EMC²

SPC BENCHMARK 1™
FULL DISCLOSURE REPORT

EMC CORPORATION
EMC VNX8000

SPC-1 V1.14

Submitted for Review: July 30, 2015
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First Edition – July 2015

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AUDIT CERTIFICATION

Qin Tao
EMC Corporation
228 South Street
Hopkinton, MA

July 27, 2015

The SPC Benchmark 1™ Reported Data listed below for the EMC VNX8000 was produced in compliance with the SPC Benchmark 1™ v1.14 Onsite Audit requirements.

SPC Benchmark 1™ v1.14 Reported Data	
Tested Storage Product (TSP) Name: EMC VNX8000	
Metric	**Reported Result**
SPC-1 IOPS™	435,067.33
SPC-1 Price-Performance	$0.41/SPC-1 IOPS™
Total ASU Capacity	1,100.585 GB
Data Protection Level	Protected 2 *(mirroring)*
Total Price (including three-year maintenance)	$176,942.25
Currency Used	U.S. Dollars
Target Country for availability, sales and support	USA

The following SPC Benchmark 1™ Onsite Audit requirements were reviewed and found compliant with 1.14 of the SPC Benchmark 1™ specification:

- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository storage items were verified by physical inspection and information supplied by EMC Corporation:
  - ✓ Physical Storage Capacity and requirements.
  - ✓ Configured Storage Capacity and requirements.
  - ✓ Addressable Storage Capacity and requirements.
  - ✓ Capacity of each Logical Volume and requirements.
  - ✓ Capacity of each Application Storage Unit (ASU) and requirements.
- The total Application Storage Unit (ASU) Capacity was filled with random data, using an auditor approved tool, prior to execution of the SPC-1 Tests.

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643 Bair Island Road, Suite 103
Redwood City, CA 94062
AuditService@storageperformance.org
650.556.9384

AUDIT CERTIFICATION *(CONT.)*

- An appropriate diagram of the Benchmark Configuration (BC)/Tested Storage Configuration (TSC).
- Physical verification of the components to match the above diagram.
- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters that were changed from default values.
- SPC-1 Workload Generator commands and parameters used for the audited SPC Test Runs.
- The following Host System requirements were verified by physical inspection and information supplied by EMC Corporation:
  - ✓ The type and number of Host Systems including the number of processors and main memory.
  - ✓ The presence and version number of the SPC-1 Workload Generator on each Host System.
  - ✓ The TSC boundary within each Host System.
- The execution of each Test, Test Phase, and Test Run was observed and found compliant with all of the requirements and constraints of Clauses 4, 5, and 11 of the SPC-1 Benchmark Specification.
- The Test Results Files and resultant Summary Results Files received from EMC Corporation for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4 and 5 of the SPC-1 Benchmark Specification:
  - ✓ Data Persistence Test
  - ✓ Sustainability Test Phase
  - ✓ IOPS Test Phase
  - ✓ Response Time Ramp Test Phase
  - ✓ Repeatability Test
- There were no differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration.
- The submitted pricing information met all of the requirements and constraints of Clause 8 of the SPC-1 Benchmark Specification.
- The Full Disclosure Report (FDR) met all of the requirements in Clause 9 of the SPC-1 Benchmark Specification.
- This successfully audited SPC measurement is not subject to an SPC Confidential Review.

Audit Notes:

There are no audit notes.

Respectfully,

Walter E. Baker

Walter E. Baker
SPC Auditor

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LETTER OF GOOD FAITH

June 5, 2015

Mr. Walter E. Baker, SPC Auditor
Gradient System, Inc.
643 Bair Island Road, Suite 103
Redwood City, CA 94063

Subject: SPC-1 Letter of Good Faith for the EMC VNX8000 Storage System

EMC is the SPC-1 Test Sponsor for the above listed product. To the best of our knowledge and belief, the required SPC-1 benchmark results and materials we have submitted for that product are complete, accurate, and in full compliance with Version 1.14 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.

Sincerely,

Jeffrey Boudreau
SVP & GM, Midrange Engineering
EMC Core Technologies

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EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact	EMC Corporation – http://www.emc.com Qin Tao – qin.tao@emc.com 228 South Street Hopkinton, MA 02748 Phone: (508) 249-7312 FAX: (508) 249-7463
Test Sponsor Alternate Contact	EMC Corporation – http://www.emc.com John Freeman – john.freeman@emc.com 228 South Street Hopkinton, MA 02748 Phone: (508) 249-5661 FAX: (508) 249-7463
Auditor	Storage Performance Council – http://www.storageperformance.org Walter E. Baker – AuditService@StoragePerformance.org 643 Bair Island Road, Suite 103 Redwood City, CA 94063 Phone: (650) 556-9384 FAX: (650) 556-9385

Revision Information and Key Dates

Revision Information and Key Dates	
SPC-1 Specification revision number	V1.14
SPC-1 Workload Generator revision number	V2.3.0
Date Results were first used publicly	July 30, 2015
Date the FDR was submitted to the SPC	July 30, 2015
Date the Priced Storage Configuration is available for shipment to customers	currently available
Date the TSC completed audit certification	July 27, 2015

Tested Storage Product (TSP) Description

EMC VNX8000 storage system delivers uncompromising scalability and flexibility for the mid-tier while providing market-leading simplicity and efficiency to minimize total cost of ownership.

Based on the powerful family of Intel Xeon E5-2600(Sandy Bridge) processors, the VNX8000 implements a modular architecture that integrates hardware components for block, file and object with concurrent support for native NAS, iSCSI, Fibre Channel, and FCoE protocols. The system leverages the patented ***MCx™ multi-core storage software operating environment*** that delivers unparalleled performance efficiency. Thin Provisioning, deduplication and compression keep these high performing systems operating at maximum effectiveness.

The VNX8000 supports block services, file services, and unified services.

Summary of Results

SPC-1 Reported Data	
Tested Storage Product (TSP) Name: EMC VNX8000	
Metric	**Reported Result**
SPC-1 IOPS™	435,067.33
SPC-1 Price-Performance™	$0.41/SPC-1 IOPS™
Total ASU Capacity	1,100.585 GB
Data Protection Level	Protected 2 *(mirroring)*
Total Price	$176,942.25
Currency Used	U.S. Dollars
Target Country for availability, sales and support	USA

SPC-1 IOPS™ represents the maximum I/O Request Throughput at the 100% load point.

SPC-1 Price-Performance™ is the ratio of **Total Price** to **SPC-1 IOPS™**.

Total ASU (Application Storage Unit) **Capacity** represents the total storage capacity available to be read and written in the course of executing the SPC-1 benchmark.

A **Data Protection Level** of **Protected 2** using ***Mirroring*** configures two or more identical copies of user data.

> ***Protected 2:*** *The single point of failure of any* ***component*** *in the configuration will not result in permanent loss of access to or integrity of the SPC-1 Data Repository.*

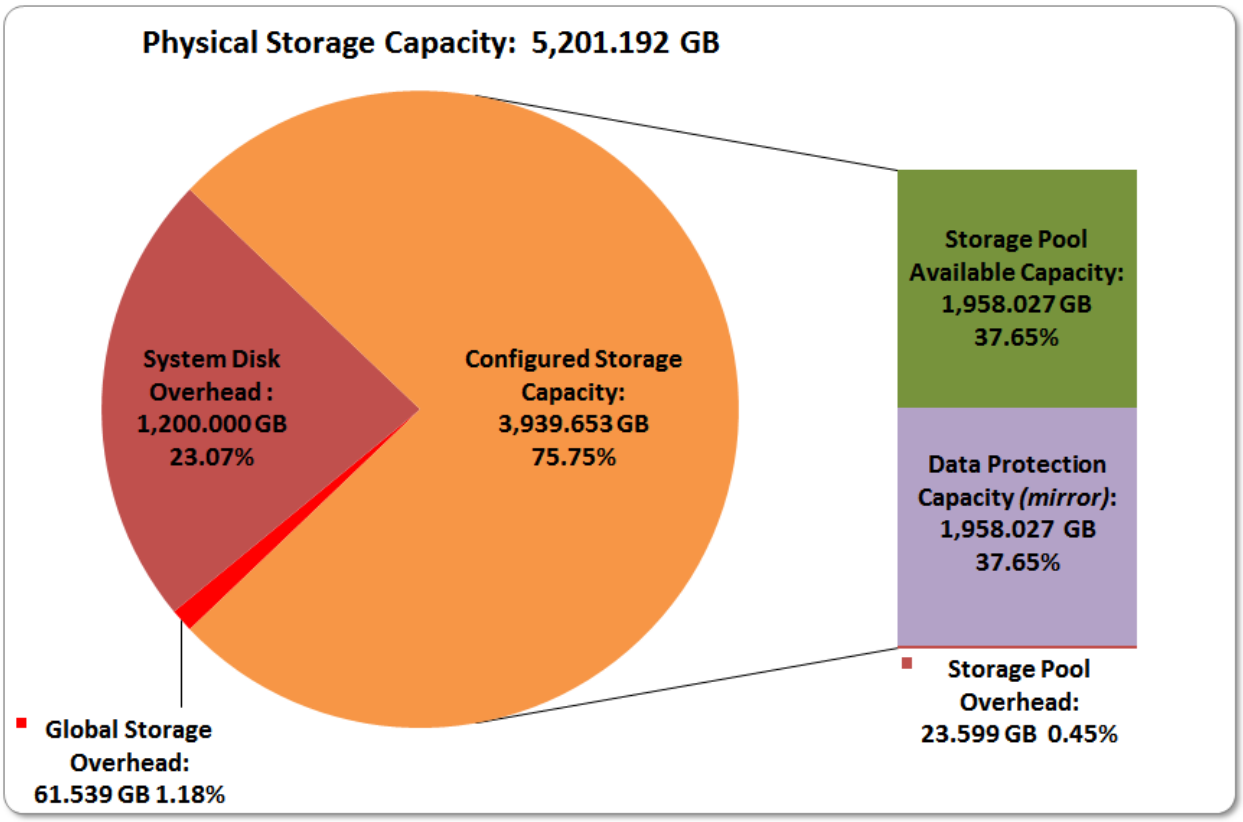
Total Price includes the cost of the Priced Storage Configuration plus three years of hardware maintenance and software support as detailed on page 16.

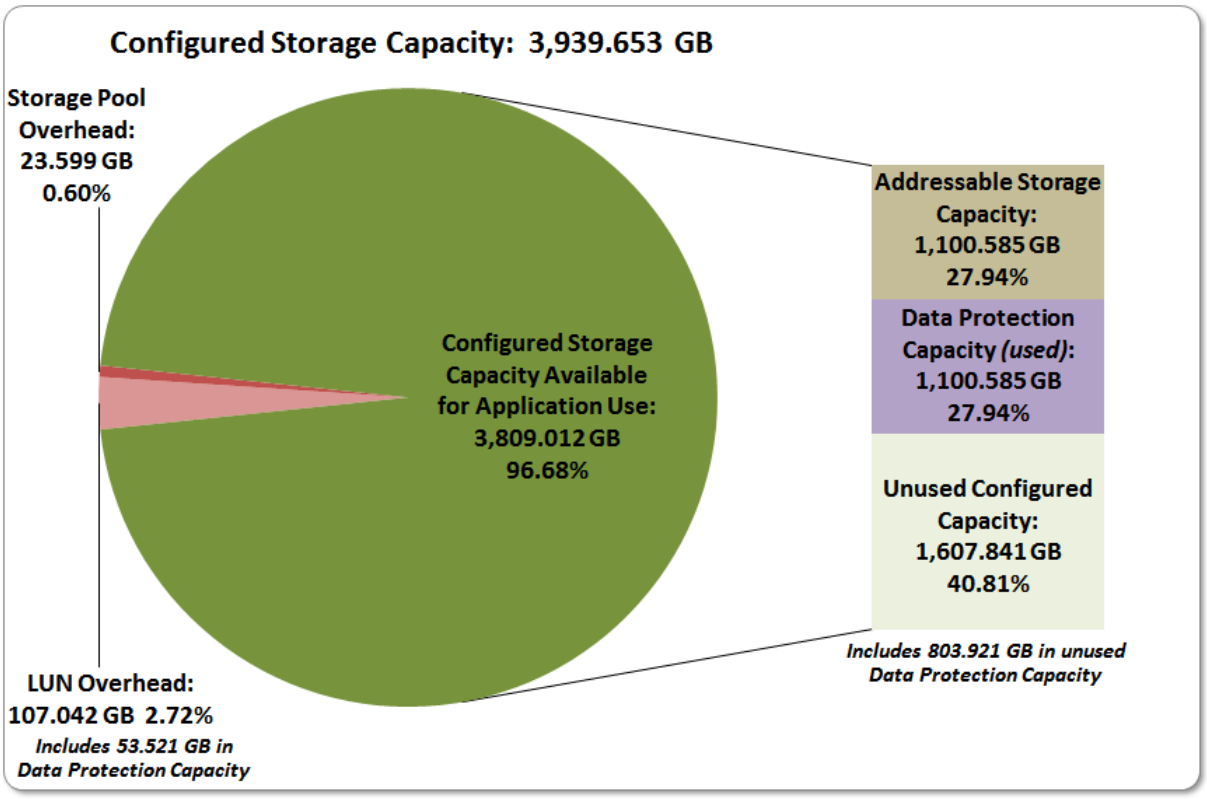
Currency Used is formal name for the currency used in calculating the **Total Price** and **SPC-1 Price-Performance™**. That currency may be the local currency of the **Target Country** or the currency of a difference country *(non-local currency)*.

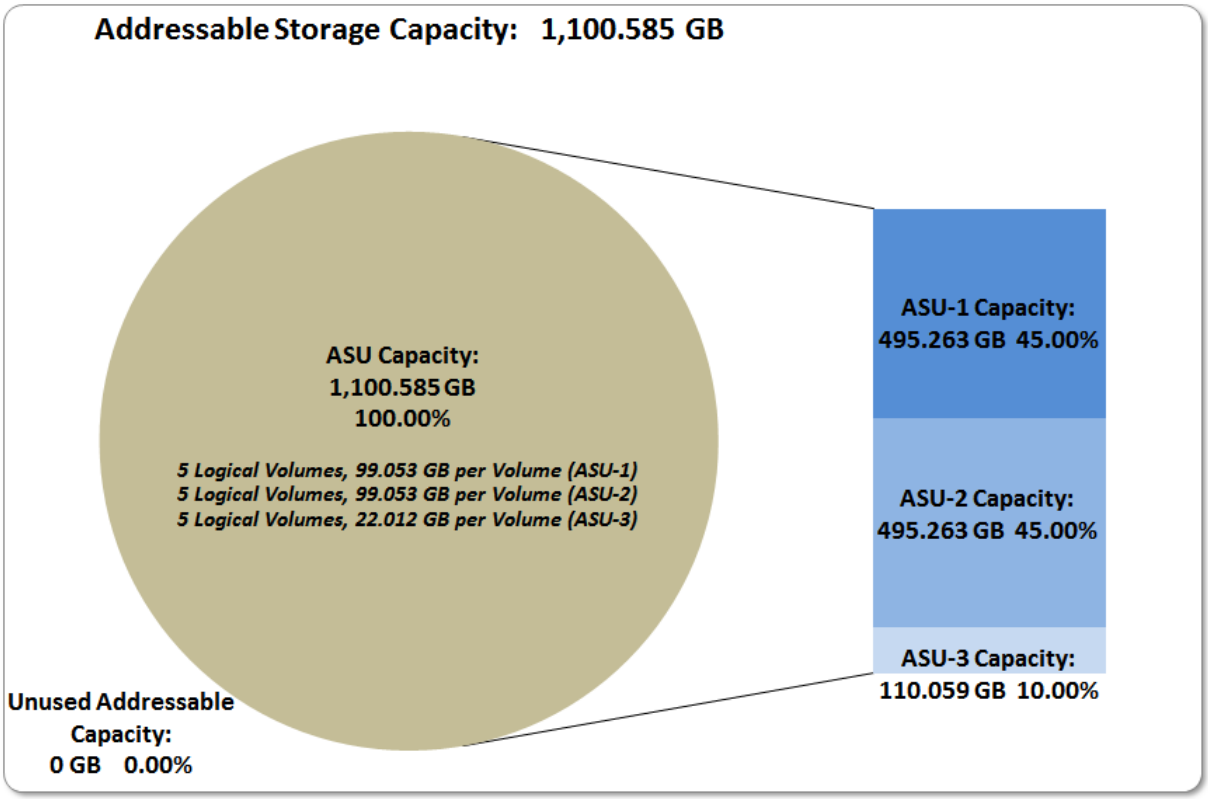
The **Target Country** is the country in which the Priced Storage Configuration is available for sale and in which the required hardware maintenance and software support is provided either directly from the Test Sponsor or indirectly via a third-party supplier.

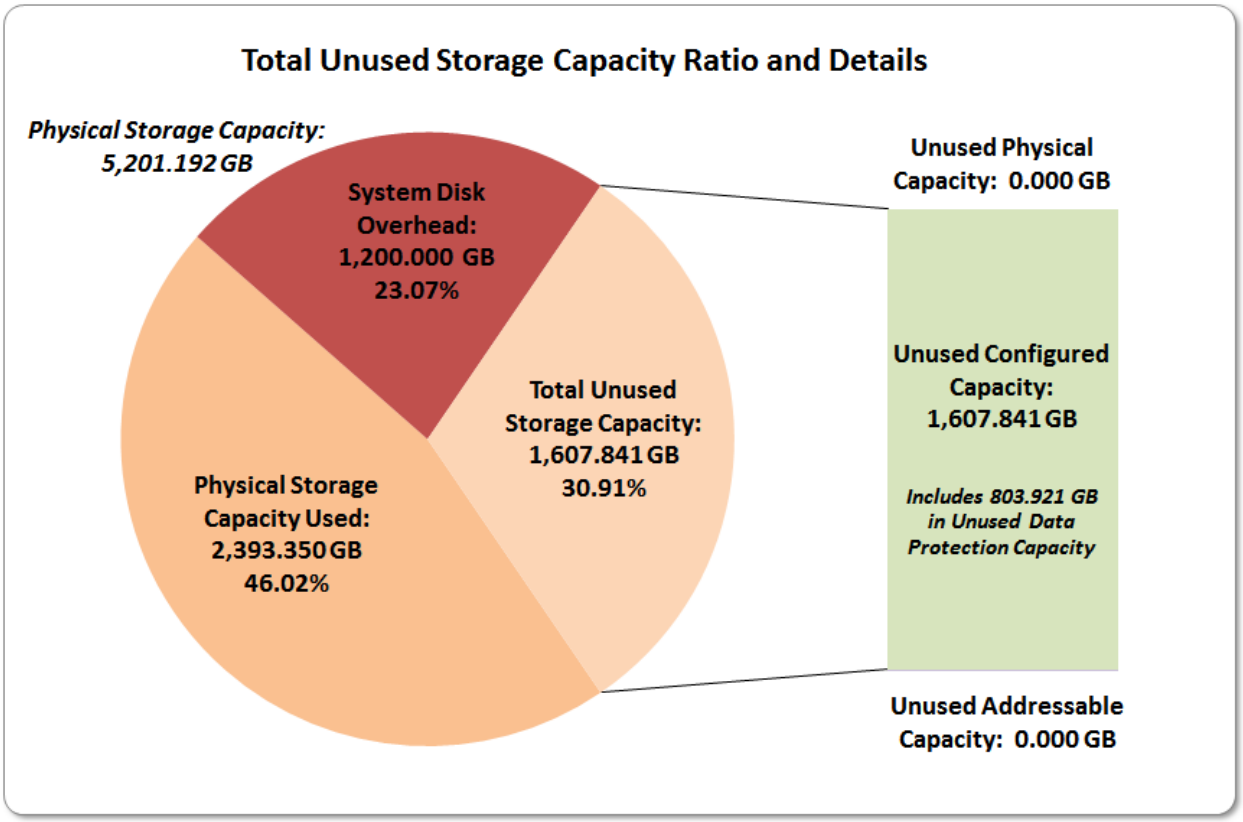
Storage Capacities, Relationships, and Utilization

The following four charts and table document the various storage capacities, used in this benchmark, and their relationships, as well as the storage utilization values required to be reported.




Configured Storage Capacity: 3,939.653 GB
Storage Pool Overhead: 23.599 GB 0.60%
Configured Storage Capacity Available for Application Use: 3,809.012 GB 96.68%
LUN Overhead: 107.042 GB 2.72%
Includes 53.521 GB in Data Protection Capacity
Addressable Storage Capacity: 1,100.585 GB 27.94%
Data Protection Capacity (used): 1,100.585 GB 27.94%
Unused Configured Capacity: 1,607.841 GB 40.81%
Includes 803.921 GB in unused Data Protection Capacity


Addressable Storage Capacity: 1,100.585 GB
ASU Capacity: 1,100.585 GB 100.00%
5 Logical Volumes, 99.053 GB per Volume (ASU-1)
5 Logical Volumes, 99.053 GB per Volume (ASU-2)
5 Logical Volumes, 22.012 GB per Volume (ASU-3)
Unused Addressable Capacity: 0 GB 0.00%
ASU-1 Capacity: 495.263 GB 45.00%
ASU-2 Capacity: 495.263 GB 45.00%
ASU-3 Capacity: 110.059 GB 10.00%



SPC-1 Storage Capacity Utilization	
Application Utilization	21.16%
Protected Application Utilization	43.35%
Unused Storage Ratio	30.91%

Application Utilization: Total ASU Capacity *(1,100.585 GB)* divided by Physical Storage Capacity *(5,201.192 GB)*.

Protected Application Utilization: (Total ASU Capacity *(1,100.585 GB)* plus total Data Protection Capacity *(1,958.027 GB)* minus unused Data Protection Capacity *(803.921 GB)*) divided by Physical Storage Capacity *(5,201.192 GB)*.

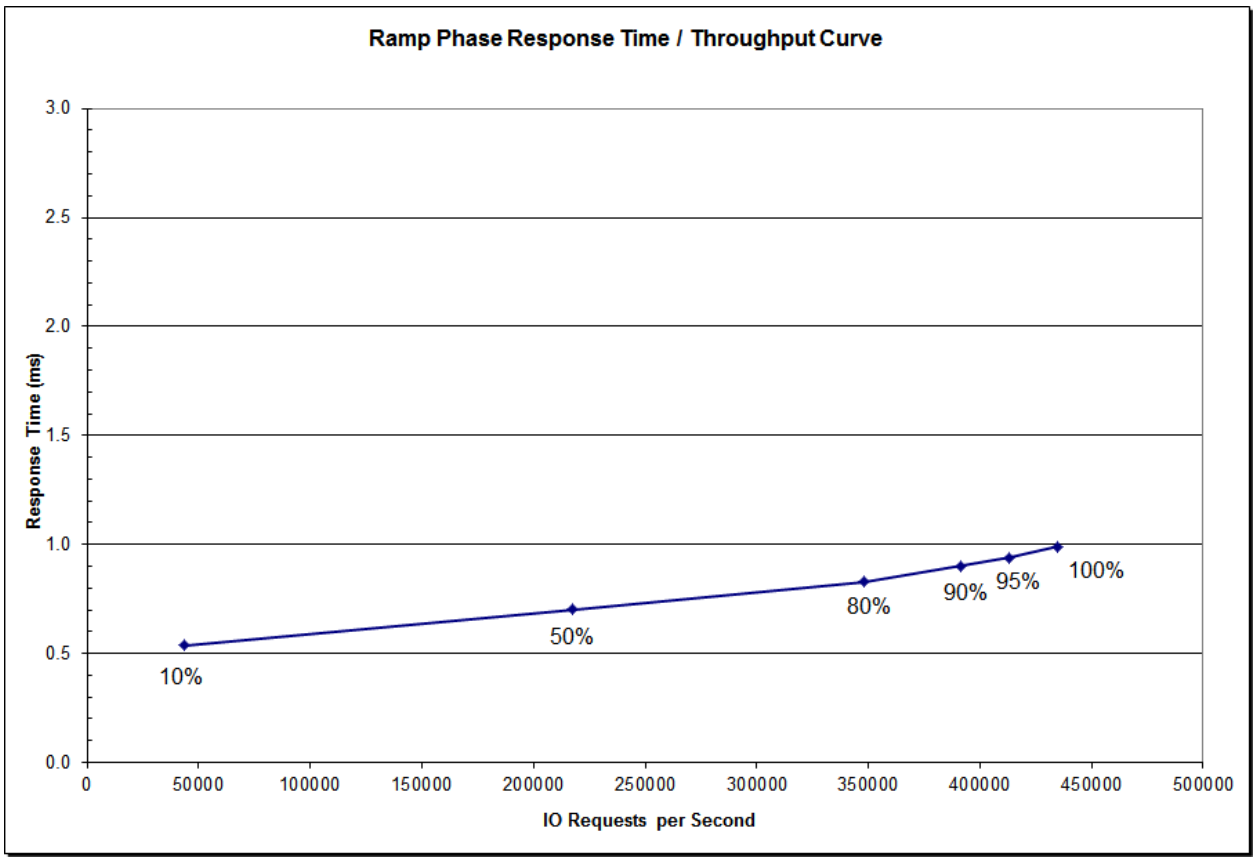
Unused Storage Ratio: Total Unused Capacity *(1,607.841 GB)* divided by Physical Storage Capacity *(5,201.192 GB)* and may not exceed 45%.

Detailed information for the various storage capacities and utilizations is available on pages 24-25.

Response Time – Throughput Curve

The Response Time-Throughput Curve illustrates the Average Response Time (milliseconds) and I/O Request Throughput at 100%, 95%, 90%, 80%, 50%, and 10% of the workload level used to generate the SPC-1 IOPS™ metric.

The Average Response Time measured at any of the above load points cannot exceed 30 milliseconds or the benchmark measurement is invalid.



