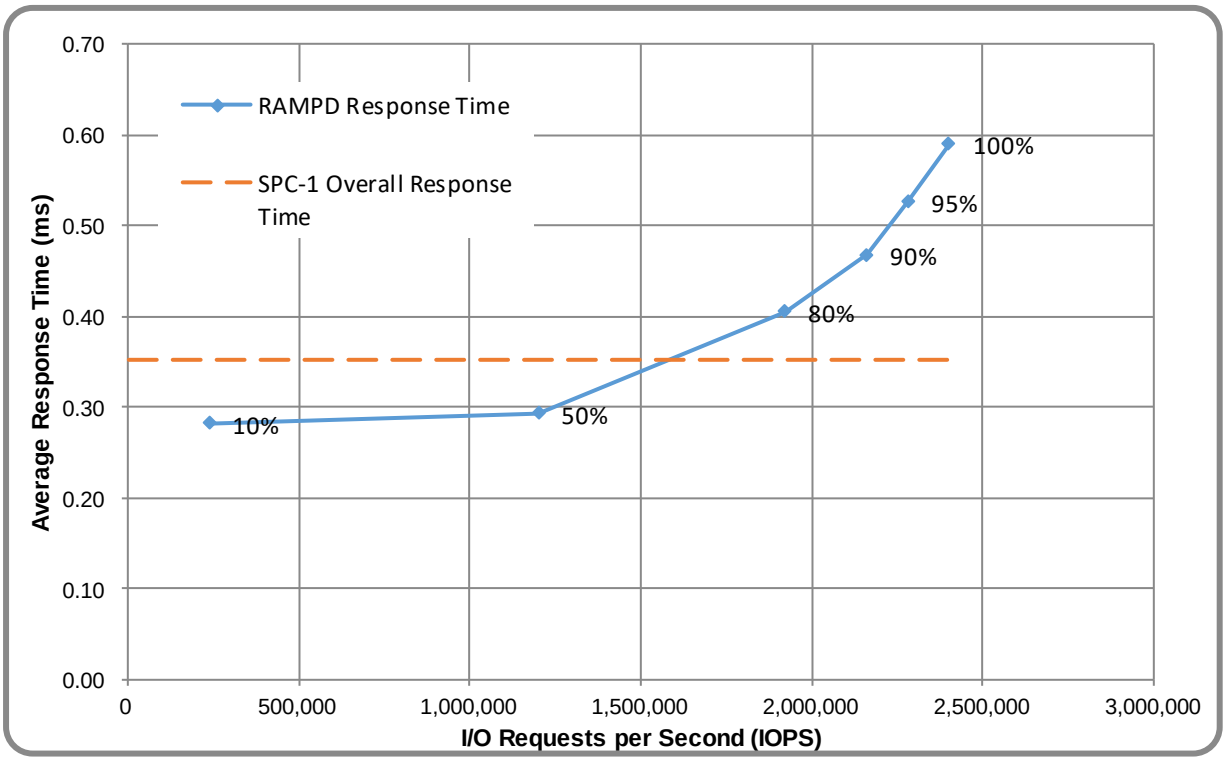
Please see Appendix B for third-party price quotations.

Discount Details: The discounts shown are based on the storage capacity purchased and are generally available.

Warranty: The 3-year maintenance and support included in the above pricing meets or exceeds a 24x7 coverage with a 4-hour response time.

Availability Date: currently available.

Response Time and Throughput Graph



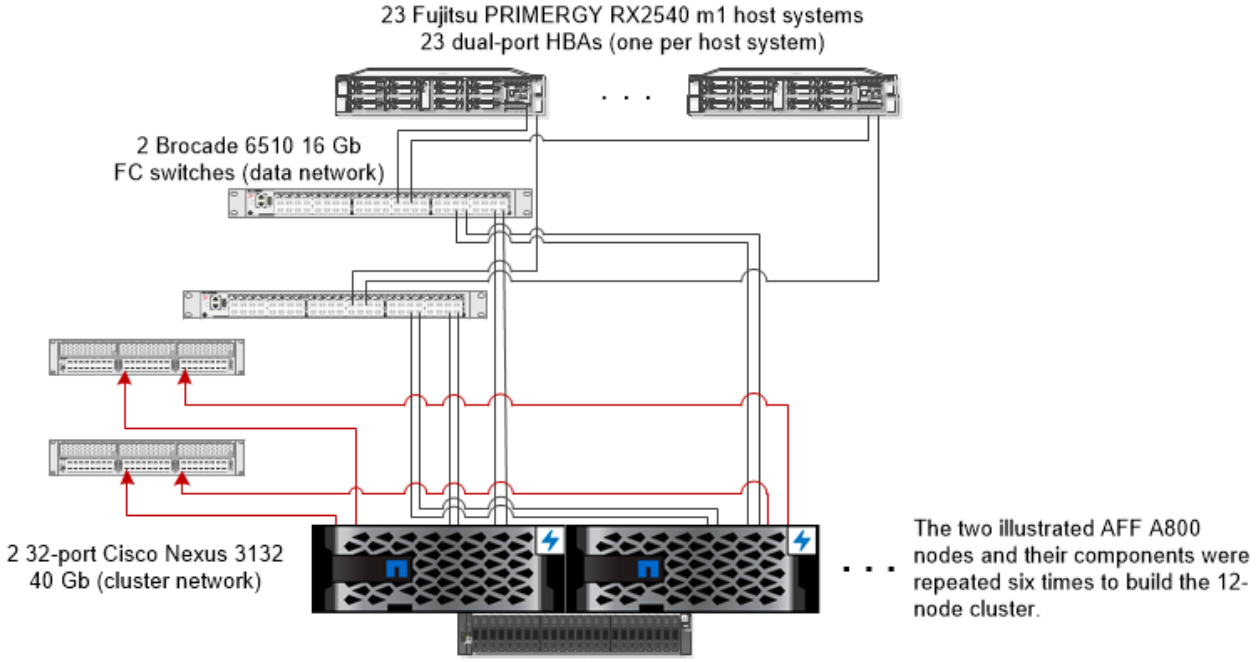
Contact Information	
Test Sponsor Primary Contact	NetApp, Inc. – www.netapp.com James Laing – jim.laing@netapp.com
SPC Auditor	InfoSizing – www.sizing.com Doug Johnson – doug@sizing.com

Revision Information	
SPC Benchmark 1™ Revision	v3.6.0
SPC-1 Workload Generator Revision	v3.0.2-1-g823a
Publication Revision History	Initial Publication

CONFIGURATION INFORMATION

Benchmark Configuration and Tested Storage Configuration

The following diagram illustrates the Benchmark Configuration (BC), including the Tested Storage Configuration (TSC) and the Host System(s).



NetApp AFF A800 storage system
6 HA controller pairs (12 storage nodes total)

This cluster includes:
1 TB memory/cache per HA pair
24 x 1.9 TB internal NVMe SSDs per HA pair (144 total)
2 QLogic 2672 16 Gb HBA Initiators per server (23 total)
2 Emulex LPe32004 32 Gb HBA Targets per HA pair (12 total)
2 Cisco Nexus 3132 40 Gb 32-port switches (cluster network)
2 Brocade 6510 16 Gb FC 48-port switches (data network)

Storage Network Configuration

Each of the 23 host systems has 2 x 16 Gb FC connections to the FC network via the Brocade FC switches. Each of the 12 storage nodes has 4 FC connections to the FC network via the Brocade FC switches.

There were no specific port mappings for any of the switches in the TSC. However, one of the ports on each HBA was connected to one data network switch, and the other port on each HBA was connected to the other data network switch. This same approach was applied to the connections from the controller nodes to the data network switches and the cluster network switches. This approach was used to improve reliability and redundancy in a business-critical environment and not for performance reasons.

Host System and Tested Storage Configuration Components

The following table lists the components of the Host System(s) and the TSC.

Host Systems
23 x Fujitsu PRIMERGY RX2540 M1 2 x Intel Xeon E5-2670 v3 (2.30 GHz, 12 Core, 30 MB L3) 256 GB Main Memory Red Hat Enterprise Linux Server 6.9 (64-bit)
Tested Storage Configuration
23 x QLogic 2672 dual-port, 16Gb HBAs
NetApp AFF A800 6 HA controller pairs (12 nodes total), each pair with: 1 TB cache (6 TB total) 8 x 32 Gbps FC ports (48 ports total) Internal NVMe drive connections (no cards, no cables) 144 x 1.92 TB NVMe SSDs (12 per node, 24 per HA pair)
2 x Brocade 6510 16 Gb FC Switches (Data Network) 2 x Cisco Nexus 3132 32-Port 40Gb (Cluster Network)

Differences Between Tested and Priced Storage Configurations

There were no differences between the TSC and the Priced Storage Configuration (PSC).

Component Changes in Revised Full Disclosure Report

The following table outlines component changes that were made in revisions to this Full Disclosure Report.

Original Component	Revised Component	Description of Change
n/a	n/a	Initial submission

Benchmark Configuration Creation Process

Customer Tuning Parameters and Options

All the customer tuning parameters and options that have been altered from their default values for this benchmark are included in Appendix C and in the Supporting Files (see Appendix A).

Tested Storage Configuration Creation

A detailed description of how the logical representation of the TSC was created is included in Appendix D and in the Supporting Files (see Appendix A).

Tested Storage Configuration Inventory

An inventory of the components in the TSC, as seen by the Benchmark Configuration, is included in Appendix E and in the Supporting Files (see Appendix A).

Workload Generator Storage Configuration

The SPC-1 Workload Generator storage configuration commands and parameters used to invoke the execution of the tests are included in Appendix F and in the Supporting Files (see Appendix A).

Logical Volume Capacity and Application Storage Unit Mapping

The following table details the capacity of the Application Storage Units (ASUs) and how they are mapped to logical volumes (LVs). All capacities are reported in GB.

	LVs / ASU	LV Capacity	Used / LV	Total / ASU	% ASU Capacity	Optimized*
ASU-1	1	82,204.0	82,204.0	82,204.0	45.0%	Yes
ASU-2	1	82,204.3	82,204.3	82,204.3	45.0%	Yes
ASU-3	1	18,265.8	18,265.8	18,265.8	10.0%	Yes
	SPC-1 ASU Capacity			182,674	*See Space Optimization Techniques	

Physical Storage Capacity and Utilization

The following table details the Physical Capacity of the storage devices and the Physical Capacity Utilization (percentage of Total Physical Capacity used) in support of hosting the ASUs. All capacities are reported in GB.

Devices	Count	Physical Capacity	Total Capacity
NVMe SSD	144	1,920.4	276,535.2
Total Physical Capacity			**276,535**
Physical Capacity Utilization			**66.06%**

Data Protection

The data protection level used for all LVs was **Protected 2 (RAID DP®)**, which provides double-parity RAID protection against data loss with negligible performance overhead and no cost penalty compared to single-parity RAID.

