SPC BENCHMARK 1™
FULL DISCLOSURE REPORT

HEWLETT PACKARD ENTERPRISE
HPE 3PAR STORESERV 8440 STORAGE SYSTEM

SPC-1 V1.14

Submitted for Review: April 27, 2016
Submission Identifier: A00176
Revised: June 2, 2016

First Edition – April 2016

Trademarks

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AUDIT CERTIFICATION

Bill McCormack
Hewlett Packard Enterprise
4209 Technology Drive
Fremont, CA 94538

April 25, 2016

The SPC Benchmark 1™ Reported Data listed below for the HPE 3PAR StoreServ 8440 Storage System was produced in compliance with the SPC Benchmark 1™ v1.14 Remote Audit requirements.

SPC Benchmark 1™ v1.14 Reported Data	
Tested Storage Product (TSP) Name: HPE 3PAR StoreServ 8440 Storage System	
Metric	**Reported Result**
SPC-1 IOPS™	545,164.29
SPC-1 Price-Performance	$0.23/SPC-1 IOPS™
Total ASU Capacity	5,267.598 GB
Data Protection Level	Protected 2 *(Mirroring)*
Total Price (including three-year maintenance)	$126,558.24
Currency Used	U.S. Dollars
Target Country for availability, sales and support	USA

The following SPC Benchmark 1™ Remote 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 information supplied by Hewlett Packard Enterprise:
  - ✓ 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.

Gradient Systems, Inc.
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).
- 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 information supplied by Hewlett Packard Enterprise:
  - ✓ The type 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 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 Hewlett Packard Enterprise 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
- The differences between the Priced Storage Configuration and the Tested Storage Configuration if applied to the Tested Storage Configuration would have no impact on the SPC-1 Reported Data.
- 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 were no audit notes or exceptions.

Respectfully,

Walter E. Baker

Walter E. Baker
SPC Auditor

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LETTER OF GOOD FAITH

Hewlett Packard Enterprise

LETTER OF GOOD FAITH

Date: February 8, 2016

From: Philip Tamer
Vice President of 3PAR Engineering
Hewlett Packard Enterprise
4209 Technology Drive
Fremont, CA 94538

To: Walter E. Baker
SPC Administrator and Auditor
Gradient Systems, Inc.
643 Bair Island Road, Suite 103
Redwood City, CA 94063

Subject: SPC-1 Letter of Good Faith for the HPE 3PAR StoreServ 8440

Hewlett Packard Enterprise 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 V1.14 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.

Signed: Date:

Philip Tamer
Vice President of 3PAR Engineering

2/8/2016
Date of Signature

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact	Hewlett Packard Enterprise – http://www.hpe.com Bill McCormack – Bill.McCormack@hpe.com 4209 Technology Drive Fremont, CA 94538 Phone: (510) 344-4206
Test Sponsor Alternate Contact	Hewlett Packard Enterprise – http://www.hpe.com Chuck Paridon – Chuck.Paridon@hpe.com 8000 Foothills Blvd. M/S 5785 Roseville, CA 95747 Phone: (916) 472-8239
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	April 27, 2016
Date the FDR was submitted to the SPC	April 27, 2016
Date the revised was submitted to the SPC The original Full Disclosure Report (FDR) included a segment of code, used in preliminary, internal measurements, but was not used in the final audited measurements. That code has been removed in this revision.	June 2, 2016
Date the Priced Storage Configuration is available for shipment to customers	currently available
Date the TSC completed audit certification	April 25, 2016

Tested Storage Product (TSP) Description

HPE 3PAR StoreServ 8440 Storage is a converged flash array that delivers affordable high performance and scalability with Tier-1 data services and quad-node resiliency. It offers the performance advantages of a purpose-built, flash-optimized architecture without compromising resiliency, efficiency, or data mobility, and with the flexibility to use both SSDs and HDDs.