Response Time – Throughput Data

	10% Load	50% Load	80% Load	90% Load	95% Load	100% Load
I/O Request Throughput	43,505.81	217,516.82	348,017.00	391,486.38	413,233.32	435,067.33
Average Response Time (ms):						
All ASUs	0.54	0.70	0.83	0.90	0.94	0.99
ASU-1	0.51	0.66	0.78	0.85	0.88	0.93
ASU-2	0.55	0.72	0.87	0.95	0.99	1.05
ASU-3	0.59	0.79	0.92	1.00	1.04	1.09
Reads	0.48	0.58	0.71	0.77	0.81	0.86
Writes	0.57	0.78	0.91	0.98	1.02	1.08

Priced Storage Configuration Pricing

Product	Product Description	Qty	Unit List Price	Product List Price
VNXB80SPE	VNX8000 Storage Processor Enclosure(SPE) with Standard Memory Configuration of 128 GB per SP (256 GB total), 2X4-port 6Gb SAS I/O modules per SP Base Configuration	1	$ 64,277.00	$ 64,277.00
VNXBRACK-40U	VNXB 40U Rack with Front Panel, PDUs	1	$ 2,484.00	$ 2,484.00
VNXB6GSDAE25P	VNXB 25X2.5 Slot 6G SAS PRI Disk Array Enclosure(DAE)	4	$ 4,942.00	$ 19,768.00
V-V4-230015	VNX 300GB 15K 2.5" 4 Vault Disk Set	1	$ 4,970.00	$ 4,970.00
V4-2S6FX-100	VNX 100GB 2.5" FAST VP SSD	40	$ 1,855.00	$ 74,200.00
VNXB-OM3-3M	3M MM FIBRE Cable LC-LC	32	$ 187.00	$ 5,984.00
VSPBM8GFFEA	VNXB 4 Port 8G FC IO Module Pair(SFPs included)	4	$ 3,696.00	$ 14,784.00
VBPW40U-US	CAB QUAD Power Cord US Twistlock	1	$ 680.00	$ 680.00
Total Hardware:				***$ 187,147.00***
VNXBOEPERFTB	VNXB OE PER TB Performance	4	$ 729.00	$ 2,916.00
UNISB-VNX8000	VNX8000 Unisphere Block Suite=IC	1	$ 65,070.00	$ 65,070.00
VNX80-KIT	VNX8000 Documentation Kit=IC	1	$ -	$ -
VNXOE-8000	VNX8000 Operating Environment	1	$ -	$ -
Total Software:				***$ 67,986.00***
PSINST-ESRS	ZERO DOLLAR ESRS INSTALL	1	$ -	$ -
M-PRESWE-001	PREMIUM SW SUPPORT	1	$ 35,138.00	$ 35,138.00
WU-PREHWE-01	PREMIUM HW SUPPORT-WARR UPG	1	$ 16,024.00	$ 16,024.00
Total Warranty & Maintenance:				***$ 51,162.00***
LPE12002-E-G	8Gb HBAs - Emulex LightPulse LPE12002 2-Port	16	$ 530.00	$ 8,480.00
Total Third Party Components				***$ 8,480.00***

Category	List Price Total	Discount	Discounted Price
Hardware	$ 187,147.00	45%	$ 102,930.85
Software	$ 67,986.00	45%	$ 37,392.30
Warranty & Maintenance	$ 51,162.00	45%	$ 28,139.10
Third Party Components	$ 8,480.00		$ 8,480.00
Total:	$ 314,775.00		**$ 176,942.25**

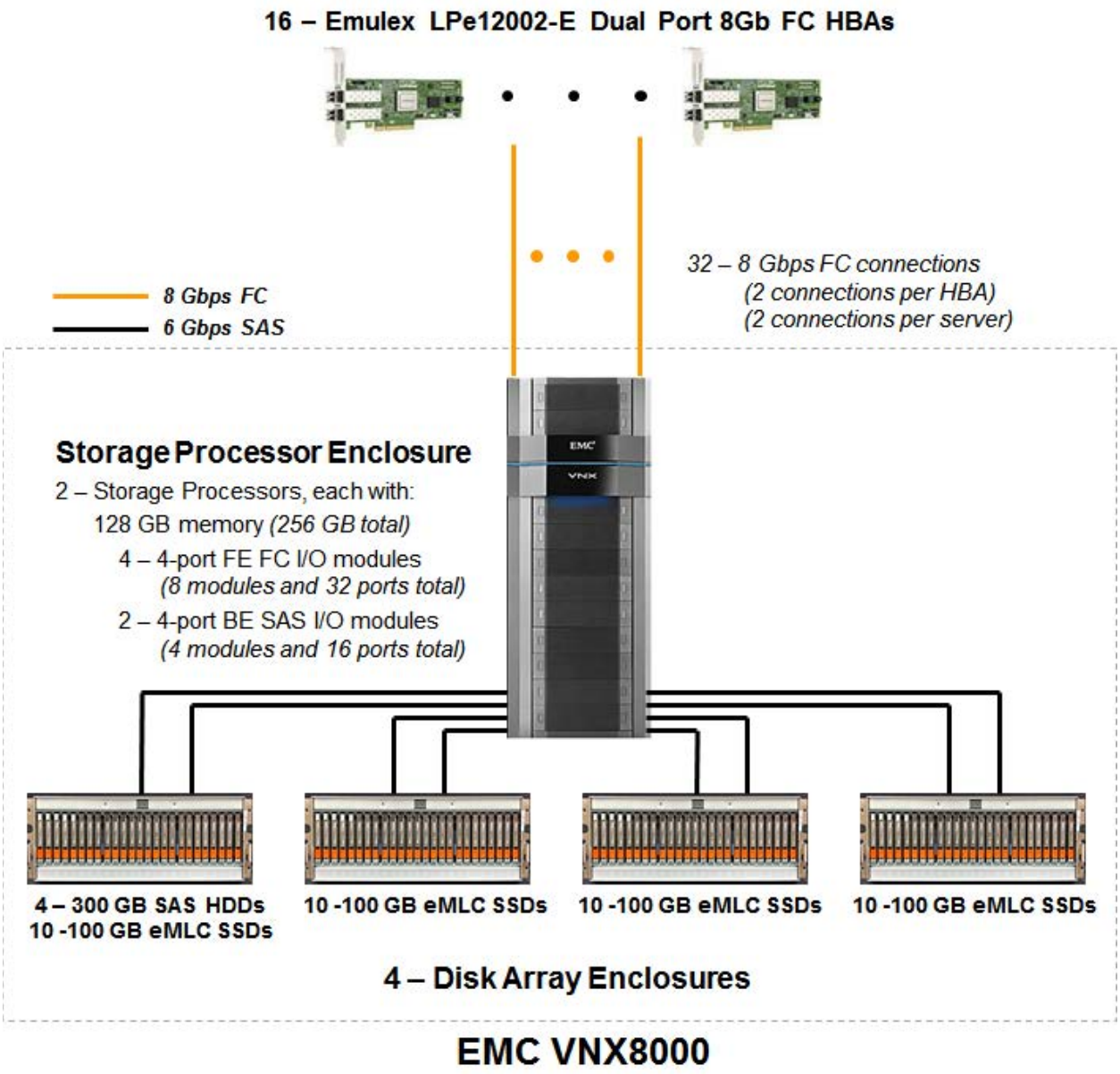
The above pricing includes hardware maintenance and software support for three years, 7 days per week, 24 hours per day. The hardware maintenance and software support provides the following:

- Acknowledgement of new and existing problems within four (4) hours.
- Onsite presence of a qualified maintenance engineer or provision of a customer replaceable part within four (4) hours of the above acknowledgement for any hardware failure that results in an inoperative Price Storage Configuration that can be remedied by the repair or replacement of a Priced Storage Configuration component.

Differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration

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

Priced Storage Configuration Diagram



Priced Storage Configuration Components

Priced Storage Configuration
16 – Emulex LightPulse LPe12002-E Dual Port 8Gb FC HBAs
EMC VNX8000 Dual VNX8000 Storage Processor, each with 128 GB memory *(256 GB total)* 2 – 4 port 6 Gb SAS I/O modules *(4 modules total, 16 ports total and 8 ports used)*
4 – 4 port 8Gb FC I/O Module pairs *(SFPs included)* *(4 modules and 16 ports per Storage Processor, 32 ports total and used)*
4 – 25 x 2.5” slot 6Gb SAS Disk Array Enclosures
4 – 15K RPM 2.5” 300 GB SAS HDDs
40 – 100 GB 2.5” eMLC SSDs
1 – 40U Rack with Front Panel and PDUs

In each of the following sections of this document, the appropriate Full Disclosure Report requirement, from the SPC-1 benchmark specification, is stated in italics followed by the information to fulfill the stated requirement.

CONFIGURATION INFORMATION

Benchmark Configuration (BC)/Tested Storage Configuration (TSC) Diagram

Clause 9.4.3.4.1

A one page Benchmark Configuration (BC)/Tested Storage Configuration (TSC) diagram shall be included in the FDR…

The Benchmark Configuration (BC)/Tested Storage Configuration (TSC) is illustrated on page 20 *(Benchmark Configuration/Tested Storage Configuration Diagram)*.

Storage Network Configuration

Clause 9.4.3.4.1

…

5. *If the TSC contains network storage, the diagram will include the network configuration. If a single diagram is not sufficient to illustrate both the Benchmark Configuration and network configuration in sufficient detail, the Benchmark Configuration diagram will include a high-level network illustration as shown in Figure 9-8. In that case, a separate, detailed network configuration diagram will also be included as described in Clause 9.4.3.4.2.*

Clause 9.4.3.4.2

If a storage network was configured as a part of the Tested Storage Configuration and the Benchmark Configuration diagram described in Clause 9.4.3.4.1 contains a high-level illustration of the network configuration, the Executive Summary will contain a one page topology diagram of the storage network as illustrated in Figure 9-9.

The Tested Storage Configuration (TSC) was configured with direct-attached storage.

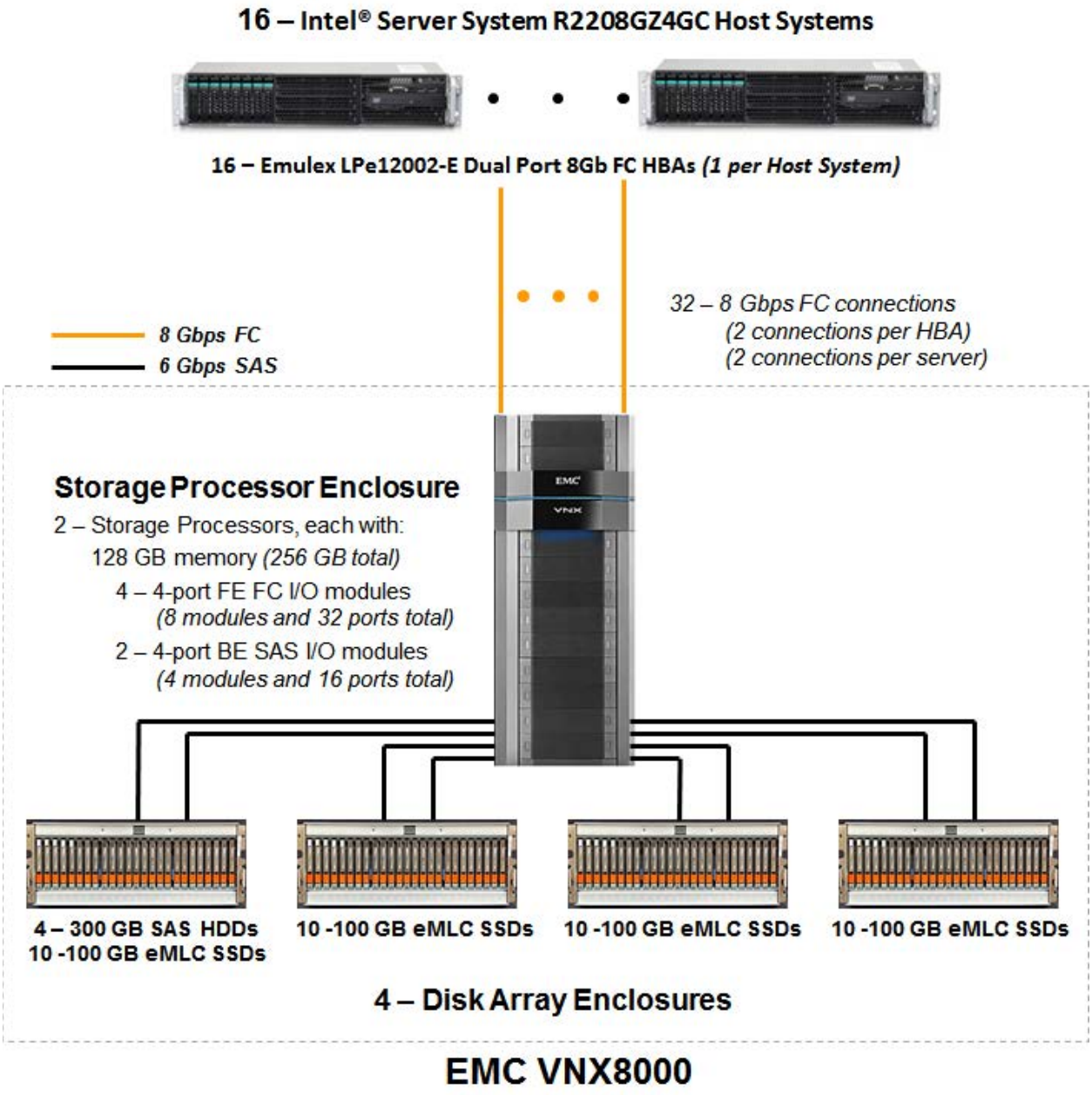
Host System(s) and Tested Storage Configuration (TSC) Table of Components

Clause 9.4.3.4.3

The FDR will contain a table that lists the major components of each Host System and the Tested Storage Configuration (TSC).

The Host System(s) and TSC table of components may be found on page 21 *(Host System and Tested Storage Configuration Components)*.

Benchmark Configuration/Tested Storage Configuration Diagram



Host System and Tested Storage Configuration Components

Host System
16 – Intel® Server System R2208GZ4GC, with: 2 – Intel® Xeon® 2.00 GHz E5-2620 processors 6 cores per processor and 15 MB Intel® Smart Cache 128 GB main memory Windows Server 2008 R2 Enterprise with SP1 PCIe
Tested Storage Configuration (TSC) Components
16 – Emulex LightPulse LPe12002-E Dual Port 8Gb FC HBAs
EMC VNX8000 Dual VNX8000 Storage Processor, each with 128 GB memory *(256 GB total)* 2 – 4 port 6 Gb SAS I/O modules *(4 modules total, 16 ports total and 8 ports used)*
4 – 4 port 8Gb FC I/O Module pairs *(SFPs included)* *(4 modules and 16 ports per Storage Processor,* *32 ports total and used)*
4 – 25 x 2.5” slot 6Gb SAS Disk Array Enclosures
4 – 15K RPM 2.5” 300 GB SAS HDDs
40 – 100 GB 2.5” eMLC SSDs
1 – 40U Rack with Front Panel and PDUs

Customer Tunable Parameters and Options

Clause 9.4.3.5.1

All Benchmark Configuration (BC) components with customer tunable parameter and options that have been altered from their default values must be listed in the FDR. The FDR entry for each of those components must include both the name of the component and the altered value of the parameter or option. If the parameter name is not self-explanatory to a knowledgeable practitioner, a brief description of the parameter's use must also be included in the FDR entry.

Appendix B: Customer Tunable Parameters and Options on page 65 contains the customer tunable parameters and options that have been altered from their default values for this benchmark.

Tested Storage Configuration (TSC) Description

Clause 9.4.3.5.2

The FDR must include sufficient information to recreate the logical representation of the TSC. In addition to customer tunable parameters and options (Clause 4.2.4.5.3), that information must include, at a minimum:

- *A diagram and/or description of the following:*
  - *All physical components that comprise the TSC. Those components are also illustrated in the BC Configuration Diagram in Clause 9.2.4.4.1 and/or the Storage Network Configuration Diagram in Clause 9.2.4.4.2.*
  - *The logical representation of the TSC, configured from the above components that will be presented to the Workload Generator.*
- *Listings of scripts used to create the logical representation of the TSC.*
- *If scripts were not used, a description of the process used with sufficient detail to recreate the logical representation of the TSC.*

Appendix C: Tested Storage Configuration (TSC) Creation on page 66 contains the detailed information that describes how to create and configure the logical TSC.

SPC-1 Workload Generator Storage Configuration

Clause 9.4.3.5.3

The FDR must include all SPC-1 Workload Generator storage configuration commands and parameters.

The SPC-1 Workload Generator storage configuration commands and parameters for this measurement appear in Appendix D: SPC-1 Workload Generator Storage Commands and Parameters on page 73.

ASU Pre-Fill

Clause 5.3.3

Each of the three SPC-1 ASUs (ASU-1, ASU-2 and ASU-3) is required to be completely filled with specified content prior to the execution of audited SPC-1 Tests. The content is required to consist of random data pattern such as that produced by an SPC recommended tool.

The configuration file used to complete the required ASU pre-fill appears in Appendix D: SPC-1 Workload Generator Storage Commands and Parameters on page 73.

SPC-1 DATA REPOSITORY

This portion of the Full Disclosure Report presents the detailed information that fully documents the various SPC-1 storage capacities and mappings used in the Tested Storage Configuration. SPC-1 Data Repository Definitions on page 61 contains definitions of terms specific to the SPC-1 Data Repository.

Storage Capacities and Relationships

Clause 9.4.3.6.1

Two tables and four charts documenting the storage capacities and relationships of the SPC-1 Storage Hierarchy (Clause 2.1) shall be included in the FDR. … The capacity value in each chart may be listed as an integer value, for readability, rather than the decimal value listed in the table below.

SPC-1 Storage Capacities

The Physical Storage Capacity consisted of 5,201.192 GB distributed over 40 solid state drives (SSDs) each with a formatted capacity of 100.030 GB and 4 disk drives (HDDs) each with a formatted capacity of 300.00 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 61.566 GB (1.18%) of the Physical Storage Capacity. There was 1,607.841 GB (40.81%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 100.00% of the Addressable Storage Capacity resulting in 0.000 GB (0.00%) of Unused Storage within the Addressable Storage Capacity. The Data Protection *(Mirroring)* capacity was 1,958.027 GB of which 1,154.106 GB was utilized. The total Unused Storage capacity was 1,607.841 GB.

Note: The configured Storage Devices may include additional storage capacity reserved for system overhead, which is not accessible for application use. That storage capacity may not be included in the value presented for Physical Storage Capacity.

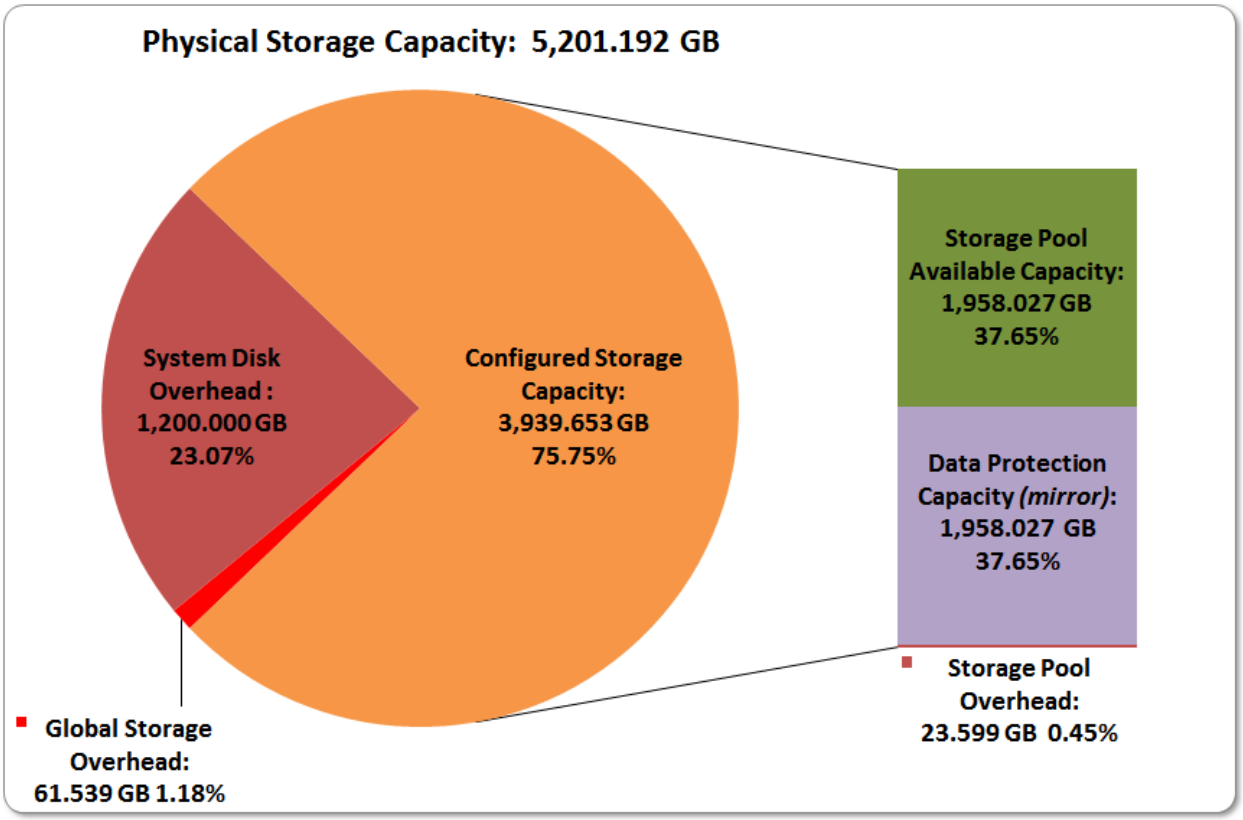
SPC-1 Storage Capacities

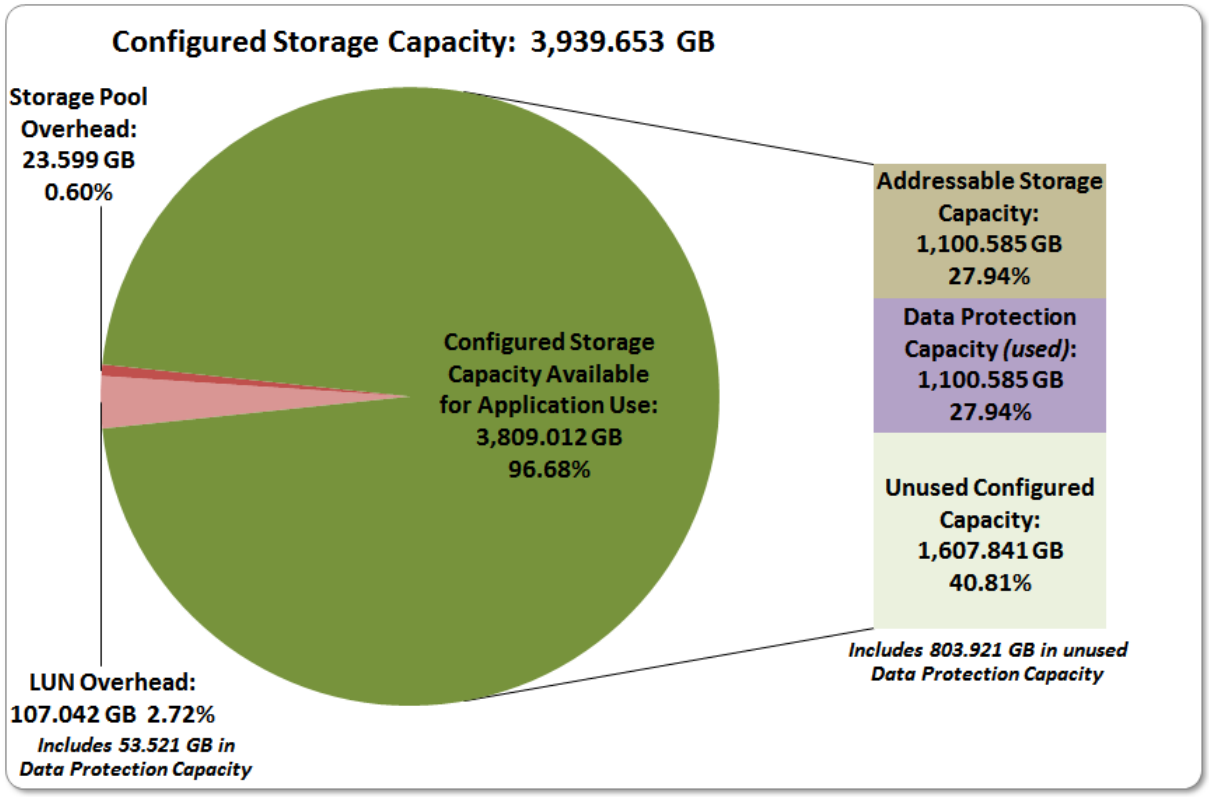
Storage Hierarchy Component	Units	Capacity
Total ASU Capacity	Gigabytes (GB)	1,100.585
Addressable Storage Capacity	Gigabytes (GB)	1,100.585
Configured Storage Capacity	Gigabytes (GB)	3,939.653
Physical Storage Capacity	Gigabytes (GB)	5,201.192
Data Protection *(Mirroring)*	Gigabytes (GB)	1,958.027
Required Storage *(various overhead)*	Gigabytes (GB)	1,330.641
Global Storage Overhead	Gigabytes (GB)	61.566
Total Unused Storage	Gigabytes (GB)	1,607.841