BENCHMARK EXECUTION RESULTS

This portion of the Full Disclosure Report documents the results of the various SPC-1 Tests, Test Phases, and Test Runs.

Benchmark Execution Overview

Workload Generator Input Parameters

The SPC-1 Workload Generator commands and input parameters for the Test Phases are presented in the Supporting Files (see Appendix A).

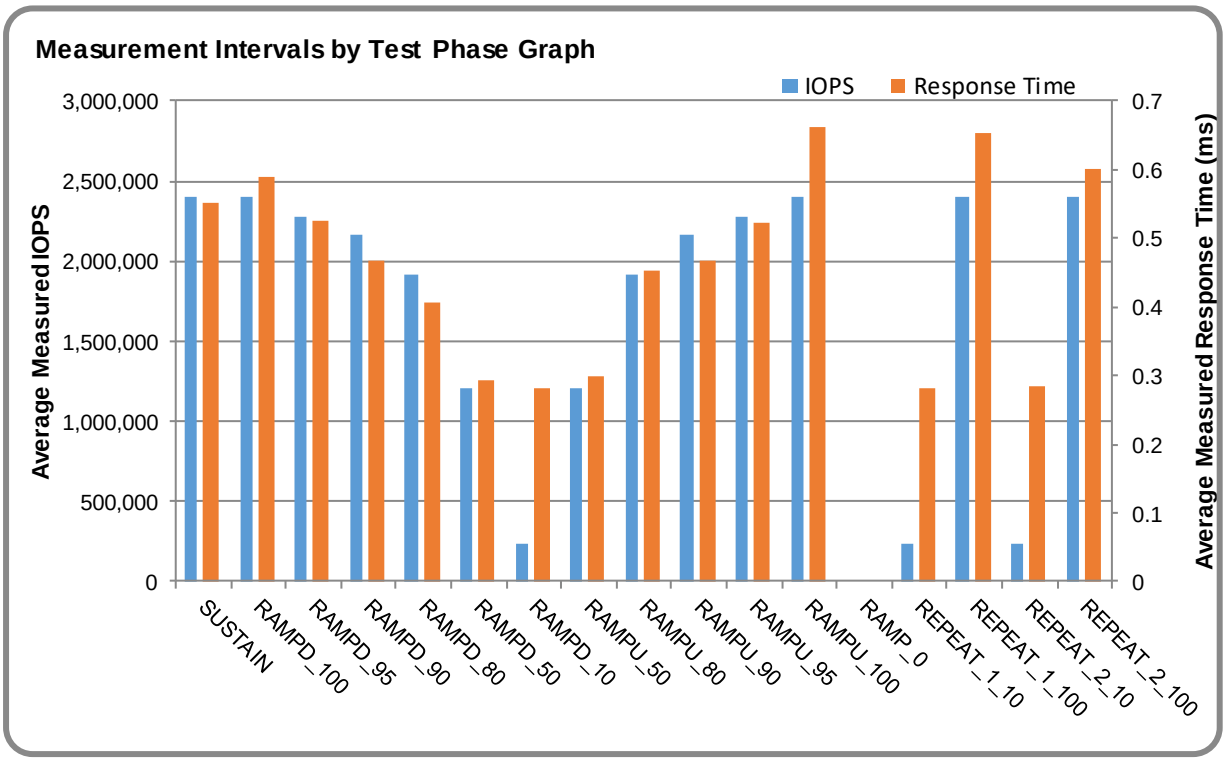
Primary Metrics Test Phases

The benchmark execution consists of the Primary Metrics Test Phases, including the Test Phases SUSTAIN, RAMPD_100 to RAMPD_10, RAMPU_50 to RAMPU_100, RAMP_0, REPEAT_1 and REPEAT_2.

Each Test Phase starts with a transition period followed by a Measurement Interval (MI).

Measurement Intervals by Test Phase Graph

The following graph presents the average IOPS and the average Response Times measured over the MI of each Test Phase.



Exception and Waiver

Per SPC-1 v3.6.0 Clause 6.2.5, an exception was made by the auditor to the requirement for an uninterrupted benchmark execution sequence. The execution of the final Persistence Test did not immediately follow the Primary Metrics Test. This exception has no impact on any of the reported metrics.

SUSTAIN Test Phase

SUSTAIN – Results File

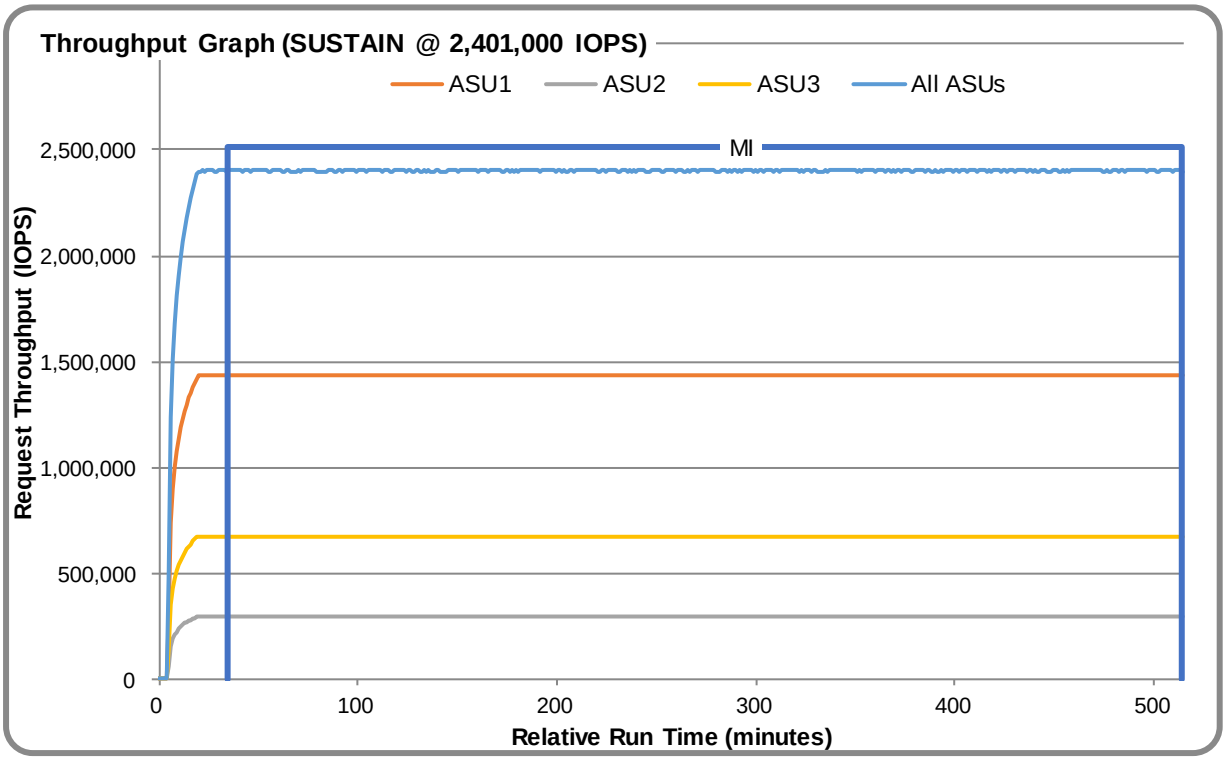
The results file generated during the execution of the SUSTAIN Test Phase is included in the Supporting Files (see Appendix A) as follows:

- **SPC1_METRICS_0_Raw_Results.xlsx**

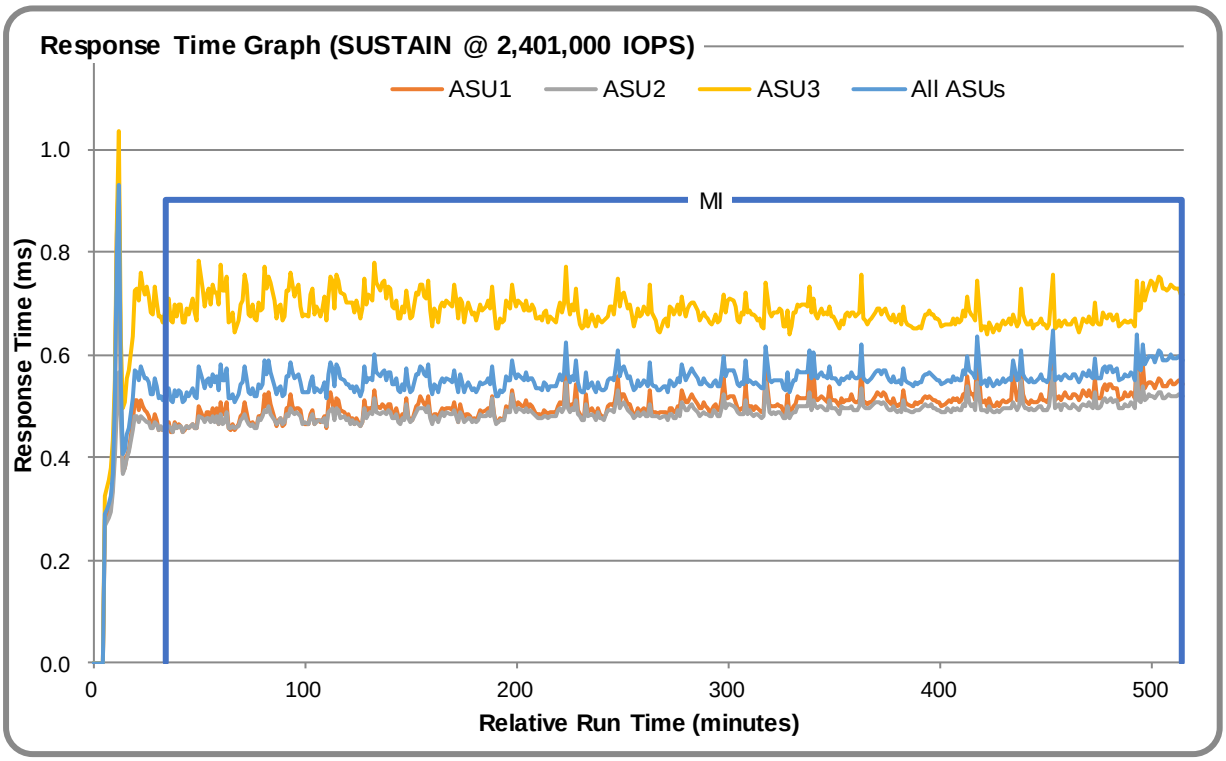
SUSTAIN – Execution Times

Interval	Start Date & Time	End Date & Time	Duration
Transition Period	12-Jun-18 02:07:04	12-Jun-18 02:37:04	0:30:00
Measurement Interval	12-Jun-18 02:37:04	12-Jun-18 10:37:05	8:00:01