The flash-optimized 3PAR architecture allows the HPE 3PAR StoreServ 8440 to deliver unmatched versatility, performance, and density. The HPE 3PAR StoreServ 8440 features the Gen5 Thin Express ASIC for silicon-based hardware acceleration of thin technologies, including inline deduplication, to reduce acquisition and operational costs.

Enhanced Tier-1 storage capabilities for always-on data access and fine-grained Quality of Service (QoS) controls ensure predictable service levels for all workload types, while bi-directional data mobility enables virtually limitless elastic pools of storage to support the most rigorous on-demand infrastructure.

The HPE 3PAR StoreServ 8440 also enables true multi-protocol convergence with support of FC/iSCSI/FCoE/NFS/SMB and Object Access. Features like 3PAR Adaptive Sparing ensure SSD media endurance and enable a low $/GB, making flash affordable for any application.

Summary of Results

SPC-1 Reported Data	
Tested Storage Product (TSP) Name: HPE 3PAR StoreServ 8440 Storage System	
Metric	**Reported Result**
SPC-1 IOPS™	545,164.29
SPC-1 Price-Performance™	$0.23/SPC-1 IOPS™
Total ASU Capacity	5,267.598 GB
Data Protection Level	Protected 2 *(Mirroring)*
Total Price	$126,558.24
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.*

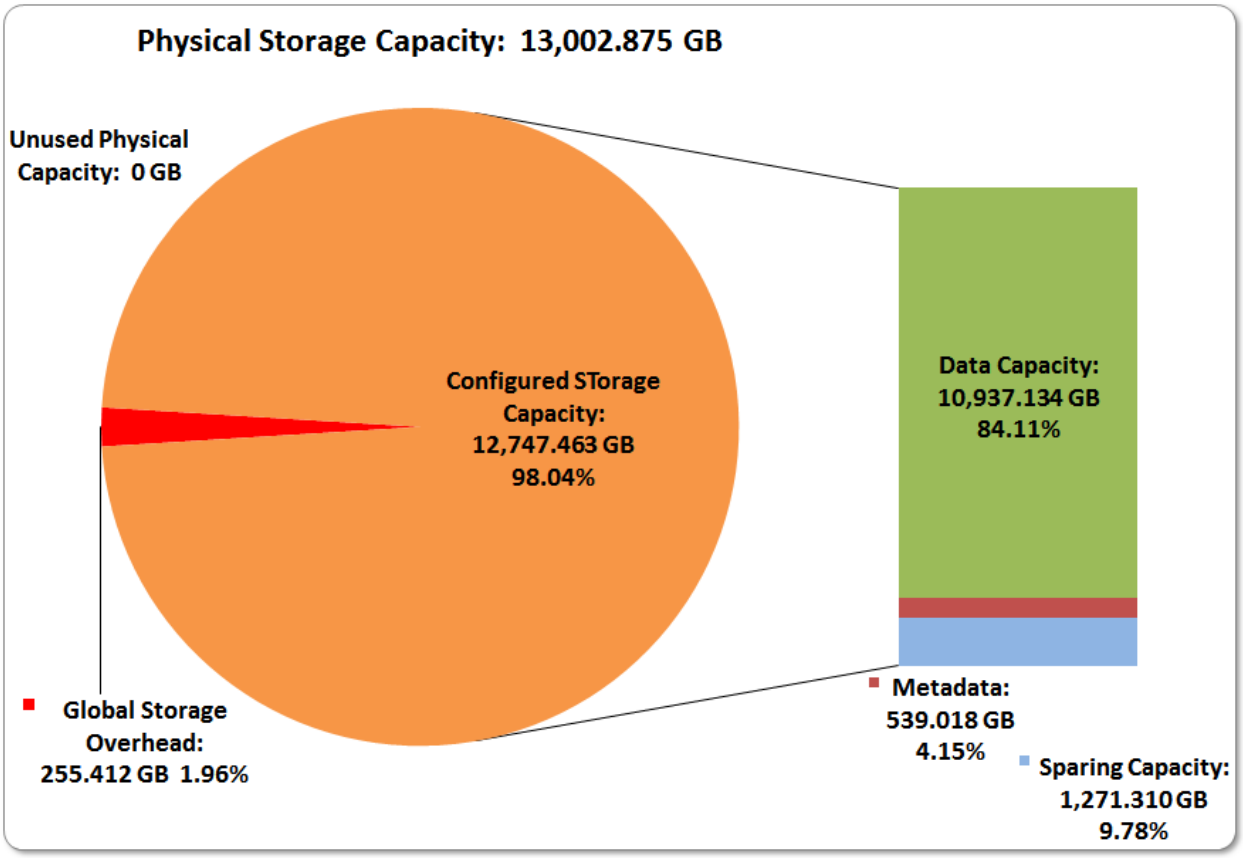
Total Price includes the cost of the Priced Storage Configuration plus three years of hardware maintenance and software support as detailed on page 17.