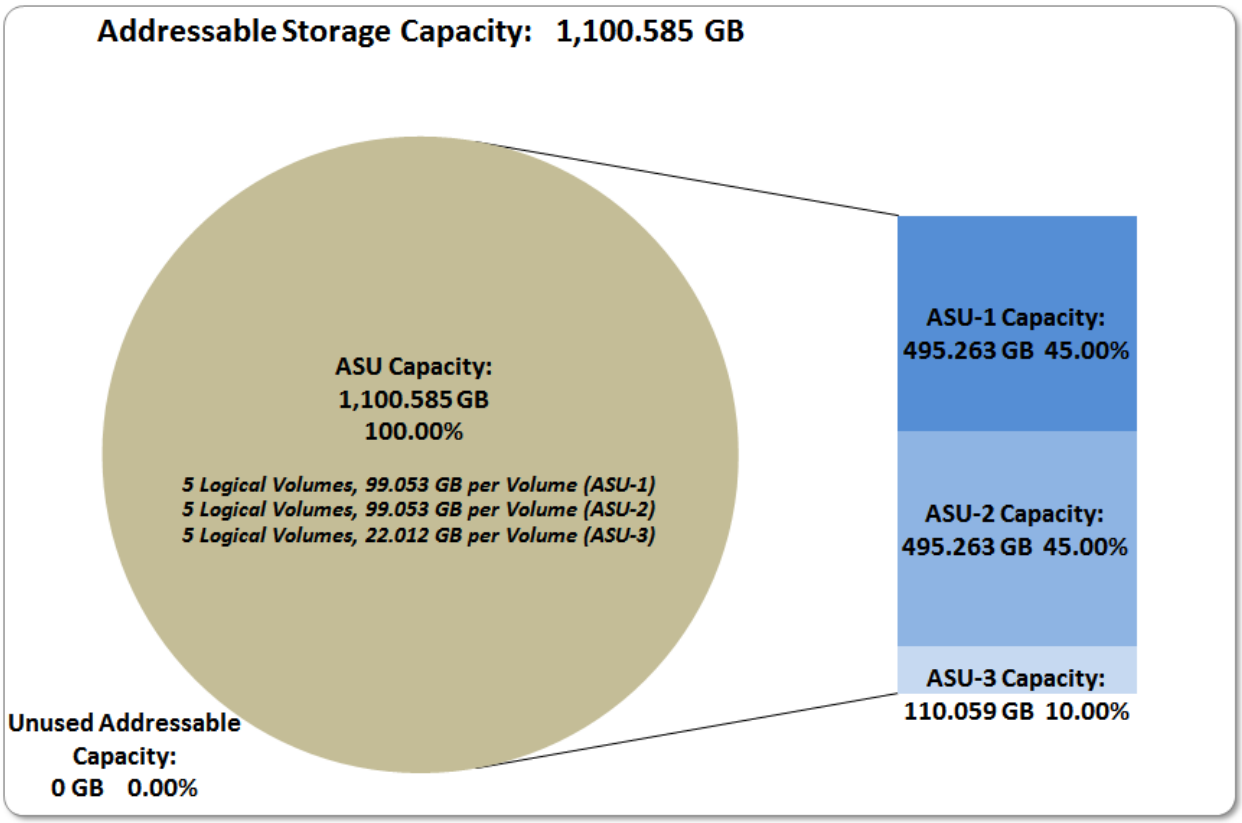
SPC-1 Storage Hierarchy Ratios

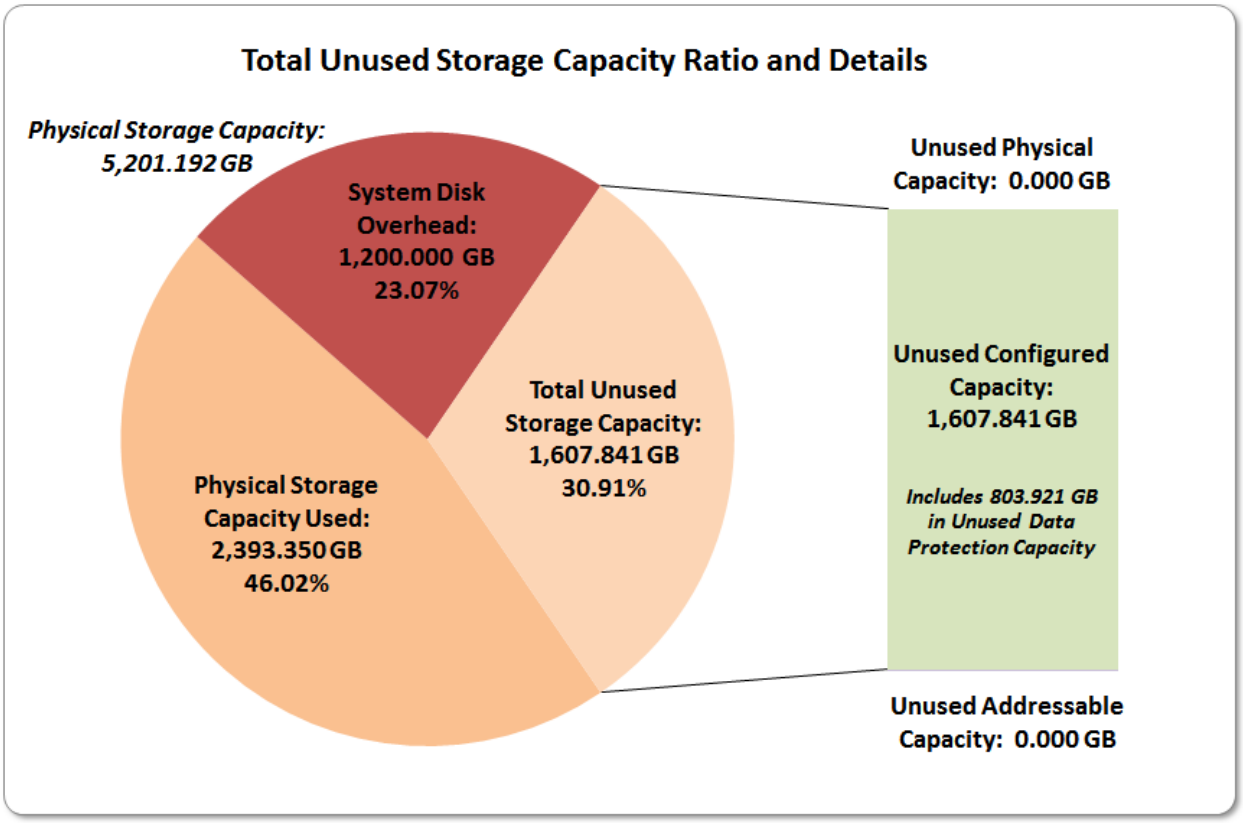
	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	27.94%	21.16%
Required for Data Protection *(Mirroring)*		49.70%	37.65%
Addressable Storage Capacity		27.94%	21.16%
Required Storage		33.78%	25.58%
Configured Storage Capacity			75.75%
Global Storage Overhead			1.18%
Unused Storage:			
Addressable	0.00%		
Configured		40.81%	
Physical			0.00%

SPC-1 Storage Capacity Charts




Configured Storage Capacity: 3,939.653 GB
Storage Pool Overhead: 23.599 GB 0.60%
Configured Storage Capacity Available for Application Use: 3,809.012 GB 96.68%
LUN Overhead: 107.042 GB 2.72%
Includes 53.521 GB in Data Protection Capacity
Addressable Storage Capacity: 1,100.585 GB 27.94%
Data Protection Capacity (used): 1,100.585 GB 27.94%
Unused Configured Capacity: 1,607.841 GB 40.81%
Includes 803.921 GB in unused Data Protection Capacity


Addressable Storage Capacity: 1,100.585 GB
ASU Capacity: 1,100.585 GB 100.00%
5 Logical Volumes, 99.053 GB per Volume (ASU-1)
5 Logical Volumes, 99.053 GB per Volume (ASU-2)
5 Logical Volumes, 22.012 GB per Volume (ASU-3)
Unused Addressable Capacity: 0 GB 0.00%
ASU-1 Capacity: 495.263 GB 45.00%
ASU-2 Capacity: 495.263 GB 45.00%
ASU-3 Capacity: 110.059 GB 10.00%



Storage Capacity Utilization

Clause 9.4.3.6.2

The FDR will include a table illustrating the storage capacity utilization values defined for Application Utilization (Clause 2.8.1), Protected Application Utilization (Clause 2.8.2), and Unused Storage Ratio (Clause 2.8.3).

Clause 2.8.1

Application Utilization is defined as Total ASU Capacity divided by Physical Storage Capacity.

Clause 2.8.2

Protected Application Utilization is defined as (Total ASU Capacity plus total Data Protection Capacity minus unused Data Protection Capacity) divided by Physical Storage Capacity.

Clause 2.8.3

Unused Storage Ratio is defined as Total Unused Capacity divided by Physical Storage Capacity and may not exceed 45%.

SPC-1 Storage Capacity Utilization	
Application Utilization	21.16%
Protected Application Utilization	43.35%
Unused Storage Ratio	30.91%

Logical Volume Capacity and ASU Mapping

Clause 9.4.3.6.3

A table illustrating the capacity of each ASU and the mapping of Logical Volumes to ASUs shall be provided in the FDR. … Logical Volumes shall be sequenced in the table from top to bottom per its position in the contiguous address space of each ASU. The capacity of each Logical Volume shall be stated. … In conjunction with this table, the Test Sponsor shall provide a complete description of the type of data protection (see Clause 2.4.5) used on each Logical Volume.

Logical Volume Capacity and Mapping		
ASU-1 (495.263 GB)	**ASU-2 (495.263 GB)**	**ASU-3 (110.059 GB)**
5 Logical Volumes 99.053 GB per Logical Volume (99.053 GB used per Logical Volume)	5 Logical Volumes 99.053 GB per Logical Volume (99.053 GB used per Logical Volume)	5 Logical Volumes 22.012 GB per Logical Volume (22.012 GB used per Logical Volume)

The Data Protection Level used for all Logical Volumes was **Protected 2** using ***Mirroring*** as described on page 11. See "ASU Configuration" in the **IOPS Test Results File** for more detailed configuration information.

SPC-1 BENCHMARK EXECUTION RESULTS

This portion of the Full Disclosure Report documents the results of the various SPC-1 Tests, Test Phases, and Test Runs. An SPC-1 glossary on page 61 contains definitions of terms specific to the SPC-1 Tests, Test Phases, and Test Runs.

Clause 5.4.3

The Tests must be executed in the following sequence: Primary Metrics, Repeatability, and Data Persistence. That required sequence must be uninterrupted from the start of Primary Metrics to the completion of Persistence Test Run 1. Uninterrupted means the Benchmark Configuration shall not be power cycled, restarted, disturbed, altered, or adjusted during the above measurement sequence. If the required sequence is interrupted other than for the Host System/TSC power cycle between the two Persistence Test Runs, the measurement is invalid.

SPC-1 Tests, Test Phases, and Test Runs

The SPC-1 benchmark consists of the following Tests, Test Phases, and Test Runs:

- **Primary Metrics Test**
  - Sustainability Test Phase and Test Run
  - IOPS Test Phase and Test Run
  - Response Time Ramp Test Phase
    - 95% of IOPS Test Run
    - 90% of IOPS Test Run
    - 80% of IOPS Test Run
    - 50% of IOPS Test Run
    - 10% of IOPS Test Run (LRT)
- **Repeatability Test**
  - Repeatability Test Phase 1
    - 10% of IOPS Test Run (LRT)
    - IOPS Test Run
  - Repeatability Test Phase 2
    - 10% of IOPS Test Run (LRT)
    - IOPS Test Run
- **Data Persistence Test**
  - Data Persistence Test Run 1
  - Data Persistence Test Run 2

Each Test is an atomic unit that must be executed from start to finish before any other Test, Test Phase, or Test Run may be executed.

The results from each Test, Test Phase, and Test Run are listed below along with a more detailed explanation of each component.

"Ramp-Up" Test Runs

Clause 5.3.13

In order to warm-up caches or perform the initial ASU data migration in a multi-tier configuration, a Test Sponsor may perform a series of "Ramp-Up" Test Runs as a substitute for an initial, gradual Ramp-Up.

Clause 5.3.13.3

The "Ramp-Up" Test Runs will immediately precede the Primary Metrics Test as part of the uninterrupted SPC-1 measurement sequence.

Clause 9.4.3.7.1

If a series of "Ramp-Up" Test Runs were included in the SPC-1 measurement sequence, the FDR shall report the duration (ramp-up and measurement interval), BSU level, SPC-1 IOPS and average response time for each "Ramp-Up" Test Run in an appropriate table.

There were no "Ramp-Up" Test Runs executed.

Primary Metrics Test – Sustainability Test Phase

Clause 5.4.4.1.1

The Sustainability Test Phase has exactly one Test Run and shall demonstrate the maximum sustainable I/O Request Throughput within at least a continuous eight (8) hour Measurement Interval. This Test Phase also serves to insure that the TSC has reached Steady State prior to reporting the final maximum I/O Request Throughput result (SPC-1 IOPS™).

Clause 5.4.4.1.2

The computed I/O Request Throughput of the Sustainability Test must be within 5% of the reported SPC-1 IOPS™ result.

Clause 5.4.4.1.4

The Average Response Time, as defined in Clause 5.1.1, will be computed and reported for the Sustainability Test Run and cannot exceed 30 milliseconds. If the Average Response time exceeds that 30-milliseconds constraint, the measurement is invalid.

Clause 9.4.3.7.2

For the Sustainability Test Phase the FDR shall contain:

1. *A Data Rate Distribution graph and data table.*
2. *I/O Request Throughput Distribution graph and data table.*
3. *A Response Time Frequency Distribution graph and table.*
4. *An Average Response Time Distribution graph and table.*
5. *The human readable Test Run Results File produced by the Workload Generator (may be included in an appendix).*
6. *A listing or screen image of all input parameters supplied to the Workload Generator (may be included in an appendix).*
7. *The Measured Intensity Multiplier for each I/O stream.*
8. *The variability of the Measured Intensity Multiplier, as defined in Clause 5.3.13.3.*

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in Appendix E: SPC-1 Workload Generator Input Parameters on Page 77.

Sustainability Test Results File

A link to the test results file generated from the Sustainability Test Run is listed below.

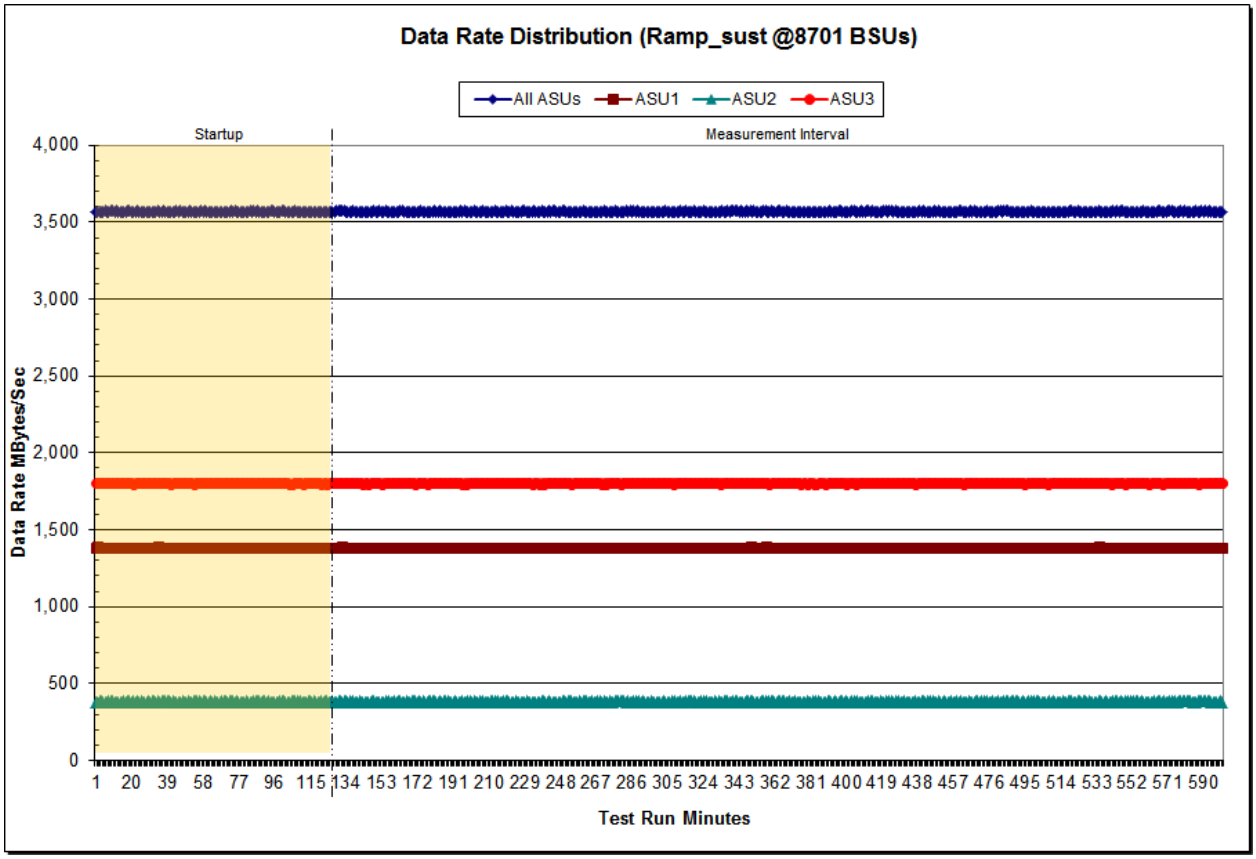
Sustainability Test Results File

Sustainability – Data Rate Distribution Data (MB/second)

The Sustainability Data Rate table of data is not embedded in this document due to its size. The table is available via the following URL:

Sustainability Data Rate Table

Sustainability – Data Rate Distribution Graph

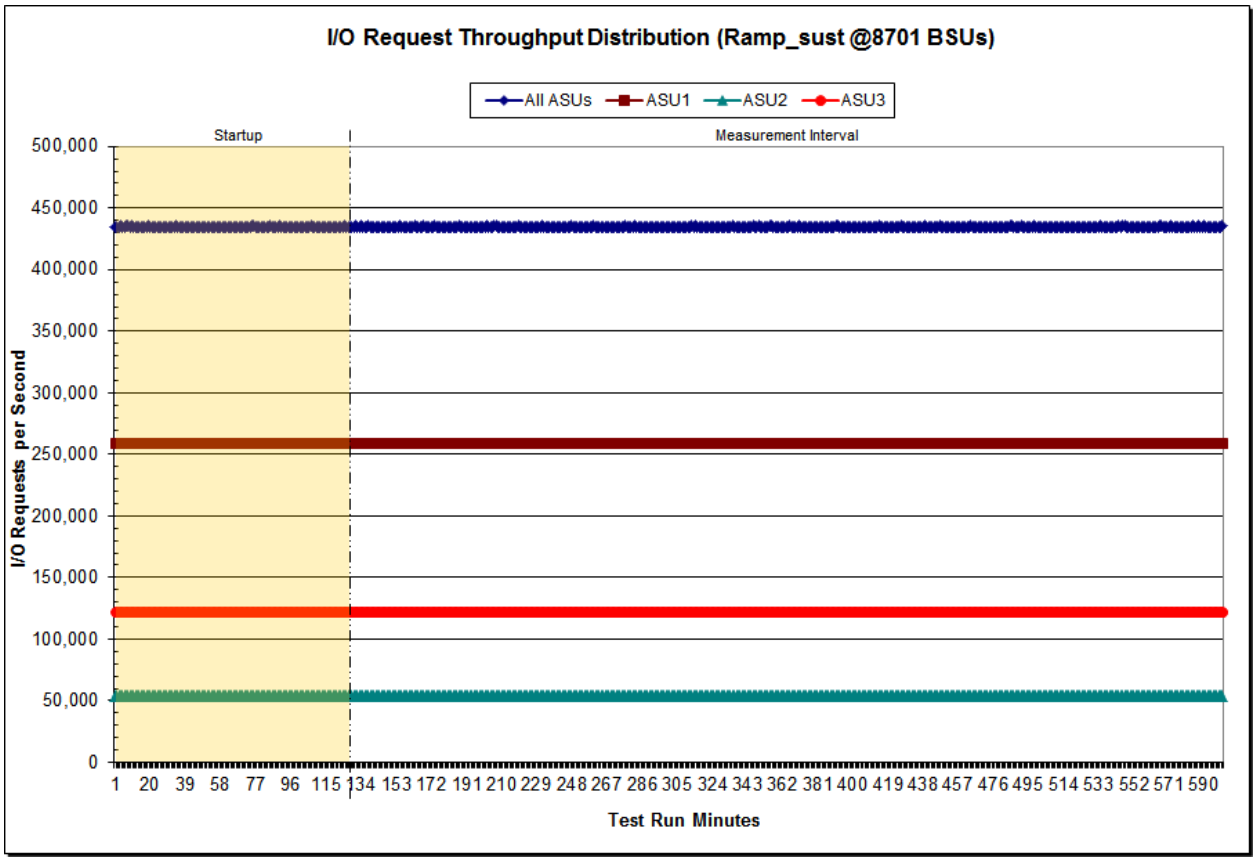


Sustainability – I/O Request Throughput Distribution Data

The Sustainability I/O Request Throughput table of data is not embedded in this document due to its size. The table is available via the following URL:

Sustainability I/O Request Throughput Table

Sustainability – I/O Request Throughput Distribution Graph

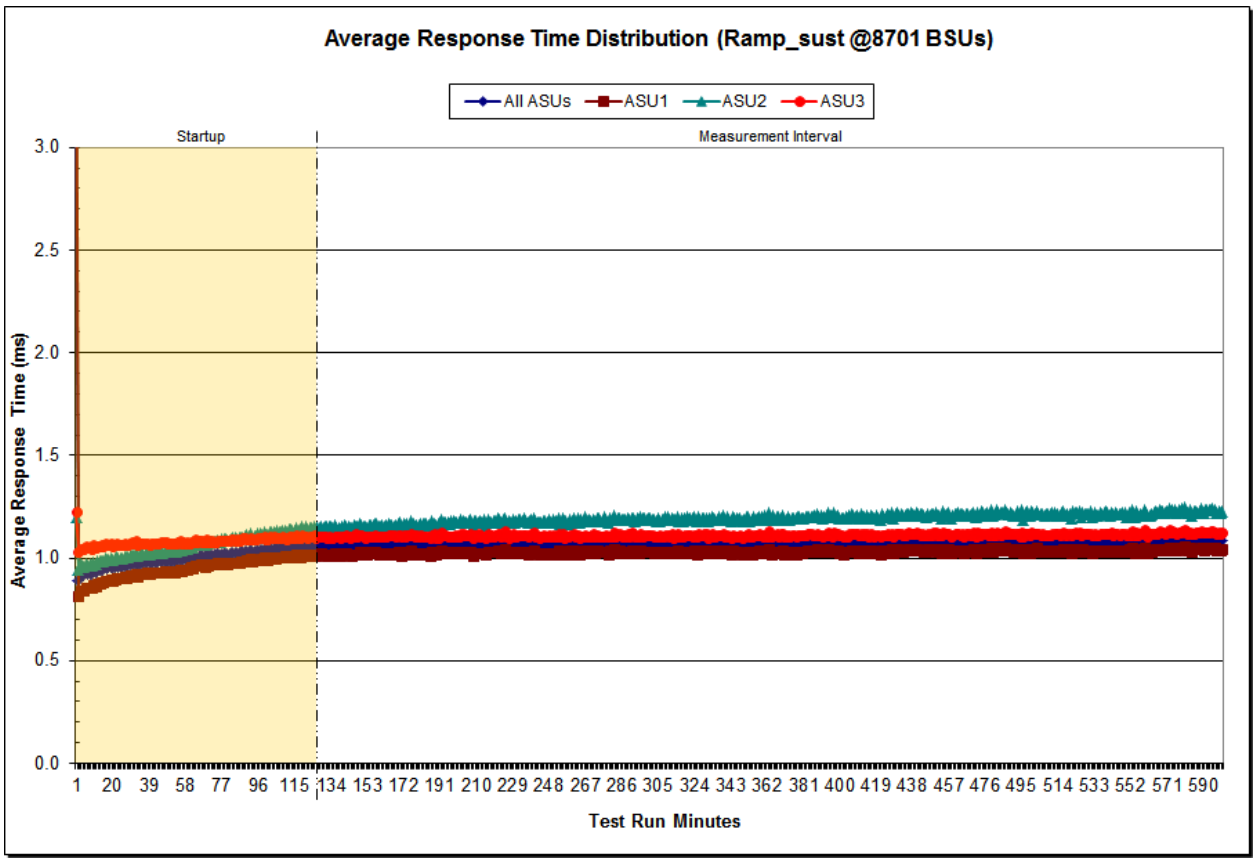


Sustainability – Average Response Time (ms) Distribution Data

The Sustainability Average Response Time table of data is not embedded in this document due to its size. The table is available via the following URL:

Sustainability Average Response Time Table

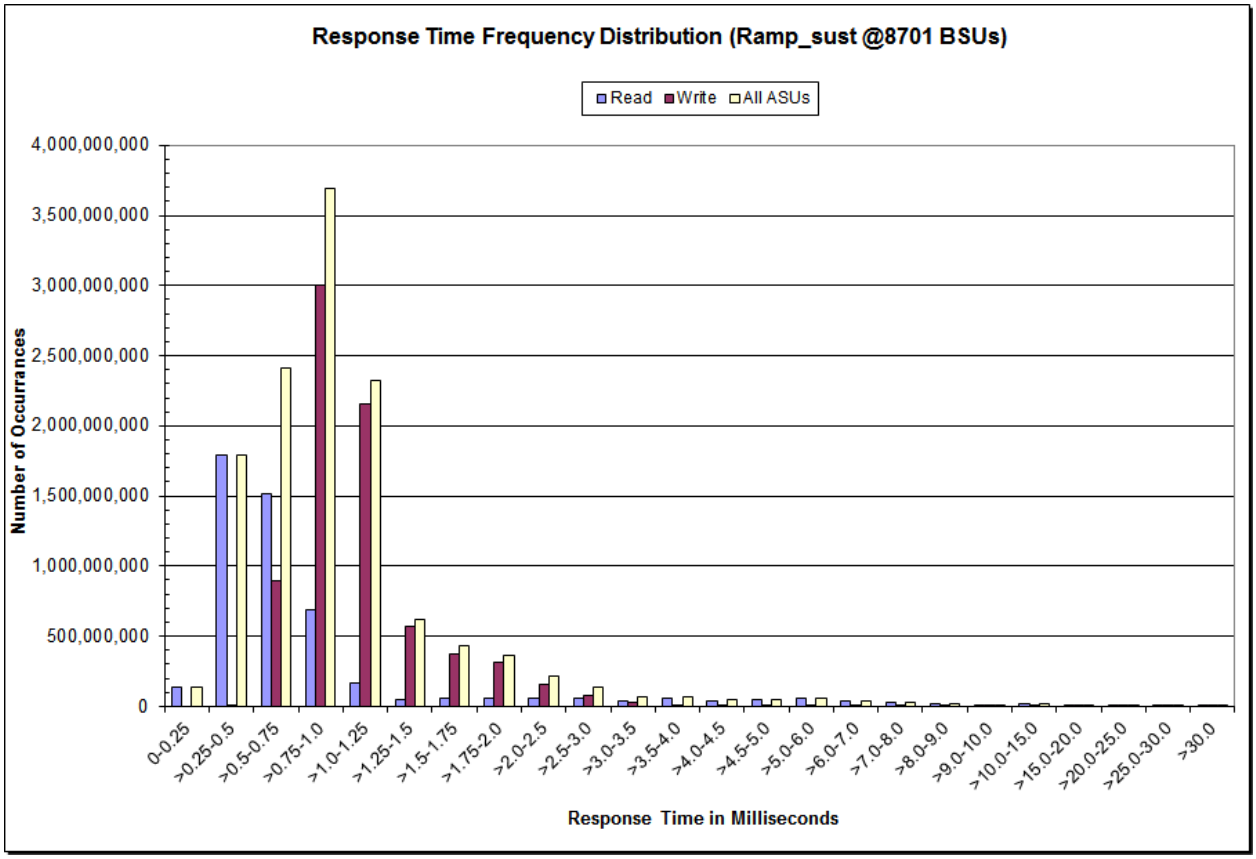
Sustainability – Average Response Time (ms) Distribution Graph



Sustainability – Response Time Frequency Distribution Data

Response Time (ms)	0-0.25	>0.25-0.5	>0.5-0.75	>0.75-1.0	>1.0-1.25	>1.25-1.5	>1.5-1.75	>1.75-2.0
Read	132,020,384	1,791,814,662	1,517,492,825	685,509,371	169,106,541	52,087,123	56,388,012	54,706,883
Write	0	2,807,321	891,387,206	3,003,463,798	2,153,872,545	568,262,270	374,488,475	311,653,013
All ASUs	132,020,384	1,794,621,983	2,408,880,031	3,688,973,169	2,322,979,086	620,349,393	430,876,487	366,359,896
ASU1	117,559,320	1,572,566,237	1,711,062,342	1,912,256,971	1,029,943,226	269,756,235	195,458,848	169,979,351
ASU2	14,461,064	220,947,077	319,640,446	426,701,192	254,927,881	69,435,727	51,065,749	44,738,001
ASU3	0	1,108,669	378,177,243	1,350,015,006	1,038,107,979	281,157,431	184,351,890	151,642,544
Response Time (ms)	**>2.0-2.5**	**>2.5-3.0**	**>3.0-3.5**	**>3.5-4.0**	**>4.0-4.5**	**>4.5-5.0**	**>5.0-6.0**	**>6.0-7.0**
Read	54,215,338	58,343,620	40,501,678	57,966,955	38,675,613	46,915,610	58,799,801	40,714,445
Write	156,931,041	74,220,737	27,525,246	12,116,144	5,164,759	2,368,478	1,731,550	591,199
All ASUs	211,146,379	132,564,357	68,026,924	70,083,099	43,840,372	49,284,088	60,531,351	41,305,644
ASU1	106,659,715	76,222,268	42,724,629	49,978,122	32,044,101	37,227,012	46,008,322	31,574,142
ASU2	28,273,681	20,711,087	11,948,578	14,274,163	9,292,379	10,910,893	13,682,544	9,446,942
ASU3	76,212,983	35,631,002	13,353,717	5,830,814	2,503,892	1,146,183	840,485	284,560
Response Time (ms)	**>7.0-8.0**	**>8.0-9.0**	**>9.0-10.0**	**>10.0-15.0**	**>15.0-20.0**	**>20.0-25.0**	**>25.0-30.0**	**>30.0**
Read	31,831,241	21,491,821	12,662,167	18,162,168	1,700,176	229,300	74,887	197,737
Write	286,327	165,548	104,491	211,028	89,236	63,063	50,057	180,820
All ASUs	32,117,568	21,657,369	12,766,658	18,373,196	1,789,412	292,363	124,944	378,557
ASU1	24,574,792	16,492,524	9,680,277	13,805,350	1,305,778	222,578	110,403	368,817
ASU2	7,410,086	5,094,051	3,046,307	4,511,880	477,369	68,689	14,257	8,238
ASU3	132,690	70,794	40,074	55,966	6,265	1,096	284	1,502

Sustainability – Response Time Frequency Distribution Graph



Sustainability – Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

IM – Intensity Multiplier: *The ratio of I/Os for each I/O stream relative to the total I/Os for all I/O streams (ASU1-1 – ASU3-1) as required by the benchmark specification.*

Clauses 5.1.10 and 5.3.15.2

MIM – Measured Intensity Multiplier: *The Measured Intensity Multiplier represents the ratio of measured I/Os for each I/O stream relative to the total I/Os measured for all I/O streams (ASU1-1 – ASU3-1). This value may differ from the corresponding Expected Intensity Multiplier by no more than 5%.*

Clause 5.3.15.3

COV – Coefficient of Variation: *This measure of variation for the Measured Intensity Multiplier cannot exceed 0.2.*

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.001	0.000	0.001	0.000	0.001	0.001	0.001	0.000

Primary Metrics Test – IOPS Test Phase

Clause 5.4.4.2

The IOPS Test Phase consists of one Test Run at the 100% load point with a Measurement Interval of ten (10) minutes. The IOPS Test Phase immediately follows the Sustainability Test Phase without any interruption or manual intervention.

The IOPS Test Run generates the SPC-1 IOPS™ primary metric, which is computed as the I/O Request Throughput for the Measurement Interval of the IOPS Test Run.

The Average Response Time is computed for the IOPS Test Run and cannot exceed 30 milliseconds. If the Average Response Time exceeds the 30 millisecond constraint, the measurement is invalid.

Clause 9.4.3.7.3

For the IOPS Test Phase the FDR shall contain:

1. *I/O Request Throughput Distribution (data and graph).*
2. *A Response Time Frequency Distribution.*
3. *An Average Response Time Distribution.*
4. *The human readable Test Run Results File produced by the Workload Generator.*
5. *A listing or screen image of all input parameters supplied to the Workload Generator.*
6. *The total number of I/O Requests completed in the Measurement Interval as well as the number of I/O Requests with a Response Time less than or equal to 30 milliseconds and the number of I/O Requests with a Response Time greater than 30 milliseconds.*

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in Appendix E: SPC-1 Workload Generator Input Parameters on Page 77.

IOPS Test Results File

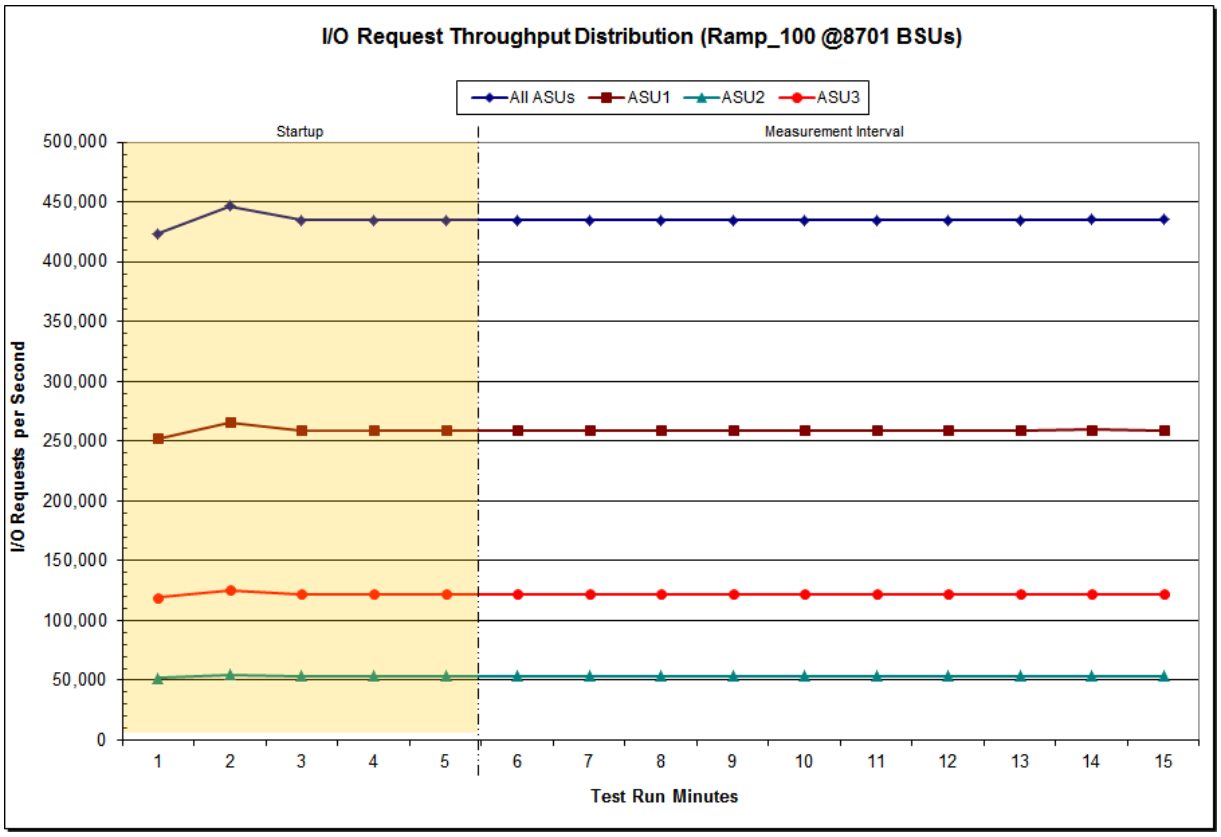
A link to the test results file generated from the IOPS Test Run is listed below.

IOPS Test Results File

IOPS Test Run – I/O Request Throughput Distribution Data

8,701 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:44:02	19:49:03	0-4	0:05:01
Measurement Interval	19:49:03	19:59:03	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	423,713.73	252,514.43	52,120.85	119,078.45
1	446,415.35	266,032.72	54,949.52	125,433.12
2	434,939.78	259,273.03	53,468.20	122,198.55
3	435,131.78	259,280.97	53,550.58	122,300.23
4	435,015.67	259,248.12	53,506.67	122,260.88
5	435,094.67	259,245.85	53,546.05	122,302.77
6	434,926.33	259,213.40	53,524.03	122,188.90
7	434,966.42	259,274.82	53,473.82	122,217.78
8	435,005.65	259,285.22	53,462.23	122,258.20
9	435,033.10	259,276.32	53,574.70	122,182.08
10	435,031.47	259,238.38	53,541.28	122,251.80
11	435,125.63	259,343.27	53,531.62	122,250.75
12	435,076.33	259,258.13	53,541.57	122,276.63
13	435,244.22	259,499.33	53,514.08	122,230.80
14	435,169.50	259,377.62	53,529.52	122,262.37
Average	***435,067.33***	***259,301.23***	***53,523.89***	***122,242.21***

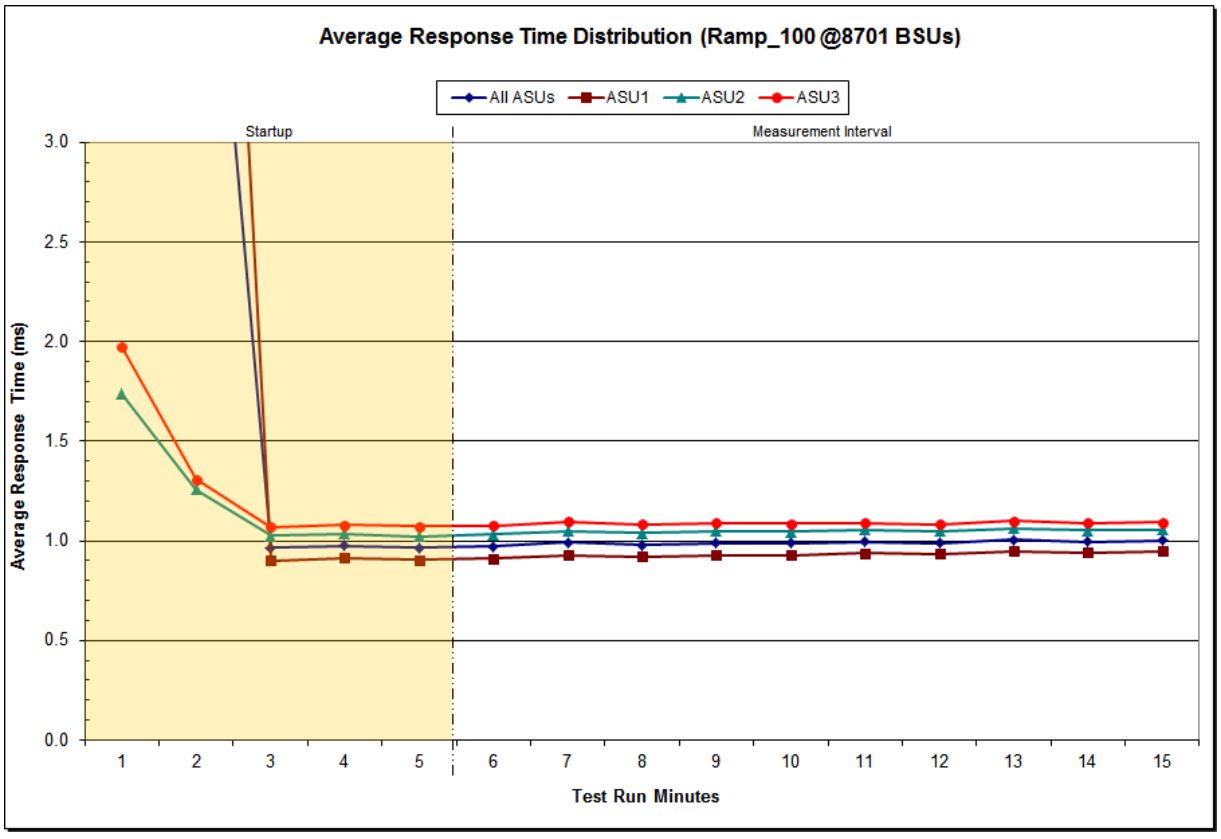
IOPS Test Run – I/O Request Throughput Distribution Graph



IOPS Test Run – Average Response Time (ms) Distribution Data

8,701 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:44:02	19:49:03	0-4	0:05:01
Measurement Interval	19:49:03	19:59:03	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	29.86	48.81	1.74	1.97
1	5.22	7.89	1.26	1.31
2	0.96	0.90	1.02	1.07
3	0.98	0.91	1.04	1.08
4	0.97	0.90	1.02	1.07
5	0.97	0.91	1.03	1.08
6	0.99	0.93	1.05	1.10
7	0.98	0.92	1.04	1.08
8	0.99	0.93	1.05	1.09
9	0.99	0.93	1.05	1.09
10	0.99	0.94	1.05	1.09
11	0.99	0.93	1.05	1.08
12	1.01	0.95	1.06	1.10
13	1.00	0.94	1.05	1.09
14	1.00	0.95	1.05	1.09
Average	***0.99***	***0.93***	***1.05***	***1.09***

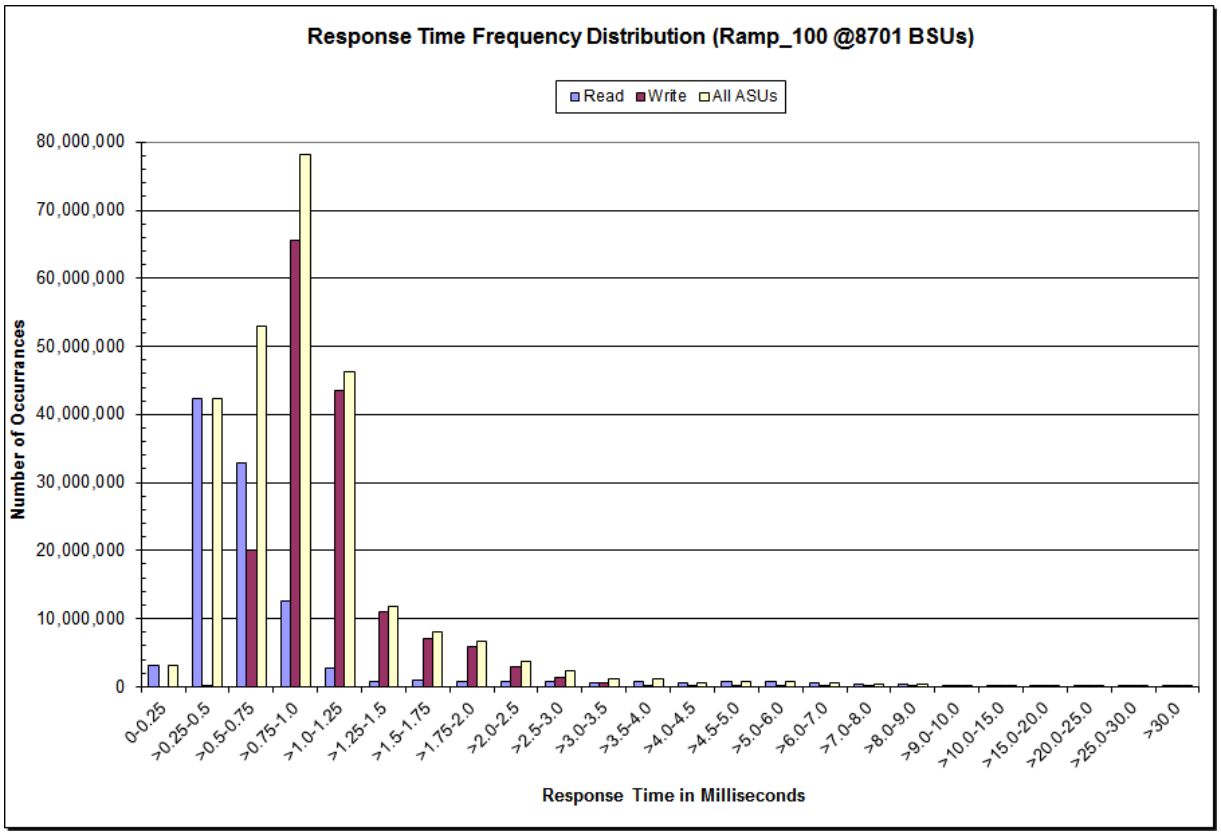
IOPS Test Run – Average Response Time (ms) Distribution Graph



IOPS Test Run –Response Time Frequency Distribution Data

Response Time (ms)	0-0.25	>0.25-0.5	>0.5-0.75	>0.75-1.0	>1.0-1.25	>1.25-1.5	>1.5-1.75	>1.75-2.0
Read	3,126,648	42,259,574	32,834,200	12,652,288	2,727,382	819,821	881,431	841,359
Write	0	65,179	20,067,278	65,502,795	43,538,198	10,904,716	7,094,238	5,801,137
All ASUs	3,126,648	42,324,753	52,901,478	78,155,083	46,265,580	11,724,537	7,975,669	6,642,496
ASU1	2,770,926	36,994,886	37,095,750	39,363,779	20,291,857	5,065,691	3,580,448	3,045,233
ASU2	355,722	5,304,233	7,289,972	9,291,038	4,887,275	1,236,205	898,038	767,958
ASU3	0	25,634	8,515,756	29,500,266	21,086,448	5,422,641	3,497,183	2,829,305
Response Time (ms)	**>2.0-2.5**	**>2.5-3.0**	**>3.0-3.5**	**>3.5-4.0**	**>4.0-4.5**	**>4.5-5.0**	**>5.0-6.0**	**>6.0-7.0**
Read	821,409	852,709	589,948	842,999	554,181	663,423	814,032	559,556
Write	2,826,837	1,392,144	488,970	218,514	86,233	38,924	25,735	7,947
All ASUs	3,648,246	2,244,853	1,078,918	1,061,513	640,414	702,347	839,767	567,503
ASU1	1,802,311	1,229,787	652,017	735,346	455,443	518,150	635,722	439,360
ASU2	472,308	344,619	189,575	220,618	142,904	165,457	191,615	124,447
ASU3	1,373,627	670,447	237,326	105,549	42,067	18,740	12,430	3,696
Response Time (ms)	**>7.0-8.0**	**>8.0-9.0**	**>9.0-10.0**	**>10.0-15.0**	**>15.0-20.0**	**>20.0-25.0**	**>25.0-30.0**	**>30.0**
Read	435,285	282,657	160,082	214,267	17,651	3,126	1,483	4,312
Write	3,957	2,314	1,600	3,935	2,328	1,540	1,291	4,303
All ASUs	439,242	284,971	161,682	218,202	19,979	4,666	2,774	8,615
ASU1	343,795	226,604	128,956	174,018	15,378	3,915	2,582	8,503
ASU2	93,790	57,479	32,197	43,409	4,425	712	187	103
ASU3	1,657	888	529	775	176	39	5	9

IOPS Test Run –Response Time Frequency Distribution Graph



IOPS Test Run – I/O Request Information

I/O Requests Completed in the Measurement Interval	I/O Requests Completed with Response Time = or < 30 ms	I/O Requests Completed with Response Time > 30 ms
261,039,936	261,031,321	8,615

IOPS Test Run – Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

IM – Intensity Multiplier: *The ratio of I/Os for each I/O stream relative to the total I/Os for all I/O streams (ASU1-1 – ASU3-1) as required by the benchmark specification.*

Clauses 5.1.10 and 5.3.15.2

MIM – Measured Intensity Multiplier: *The Measured Intensity Multiplier represents the ratio of measured I/Os for each I/O stream relative to the total I/Os measured for all I/O streams (ASU1-1 – ASU3-1). This value may differ from the corresponding Expected Intensity Multiplier by no more than 5%.*

Clause 5.3.15.3

COV – Coefficient of Variation: *This measure of variation for the Measured Intensity Multiplier cannot exceed 0.2.*

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2810	0.0700	0.2101	0.0180	0.0700	0.0350	0.2810
COV	0.001	0.000	0.001	0.000	0.002	0.001	0.001	0.000

Primary Metrics Test – Response Time Ramp Test Phase

Clause 5.4.4.3

The Response Time Ramp Test Phase consists of five Test Runs, one each at 95%, 90%, 80%, 50%, and 10% of the load point (100%) used to generate the SPC-1 IOPS™ primary metric. Each of the five Test Runs has a Measurement Interval of ten (10) minutes. The Response Time Ramp Test Phase immediately follows the IOPS Test Phase without any interruption or manual intervention.

The five Response Time Ramp Test Runs, in conjunction with the IOPS Test Run (100%), demonstrate the relationship between Average Response Time and I/O Request Throughput for the Tested Storage Configuration (TSC) as illustrated in the response time/throughput curve on page 15.

In addition, the Average Response Time measured during the 10% Test Run is the value for the SPC-1 LRT™ metric. That value represents the Average Response Time of a lightly loaded TSC.

Clause 9.4.3.7.4

The following content shall appear in the FDR for the Response Time Ramp Phase:

1. *A Response Time Ramp Distribution.*
2. *The human readable Test Run Results File produced by the Workload Generator for each Test Run within the Response Time Ramp Test Phase.*
3. *For the 10% Load Level Test Run (SPC-1 LRT™ metric) an Average Response Time Distribution.*
4. *A listing or screen image of all input parameters supplied to the Workload Generator.*

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in Appendix E: SPC-1 Workload Generator Input Parameters on Page 77.

Response Time Ramp Test Results File

A link to each test result file generated from each Response Time Ramp Test Run list listed below.

95% Load Level

90% Load Level

80% Load Level

50% Load Level

10% Load Level

Response Time Ramp Distribution (IOPS) Data

The five Test Runs that comprise the Response Time Ramp Phase are executed at 95%, 90%, 80%, 50%, and 10% of the Business Scaling Unit (BSU) load level used to produce the SPC-1 IOPS™ primary metric. The 100% BSU load level is included in the following Response Time Ramp data table and graph for completeness.