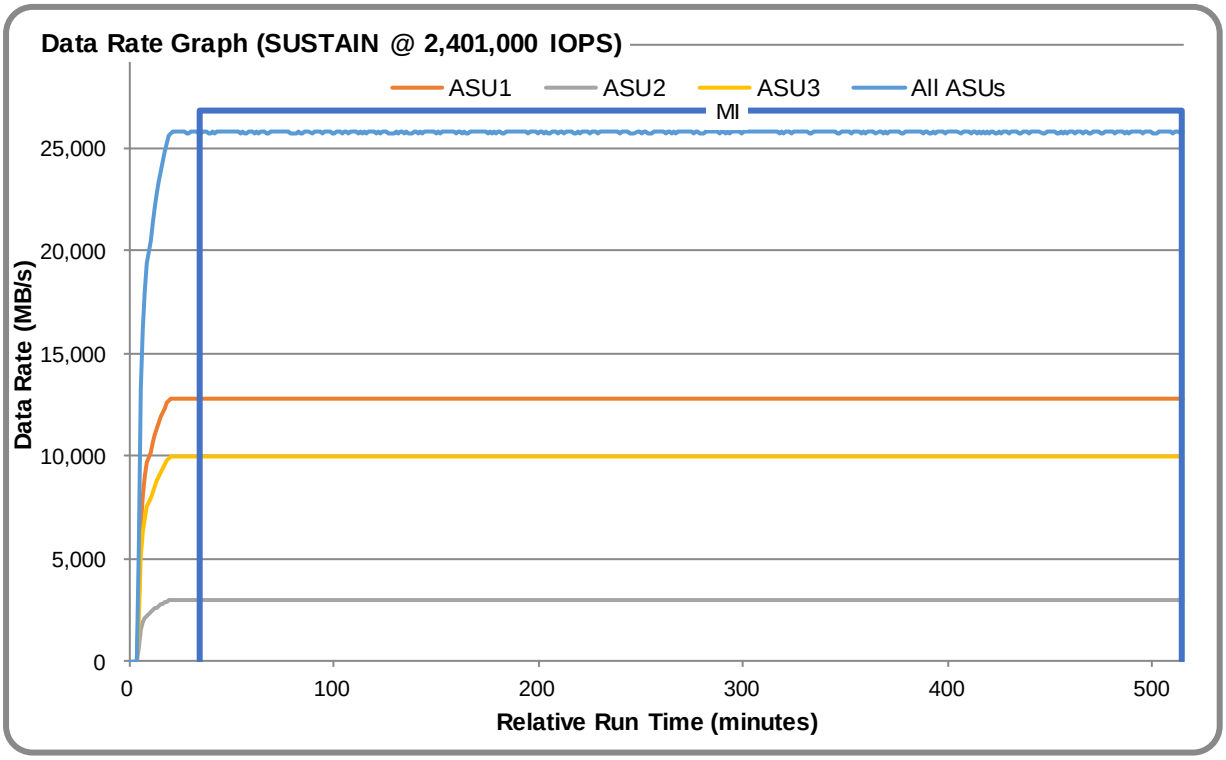
SUSTAIN – Throughput Graph



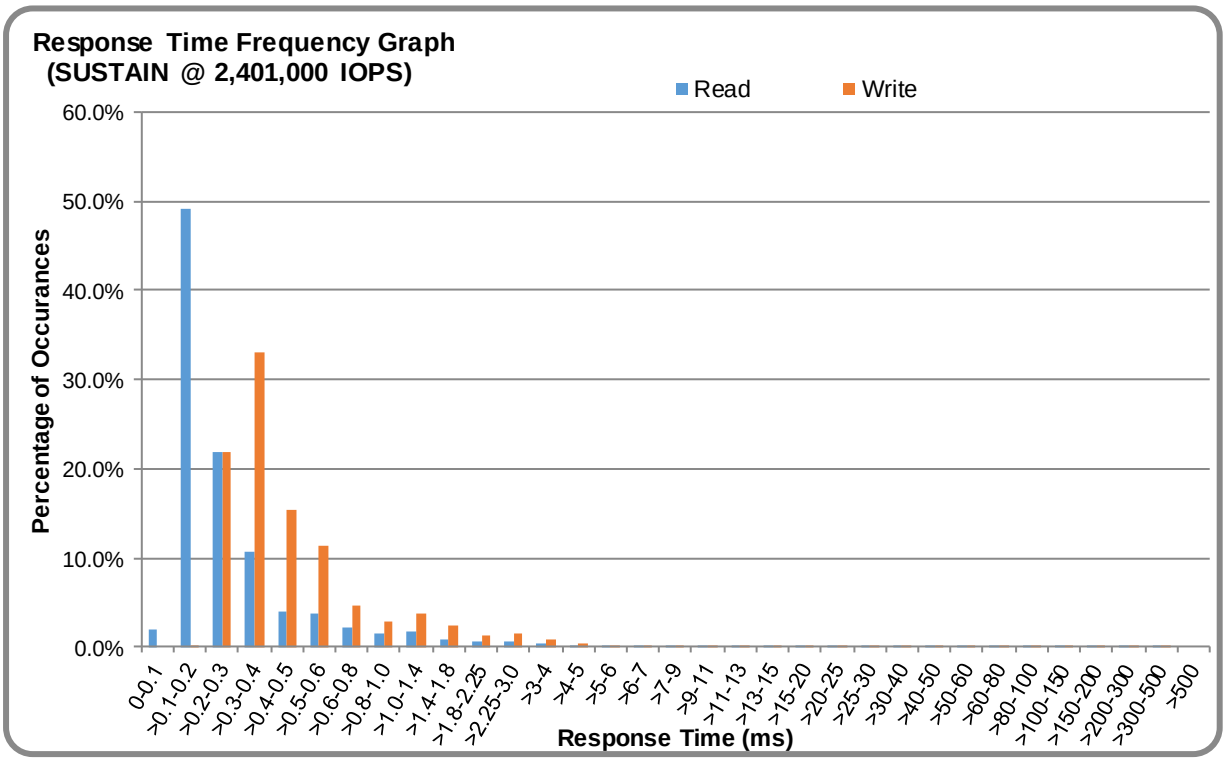
SUSTAIN – Response Time Graph



SUSTAIN – Data Rate Graph



SUSTAIN – Response Time Frequency Graph



SUSTAIN – Intensity Multiplier

The following table lists the targeted intensity multiplier (Defined), the measured intensity multiplier (Measured) for each I/O stream, its coefficient of variation (Variation), and the percentage of difference (Difference) between Defined and Measured.

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
Defined	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
Measured	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
Variation	0.0004	0.0001	0.0003	0.0002	0.0006	0.0003	0.0004	0.0001
Difference	0.008%	0.002%	0.004%	0.001%	0.003%	0.004%	0.003%	0.002%

RAMPD_100 Test Phase

RAMPD_100 – Results File

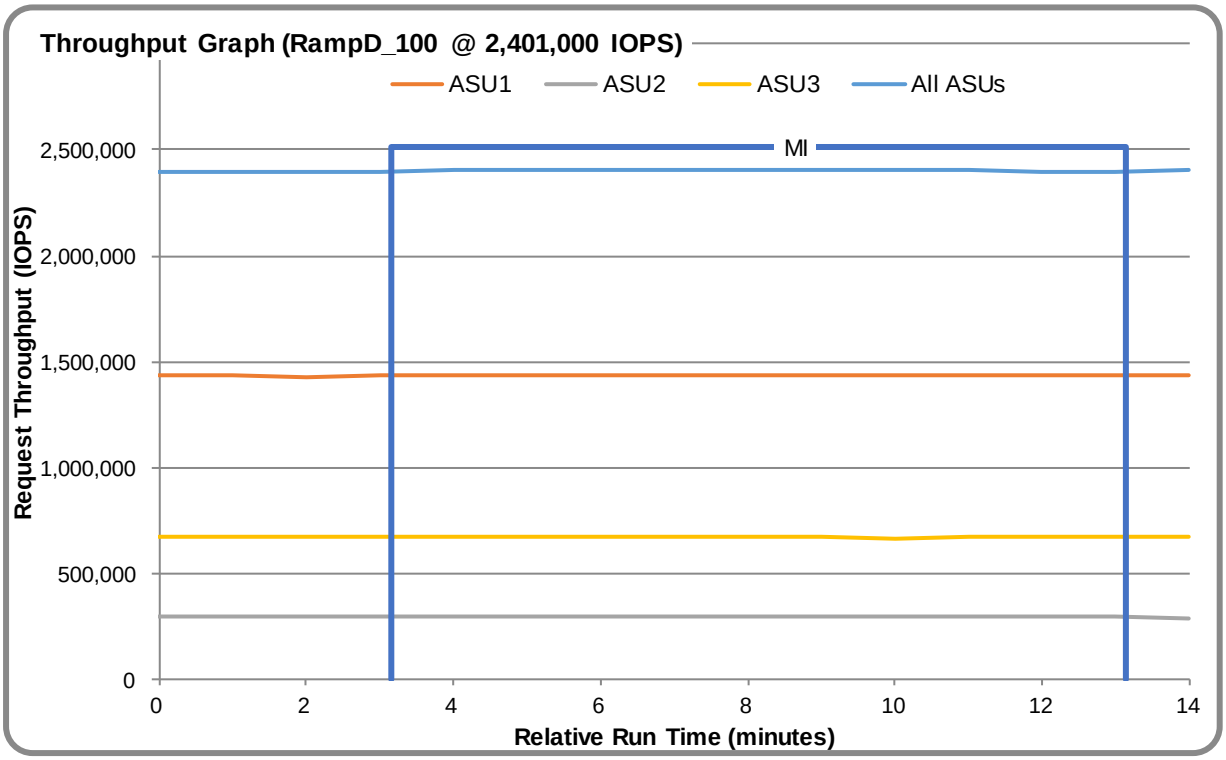
The results file generated during the execution of the RAMPD_100 Test Phase is included in the Supporting Files (see Appendix A) as follows:

- **SPC1_METRICS_0_Raw_Results.xlsx**

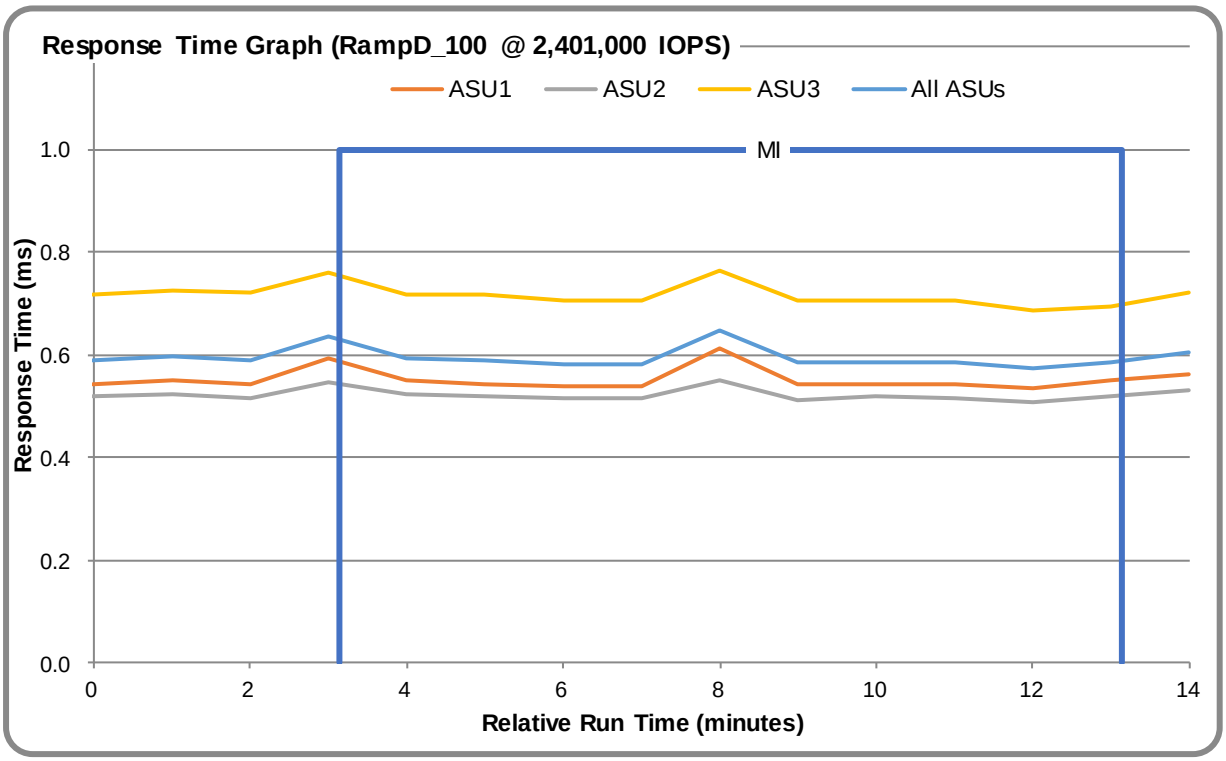
RAMPD_100 – Execution Times

Interval	Start Date & Time	End Date & Time	Duration
Transition Period	12-Jun-18 10:38:04	12-Jun-18 10:41:05	0:03:01
Measurement Interval	12-Jun-18 10:41:05	12-Jun-18 10:51:05	0:10:00

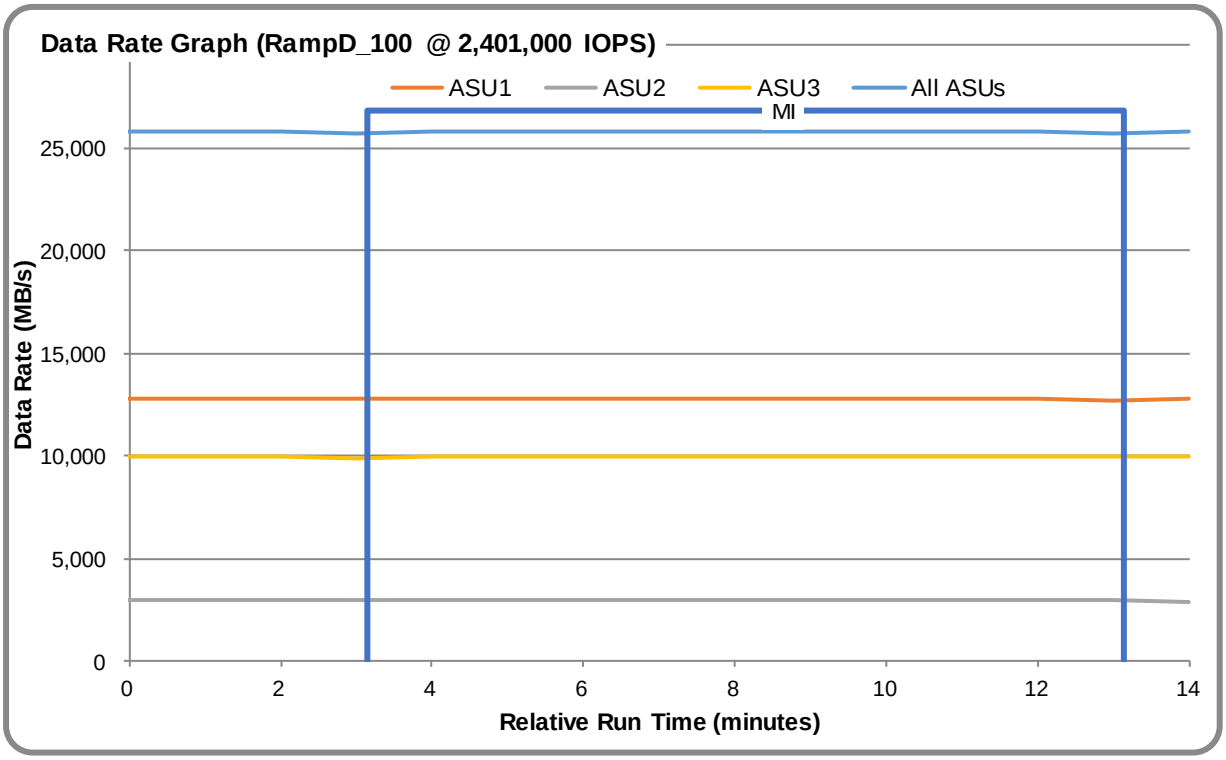
RAMPD_100 – Throughput Graph



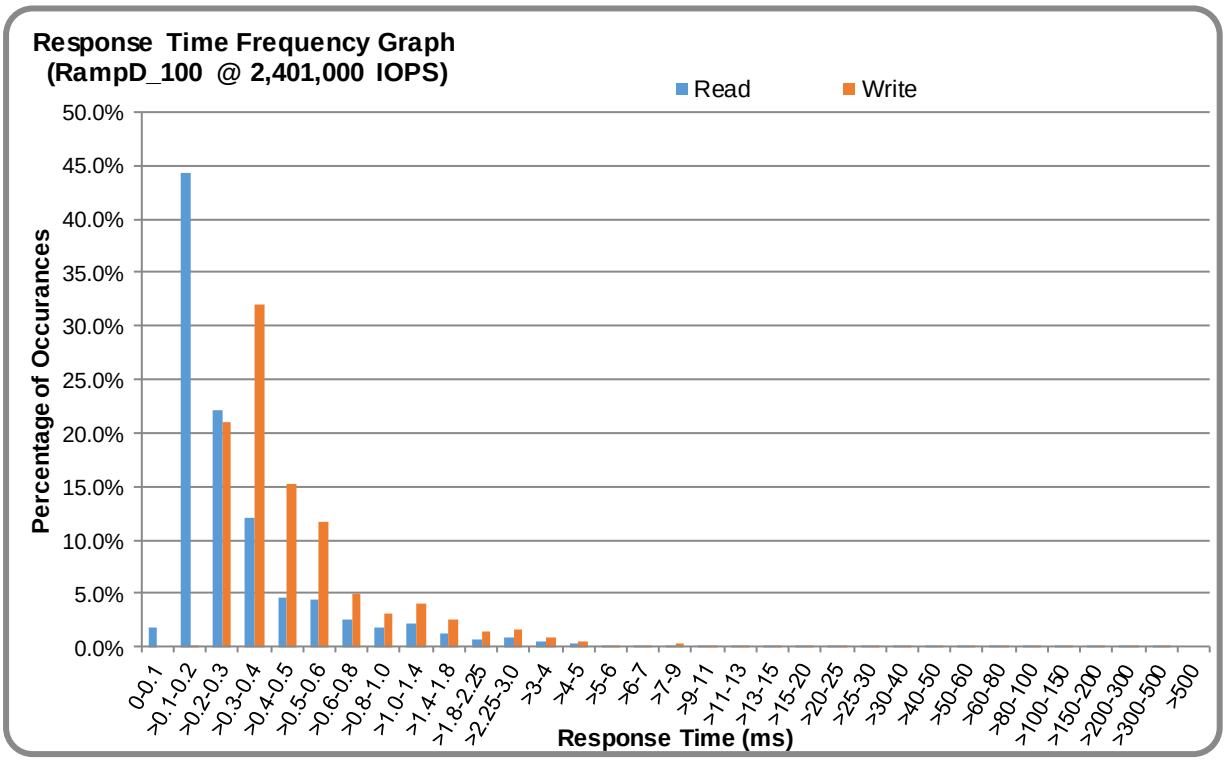
RAMPD_100 – Response Time Graph



RAMPD_100 – Data Rate Graph



RAMPD_100 – Response Time Frequency Graph



RAMPD_100 – Intensity Multiplier

The following table lists the targeted intensity multiplier (Defined), the measured intensity multiplier (Measured) for each I/O stream, its coefficient of variation (Variation), and the percentage of difference (Difference) between Defined and Measured.

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
Defined	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
Measured	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
Variation	0.0004	0.0001	0.0002	0.0002	0.0006	0.0001	0.0003	0.0001
Difference	0.003%	0.002%	0.003%	0.003%	0.035%	0.022%	0.009%	0.002%

RAMPD_100 – I/O Request Summary

I/O Requests Completed in the Measurement Interval	1,440,695,660
I/O Requests Completed with Response Time <= 30 ms	1,440,543,621
I/O Requests Completed with Response Time > 30 ms	152,039