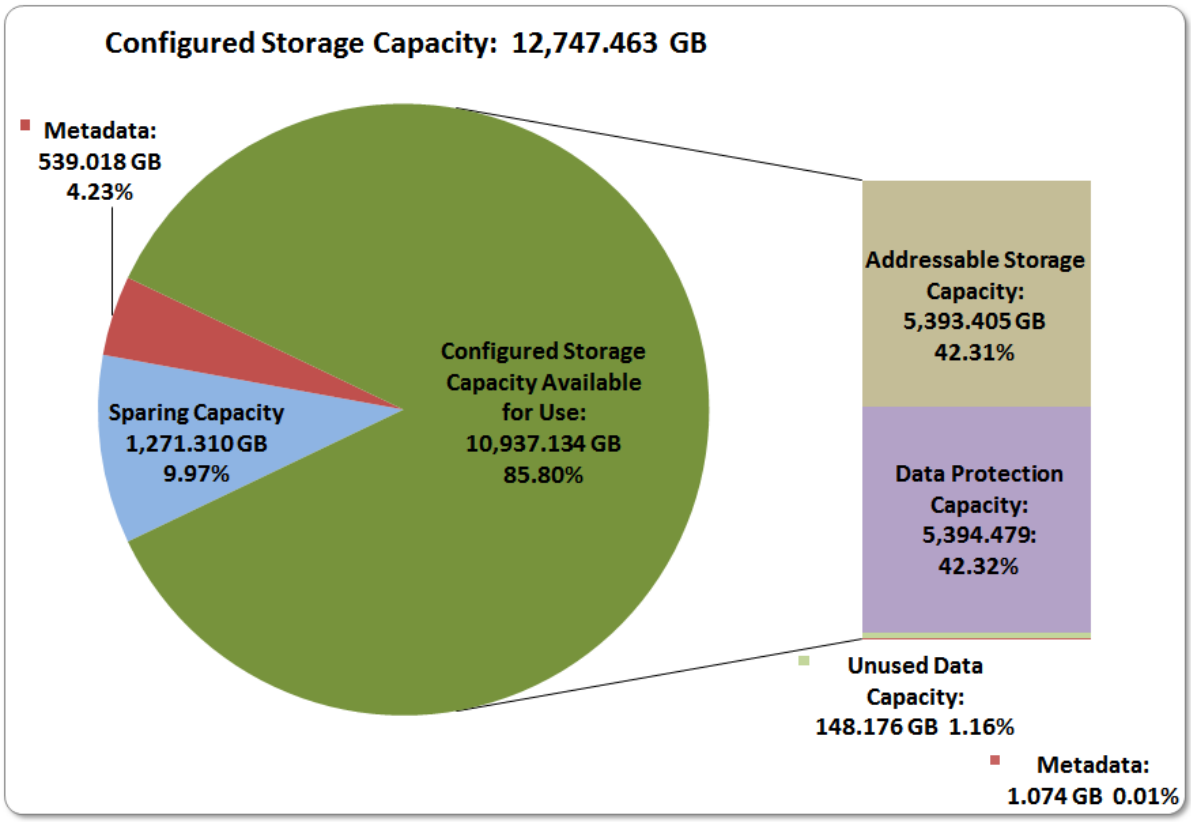
Currency Used is formal name for the currency used in calculating the **Total Price** and **SPC-1 Price-Performance™**. That currency may be the local currency of the **Target Country** or the currency of a difference country *(non-local currency)*.