100% Load Level: 8,701 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:44:02	19:49:03	0-4	0:05:01
Measurement Interval	19:49:03	19:59:03	5-14	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	423,713.73	252,514.43	52,120.85	119,078.45
1	446,415.35	266,032.72	54,949.52	125,433.12
2	434,939.78	259,273.03	53,468.20	122,198.55
3	435,131.78	259,280.97	53,550.58	122,300.23
4	435,015.67	259,248.12	53,506.67	122,260.88
5	435,094.67	259,245.85	53,546.05	122,302.77
6	434,926.33	259,213.40	53,524.03	122,188.90
7	434,966.42	259,274.82	53,473.82	122,217.78
8	435,005.65	259,285.22	53,462.23	122,258.20
9	435,033.10	259,276.32	53,574.70	122,182.08
10	435,031.47	259,238.38	53,541.28	122,251.80
11	435,125.63	259,343.27	53,531.62	122,250.75
12	435,076.33	259,258.13	53,541.57	122,276.63
13	435,244.22	259,499.33	53,514.08	122,230.80
14	435,169.50	259,377.62	53,529.52	122,262.37
Average	***435,067.33***	***259,301.23***	***53,523.89***	***122,242.21***

95% Load Level: 8,265 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:00:16	20:05:17	0-4	0:05:01
Measurement Interval	20:05:17	20:15:17	5-14	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	413,252.02	246,305.37	50,861.85	116,084.80
1	413,288.47	246,297.23	50,853.97	116,137.27
2	413,235.12	246,309.22	50,845.77	116,080.13
3	413,254.32	246,291.42	50,804.37	116,158.53
4	413,354.17	246,364.53	50,852.80	116,136.83
5	413,242.45	246,280.68	50,827.93	116,133.83
6	413,219.82	246,325.43	50,801.33	116,093.05
7	413,315.97	246,309.30	50,866.10	116,140.57
8	413,243.42	246,333.83	50,803.78	116,105.80
9	413,312.80	246,351.58	50,788.28	116,172.93
10	413,208.02	246,275.13	50,780.62	116,152.27
11	413,217.72	246,255.90	50,835.13	116,126.68
12	413,070.95	246,236.00	50,796.00	116,038.95
13	413,287.25	246,288.40	50,852.63	116,146.22
14	413,214.78	246,224.15	50,821.43	116,169.20
Average	***413,233.32***	***246,288.04***	***50,817.33***	***116,127.95***

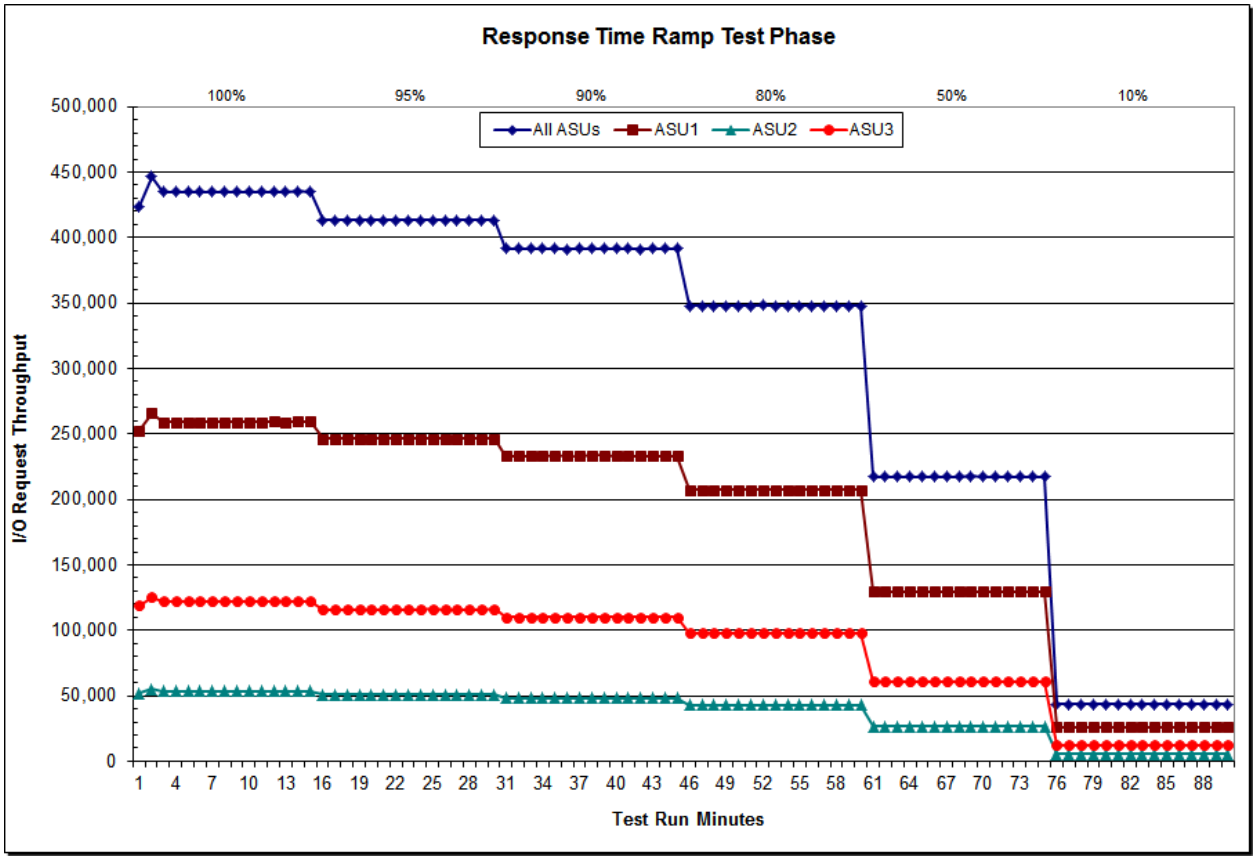
90% Load Level: 7,830 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:16:29	20:21:30	0-4	0:05:01
Measurement Interval	20:21:30	20:31:30	5-14	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	391,449.33	233,342.00	48,140.83	109,966.50
1	391,498.23	233,308.27	48,136.20	110,053.77
2	391,621.20	233,415.18	48,198.72	110,007.30
3	391,491.12	233,322.83	48,142.12	110,026.17
4	391,623.68	233,472.40	48,156.18	109,995.10
5	391,342.32	233,210.40	48,137.28	109,994.63
6	391,483.88	233,362.05	48,105.10	110,016.73
7	391,717.17	233,489.50	48,187.87	110,039.80
8	391,592.93	233,492.90	48,116.93	109,983.10
9	391,499.98	233,372.50	48,137.53	109,989.95
10	391,433.17	233,332.98	48,120.45	109,979.73
11	391,371.93	233,262.90	48,144.87	109,964.17
12	391,498.60	233,313.70	48,166.77	110,018.13
13	391,501.22	233,294.53	48,156.02	110,050.67
14	391,422.63	233,299.08	48,211.92	109,911.63
Average	***391,486.38***	***233,343.06***	***48,148.47***	***109,994.86***

80% Load Level: 6,960 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:32:34	20:37:35	0-4	0:05:01
Measurement Interval	20:37:35	20:47:35	5-14	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	347,883.48	207,338.00	42,773.30	97,772.18
1	347,872.83	207,276.52	42,776.05	97,820.27
2	347,957.12	207,369.87	42,803.15	97,784.10
3	347,919.72	207,349.38	42,797.28	97,773.05
4	347,948.80	207,400.58	42,781.95	97,766.27
5	347,929.53	207,366.42	42,795.85	97,767.27
6	348,115.52	207,456.07	42,831.70	97,827.75
7	348,061.13	207,430.12	42,830.52	97,800.50
8	347,921.58	207,392.75	42,781.57	97,747.27
9	348,052.87	207,455.17	42,805.45	97,792.25
10	348,025.65	207,501.93	42,740.72	97,783.00
11	348,001.35	207,433.15	42,847.13	97,721.07
12	347,939.27	207,382.38	42,780.35	97,776.53
13	348,067.98	207,404.02	42,797.33	97,866.63
14	348,055.10	207,447.42	42,822.83	97,784.85
Average	***348,017.00***	***207,426.94***	***42,803.35***	***97,786.71***

Response Time Ramp Distribution (IOPS) Data *(continued)*

50% Load Level: 4,350 BSUs	Start	Stop	Interval	Duration	10% Load Level: 870 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:48:20	20:53:21	0-4	0:05:01	Start-Up/Ramp-Up	21:03:42	21:08:43	0-4	0:05:01
Measurement Interval	20:53:21	21:03:21	5-14	0:10:00	Measurement Interval	21:08:43	21:18:43	5-14	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	*(60 second intervals)*	All ASUs	ASU-1	ASU-2	ASU-3
0	217,490.95	129,628.05	26,756.28	61,106.62	0	43,573.87	25,960.47	5,374.45	12,238.95
1	217,492.58	129,654.05	26,756.15	61,082.38	1	43,452.67	25,905.57	5,355.08	12,192.02
2	217,510.10	129,598.90	26,767.27	61,143.93	2	43,479.83	25,937.97	5,338.20	12,203.67
3	217,453.42	129,591.85	26,724.65	61,136.92	3	43,525.68	25,950.37	5,352.27	12,223.05
4	217,425.88	129,581.02	26,763.30	61,081.57	4	43,490.12	25,923.37	5,352.55	12,214.20
5	217,523.48	129,623.17	26,766.08	61,134.23	5	43,496.15	25,910.43	5,359.60	12,226.12
6	217,571.97	129,675.70	26,737.67	61,158.60	6	43,518.18	25,927.45	5,363.38	12,227.35
7	217,424.73	129,584.82	26,732.92	61,107.00	7	43,488.58	25,913.03	5,363.37	12,212.18
8	217,602.00	129,721.02	26,752.78	61,128.20	8	43,531.98	25,950.53	5,360.07	12,221.38
9	217,479.50	129,580.07	26,754.38	61,145.05	9	43,504.87	25,932.88	5,352.65	12,219.33
10	217,561.72	129,704.60	26,754.33	61,102.78	10	43,504.18	25,940.73	5,336.93	12,226.52
11	217,562.15	129,650.88	26,780.47	61,130.80	11	43,506.27	25,914.85	5,357.47	12,233.95
12	217,505.97	129,646.82	26,733.33	61,125.82	12	43,514.47	25,937.72	5,348.72	12,228.03
13	217,413.78	129,530.25	26,748.52	61,135.02	13	43,510.13	25,934.10	5,368.08	12,207.95
14	217,522.93	129,690.80	26,780.92	61,051.22	14	43,483.28	25,892.67	5,363.00	12,227.62
Average	***217,516.82***	***129,640.81***	***26,754.14***	***61,121.87***	***Average***	***43,505.81***	***25,925.44***	***5,357.33***	***12,223.04***

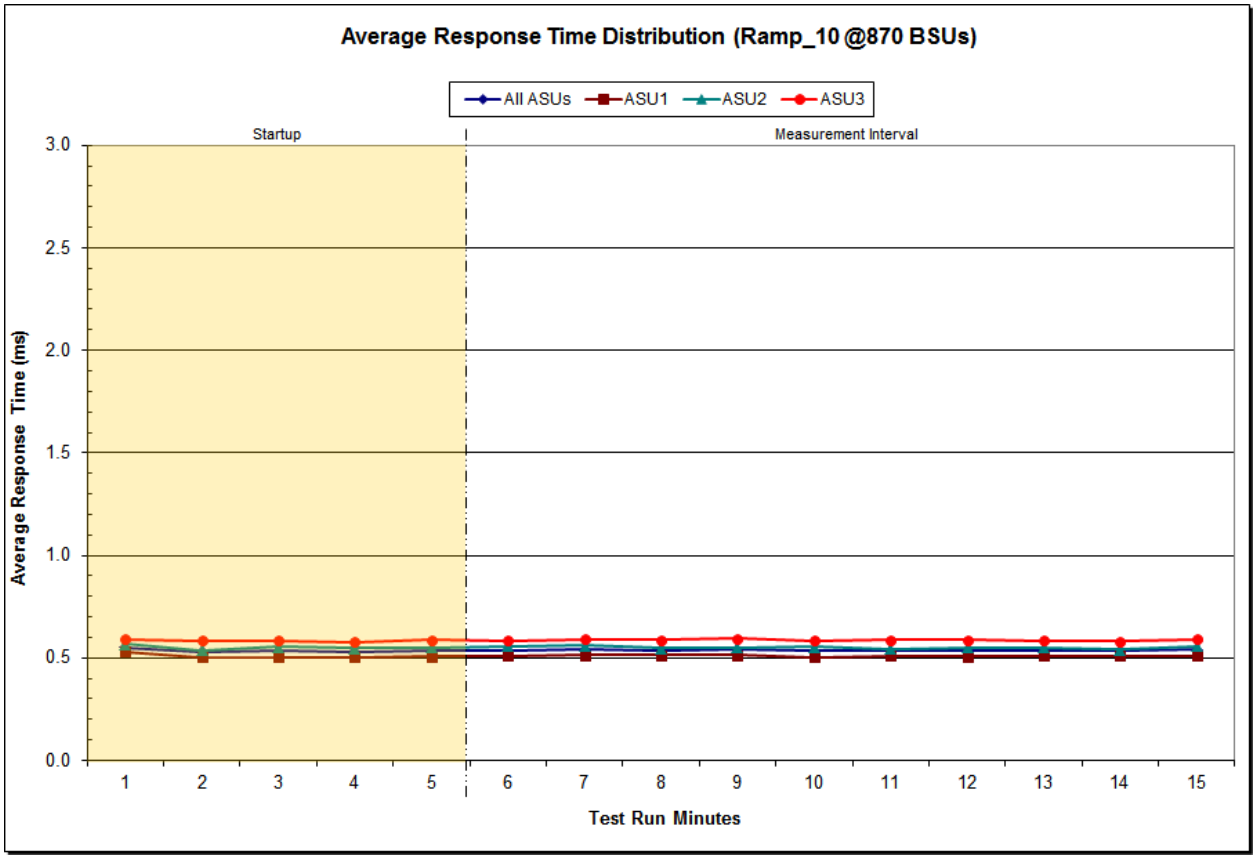
Response Time Ramp Distribution (IOPS) Graph



SPC-1 LRT™ Average Response Time (ms) Distribution Data

870 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:03:42	21:08:43	0-4	0:05:01
Measurement Interval	21:08:43	21:18:43	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	0.53	0.51	0.55	0.59
1	0.53	0.50	0.54	0.58
2	0.53	0.50	0.55	0.58
3	0.53	0.50	0.55	0.58
4	0.53	0.51	0.55	0.59
5	0.54	0.51	0.56	0.58
6	0.54	0.52	0.56	0.59
7	0.54	0.51	0.55	0.59
8	0.54	0.51	0.55	0.59
9	0.53	0.51	0.55	0.58
10	0.54	0.51	0.54	0.59
11	0.54	0.51	0.55	0.59
12	0.53	0.51	0.55	0.58
13	0.53	0.51	0.54	0.58
14	0.54	0.51	0.56	0.59
Average	*0.54*	*0.51*	*0.55*	*0.59*

SPC-1 LRT™ Average Response Time (ms) Distribution Graph



SPC-1 LRT™ (10%) – Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

IM – Intensity Multiplier: *The ratio of I/Os for each I/O stream relative to the total I/Os for all I/O streams (ASU1-1 – ASU3-1) as required by the benchmark specification.*

Clauses 5.1.10 and 5.3.15.2

MIM – Measured Intensity Multiplier: *The Measured Intensity Multiplier represents the ratio of measured I/Os for each I/O stream relative to the total I/Os measured for all I/O streams (ASU1-1 – ASU3-1). This value may differ from the corresponding Expected Intensity Multiplier by no more than 5%.*

Clause 5.3.15.3

COV – Coefficient of Variation: *This measure of variation for the Measured Intensity Multiplier cannot exceed 0.2.*

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2809	0.0699	0.2100	0.0180	0.0701	0.0351	0.2810
COV	0.002	0.001	0.003	0.001	0.004	0.002	0.003	0.001

Repeatability Test

Clause 5.4.5

The Repeatability Test demonstrates the repeatability and reproducibility of the SPC-1 IOPS™ primary metric and the SPC-1 LRT™ metric generated in earlier Test Runs.

There are two identical Repeatability Test Phases. Each Test Phase contains two Test Runs. Each of the Test Runs will have a Measurement Interval of no less than ten (10) minutes. The two Test Runs in each Test Phase will be executed without interruption or any type of manual intervention.

The first Test Run in each Test Phase is executed at the 10% load point. The Average Response Time from each of the Test Runs is compared to the SPC-1 LRT™ metric. Each Average Response Time value must be less than the SPC-1 LRT™ metric plus 5% or less than the SPC-1 LRT™ metric plus one (1) millisecond (ms).

The second Test Run in each Test Phase is executed at the 100% load point. The I/O Request Throughput from the Test Runs is compared to the SPC-1 IOPS™ primary metric. Each I/O Request Throughput value must be greater than the SPC-1 IOPS™ primary metric minus 5%. In addition, the Average Response Time for each Test Run cannot exceed 30 milliseconds.

If any of the above constraints are not met, the benchmark measurement is invalid.

Clause 9.4.3.7.5

The following content shall appear in the FDR for each Test Run in the two Repeatability Test Phases:

1. *A table containing the results of the Repeatability Test.*
2. *An I/O Request Throughput Distribution graph and table.*
3. *An Average Response Time Distribution graph and table.*
4. *The human readable Test Run Results File produced by the Workload Generator.*
5. *A listing or screen image of all input parameters supplied to the Workload Generator.*

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in Appendix E: SPC-1 Workload Generator Input Parameters on Page 77.

Repeatability Test Results File

The values for the SPC-1 IOPS™, SPC-1 LRT™, and the Repeatability Test measurements are listed in the tables below.

	SPC-1 IOPS™
Primary Metrics	***435,067.33***
Repeatability Test Phase 1	435,051.97
Repeatability Test Phase 2	435,052.78

The SPC-1 IOPS™ values in the above table were generated using 100% of the specified Business Scaling Unit (BSU) load level. Each of the Repeatability Test Phase values for SPC-1 IOPS™ must greater than 95% of the reported SPC-1 IOPS™ Primary Metric.

	SPC-1 LRT™
Primary Metrics	***0.54 ms***
Repeatability Test Phase 1	0.52 ms
Repeatability Test Phase 2	0.53 ms

The average response time values in the SPC-1 LRT™ column were generated using 10% of the specified Business Scaling Unit (BSU) load level. Each of the Repeatability Test Phase values for SPC-1 LRT™ must be less than 105% of the reported SPC-1 LRT™ Primary Metric or less than the reported SPC-1 LRT™ Primary Metric plus one (1) millisecond (ms).

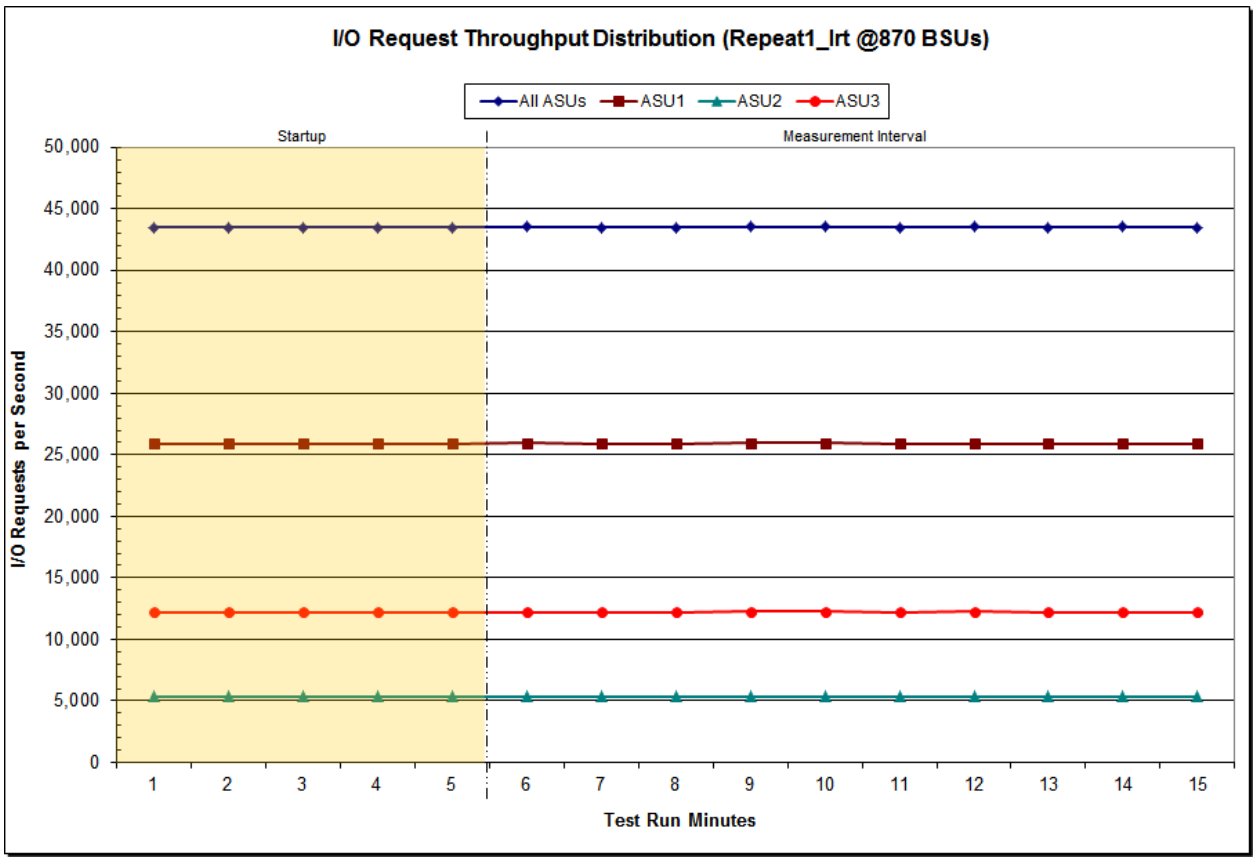
A link to the test result file generated from each Repeatability Test Run is listed below.

Repeatability Test Phase 1, Test Run 1 (LRT)
Repeatability Test Phase 1, Test Run 2 (IOPS)
Repeatability Test Phase 2, Test Run 1 (LRT)
Repeatability Test Phase 2, Test Run 2 (IOPS)

Repeatability 1 LRT – I/O Request Throughput Distribution Data

870 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:19:50	21:24:50	0-4	0:05:00
Measurement Interval	21:24:50	21:34:50	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	43,486.42	25,908.03	5,348.17	12,230.22
1	43,488.22	25,923.68	5,347.75	12,216.78
2	43,482.73	25,892.78	5,358.28	12,231.67
3	43,494.33	25,938.70	5,352.12	12,203.52
4	43,501.08	25,934.07	5,362.87	12,204.15
5	43,524.03	25,957.77	5,338.63	12,227.63
6	43,486.78	25,913.65	5,360.22	12,212.92
7	43,467.00	25,925.08	5,355.75	12,186.17
8	43,544.75	25,956.02	5,347.90	12,240.83
9	43,557.90	25,959.45	5,353.23	12,245.22
10	43,478.25	25,930.52	5,335.33	12,212.40
11	43,519.68	25,934.38	5,347.23	12,238.07
12	43,470.93	25,922.70	5,335.12	12,213.12
13	43,528.08	25,936.47	5,360.40	12,231.22
14	43,464.78	25,896.18	5,346.60	12,222.00
Average	***43,504.22***	***25,933.22***	***5,348.04***	***12,222.96***

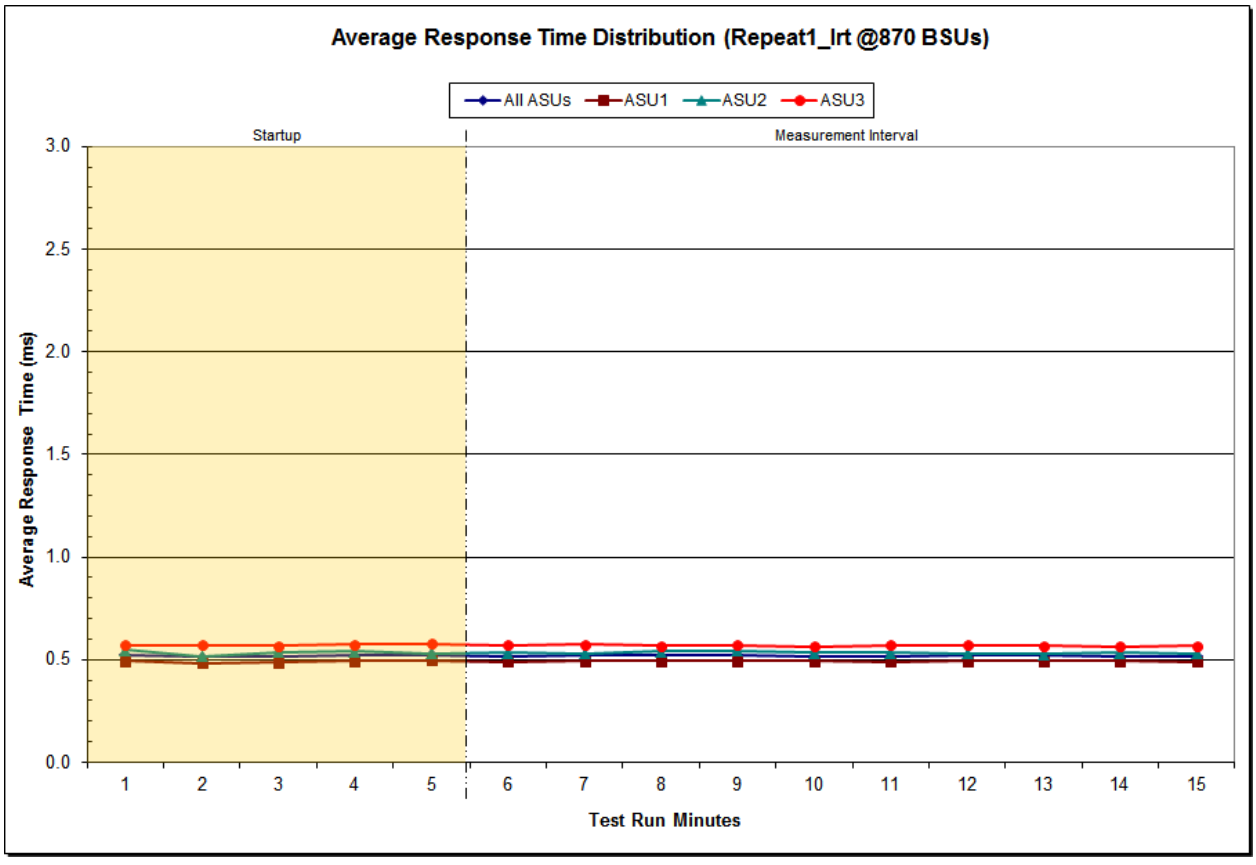
Repeatability 1 LRT – I/O Request Throughput Distribution Graph



Repeatability 1 LRT –Average Response Time (ms) Distribution Data

870 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:19:50	21:24:50	0-4	0:05:00
Measurement Interval	21:24:50	21:34:50	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.52	0.49	0.55	0.57
1	0.51	0.48	0.52	0.57
2	0.52	0.49	0.54	0.57
3	0.52	0.49	0.54	0.57
4	0.52	0.50	0.53	0.58
5	0.52	0.49	0.53	0.57
6	0.52	0.49	0.53	0.57
7	0.52	0.49	0.54	0.57
8	0.52	0.49	0.54	0.57
9	0.52	0.49	0.53	0.56
10	0.52	0.49	0.53	0.57
11	0.52	0.49	0.53	0.57
12	0.52	0.49	0.53	0.57
13	0.52	0.49	0.53	0.56
14	0.52	0.49	0.53	0.57
Average	***0.52***	***0.49***	***0.53***	***0.57***