Response Time Ramp Test

Response Time Ramp Test – Results File

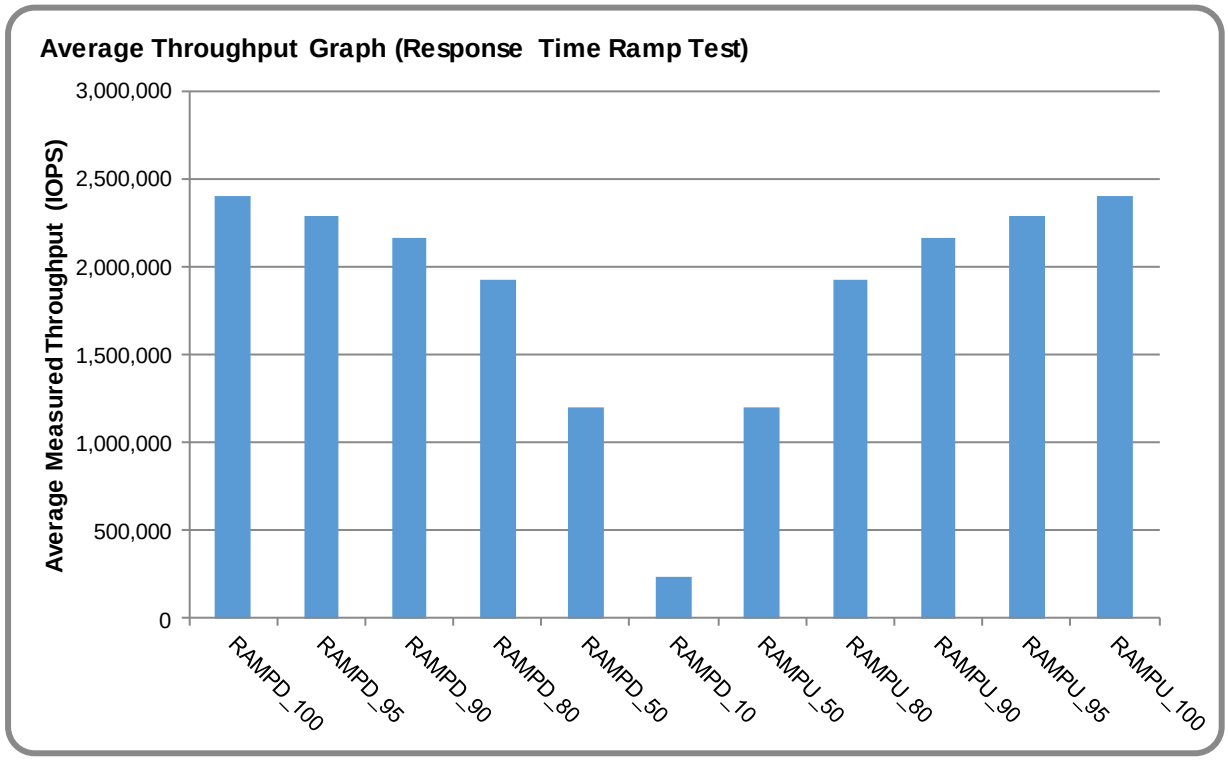
The results file generated during the execution of the Response Time Ramp Test is included in the Supporting Files (see Appendix A) as follows:

- **SPC1_METRICS_0_Raw_Results.xlsx**

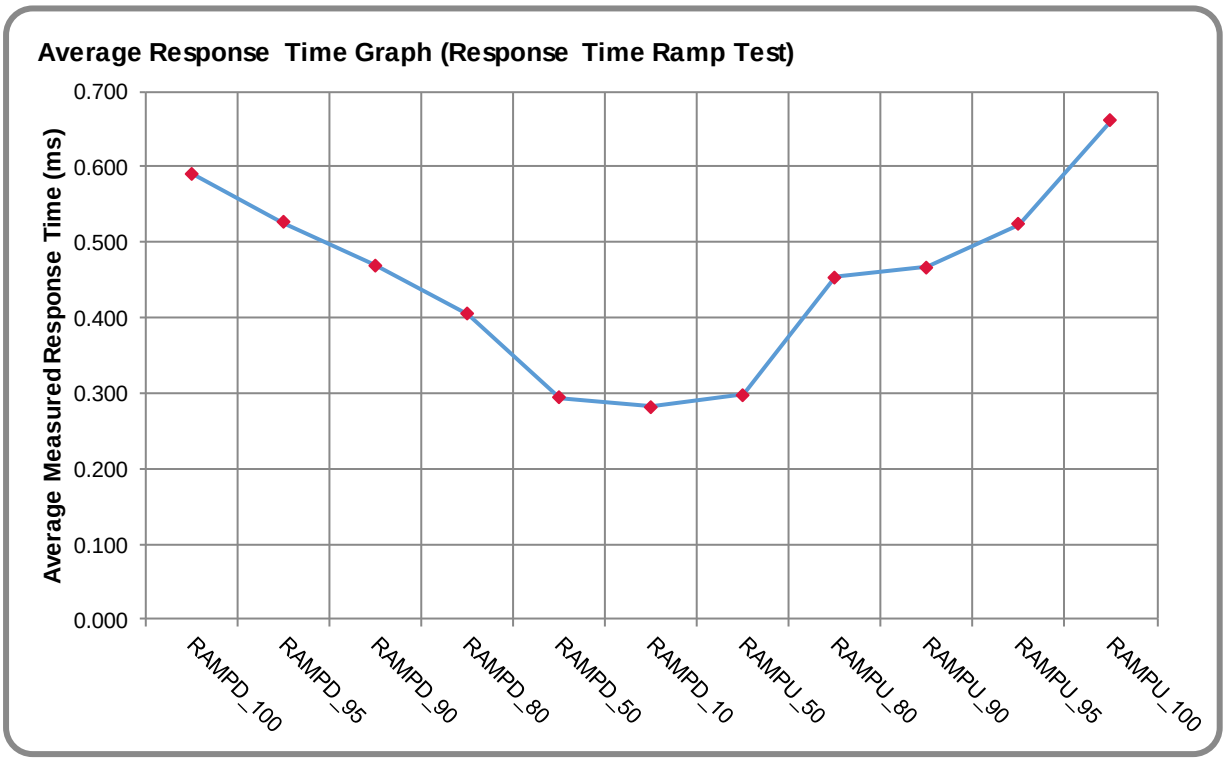
Response Time Ramp Test – Phases

The Response Time Ramp Test is comprised of 11 Test Phases, including six Ramp-Down Phases (executed at 100%, 95%, 90%, 80%, 50%, and 10% of the Business Scaling Unit) and five Ramp-Up Phases (executed at 50%, 80%, 90%, 95%, and 100% of the Business Scaling Unit).

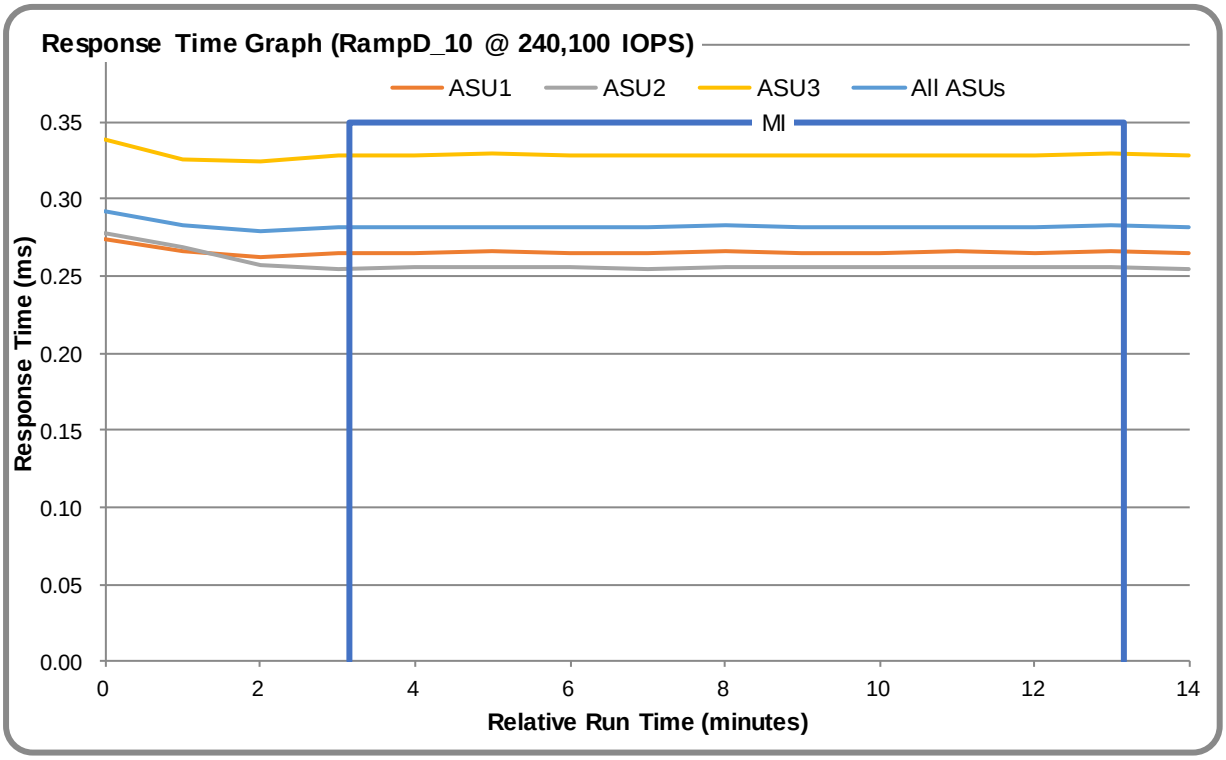
Response Time Ramp Test – Average Throughput Graph



Response Time Ramp Test – Average Response Time Graph



Response Time Ramp Test – RAMPD_10 Response Time Graph



Repeatability Test

Repeatability Test Results File

The results file generated during the execution of the Repeatability Test is included in the Supporting Files (see Appendix A) as follows:

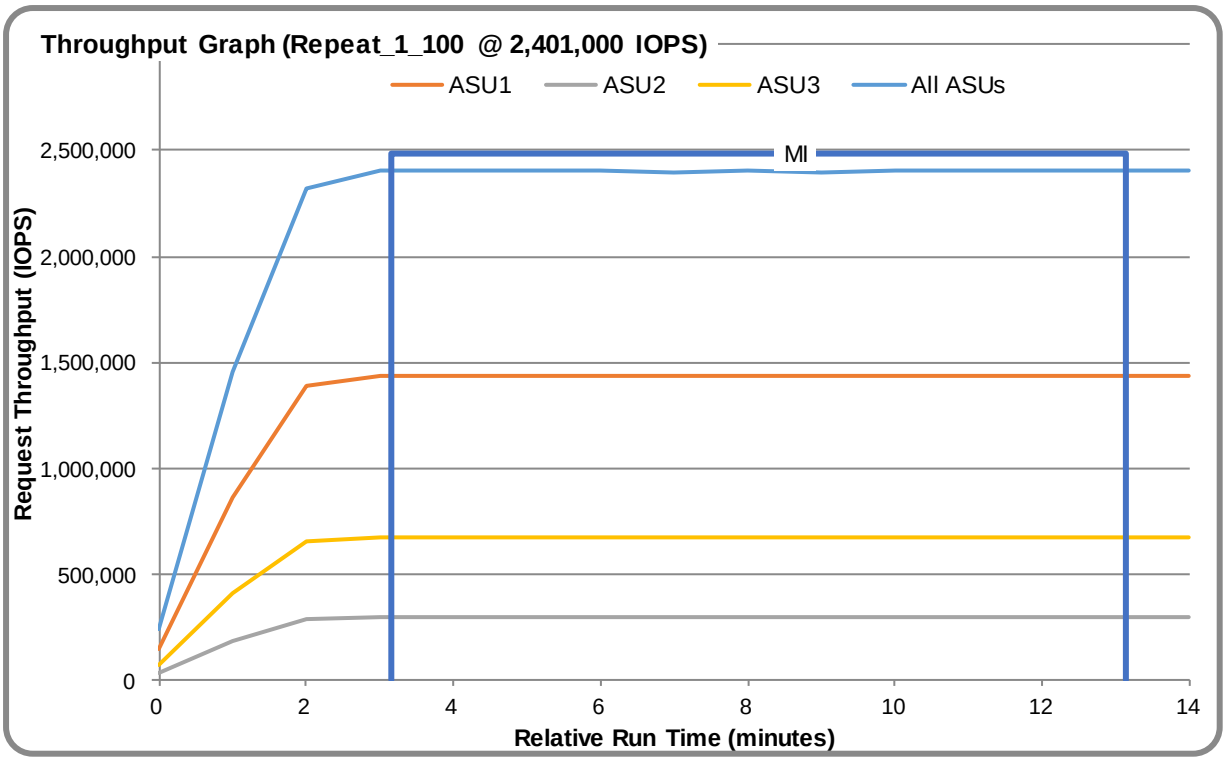
- **SPC1_METRICS_0_Raw_Results.xlsx**

Repeatability Test Results

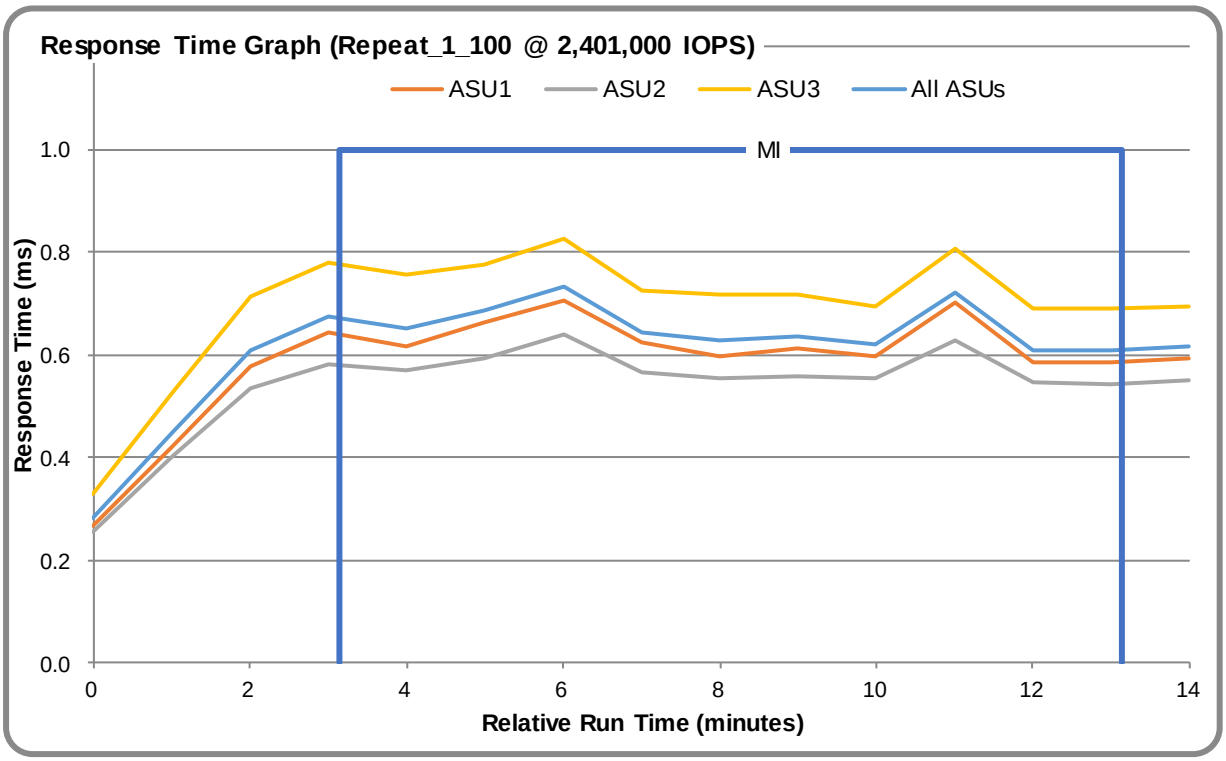
The throughput measurements for the Response Time Ramp Test (RAMPD) and the Repeatability Test Phases (REPEAT_1 and REPEAT_2) are listed in the table below.

Test Phase	100% IOPS	10% IOPS
RAMPD	2,401,171.8	240,124.6
REPEAT_1	2,401,157.2	240,088.5
REPEAT_2	2,401,193.1	240,112.4

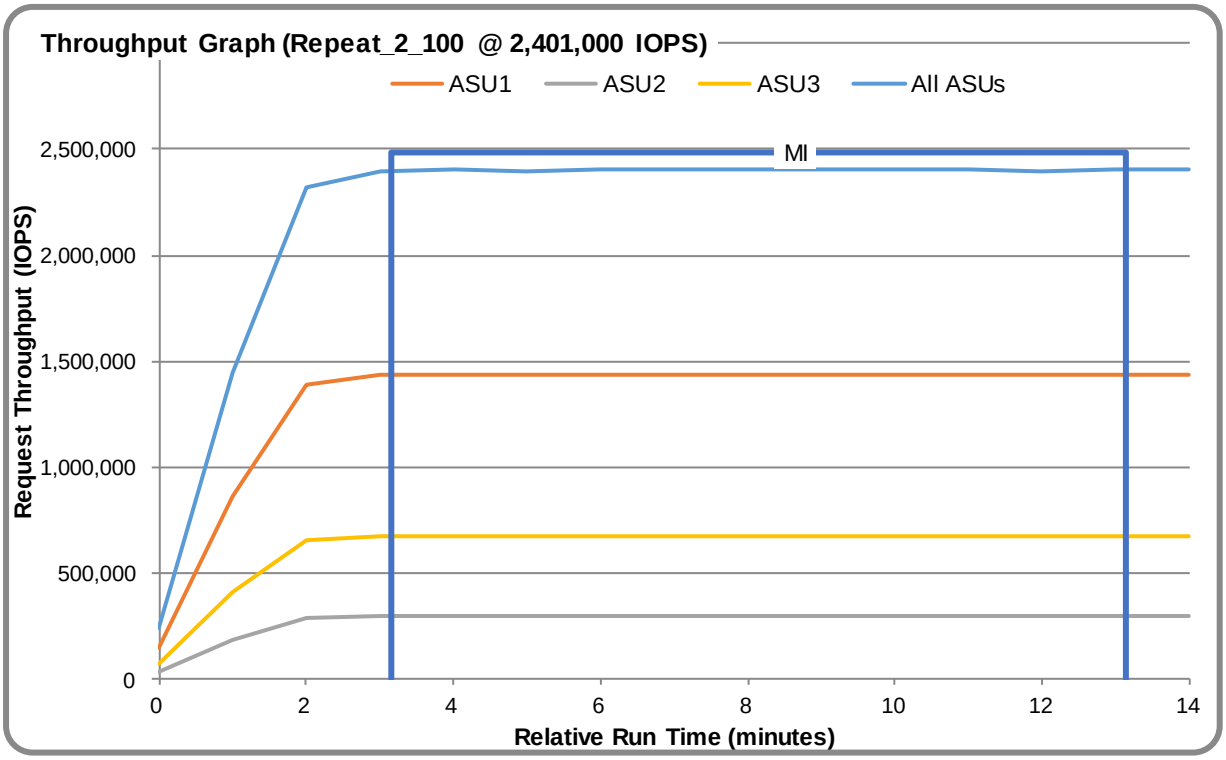
REPEAT_1_100 – Throughput Graph



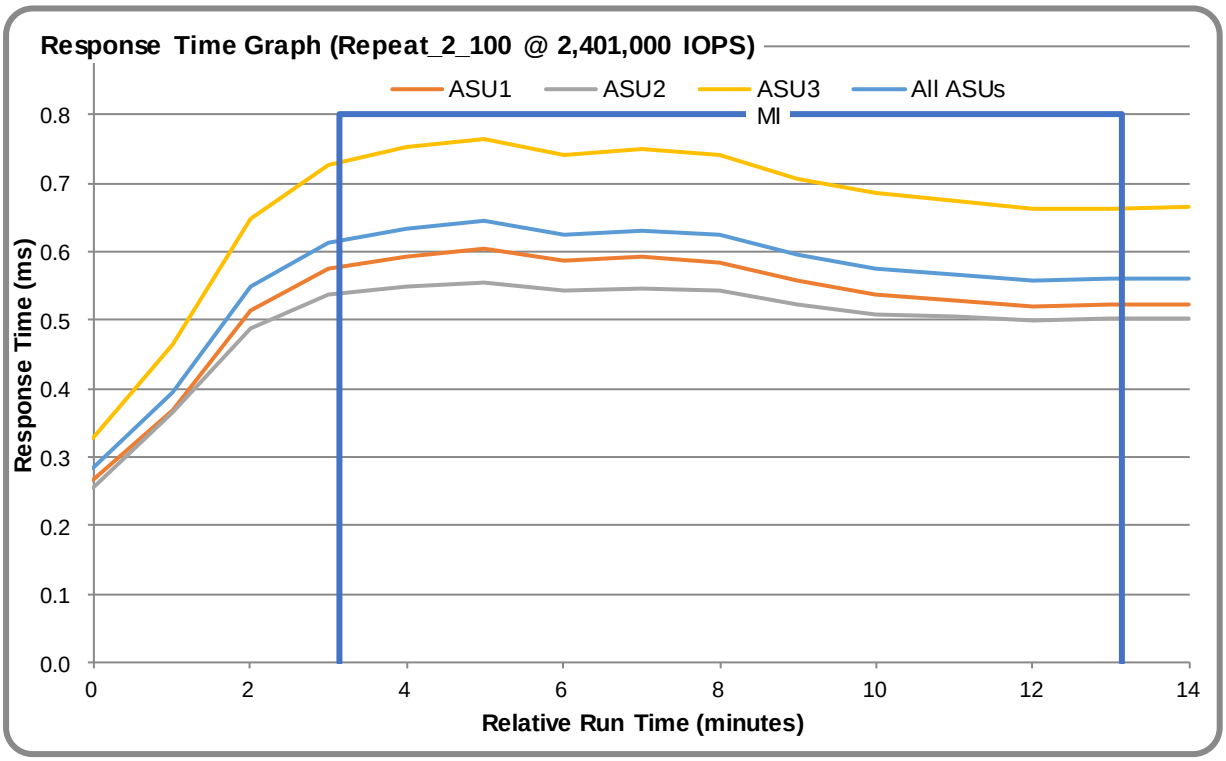
REPEAT_1_100 – Response Time Graph



REPEAT_2_100 – Throughput Graph



REPEAT_2_100 – Response Time Graph



Repeatability Test – Intensity Multiplier

The following tables lists the targeted intensity multiplier (Defined), the measured intensity multiplier (Measured) for each I/O stream, its coefficient of variation (Variation), and the percent of difference (Difference) between Defined and Measured.