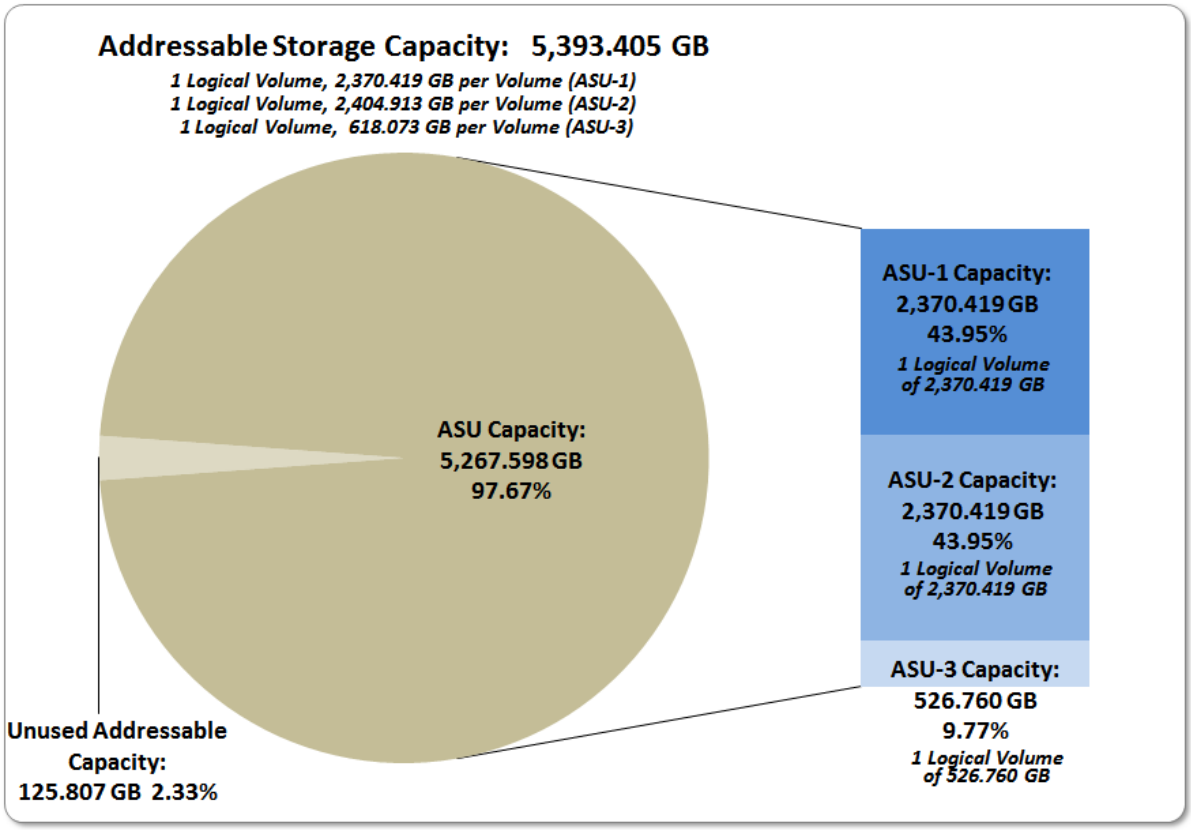
The **Target Country** is the country in which the Priced Storage Configuration is available for sale and in which the required hardware maintenance and software support is provided either directly from the Test Sponsor or indirectly via a third-party supplier.