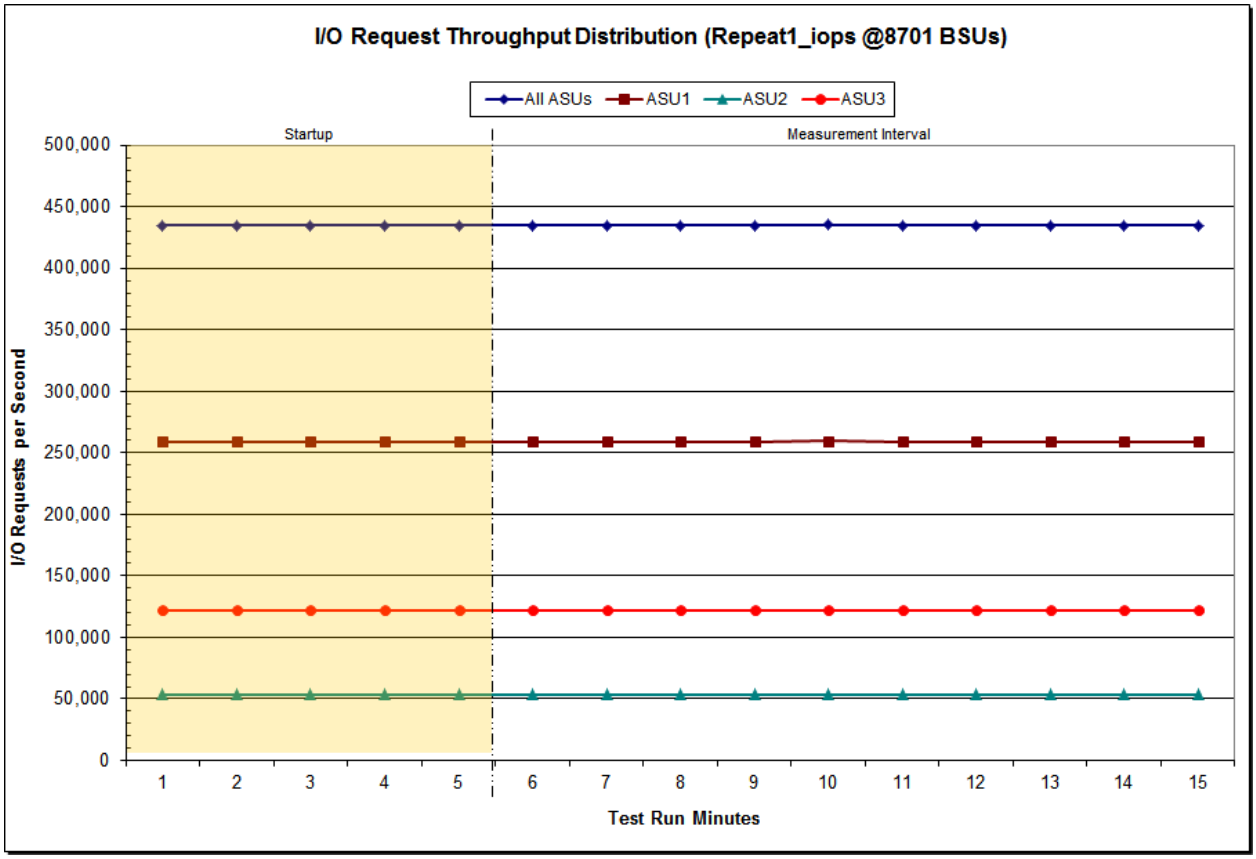
Repeatability 1 LRT –Average Response Time (ms) Distribution Graph



Repeatability 1 IOPS – I/O Request Throughput Distribution Data

8,701 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:35:36	21:40:37	0-4	0:05:01
Measurement Interval	21:40:37	21:50:37	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	435,105.03	259,384.67	53,463.85	122,256.52
1	435,075.43	259,330.22	53,465.65	122,279.57
2	435,037.42	259,264.55	53,555.58	122,217.28
3	435,034.42	259,188.78	53,498.27	122,347.37
4	435,125.60	259,387.08	53,513.08	122,225.43
5	435,024.77	259,289.55	53,518.68	122,216.53
6	435,068.07	259,279.97	53,483.42	122,304.68
7	434,975.92	259,254.78	53,501.87	122,219.27
8	435,115.52	259,300.03	53,559.03	122,256.45
9	435,245.83	259,399.93	53,500.32	122,345.58
10	434,977.20	259,277.88	53,498.40	122,200.92
11	434,930.42	259,150.52	53,468.78	122,311.12
12	435,077.62	259,364.72	53,487.47	122,225.43
13	435,075.80	259,282.52	53,477.83	122,315.45
14	435,028.60	259,213.27	53,542.28	122,273.05
Average	***435,051.97***	***259,281.32***	***53,503.81***	***122,266.85***

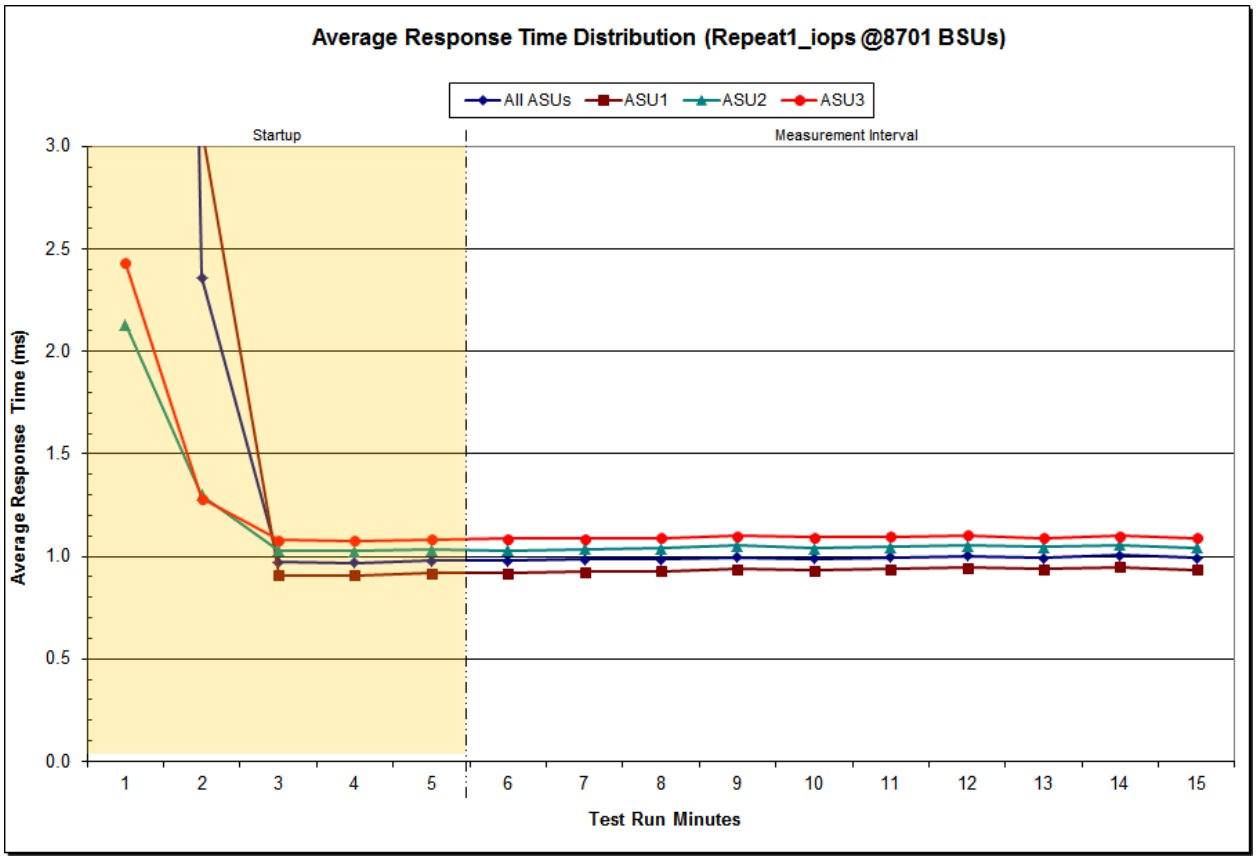
Repeatability 1 IOPS – I/O Request Throughput Distribution Graph



Repeatability 1 IOPS –Average Response Time (ms) Distribution Data

8,701 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:35:36	21:40:37	0-4	0:05:01
Measurement Interval	21:40:37	21:50:37	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	21.12	33.84	2.13	2.43
1	2.36	3.09	1.30	1.28
2	0.97	0.91	1.03	1.08
3	0.97	0.91	1.03	1.07
4	0.98	0.92	1.03	1.08
5	0.98	0.92	1.03	1.09
6	0.98	0.93	1.04	1.09
7	0.99	0.93	1.04	1.09
8	1.00	0.94	1.05	1.10
9	0.99	0.93	1.04	1.09
10	1.00	0.94	1.05	1.10
11	1.00	0.94	1.05	1.10
12	0.99	0.94	1.05	1.09
13	1.00	0.95	1.06	1.10
14	0.99	0.94	1.04	1.09
Average	***0.99***	***0.93***	***1.04***	***1.09***

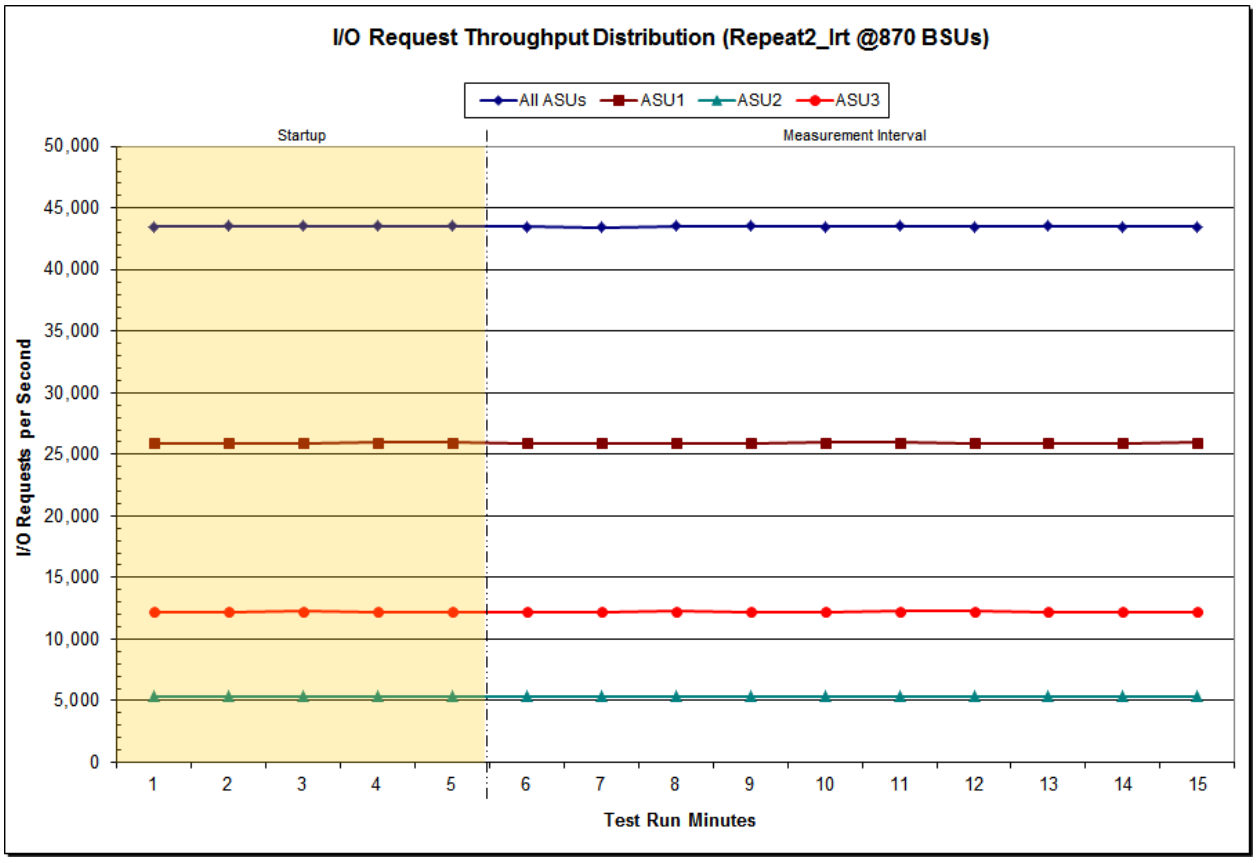
Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph



Repeatability 2 LRT – I/O Request Throughput Distribution Data

870 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:51:46	21:56:46	0-4	0:05:00
Measurement Interval	21:56:46	22:06:46	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	43,502.58	25,920.05	5,346.95	12,235.58
1	43,518.85	25,927.63	5,357.45	12,233.77
2	43,542.07	25,934.43	5,366.48	12,241.15
3	43,531.58	25,958.88	5,353.92	12,218.78
4	43,527.72	25,943.97	5,355.82	12,227.93
5	43,467.05	25,902.73	5,355.77	12,208.55
6	43,450.60	25,912.02	5,337.53	12,201.05
7	43,561.63	25,938.65	5,362.55	12,260.43
8	43,516.62	25,937.73	5,350.33	12,228.55
9	43,476.30	25,943.52	5,337.93	12,194.85
10	43,529.50	25,943.63	5,348.53	12,237.33
11	43,515.83	25,917.82	5,356.30	12,241.72
12	43,520.15	25,937.88	5,353.07	12,229.20
13	43,510.18	25,930.12	5,362.82	12,217.25
14	43,511.72	25,965.52	5,337.50	12,208.70
Average	***43,505.96***	***25,932.96***	***5,350.23***	***12,222.76***

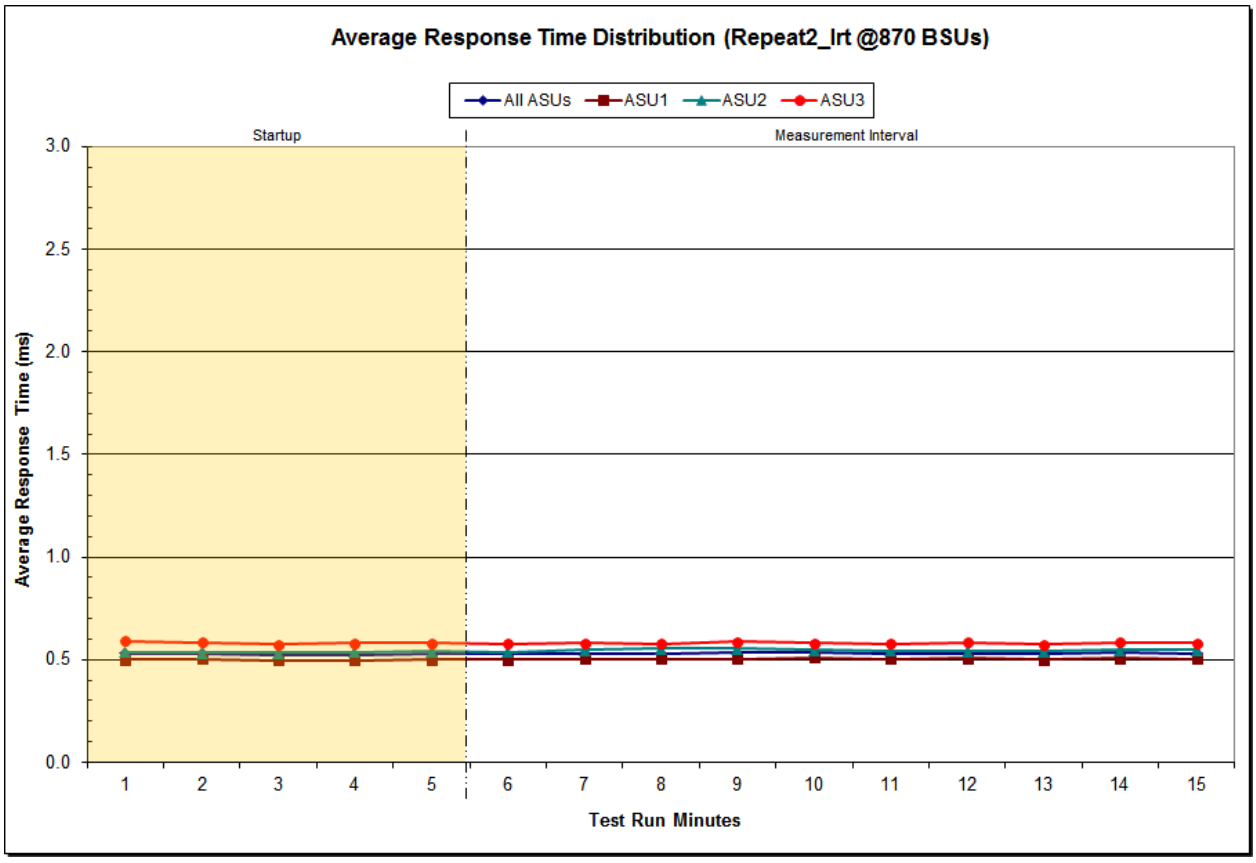
Repeatability 2 LRT – I/O Request Throughput Distribution Graph



Repeatability 2 LRT –Average Response Time (ms) Distribution Data

870 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:51:46	21:56:46	0-4	0:05:00
Measurement Interval	21:56:46	22:06:46	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.53	0.50	0.54	0.59
1	0.53	0.50	0.53	0.59
2	0.52	0.50	0.53	0.57
3	0.52	0.50	0.54	0.58
4	0.53	0.50	0.54	0.58
5	0.53	0.50	0.54	0.58
6	0.53	0.50	0.55	0.58
7	0.53	0.50	0.55	0.58
8	0.53	0.50	0.55	0.59
9	0.53	0.51	0.55	0.58
10	0.53	0.50	0.54	0.58
11	0.53	0.51	0.54	0.58
12	0.53	0.50	0.54	0.57
13	0.53	0.51	0.55	0.58
14	0.53	0.50	0.55	0.58
Average	***0.53***	***0.50***	***0.55***	***0.58***

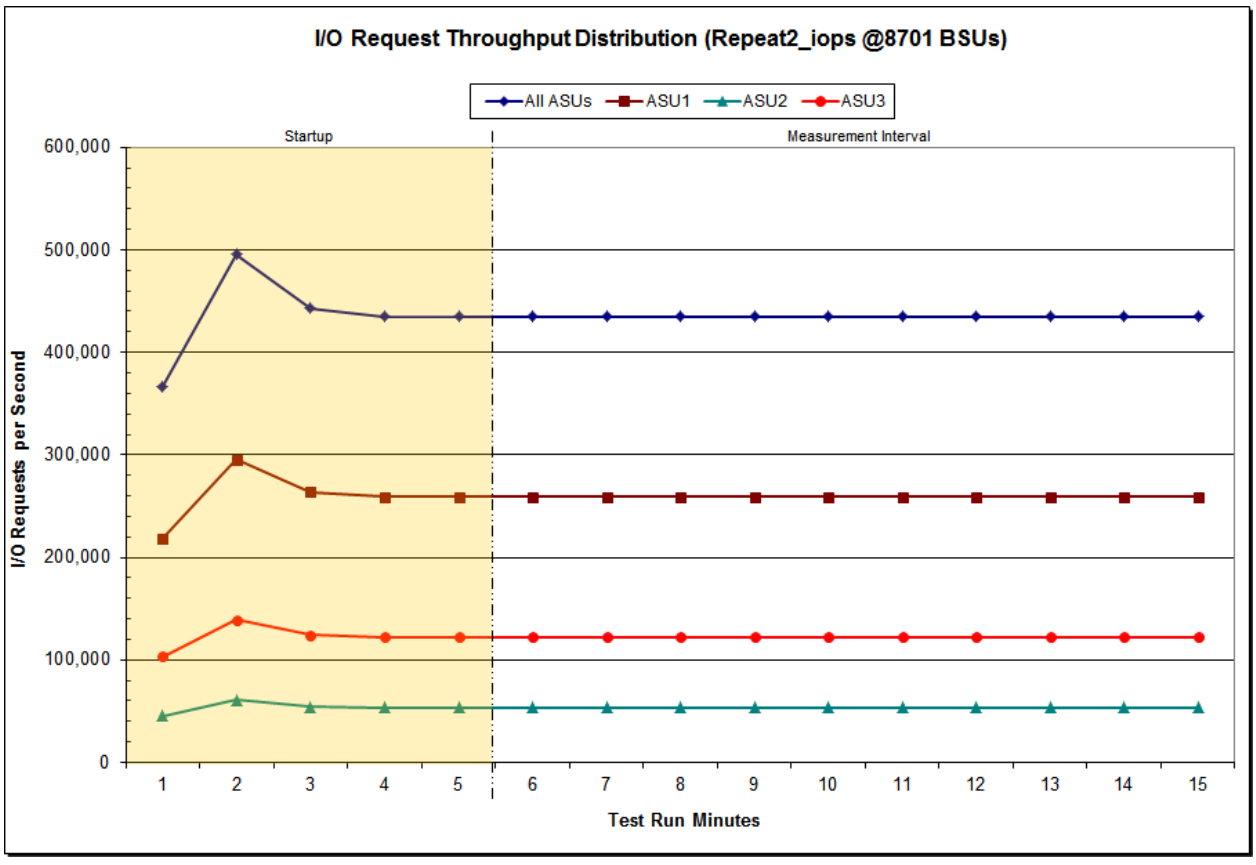
Repeatability 2 LRT –Average Response Time (ms) Distribution Graph



Repeatability 2 IOPS – I/O Request Throughput Distribution Data

8,701 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	22:07:30	22:12:31	0-4	0:05:01
Measurement Interval	22:12:31	22:22:31	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	366,900.27	218,676.05	45,121.38	103,102.83
1	495,303.57	295,193.13	60,869.33	139,241.10
2	442,845.70	264,033.60	54,474.67	124,337.43
3	435,077.13	259,346.92	53,519.42	122,210.80
4	435,106.27	259,355.57	53,489.95	122,260.75
5	434,993.20	259,257.32	53,456.05	122,279.83
6	435,159.53	259,276.93	53,548.12	122,334.48
7	434,982.12	259,195.97	53,474.27	122,311.88
8	435,003.47	259,318.20	53,461.73	122,223.53
9	435,053.02	259,331.53	53,506.53	122,214.95
10	435,114.27	259,328.07	53,507.22	122,278.98
11	435,090.70	259,311.00	53,479.58	122,300.12
12	435,056.95	259,231.42	53,563.82	122,261.72
13	435,074.60	259,336.57	53,491.48	122,246.55
14	434,999.92	259,277.90	53,509.10	122,212.92
Average	***435,052.78***	***259,286.49***	***53,499.79***	***122,266.50***

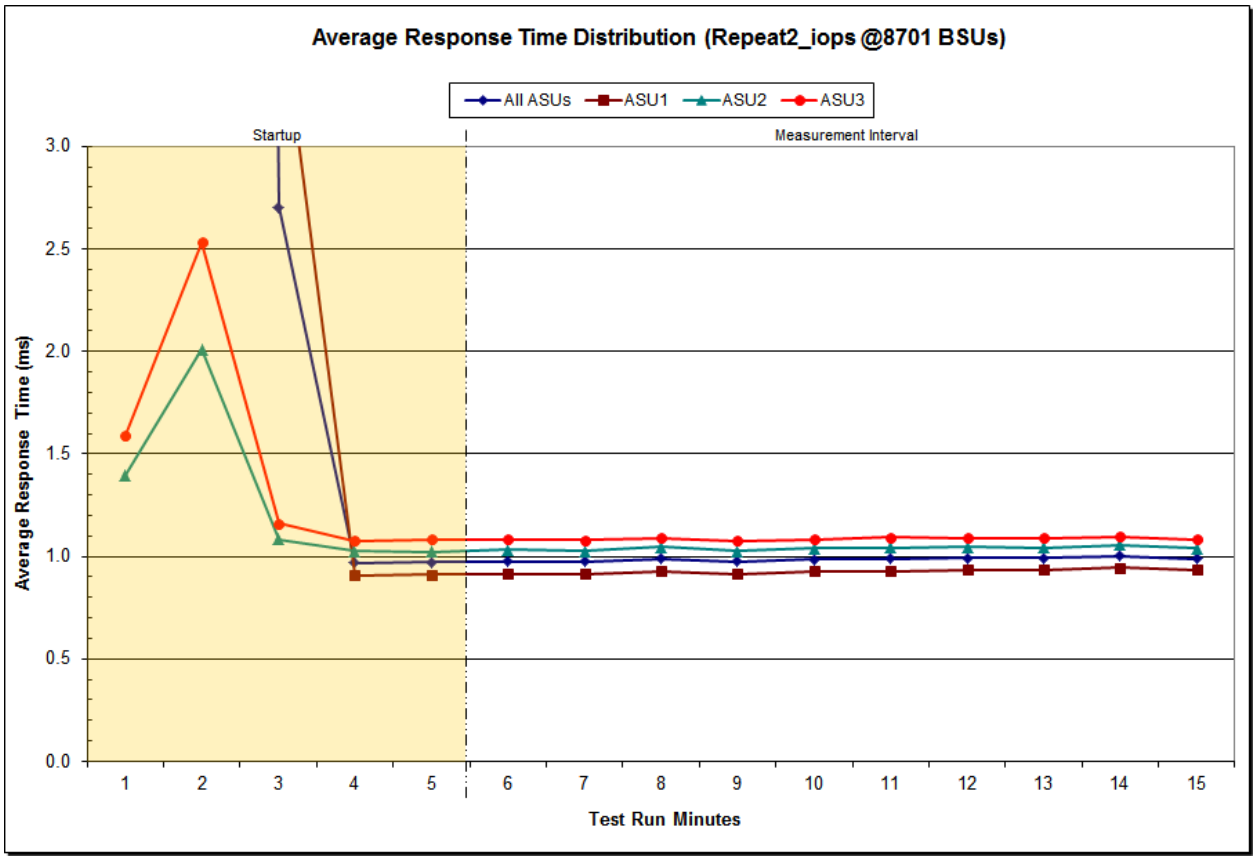
Repeatability 2 IOPS – I/O Request Throughput Distribution Graph



Repeatability 2 IOPS –Average Response Time (ms) Distribution Data

8,701 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	22:07:30	22:12:31	0-4	0:05:01
Measurement Interval	22:12:31	22:22:31	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	27.42	44.96	1.40	1.59
1	35.03	57.17	2.01	2.53
2	2.70	3.76	1.08	1.16
3	0.97	0.91	1.02	1.08
4	0.97	0.91	1.02	1.08
5	0.98	0.91	1.03	1.08
6	0.97	0.91	1.03	1.08
7	0.99	0.93	1.05	1.09
8	0.97	0.92	1.03	1.08
9	0.99	0.93	1.04	1.08
10	0.99	0.93	1.04	1.09
11	0.99	0.93	1.04	1.09
12	0.99	0.93	1.04	1.09
13	1.00	0.94	1.06	1.09
14	0.99	0.93	1.04	1.08
Average	***0.99***	***0.93***	***1.04***	***1.09***

Repeatability 2 IOPS –Average Response Time (ms) Distribution Graph



Repeatability 1 (LRT)
Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

IM – Intensity Multiplier: *The ratio of I/Os for each I/O stream relative to the total I/Os for all I/O streams (ASU1-1 – ASU3-1) as required by the benchmark specification.*

Clauses5.1.10 and 5.3.15.2

MIM – Measured Intensity Multiplier: *The Measured Intensity Multiplier represents the ratio of measured I/Os for each I/O stream relative to the total I/Os measured for all I/O streams (ASU1-1 – ASU3-1). This value may differ from the corresponding Expected Intensity Multiplier by no more than 5%.*

Clause 5.3.15.3

COV – Coefficient of Variation: *This measure of variation for the Measured Intensity Multiplier cannot exceed 0.2.*

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2811	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.003	0.001	0.002	0.001	0.006	0.002	0.003	0.001

Repeatability 1 (IOPS)
Measured Intensity Multiplier and Coefficient of Variation

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2810	0.0700	0.2099	0.0180	0.0700	0.0350	0.2810
COV	0.001	0.000	0.001	0.000	0.002	0.000	0.001	0.000

Repeatability 2 (LRT)
Measured Intensity Multiplier and Coefficient of Variation

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2810	0.0700	0.2101	0.0180	0.0700	0.0350	0.2809
COV	0.003	0.001	0.001	0.001	0.004	0.002	0.002	0.001

Repeatability 2 (IOPS)
Measured Intensity Multiplier and Coefficient of Variation

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.001	0.000	0.001	0.000	0.002	0.001	0.001	0.000

Data Persistence Test

Clause 6

The Data Persistence Test demonstrates the Tested Storage Configuration (TSC):

- *Is capable of maintain data integrity across a power cycle.*
- *Ensures the transfer of data between Logical Volumes and host systems occurs without corruption or loss.*

The SPC-1 Workload Generator will write 16 block I/O requests at random over the total Addressable Storage Capacity of the TSC for ten (10) minutes at a minimum of 25% of the load used to generate the SPC-1 IOPS™ primary metric. The bit pattern selected to be written to each block as well as the address of the block will be retained in a log file.