REPEAT_1_100 Test Phase

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
Defined	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
Measured	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
Variation	0.0004	0.0002	0.0004	0.0002	0.0005	0.0002	0.0005	0.0001
Difference	0.019%	0.000%	0.001%	0.000%	0.024%	0.002%	0.002%	0.000%

REPEAT_2_100 Test Phase

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
Defined	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
Measured	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
Variation	0.0006	0.0001	0.0002	0.0002	0.0007	0.0004	0.0004	0.0001
Difference	0.003%	0.008%	0.008%	0.000%	0.019%	0.011%	0.013%	0.003%

Space Optimization Techniques

Description of Utilized Techniques

AFF systems are built with innovative inline data reduction technologies that provide significant space savings for a typical use case.

• The inline data compaction technology uses an innovative approach to place multiple logical data blocks from the same volume into a single 4KB block. It provides substantial space savings in addition to inline compression for database workloads that have relatively small I/O sizes.

• The inline compression has a near-zero performance impact. Incompressible data detection eliminates wasted cycles.

• The inline deduplication increases space savings by eliminating redundant blocks.

See NetApp technical report TR-4476 for complete details on implementing NetApp data compression, NetApp deduplication, and NetApp data compaction running on NetApp ONTAP® software.

Physical Free Space Metrics

The following table lists the Physical Free Space as measured at each of the required points during test execution. If space optimization techniques were not used, "NA" is reported.

Physical Free Space Measurement	Free Space (GB)
After Logical Volume Creation	214,457.80
After ASU Pre-Fill	103,811.17
After Repeatability Test Phase	92,844.16

Space Optimization Metrics

The following table lists the required space optimization metrics. If space optimization techniques were not used, "NA" is reported.

Metric	Value
SPC-1 Space Optimization Ratio	1.50
SPC-1 Space Effectiveness Ratio	1.76

Data Persistence Test

Data Persistence Test Results File

The results files generated during the execution of the Data Persistence Test is included in the Supporting Files (see Appendix A) as follows:

- **SPC1_PERSIST_1_0_Raw_Results.xlsx**
- **SPC1_PERSIST_2_0_Raw_Results.xlsx**

Data Persistence Test Execution

The Data Persistence Test was executed using the following sequence of steps:

- The PERSIST_1_0 Test Phase was executed to completion.
- The Benchmark Configuration was taken through an orderly shutdown process and powered off.
- The Benchmark Configuration was powered on and taken through an orderly startup process.
- The PERSIST_2_0 Test Phase was executed to completion.

Data Persistence Test Results

Data Persistence Test Phase: Persist1	
Total Number of Logical Blocks Written	493,911,139
Total Number of Logical Blocks Verified	249,018,284
Total Number of Logical Blocks Overwritten	244,892,855
Total Number of Logical Blocks that Failed Verification	0
Time Duration for Writing Test Logical Blocks (sec.)	600
Size in bytes of each Logical Block	8,192
Number of Failed I/O Requests in the process of the Test	0

Committed Data Persistence Implementation

The AFF A800 uses non-volatile battery-backed memory (NVRAM) for write caching. When a file-modifying operation is processed by the ONTAP filesystem, it is written to system memory and journaled into a non-volatile memory region backed by the NVRAM. This memory region is often referred to as the non-volatile log (NVLog). The NVLog is mirrored between the storage controller HA pairs and protects the filesystem from any Single-Point-Of-Failure (SPOF) until the data is de-staged to disk through a consistency point (CP). In the event of an abrupt failure, data which was committed to the NVLog but has not yet reached its final destination (disk) is read back from the NVLog and subsequently written to disk through a CP.

APPENDIX A: SUPPORTING FILES

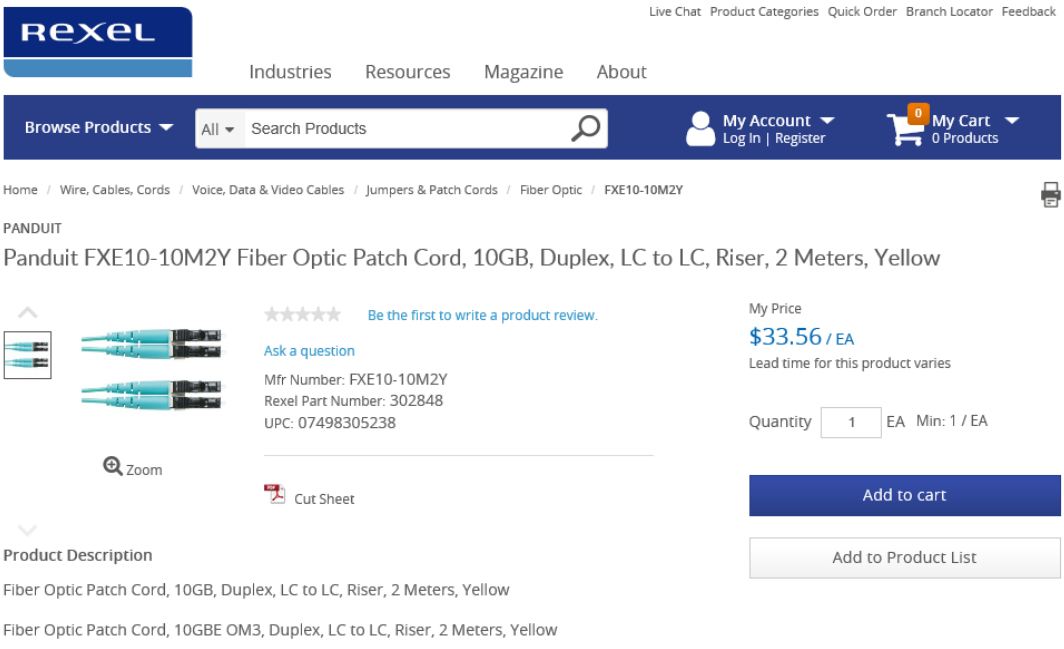
The following table details the content of the Supporting Files provided as part of this Full Disclosure Report.

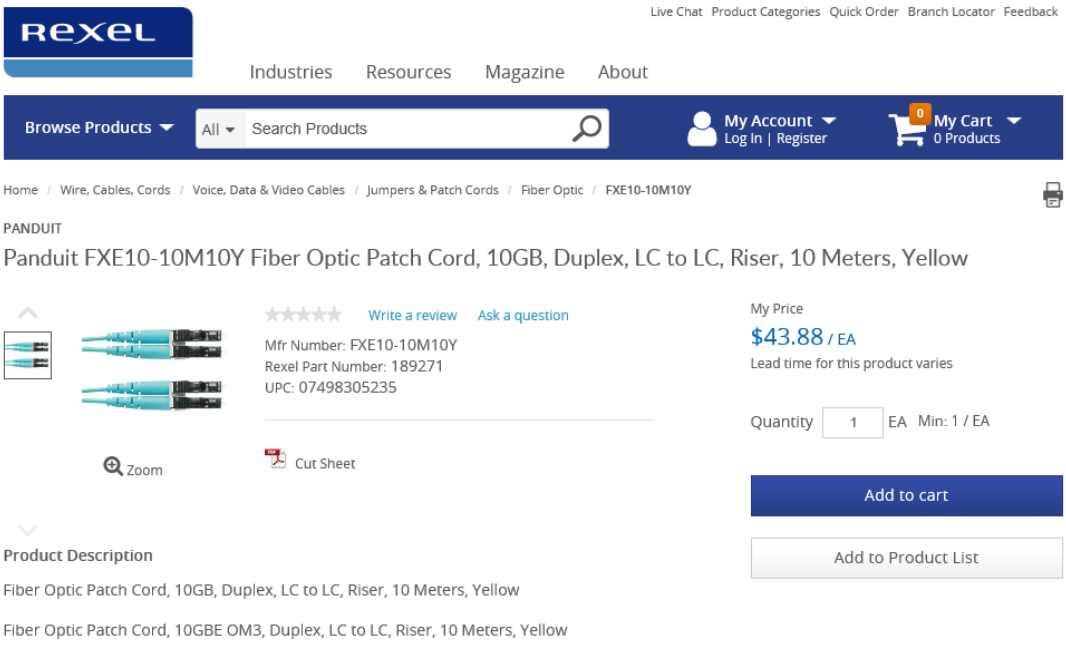
File Name	Description	Location
/SPC1_RESULTS	**Data reduction worksheets**	**root**
SPC1_INIT_0_Raw_Results.xlsx	Raw results for INIT Test Phase	/SPC1_RESULTS
SPC1_METRICS_0_Quick_Look.xlsx	Quick Look Test Run Overview	/SPC1_RESULTS
SPC1_METRICS_0_Raw_Results.xlsx	Raw results for Primary Metrics Test	/SPC1_RESULTS
SPC1_METRICS_0_Summary_Results.xlsx	Primary Metrics Summary	/SPC1_RESULTS
SPC1_PERSIST_1_0_Raw_Results.xlsx	Raw results for PERSIST1 Test Phase	/SPC1_RESULTS
SPC1_PERSIST_2_0_Raw_Results.xlsx	Raw results for PERSIST2 Test Phase	/SPC1_RESULTS
SPC1_Run_Set_Overview.xlsx	Run Set Overview Worksheet	/SPC1_RESULTS
SPC1_VERIFY_0_Raw_Results.xlsx	Raw results for first VERIFY Test Phase	/SPC1_RESULTS
SPC1_VERIFY_1_Raw_Results.xlsx	Raw results for second VERIFY Test Phase	/SPC1_RESULTS
/C_Tuning	**Tuning parameters and options**	**root**
99-lun-captan-udev.rules	Tuning of Linux Parameters on Clients	/C_Tuning
lvm.conf	Logical Volume configuration file	/C_Tuning
multipath.conf	Multipath configuration file	/C_Tuning
/D_Creation	**Storage configuration creation**	**root**
build_logs.tar.gz	Client and Storage Configuration Logs	/D_Creation
aggr_create_spc1_A800.sh	Create aggregates before build automation runs to create environment	/D_Creation
no_aggr_snapshots.sh	Disable Aggr-level snapshots	/D_Creation
portset_create.sh	Set up ONTAP portsets, igroups, and configure Logical Interfaces (LIFs).	/D_Creation
run_populate_igroup.sh	add initiators to igroups	/D_Creation
run_remap_luns.sh	map LUNs to igroups	/D_Creation
/E_Inventory	**Configuration inventory**	**root**
collect.before.audit.inventory.sh	Creates inventory information file before test run	/E_Inventory
collect.after.audit.inventory.sh	Created inventory information file after test run	/E_Inventory
before.audit.inventory.results.txt	Output of before-test inventory script	/E_Inventory
after.audit.inventory.results.txt	Output of after-test inventory script	/E_Inventory
/F_Generator	**Workload generator**	**root**
23HOST.HST	Host definition file for SPC1 benchmark execution	/F_Generator