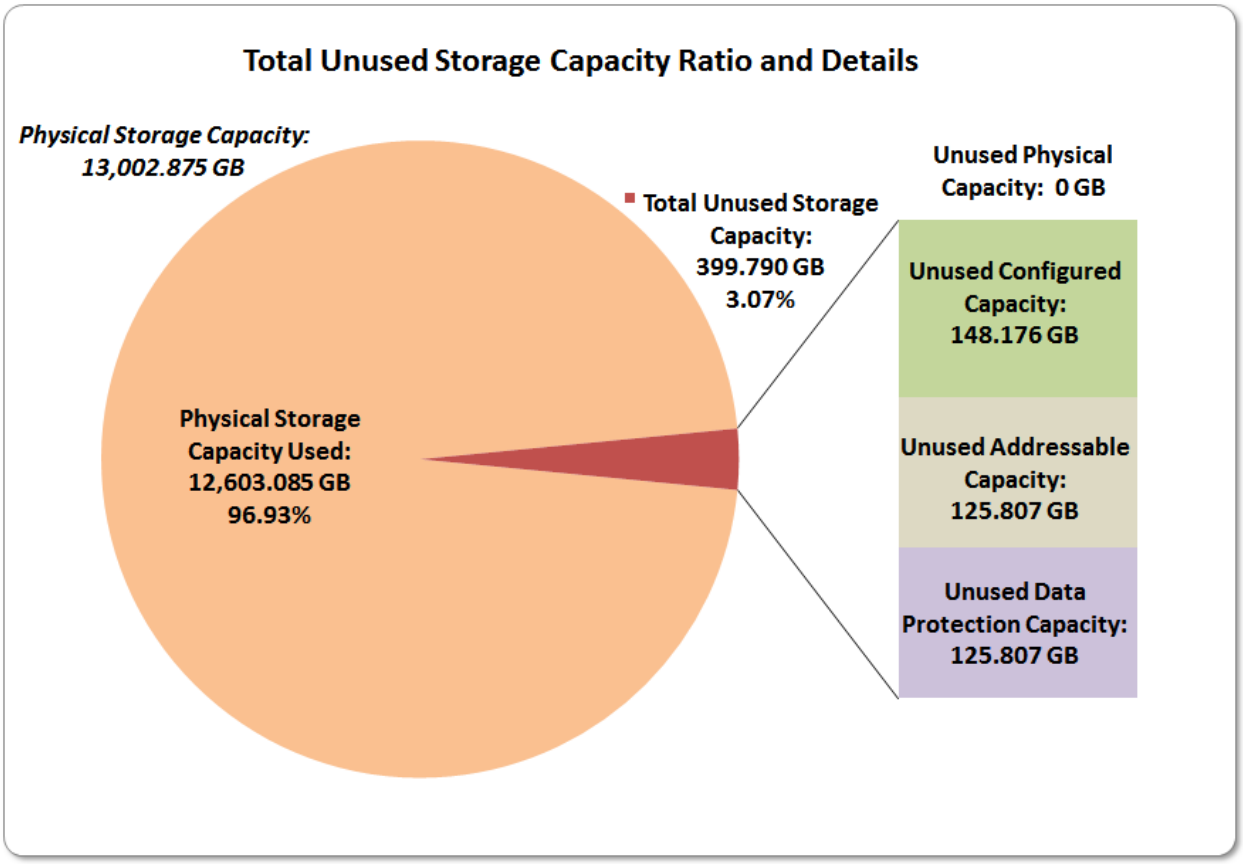
Storage Capacities, Relationships, and Utilization