The Tested Storage Configuration (TSC) will be shutdown and restarted using a power off/power on cycle at the end of the above sequence of write operations. In addition, any caches employing battery backup must be flushed/emptied.

The SPC-1 Workload Generator will then use the above log file to verify each block written contains the correct bit pattern.

Clause 9.4.3.8

The following content shall appear in this section of the FDR:

1. *A listing or screen image of all input parameters supplied to the Workload Generator.*
2. *For the successful Data Persistence Test Run, a table illustrating key results. The content, appearance, and format of this table are specified in Table 9-12. Information displayed in this table shall be obtained from the Test Run Results File referenced below in #3.*
3. *For the successful Data Persistence Test Run, the human readable Test Run Results file produced by the Workload Generator (may be contained in an appendix).*

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in Appendix E: SPC-1 Workload Generator Input Parameters on Page 77.

Data Persistence Test Results File

A link to each test result file generated from each Data Persistence Test is listed below.

Persistence 1 Test Results File

Persistence 2 Test Results File

Data Persistence Test Results

Data Persistence Test Results	
Data Persistence Test Run Number: 1	
Total Number of Logical Blocks Written	741,495
Total Number of Logical Blocks Verified	528,948
Total Number of Logical Blocks that Failed Verification	0
Time Duration for Writing Test Logical Blocks	5 minutes
Size in bytes of each Logical Block	1024
Number of Failed I/O Requests in the process of the Test	0

If approved by the SPC Auditor, the SPC-2 Persistence Test may be used to meet the SPC-1 persistence requirements. Both the SPC-1 and SPC-2 Persistence Tests provide the same level of functionality and verification of data integrity. The SPC-2 Persistence Test may be easily configured to address an SPC-1 storage configuration. The SPC-2 Persistence Test extends the size of storage configurations that may be tested and significantly reduces the test duration of such configurations.

The SPC-2 Persistence Test was approved for use in this set of audited measurements.

In some cases the same address was the target of multiple writes, which resulted in more Logical Blocks Written than Logical Blocks Verified. In the case of multiple writes to the same address, the pattern written and verified must be associated with the last write to that address.

PRICED STORAGE CONFIGURATION AVAILABILITY DATE

Clause 9.4.3.9

The committed delivery data for general availability (Availability Date) of all products that comprise the Priced Storage Configuration must be reported. When the Priced Storage Configuration includes products or components with different availability dates, the reported Availability Date for the Priced Storage Configuration must be the date at which all components are committed to be available.

The EMC VNX8000 as documented in this Full Disclosure Report is currently available for customer purchase and shipment.

PRICING INFORMATION

Clause 9.4.3.3.6

The Executive Summary shall contain a pricing spreadsheet as documented in Clause 8.3.1.

Pricing information may be found in the Priced Storage Configuration Pricing section on page 16.

TESTED STORAGE CONFIGURATION (TSC) AND PRICED STORAGE CONFIGURATION DIFFERENCES

Clause 9.4.3.3.8

The Executive Summary shall contain a list of all differences between the Tested Storage Configuration (TSC) and the Priced Storage Configuration.

A list of all differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration may be found in the Executive Summary portion of this document on page 16.

ANOMALIES OR IRREGULARITIES

Clause 9.4.3.10

The FDR shall include a clear and complete description of any anomalies or irregularities encountered in the course of executing the SPC-1 benchmark that may in any way call into question the accuracy, verifiability, or authenticity of information published in this FDR.

There were no anomalies or irregularities encountered during the SPC-1 Onsite Audit of the EMC VNX8000.

APPENDIX A: SPC-1 GLOSSARY

"Decimal" *(powers of ten)* Measurement Units

In the storage industry, the terms "kilo", "mega", "giga", "tera", "peta", and "exa" are commonly used prefixes for computing performance and capacity. For the purposes of the SPC workload definitions, all of the following terms are defined in "powers of ten" measurement units.

A kilobyte (KB) is equal to 1,000 (10^3) bytes.

A megabyte (MB) is equal to 1,000,000 (10^6) bytes.

A gigabyte (GB) is equal to 1,000,000,000 (10^9) bytes.

A terabyte (TB) is equal to 1,000,000,000,000 (10^{12}) bytes.

A petabyte (PB) is equal to 1,000,000,000,000,000 (10^{15}) bytes

An exabyte (EB) is equal to 1,000,000,000,000,000,000 (10^{18}) bytes

"Binary" *(powers of two)* Measurement Units

The sizes reported by many operating system components use "powers of two" measurement units rather than "power of ten" units. The following standardized definitions and terms are also valid and may be used in this document.

A kibibyte (KiB) is equal to 1,024 (2^{10}) bytes.

A mebibyte (MiB) is equal to 1,048,576 (2^{20}) bytes.

A gigibyte (GiB) is equal to 1,073,741,824 (2^{30}) bytes.

A tebibyte (TiB) is equal to 1,099,511,627,776 (2^{40}) bytes.

A pebibyte (PiB) is equal to 1,125,899,906,842,624 (2^{50}) bytes.

An exbibyte (EiB) is equal to 1,152,921,504,606,846,967 (2^{60}) bytes.

SPC-1 Data Repository Definitions

Total ASU Capacity: The total storage capacity read and written in the course of executing the SPC-1 benchmark.

Application Storage Unit (ASU): The logical interface between the storage and SPC-1 Workload Generator. The three ASUs (Data, User, and Log) are typically implemented on one or more Logical Volume.

Logical Volume: The division of Addressable Storage Capacity into individually addressable logical units of storage used in the SPC-1 benchmark. Each Logical Volume is implemented as a single, contiguous address space.

Addressable Storage Capacity: The total storage (sum of Logical Volumes) that can be read and written by application programs such as the SPC-1 Workload Generator.

Configured Storage Capacity: This capacity includes the Addressable Storage Capacity and any other storage (parity disks, hot spares, etc.) necessary to implement the Addressable Storage Capacity.

Physical Storage Capacity: The formatted capacity of all storage devices physically present in the Tested Storage Configuration (TSC).

Data Protection Overhead: The storage capacity required to implement the selected level of data protection.

Required Storage: The amount of Configured Storage Capacity required to implement the Addressable Storage Configuration, excluding the storage required for the three ASUs.

Global Storage Overhead: The amount of Physical Storage Capacity that is required for storage subsystem use and unavailable for use by application programs.

Total Unused Storage: The amount of storage capacity available for use by application programs but not included in the Total ASU Capacity.

SPC-1 Data Protection Levels

Protected 1: The single point of failure of any ***storage device*** in the configuration will not result in permanent loss of access to or integrity of the SPC-1 Data Repository.

Protected 2: The single point of failure of any ***component*** in the configuration will not result in permanent loss of access to or integrity of the SPC-1 Data Repository.

SPC-1 Test Execution Definitions

Average Response Time: The sum of the Response Times for all Measured I/O Requests divided by the total number of Measured I/O Requests.

Completed I/O Request: An I/O Request with a Start Time and a Completion Time (see "I/O Completion Types" below).

Completion Time: The time recorded by the Workload Generator when an I/O Request is satisfied by the TSC as signaled by System Software.

Data Rate: The data transferred in all Measured I/O Requests in an SPC-1 Test Run divided by the length of the Test Run in seconds.

Expected I/O Count: For any given I/O Stream and Test Phase, the product of 50 times the BSU level, the duration of the Test Phase in seconds, and the Intensity Multiplier for that I/O Stream.

Failed I/O Request: Any I/O Request issued by the Workload Generator that could not be completed or was signaled as failed by System Software. A Failed I/O Request has no Completion Time (see "I/O Completion Types" below).

I/O Request Throughput: The total number of Measured I/O requests in an SPC-1 Test Run divided by the duration of the Measurement Interval in seconds.

In-Flight I/O Request: An I/O Request issued by the I/O Command Generator to the TSC that has a recorded Start Time, but does not complete within the Measurement Interval (see "I/O Completion Types" below).

Measured I/O Request: A Completed I/O Request with a Completion Time occurring within the Measurement Interval (see "I/O Completion Types" below).

Measured Intensity Multiplier: The percentage of all Measured I/O Requests that were issued by a given I/O Stream.

Measurement Interval: The finite and contiguous time period, after the TSC has reached Steady State, when data is collected by a Test Sponsor to generate an SPC-1 test result or support an SPC-1 test result.

Ramp-Up: The time required for the Benchmark Configuration (BC) to produce Steady State throughput after the Workload Generator begins submitting I/O Requests to the TSC for execution.

Ramp-Down: The time required for the BC to complete all I/O Requests issued by the Workload Generator. The Ramp-Down period begins when the Workload Generator ceases to issue new I/O Requests to the TSC.

Response Time: The Response Time of a Measured I/O Request is its Completion Time minus its Start Time.

Start Time: The time recorded by the Workload Generator when an I/O Request is submitted, by the Workload Generator, to the System Software for execution on the Tested Storage Configuration (TSC).

Start-Up: The period that begins after the Workload Generator starts to submit I/O requests to the TSC and ends at the beginning of the Measurement Interval.

Shut-Down: The period between the end of the Measurement Interval and the time when all I/O Requests issued by the Workload Generator have completed or failed.

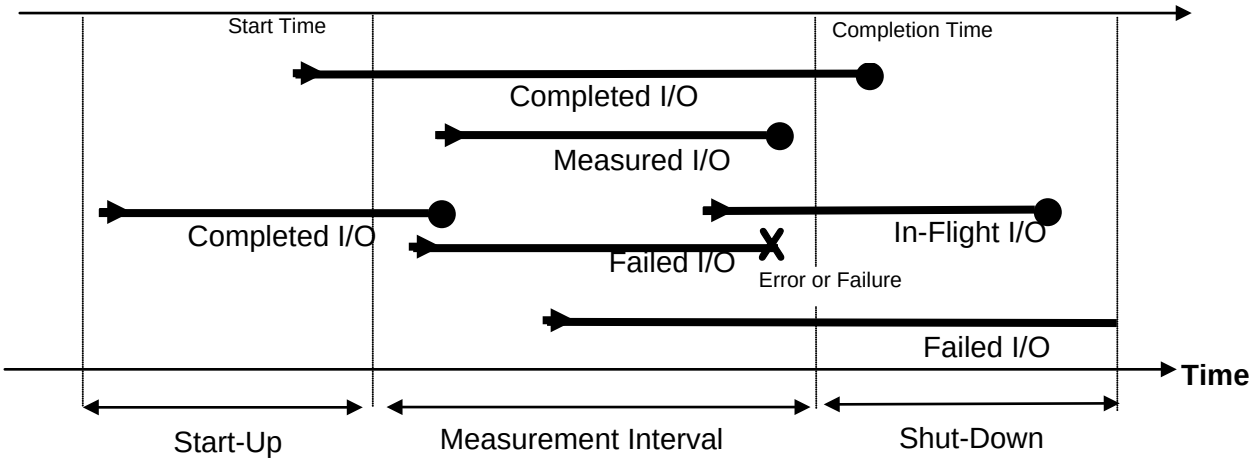
Steady State: The consistent and sustainable throughput of the TSC. During this period the load presented to the TSC by the Workload Generator is constant.

Test: A collection of Test Phases and or Test Runs sharing a common objective.

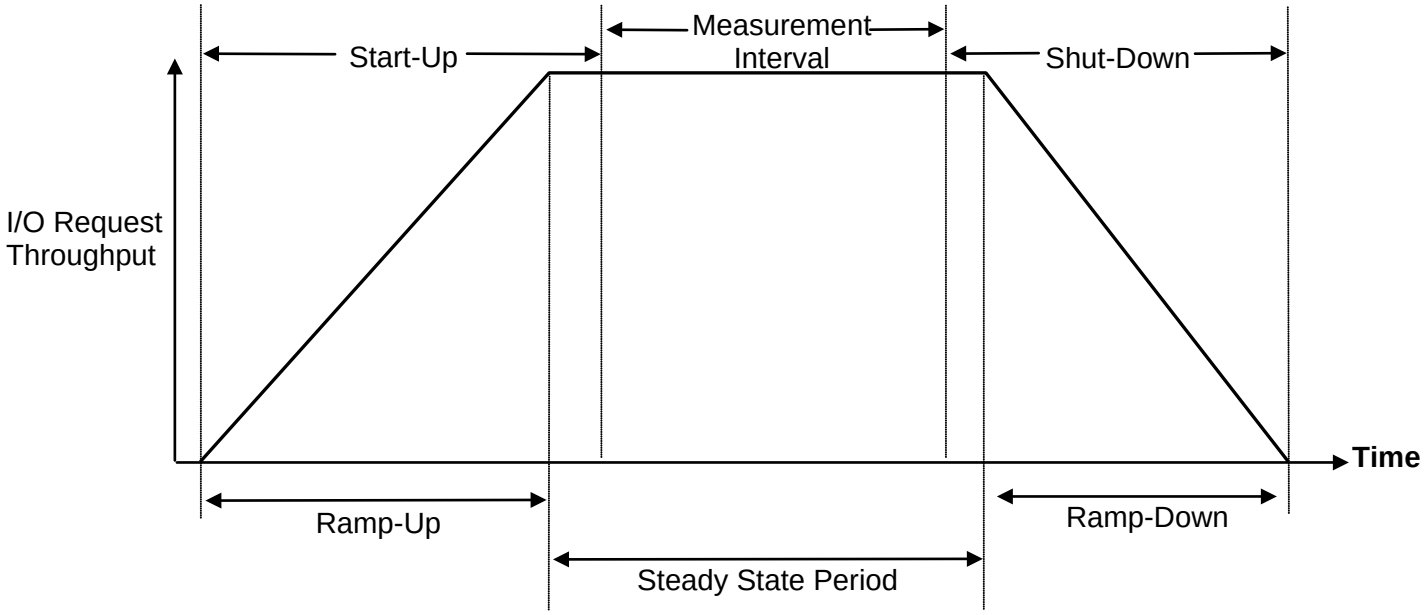
Test Run: The execution of SPC-1 for the purpose of producing or supporting an SPC-1 test result. SPC-1 Test Runs may have a finite and measured Ramp-Up period, Start-Up period, Shut-Down period, and Ramp-Down period as illustrated in the "SPC-1 Test Run Components" below. All SPC-1 Test Runs shall have a Steady State period and a Measurement Interval.

Test Phase: A collection of one or more SPC-1 Test Runs sharing a common objective and intended to be run in a specific sequence.

I/O Completion Types



SPC-1 Test Run Components



APPENDIX B: CUSTOMER TUNABLE PARAMETERS AND OPTIONS

Windows Server 2008 Power Options

Windows power plan is a collection of hardware and system settings that manage how your computer uses power. You can use power plans to reduce the amount of power your computer uses, maximize performance, or balance the two.

The **High performance** option increases performance at the cost of high energy consumption. It is used in environment with low latency and application code sensitive to processor frequency changes. More details on this option can be found in the link below: https://msdn.microsoft.com/enus/library/windows/hardware/dn529134

On 16 Windows 2008 Server Host System, Windows Power Options were changed to **High performance** with the following steps:

1. Open **Windows Control Panel**, click to open **Hardware**, then **Power Options**.
2. Click **Change power-saving settings**, select the **High performance** option.

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

Storage Array Management

The EMC Storage Management CLI utility, **Navisphere CLI**, is installed on a server which has network connection to EMC VNX8000 Storage Processor. Navisphere CLI commands are executed by using the following syntax:

naviseccli –h <IPaddress> –user <username> -password <password> -scope 0 CMD <optional arguments>

CMD refers to the set of commands that can be used with the **Navisphere CLI** utility.

The **Navisphere CLI** utility is available as a free download from the EMC support website for customers with an EMC account.

Extended Cache

VNX8000 Extended Cache Enabler was installed on the TSC to maximize system cache capacity, as no data services were included in the configuration.

In the general case, system memory space is shared by the cache and data services, with each receiving an allocation. However, if data services are not required in a specific deployment, the **VNX8000 Extended Cache Enabler** can be used to allocate the full available memory space to cache, as any allocated to data services would not be used.

In a customer engagement for a new system, EMC account and field support staff review the intended configuration, application, and use cases and determine if the Extended Cache feature is appropriate for that deployment and if it would provide a benefit. If so, they would inform the customer and recommend that it to be included.

The **VNX8000 Extended Cache Enabler** is available to EMC customers through EMC Request for Product Qualification (RPQ) at no cost. EMC field support staff follows the standard RPQ process by including the proper documentation with the order. This is reviewed and approved by Product Management, and the **VNX8000 Extended Cache Enabler** software package is provided.

To install the enabler using the EMC **Navisphere CLI**, which will reconfigure the memory space, the following ***naviseccli*** command is used:

naviseccli –h <IPaddress> -user <user> -password <password> -scope 0 ndu –install ExtendedCacheEnabler-01.01.5.001-armada64_free.ena

The enabler can also be installed and memory space reconfigured through the EMC standard management software, **Unisphere Service Manager** (USM), via a GUI.

The **Unisphere Service Manager** is also available as a free download from the EMC support website for customers with an EMC account.

Either EMC field support staff or the customers themselves can install the enabler.

Storage Configuration

The steps to configure the TSC are summarized below. Referenced scripts, with the appropriate ***naviseccli*** commands, are executed in a Windows command prompt window on a server as described above in the Storage Array Management section.

Each referenced script appears below in the Referenced Scripts section.

1. Change Windows 2008 Server Power Option to **High performance** on each of the 16 Host Systems as described in *Appendix B: Customer Tunable Parameters and Options*.
2. Install **VNX8000 Extended Cache Enabler** as as described in the above Extended Cache section.
3. Execute the **hotspare.bat** script to set hot spare policy for SSDs to remove the requirement for hot spare drives.
4. Execute the **create_pool.bat** script to create 1 Storage Pool using all 40 SSD drives with RAID 1/0.
5. After the Storage Pool is created, execute the **create_LUNs.bat** script to create 15 LUNs in the Storage Pool, which are the SPC-1 Logical Volumes *(5 logical volumes for each of the three ASUs)*.
6. Execute the **create_storagegroup.bat** script to create a Storage Group to control the the Host Systems' access to all 15 LUNs.
7. Execute the **sethost_failover.bat** script to set all Host Systems' failover mode to be 0, the basic mode which doesn't require multipathing software to be installed.
8. Execute the **addHost_to_Storagegroup.bat** script to add all 16 Host Systems to the Storage Group.
9. Execute the **addLUN_to_Storagegroup.bat** script to add all 15 LUNs to the Storage Group.
10. Reboot the 16 Host Systems to discover the LUNs.

Referenced Scripts

hotspare.bat

```
set SPA=192.168.1.30
set SPB=192.168.1.31

set user="user"
set password="password"


REM
REM SET HOTSPARE POLICY
REM
naviseccli -h %SPA% -user %user% -password %password% -scope 0 hotsparepolicy -set 1
-keep1unusedper 0 -o
```

create_pool.bat

```
set SPA=192.168.1.30
set SPB=192.168.1.31

set user="user"
set password="password"


REM
REM CREAT STORAGE POOL
REM
naviseccli -h %SPA% -user %user% -password %password% -scope 0 storagepool -create -
rtype r_10 -disks 0_0_4  0_0_5  0_0_6  0_0_7  0_0_8  0_0_9  0_0_10  0_0_11 0_0_12
0_0_13 2_0_0 2_0_1 2_0_2 2_0_3 2_0_4 2_0_5 2_0_6 2_0_7 2_0_8 2_0_9 5_0_0 5_0_1 5_0_2
5_0_3 5_0_4 5_0_5 5_0_6 5_0_7 5_0_8 5_0_9 7_0_0 7_0_1 7_0_2 7_0_3 7_0_4 7_0_5 7_0_6
7_0_7 7_0_8 7_0_9 -initialverify no
```

create_LUNs.bat

```
set SPA=192.168.1.30
set SPB=192.168.1.31

set user="user"
set password="password"


REM
REM CREATE LUNS
REM

REM ASU1 5 LUNs
naviseccli -h %SPA% -user %user% -password %password% -scope 0 lun -create -type
NonThin -sp A -l 0 -capacity 94464 -sq mb -poolID 0
TIMEOUT /T 60 /NOBREAK
naviseccli -h %SPB% -user %user% -password %password% -scope 0 lun -create -type
NonThin -sp B -l 1 -capacity 94464 -sq mb -poolID 0
TIMEOUT /T 60 /NOBREAK
naviseccli -h %SPA% -user %user% -password %password% -scope 0 lun -create -type
NonThin -sp A -l 2 -capacity 94464 -sq mb -poolID 0
TIMEOUT /T 60 /NOBREAK
```

```
naviseccli -h %SPB% -user %user% -password %password% -scope 0 lun -create -type
NonThin -sp B -l 3 -capacity 94464 -sq mb -poolID 0
TIMEOUT /T 60 /NOBREAK
naviseccli -h %SPA% -user %user% -password %password% -scope 0 lun -create -type
NonThin -sp A -l 4 -capacity 94464 -sq mb -poolID 0
TIMEOUT /T 60 /NOBREAK

REM ASU2 5 LUNs
naviseccli -h %SPB% -user %user% -password %password% -scope 0 lun -create -type
NonThin -sp B -l 5 -capacity 94464 -sq mb -poolID 0
TIMEOUT /T 60 /NOBREAK
naviseccli -h %SPA% -user %user% -password %password% -scope 0 lun -create -type
NonThin -sp A -l 6 -capacity 94464 -sq mb -poolID 0
TIMEOUT /T 60 /NOBREAK
naviseccli -h %SPB% -user %user% -password %password% -scope 0 lun -create -type
NonThin -sp B -l 7 -capacity 94464 -sq mb -poolID 0
TIMEOUT /T 60 /NOBREAK
naviseccli -h %SPA% -user %user% -password %password% -scope 0 lun -create -type
NonThin -sp A -l 8 -capacity 94464 -sq mb -poolID 0
TIMEOUT /T 60 /NOBREAK
naviseccli -h %SPB% -user %user% -password %password% -scope 0 lun -create -type
NonThin -sp B -l 9 -capacity 94464 -sq mb -poolID 0
TIMEOUT /T 60 /NOBREAK


REM ASU3 5 LUNs
naviseccli -h %SPA% -user %user% -password %password% -scope 0 lun -create -type
NonThin -sp A -l 10 -capacity 20992 -sq mb -poolID 0
TIMEOUT /T 30 /NOBREAK
naviseccli -h %SPB% -user %user% -password %password% -scope 0 lun -create -type
NonThin -sp B -l 11 -capacity 20992 -sq mb -poolID 0
TIMEOUT /T 30 /NOBREAK
naviseccli -h %SPA% -user %user% -password %password% -scope 0 lun -create -type
NonThin -sp A -l 12 -capacity 20992 -sq mb -poolID 0
TIMEOUT /T 30 /NOBREAK
naviseccli -h %SPB% -user %user% -password %password% -scope 0 lun -create -type
NonThin -sp B -l 13 -capacity 20992 -sq mb -poolID 0
TIMEOUT /T 30 /NOBREAK
naviseccli -h %SPA% -user %user% -password %password% -scope 0 lun -create -type
NonThin -sp A -l 14 -capacity 20992 -sq mb -poolID 0
TIMEOUT /T 30 /NOBREAK
```