SPC1.asu	Definition of ASU mapping to Linux logical volumes	/F_Generator
spc1v3_start1se.sh	Executes the following test phases: INIT, VERIFY, METRICS, VERIFY, PERSIST1	/F_Generator
spc1v3_start2.sh	Runs the PERSIST2 phase	/F_Generator

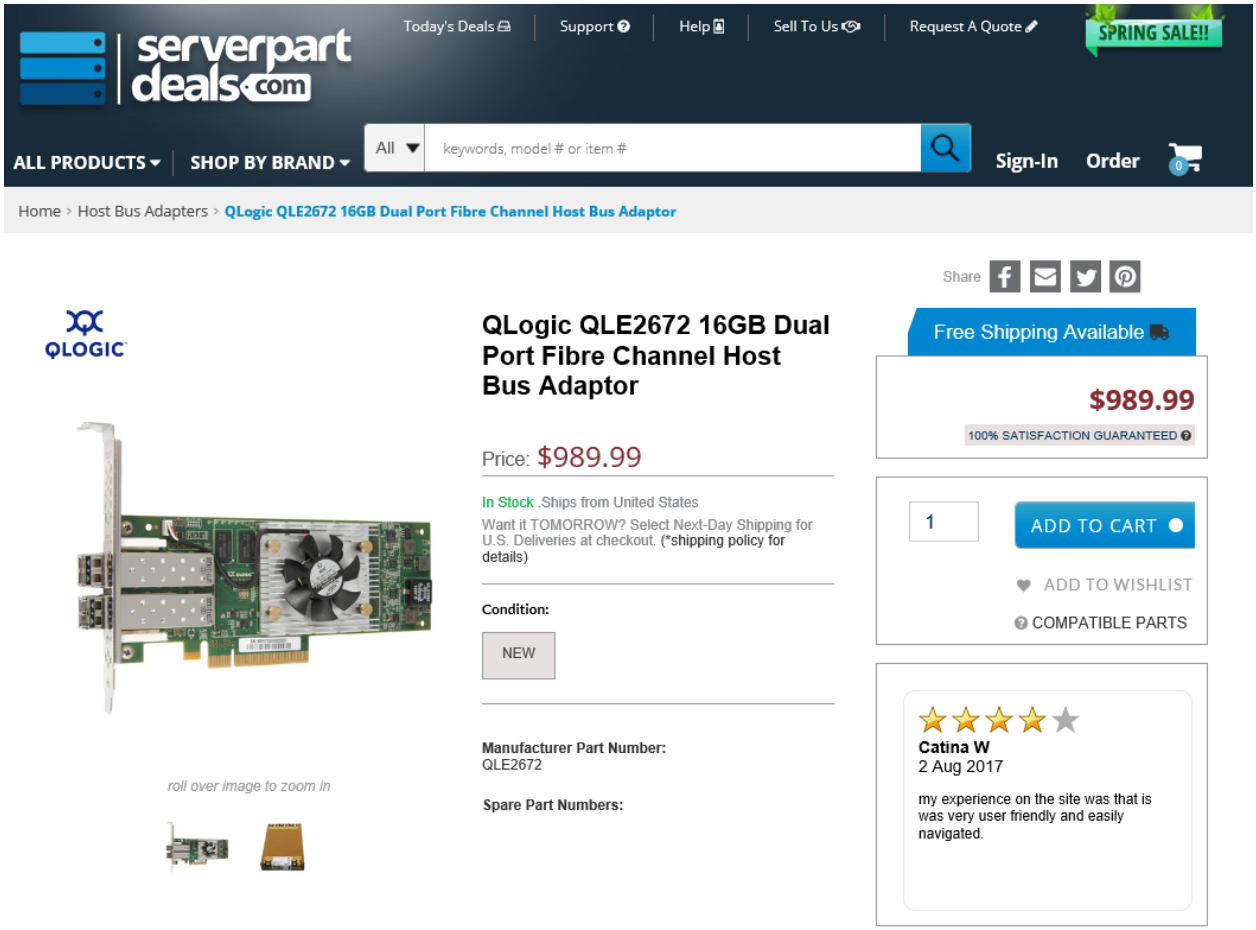
APPENDIX B: THIRD PARTY QUOTATION

Rexel USA





Serverpartdeals.com



APPENDIX C: TUNING PARAMETERS AND OPTIONS

Linux

- On each Linux client, nr_requests is set to 1024, as recommended in the SPC-1 Users Guide.
- On each Linux client, the scheduler is set to 'noop,' as recommended in the SPC-1 Users Guide.
- On each Linux client, fs.qio.max-nr is set to 1048576 as recommended in the SPC-1 Users Guide.
- On each Linux client, the queue depth is set to 2 for all scsi devices.
- Disable the firewall on Linux clients.

```
service iptables stop
chkconfig iptables off
```

Storage

- The nosnap value for the root volume is set from 'off' (default value) to 'on'.

```
node run * vol options vol0 nosnap on
```

- The NetApp Snapshot™ copy schedule is set for the root volume to `0 0 0` (no Snapshot copies).

```
node run * snap sched vol0 0 0 0
```

- Cross-volume inline deduplication is set to disabled.

```
volume efficiency modify -volume *Spc* cross-volume-inline-dedupe false
```

- Background aggregate-level deduplication is disabled by setting the value to `inline only`.

```
volume efficiency modify -policy inline-only -volume *Spc* -vserver spc1v3
```

- Aggregate Snapshot schedule is set to 0 0 0 (no Aggregate snapshots).

```
no_aggr_snapshots.sh
```

APPENDIX D: STORAGE CONFIGURATION CREATION

NetApp used automation tools to build-out (set up) the storage and clients for workload testing. This method of automation allows building and rebuilding test environments for consistent and reliable testing.

The following section gives a brief, high-level overview of the process for creating and configuring a test environment that is ready for SPC1v3 testing on a 12-node NetApp AFF A800 storage cluster. The actual steps performed are found in the full log files created by the automation tool.

The standard NetApp Application Program Interface (API) is part of the NetApp Manageability SDK library (where it is available to customers). API calls are used, as seen in the log files, to create various elements of the test storage configuration.

When the automation tool is run to create or build the test environment, NetApp assumes that the storage cluster and hosts are not in active use and are ready to be configured. The tool can detect if an entity (such as a volume, logical interfaces [LIFs], initiator group [igroup], LUN, and so on) already exists. If a specific entity already exists, it does not recreate that entity. The word bypass or bypassed in the logs indicates this occurrence.

The following steps are needed for the initial configuration of a NetApp AFF A800 storage cluster:

1. Create storage aggregates (one per storage node). Twelve aggregates are created, one for each storage node. A simple way to think of an aggregate is that it is similar in some ways to a "RAID group."

2. Create a storage virtual machine (SVM; previously called a vserver) on the storage cluster. An SVM named `spc1v3` is created. An SVM in a NetApp clustered storage configuration manages an individual workload.

3. Create a LIF for cluster management and FC that are mapped to hardware ports. API calls are used to create cluster LIFs with the physical FC target ports 2a, 2b, 2c and 2d on each storage controller with settings as shown in the log files.

Next, the build automation tool begins a loop through the hosts (clients). That is, it configures the first host and creates associated storage elements. It then proceeds to the next host. For the first host, the tool executes additional steps that are only performed once.

To configure the first host (client) machine, the tool performs the following steps:

1. Executes a variety of general or common Linux commands to set up the host machine.
2. Installs any files or packages needed on the client machine. Examples include the QLogic drivers for the HBAs and the NetApp Linux Unified Host Utilities files.
3. Creates 240 NetApp FlexVol® volumes on the storage system for use by all clients (data for ASUs).

4. Creates storage igroups.
5. Creates 240 LUNs and map the LUNs to volumes created previously.
6. Adds initiators to igroups for FC ports on the host (two per host).
7. Sets up multipath.
8. Sets up udev rules to set the queue depth on the host.

9. Creates host-side volume groups and then creates logical volumes with the `vgcreate` and `lvcreate` commands.
10. Runs additional Linux commands needed to continue host setup.
11. Creates the SPC1-specific files needed to control the hosts, slaves, and scripts that are used in the run of workload generator SPC1.

To configure the remaining hosts (hosts 2 through 23), the tool performs the following steps:

1. Runs a variety of general or common Linux commands to set up the host machine.
2. Installs any files or packages needed on the client machine. Examples include the QLogic drivers for the HBAs, and the NetApp Linux Unified Host Utilities files.
3. Adds initiators to igroups for FC ports on the host (two per host).
4. Sets up multipath.
5. Sets up udev rules to set the queue depth on the host.
6. Runs any additional Linux command needed to continue host setup.

Since the automated setup tools cannot handle the following additional steps, they are done after the automation "build" is done. The scripts are supplied as part of the supporting files.

1. All 23 Clients are halted.
2. Script portset_create.sh is run to set up Ontap portsets, igroups, and configure Logical Interfaces (LIFs).
3. Script run_populate_igroup.sh is run to add initiators to igroups.
4. Script run_remap_luns.sh is run to map LUNs to igroups.
5. Clients are now powered up. Clients will each have 960 paths to storage LUNs (240 x 4).

This completes the setup; the environment is ready to run an SPC1 benchmark test.

APPENDIX E: CONFIGURATION INVENTORY

An inventory of the TSC was collected by the script **collect.before.audit.inventory.sh** before test execution. Another inventory was collected after the final step in the test, Persist2. The second script is **collect.after.audit.inventory.sh.**

- Before - **before.audit.inventory.results.txt**
- After - **after.audit.inventory.results.txt**

APPENDIX F: WORKLOAD GENERATOR

Two primary scripts are used to run the SPC1 benchmark workload. See Appendix A, Supporting Files.

spc1v3_start1se.sh – initiates the test.

1. Collects before-test inventory data via a script as described in Appendix E.
   Saves data to: **before.audit.inventory.results.txt**
2. Collects stats for storage-optimization data reporting
3. Runs INIT phase of the SPC1 benchmark
4. Collects stats again for storage-optimization data reporting
5. Runs VERIFY phase of SPC1 benchmark
6. Runs METRICS phase which includes the required SUSTAIN, RAMP, REPEAT tests.
7. Collects stats again for storage-optimization data reporting
8. Runs another VERIFY phase of SPC1 benchmark
9. Runs PERSIST_1 phase of benchmark.

At this point, the TSC is power-cycled.

spc1v3_start2.sh – completes the test.

1. Runs the PERSIST_2 phase of the SPC1 benchmark.
2. Runs a script to collect "after test" inventory data, which is saved to file:
   after.audit.inventory.results.txt