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: 12,747.463 GB
Metadata:
539.018 GB
4.23%
Sparing Capacity
1,271.310 GB
9.97%
Configured Storage Capacity Available for Use:
10,937.134 GB
85.80%
Addressable Storage Capacity:
5,393.405 GB
42.31%
Data Protection Capacity:
5,394.479:
42.32%
Unused Data Capacity:
148.176 GB 1.16%
Metadata:
1.074 GB 0.01%


Addressable Storage Capacity: 5,393.405 GB
1 Logical Volume, 2,370.419 GB per Volume (ASU-1)
1 Logical Volume, 2,404.913 GB per Volume (ASU-2)
1 Logical Volume, 618.073 GB per Volume (ASU-3)
ASU Capacity:
5,267.598 GB
97.67%
Unused Addressable Capacity:
125.807 GB 2.33%
ASU-1 Capacity:
2,370.419 GB
43.95%
1 Logical Volume of 2,370.419 GB
ASU-2 Capacity:
2,370.419 GB
43.95%
1 Logical Volume of 2,370.419 GB
ASU-3 Capacity:
526.760 GB
9.77%
1 Logical Volume of 526.760 GB



SPC-1 Storage Capacity Utilization	
Application Utilization	40.51%
Protected Application Utilization	81.03%
Unused Storage Ratio	3.07%

Application Utilization: Total ASU Capacity *(5,267.598 GB)* divided by Physical Storage Capacity *(13,002.875 GB)*.

Protected Application Utilization: (Total ASU Capacity *(5,267.598 GB)* plus total Data Protection Capacity *(5,394.479 GB)* minus unused Data Protection Capacity *(125.807 GB)*) divided by Physical Storage Capacity *(13,002.875 GB)*.

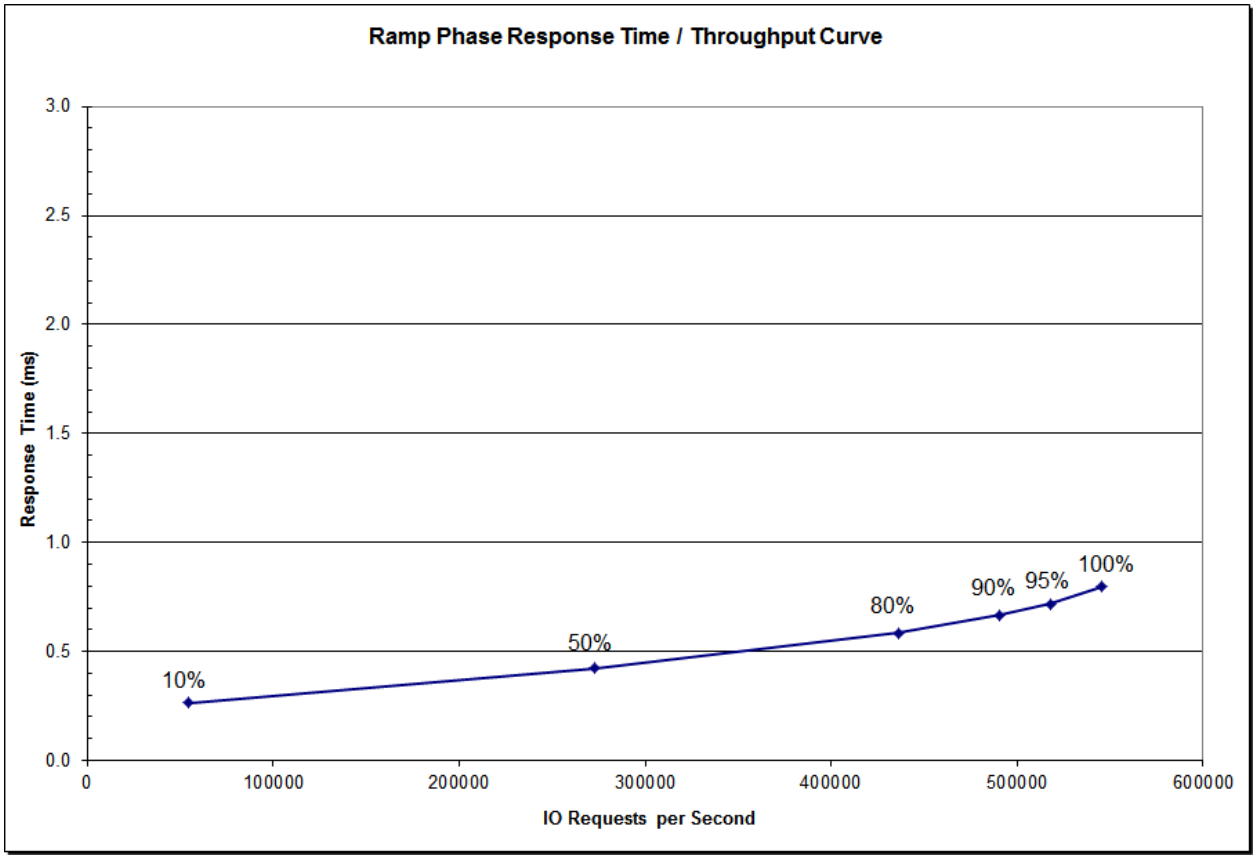
Unused Storage Ratio: Total Unused Capacity *(GB)* divided by Physical Storage Capacity *(13,002.875 GB)* and may not exceed 45%.