create_storagegroup.bat

```
set SPB=192.168.1.31

set sgname="SPC1 Storage Group"
set user="user"
set password="password"


REM
REM CREATE STORAGE GROUP
REM

naviseccli -h %SPA% -user %user% -password %password% -scope 0  storagegroup -create
-gname %sgname%
```

sethost_failover.bat

```
set SPA=192.168.1.30
set SPB=192.168.1.31
```

```
set hostip0=192.168.1.10
set hostip1=192.168.1.11
set hostip2=192.168.1.12
set hostip3=192.168.1.13
set hostip4=192.168.1.14
set hostip5=192.168.1.15
set hostip6=192.168.1.16
set hostip7=192.168.1.17
set hostip8=192.168.1.18
set hostip9=192.168.1.19
set hostip10=192.168.1.20
set hostip11=192.168.1.21
set hostip12=192.168.1.22
set hostip13=192.168.1.23
set hostip14=192.168.1.24
set hostip15=192.168.1.25


set user="user"
set password="password"



REM
REM SET HOSTS
REM

naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
sethost -ip %hostip0% -failovermode 0 -type 3 -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
sethost -ip %hostip1% -failovermode 0 -type 3 -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
sethost -ip %hostip2% -failovermode 0 -type 3 -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
sethost -ip %hostip3% -failovermode 0 -type 3 -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
sethost -ip %hostip4% -failovermode 0 -type 3 -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
sethost -ip %hostip5% -failovermode 0 -type 3 -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
sethost -ip %hostip6% -failovermode 0 -type 3 -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
sethost -ip %hostip7% -failovermode 0 -type 3 -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
sethost -ip %hostip8% -failovermode 0 -type 3 -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
sethost -ip %hostip9% -failovermode 0 -type 3 -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
sethost -ip %hostip10% -failovermode 0 -type 3 -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
sethost -ip %hostip11% -failovermode 0 -type 3 -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
sethost -ip %hostip12% -failovermode 0 -type 3 -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
sethost -ip %hostip13% -failovermode 0 -type 3 -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
sethost -ip %hostip14% -failovermode 0 -type 3 -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
sethost -ip %hostip15% -failovermode 0 -type 3 -o
```

addHost_to_Storagegroup.bat

```
set SPA=192.168.1.30
set SPB=192.168.1.31


set hostname0=COMP1
set hostname1=COMP2
set hostname2=COMP3
set hostname3=COMP4
set hostname4=COMP5
set hostname5=COMP6
set hostname6=COMP7
set hostname7=COMP8
set hostname8=COMP9
set hostname9=COMP10
set hostname10=COMP11
set hostname11=COMP12
set hostname12=COMP13
set hostname13=COMP14
set hostname14=COMP15
set hostname15=COMP16

set sgname="SPC1 Storage Group"
set user="user"
set password="password"


REM
REM CONNECT HOSTS
REM

naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
connecthost -host %hostname0% -gname %sgname% -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
connecthost -host %hostname1% -gname %sgname% -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
connecthost -host %hostname2% -gname %sgname% -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
connecthost -host %hostname3% -gname %sgname% -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
connecthost -host %hostname4% -gname %sgname% -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
connecthost -host %hostname5% -gname %sgname% -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
connecthost -host %hostname6% -gname %sgname% -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
connecthost -host %hostname7% -gname %sgname% -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
connecthost -host %hostname8% -gname %sgname% -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
connecthost -host %hostname9% -gname %sgname% -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
connecthost -host %hostname10% -gname %sgname% -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
connecthost -host %hostname11% -gname %sgname% -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
connecthost -host %hostname12% -gname %sgname% -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
connecthost -host %hostname13% -gname %sgname% -o
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
connecthost -host %hostname14% -gname %sgname% -o
```

```
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
connecthost -host %hostname15% -gname %sgname% -o
```

addLUN_to_Storagegroup.bat

```
set SPA=192.168.1.30
set SPB=192.168.1.31

set sgname="SPC1 Storage Group"
set user="user"
set password="password"


REM
REM ADD LUNS TO STORAGE GROUPS
REM

naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
addhlu -gname %sgname% -hlu 0 -alu 0
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
addhlu -gname %sgname% -hlu 1 -alu 1
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
addhlu -gname %sgname% -hlu 2 -alu 2
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
addhlu -gname %sgname% -hlu 3 -alu 3
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
addhlu -gname %sgname% -hlu 4 -alu 4
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
addhlu -gname %sgname% -hlu 5 -alu 5
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
addhlu -gname %sgname% -hlu 6 -alu 6
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
addhlu -gname %sgname% -hlu 7 -alu 7
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
addhlu -gname %sgname% -hlu 8 -alu 8
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
addhlu -gname %sgname% -hlu 9 -alu 9
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
addhlu -gname %sgname% -hlu 10 -alu 10
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
addhlu -gname %sgname% -hlu 11 -alu 11
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
addhlu -gname %sgname% -hlu 12 -alu 12
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
addhlu -gname %sgname% -hlu 13 -alu 13
naviseccli -h %SPA% -user %user% -password %password% -scope 0 -np storagegroup -
addhlu -gname %sgname% -hlu 14 -alu 14
```

APPENDIX D: SPC-1 WORKLOAD GENERATOR STORAGE COMMANDS AND PARAMETERS

ASU Pre-Fill

The content of command and parameter file, used in this benchmark to execute the required ASU pre-fill, is listed below.

```
compratio=1


sd=sd1,lun=\\.\PhysicalDrive1
sd=sd2,lun=\\.\PhysicalDrive9
sd=sd3,lun=\\.\PhysicalDrive2
sd=sd4,lun=\\.\PhysicalDrive10
sd=sd5,lun=\\.\PhysicalDrive3
sd=sd6,lun=\\.\PhysicalDrive11
sd=sd7,lun=\\.\PhysicalDrive4
sd=sd8,lun=\\.\PhysicalDrive12
sd=sd9,lun=\\.\PhysicalDrive5
sd=sd10,lun=\\.\PhysicalDrive13
sd=sd11,lun=\\.\PhysicalDrive6
sd=sd12,lun=\\.\PhysicalDrive14
sd=sd13,lun=\\.\PhysicalDrive7
sd=sd14,lun=\\.\PhysicalDrive15
sd=sd15,lun=\\.\PhysicalDrive8


wd=wd1,sd=sd1,rdpct=0,seekpct=-1,xfersize=128k
wd=wd2,sd=sd2,rdpct=0,seekpct=-1,xfersize=128k
wd=wd3,sd=sd3,rdpct=0,seekpct=-1,xfersize=128k
wd=wd4,sd=sd4,rdpct=0,seekpct=-1,xfersize=128k
wd=wd5,sd=sd5,rdpct=0,seekpct=-1,xfersize=128k
wd=wd6,sd=sd6,rdpct=0,seekpct=-1,xfersize=128k
wd=wd7,sd=sd7,rdpct=0,seekpct=-1,xfersize=128k
wd=wd8,sd=sd8,rdpct=0,seekpct=-1,xfersize=128k
wd=wd9,sd=sd9,rdpct=0,seekpct=-1,xfersize=128k
wd=wd10,sd=sd10,rdpct=0,seekpct=-1,xfersize=128k
wd=wd11,sd=sd11,rdpct=0,seekpct=-1,xfersize=128k
wd=wd12,sd=sd12,rdpct=0,seekpct=-1,xfersize=128k
wd=wd13,sd=sd13,rdpct=0,seekpct=-1,xfersize=128k
wd=wd14,sd=sd14,rdpct=0,seekpct=-1,xfersize=128k
wd=wd15,sd=sd15,rdpct=0,seekpct=-1,xfersize=128k


rd=asu_prefill,wd=wd*,iorate=max,elapsed=7200,interval=10
```

Slave JVMs

The Slave JVM command and parameter files are documented in the Slave JVMs section of *Appendix E: SPC-1 Workload Generator Input Parameters*.

Primary Metrics and Repeatability Tests

The content of SPC-1 Workload Generator command and parameter file used in this benchmark to execute the Primary Metrics *(Sustainability Test Phase, IOPS Test Phase, and Response Time Ramp Test Phase)* and Repeatability *(Repeatability Test Phase 1 and Repeatability Test Phase 2)* Tests is listed below.

```
host=master

slaves=(slave1_1,slave1_2,slave1_3,slave1_4,slave1_5,slave1_6,slave1_7,slave2_1,slav
e2_2,slave2_3,slave2_4,slave2_5,slave2_6,slave2_7,slave3_1,slave3_2,slave3_3,slave3_
4,slave3_5,slave3_6,slave3_7,slave4_1,slave4_2,slave4_3,slave4_4,slave4_5,slave4_6,s
lave4_7,slave5_1,slave5_2,slave5_3,slave5_4,slave5_5,slave5_6,slave5_7,slave6_1,slav
e6_2,slave6_3,slave6_4,slave6_5,slave6_6,slave6_7,slave7_1,slave7_2,slave7_3,slave7_
4,slave7_5,slave7_6,slave7_7,slave8_1,slave8_2,slave8_3,slave8_4,slave8_5,slave8_6,s
lave8_7,slave9_1,slave9_2,slave9_3,slave9_4,slave9_5,slave9_6,slave9_7,slave10_1,sla
ve10_2,slave10_3,slave10_4,slave10_5,slave10_6,slave10_7,slave11_1,slave11_2,slave11
_3,slave11_4,slave11_5,slave11_6,slave11_7,slave12_1,slave12_2,slave12_3,slave12_4,s
lave12_5,slave12_6,slave12_7,slave13_1,slave13_2,slave13_3,slave13_4,slave13_5,slave
13_6,slave13_7,slave14_1,slave14_2,slave14_3,slave14_4,slave14_5,slave14_6,slave14_7
,slave15_1,slave15_2,slave15_3,slave15_4,slave15_5,slave15_6,slave15_7,slave16_1,sla
ve16_2,slave16_3,slave16_4,slave16_5,slave16_6,slave16_7)

sd=asu1_1,lun=\\.\PhysicalDrive1
sd=asu1_2,lun=\\.\PhysicalDrive9
sd=asu1_3,lun=\\.\PhysicalDrive2
sd=asu1_4,lun=\\.\PhysicalDrive10
sd=asu1_5,lun=\\.\PhysicalDrive3
sd=asu2_1,lun=\\.\PhysicalDrive11
sd=asu2_2,lun=\\.\PhysicalDrive4
sd=asu2_3,lun=\\.\PhysicalDrive12
sd=asu2_4,lun=\\.\PhysicalDrive5
sd=asu2_5,lun=\\.\PhysicalDrive13
sd=asu3_1,lun=\\.\PhysicalDrive6
sd=asu3_2,lun=\\.\PhysicalDrive14
sd=asu3_3,lun=\\.\PhysicalDrive7
sd=asu3_4,lun=\\.\PhysicalDrive15
sd=asu3_5,lun=\\.\PhysicalDrive8
```

SPC-1 Persistence Test Run 1

The content of SPC-1 Workload Generator command and parameter file, used in this benchmark to execute a reduced level SPC-1 Persistence Test Run 1, is listed below.

```
sd=asu1_1,lun=\\.\PhysicalDrive1
sd=asu1_2,lun=\\.\PhysicalDrive9
sd=asu1_3,lun=\\.\PhysicalDrive2
sd=asu1_4,lun=\\.\PhysicalDrive10
sd=asu1_5,lun=\\.\PhysicalDrive3
sd=asu2_1,lun=\\.\PhysicalDrive11
sd=asu2_2,lun=\\.\PhysicalDrive4
sd=asu2_3,lun=\\.\PhysicalDrive12
sd=asu2_4,lun=\\.\PhysicalDrive5
sd=asu2_5,lun=\\.\PhysicalDrive13
sd=asu3_1,lun=\\.\PhysicalDrive6
sd=asu3_2,lun=\\.\PhysicalDrive14
sd=asu3_3,lun=\\.\PhysicalDrive7
sd=asu3_4,lun=\\.\PhysicalDrive15
sd=asu3_5,lun=\\.\PhysicalDrive8
```

SPC-2 Persistence Test

If approved by the SPC Auditor, the SPC-2 Persistence Test may be used to meet the SPC-1 persistence requirements. Both the SPC-1 and SPC-2 Persistence Tests provide the same level of functionality and verification of data integrity.

SPC-2 Persistence Test Run 1 (write phase)

```
host=localhost,jvms=6,maxstreams=100

sd=asu1_1,size=92.25g,lun=\\.\PhysicalDrive1
sd=asu1_2,size=92.25g,lun=\\.\PhysicalDrive9
sd=asu1_3,size=92.25g,lun=\\.\PhysicalDrive2
sd=asu1_4,size=92.25g,lun=\\.\PhysicalDrive10
sd=asu1_5,size=92.25g,lun=\\.\PhysicalDrive3
sd=asu2_1,size=92.25g,lun=\\.\PhysicalDrive11
sd=asu2_2,size=92.25g,lun=\\.\PhysicalDrive4
sd=asu2_3,size=92.25g,lun=\\.\PhysicalDrive12
sd=asu2_4,size=92.25g,lun=\\.\PhysicalDrive5
sd=asu2_5,size=92.25g,lun=\\.\PhysicalDrive13
sd=asu3_1,size=20.50g,lun=\\.\PhysicalDrive6
sd=asu3_2,size=20.50g,lun=\\.\PhysicalDrive14
sd=asu3_3,size=20.50g,lun=\\.\PhysicalDrive7
sd=asu3_4,size=20.50g,lun=\\.\PhysicalDrive15
sd=asu3_5,size=20.50g,lun=\\.\PhysicalDrive8

maxlatestart=1
reportinginterval=5
segmentlength=512m

rd=default,rampup=180,periods=90,measurement=300,runout=0,rampdown=0,buffers=1

rd=default,rdpct=0,xfersize=1024k
rd=TR1-291s_SPC-2-persist-w,streams=291
```

SPC-2 Persistence Test Run 2 *(read phase)*

```
host=localhost,jvms=6,maxstreams=100

sd=asu1_1,size=92.25g,lun=\\.\PhysicalDrive1
sd=asu1_2,size=92.25g,lun=\\.\PhysicalDrive9
sd=asu1_3,size=92.25g,lun=\\.\PhysicalDrive2
sd=asu1_4,size=92.25g,lun=\\.\PhysicalDrive10
sd=asu1_5,size=92.25g,lun=\\.\PhysicalDrive3
sd=asu2_1,size=92.25g,lun=\\.\PhysicalDrive11
sd=asu2_2,size=92.25g,lun=\\.\PhysicalDrive4
sd=asu2_3,size=92.25g,lun=\\.\PhysicalDrive12
sd=asu2_4,size=92.25g,lun=\\.\PhysicalDrive5
sd=asu2_5,size=92.25g,lun=\\.\PhysicalDrive13
sd=asu3_1,size=20.50g,lun=\\.\PhysicalDrive6
sd=asu3_2,size=20.50g,lun=\\.\PhysicalDrive14
sd=asu3_3,size=20.50g,lun=\\.\PhysicalDrive7
sd=asu3_4,size=20.50g,lun=\\.\PhysicalDrive15
sd=asu3_5,size=20.50g,lun=\\.\PhysicalDrive8

maxlatestart=1
reportinginterval=5
segmentlength=512m
maxpersistenceerrors=5

rd=default,buffers=1,rdpct=100,xfersize=1024k
rd=TR1-291s_SPC-2-persist-r
```

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

There were 112 Slave JVMs used in the Primary Metrics and Repeatability Tests. Those Slave JVMs were started as the first step in the execution sequence. The Slave JVMs section below documents that step.

The following script, **master_execution.bat**, was executed to invoke the following in an uninterrupted execution sequence:

- The command to execute the required ASU pre-fill.
- The commands to execute the Primary Metrics Test *(Sustainability Test Phase, IOPS Test Phase, and Response Time Ramp Test Phase)*, Repeatability Test *(Repeatability Test Phase 1 and Repeatability Test Phase 2)*, a reduced level SPC-1 Persistence Test Run 1 *(write phase)* and SPC-2 Persistence Test Run 1 *(write phase)*.
- A series of commands to create a set of storage configuration listings.

The **spc2_persist2.bat** script was executed after the required TSC power off/power on cycle to invoke the following:

- The command to execute the SPC-2 Persistence Test Run 2 *(read phase)*.
- A series of commands to create a second set of storage configuration listings.

Slave JVMs

There were 112 Slave JVMs used in the Primary Metrics and Repeatability Tests. The script, **slaves1.bat**, listed below, illustrates the commands to start the seven Slave JVMs (**slave1_1 – slave1_7**) that executed on the first Host System (**slave1**).

```
start java spc1 -f slave1_1.txt -o slave1_1
start java spc1 -f slave1_2.txt -o slave1_2
start java spc1 -f slave1_3.txt -o slave1_3
start java spc1 -f slave1_4.txt -o slave1_4
start java spc1 -f slave1_5.txt -o slave1_5
start java spc1 -f slave1_6.txt -o slave1_6
start java spc1 -f slave1_7.txt -o slave1_7
```

The following scripts were used to start the remaining 105 Slave JVMs on the remaining 15 Host Systems (**slave2** – **slave16**):

- **slaves2.bat**
- **slaves3.bat**
- **slaves4.bat**
- **slaves5.bat**
- **slaves6.bat**
- **slaves7.bat**
- **slaves8.bat**
- **slaves9.bat**
- **slaves10.bat**
- **slaves11.bat**

- **slaves12.bat**
- **slaves13.bat**
- **slaves14.bat**
- **slaves15.bat**
- **slaves16.bat**

The file, listed below, is the configuration file for the first Slave JVM (**slave1_1**)

slave1_1.txt

```
master=192.168.1.19

host=slave1_1

sd=asu1_1,lun=\\.\PhysicalDrive1
sd=asu1_2,lun=\\.\PhysicalDrive9
sd=asu1_3,lun=\\.\PhysicalDrive2
sd=asu1_4,lun=\\.\PhysicalDrive10
sd=asu1_5,lun=\\.\PhysicalDrive3
sd=asu2_1,lun=\\.\PhysicalDrive11
sd=asu2_2,lun=\\.\PhysicalDrive4
sd=asu2_3,lun=\\.\PhysicalDrive12
sd=asu2_4,lun=\\.\PhysicalDrive5
sd=asu2_5,lun=\\.\PhysicalDrive13
sd=asu3_1,lun=\\.\PhysicalDrive6
sd=asu3_2,lun=\\.\PhysicalDrive14
sd=asu3_3,lun=\\.\PhysicalDrive7
sd=asu3_4,lun=\\.\PhysicalDrive15
sd=asu3_5,lun=\\.\PhysicalDrive8
```

The following sets of configuration files were used for the remaining 111 Slave JVMs. The only difference in each configuration file was specifying the appropriate Slave JVM in the ***host=*** parameter (**slave1_2**…**slave16_7**).

- **slave1_2.txt** – **slave1_7.txt**
- **slave2_1.txt** – **slave2_7.txt**
- **slave3_1.txt** – **slave3_7.txt**
- **slave4_1.txt** – **slave4_7.txt**
- **slave5_1.txt** – **slave5_7.txt**
- **slave6_1.txt** – **slave6_7.txt**
- **slave7_1.txt** – **slave7_7.txt**
- **slave8_1.txt** – **slave8_7.txt**
- **slave9_1.txt** – **slave9_7.txt**
- **slave10_1.txt** – **slave10_7.txt**
- **slave11_1.txt** – **slave11_7.txt**
- **slave12_1.txt** – **slave12_7.txt**
- **slave13_1.txt** – **slave13_7.txt**
- **slave14_1.txt** – **slave14_7.txt**
- **slave15_1.txt** – **slave15_7.txt**
- **slave16_1.txt** – **slave16_7.txt**

master_execution.bat

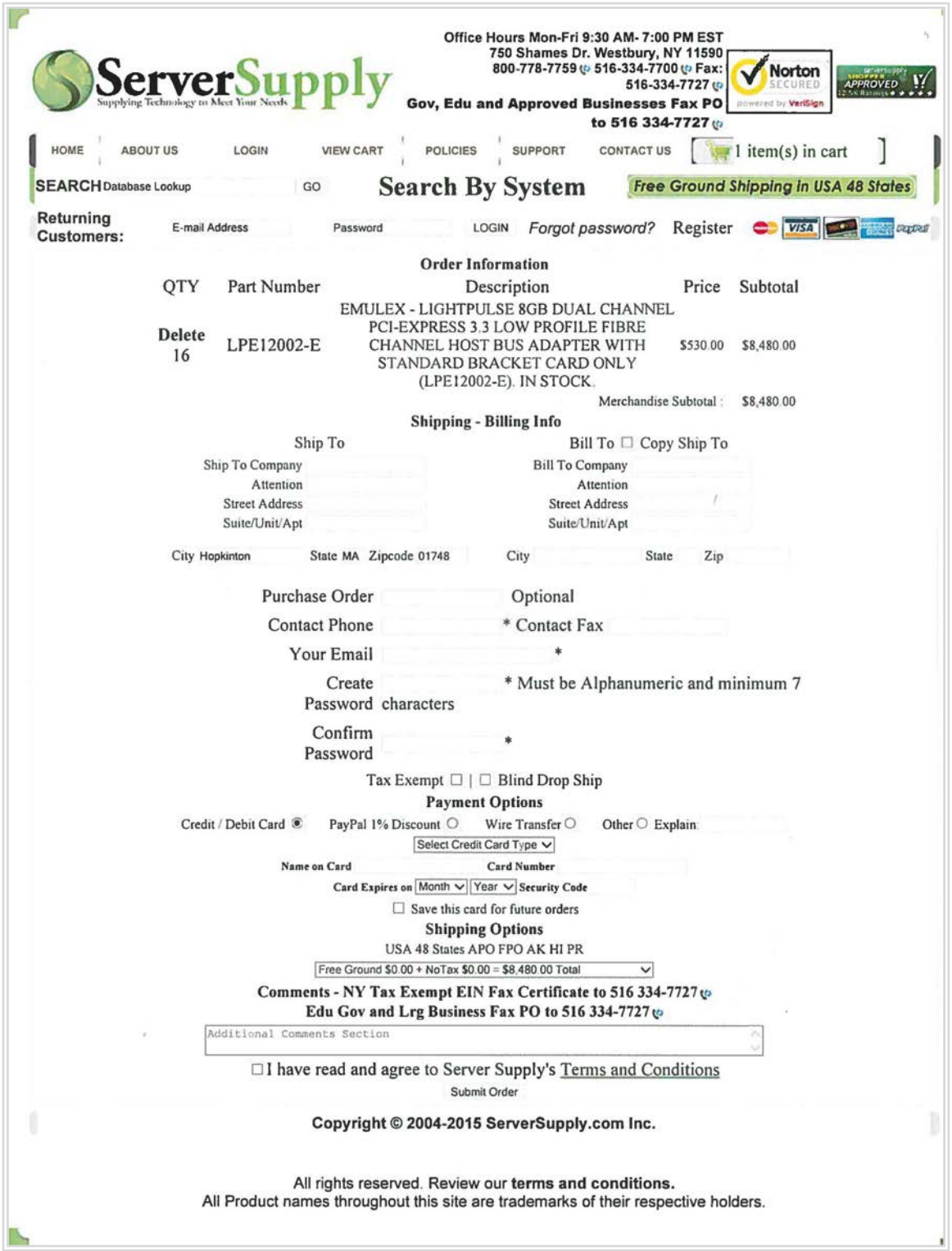
```
echo "ASU prefill started......"

cd C:\vdbench\vdbench50402

call vdbench -f C:\vdbench\vdbench50402\spc1\prefill.param -o
C:\vdbench\vdbench50402\spc1\prefill-out

echo "ASU prefill complete....."

cd c:\spc

copy /Y spc1_iops.cfg spc1.cfg

java   metrics -b 8701 -t 28800 -s 300

java  repeat1 -b 8701 -s 300

java  repeat2 -b 8701 -s 300

copy /Y spc1_persist.cfg spc1.cfg

java  persist1 -b 870

java -cp c:\spc\spc2 vdbench -w SPC2 -f spc2_persist1.cfg -o
init_spc2 -init

java -cp c:\spc\spc2 vdbench -w SPC2 -f spc2_persist1.cfg -o
persist1_spc2

naviseccli -user sysadmin -password sysadmin -scope 0 -h 192.168.1.30
getdisk > before_disklist.txt

naviseccli -user sysadmin -password sysadmin -scope 0 -h 192.168.1.30
storagepool -list > before_poollist.txt

naviseccli -user sysadmin -password sysadmin -scope 0 -h 192.168.1.30
lun -list > before_lunlist.txt
```

spc2_persist2.bat

```
java -cp c:\spc\spc2 vdbench -w SPC2 -f spc2_persist2.cfg -o persist2_spc2

naviseccli -user sysadmin -password sysadmin -scope 0 -h 192.168.1.30 getdisk >
after_disklist.txt

naviseccli -user sysadmin -password sysadmin -scope 0 -h 192.168.1.30 storagepool -
list > after_poollist.txt

naviseccli -user sysadmin -password sysadmin -scope 0 -h 192.168.1.30 lun -list >
after_lunlist.txt
```

APPENDIX F: THIRD-PARTY QUOTE

Emulex LightPulse LPE12002-E HBAs



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Merchandise Subtotal : $8,480.00

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