Detailed information for the various storage capacities and utilizations is available on pages 26-27.

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	54,502.28	272,608.21	436,137.70	490,636.32	517,873.90	545,164.29
Average Response Time (ms):						
All ASUs	0.27	0.42	0.58	0.67	0.72	0.80
ASU-1	0.27	0.46	0.65	0.74	0.79	0.86
ASU-2	0.29	0.50	0.69	0.78	0.83	0.91
ASU-3	0.25	0.31	0.39	0.46	0.52	0.62
Reads	0.32	0.64	0.94	1.07	1.14	1.24
Writes	0.23	0.28	0.35	0.40	0.44	0.51

Priced Storage Configuration Pricing

Quantity	Model #	Description
Hardware		
1	H6Z13A	HP 3PAR StoreServ 8440 4N Fld Int Base
4	H6Z00A	HP 3PAR 8000 4-pt 16Gb FC Adapter
32	N9Y06A	HPE 3PAR 8000 400GB SAS SFF SSD
2	E7Y71A	HP 3PAR 8000 SFF(2.5in) Fld Int Drv Encl
24	QK733A	HP Premier Flex LC/LC OM4 2f 2m Cbl
Software		
1	L7B93A	HP 3PAR 8440 OS Suite Base LTU
32	L7B94A	HP 3PAR 8440 OS Suite Drive LTU
1	BD362AAE	HP 3PAR StoreServ Mgmt/Core SW E-Media
1	BD363AAE	HP 3PAR OS Suite Latest E-Media
Services/Support		
1	H1K92A3	HPE 3Y Proactive Care 24x7 Service
1	H1K92A3 YTD	HP 3PAR StoreServ 8440 4N Base Supp
2	H1K92A3 YTJ	HP 3PAR 8000 Drive Encl Supp
4	H1K92A3 YTL	HP 3PAR 8000 4-pt 16Gb FC Adapter Supp
32	H1K92A3 XE0	HPE 3PAR 8000 400GB SFF SSD Supp
1	H1K92A3 YVS	HP 3PAR 8440 OS Suite Base Supp
32	H1K92A3 YVT	HP 3PAR 8440 OS Suite Drive Supp
SAN Hardware/Support 3rd Party		
12	Third Party	EMULEX SN1100E 16Gb 2P FC HBA

Product Category	Discounted Price
HPE Total	$114,942.24
3rd Party Total	$11,616.00
Grand Total	**$126,558.24**

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.

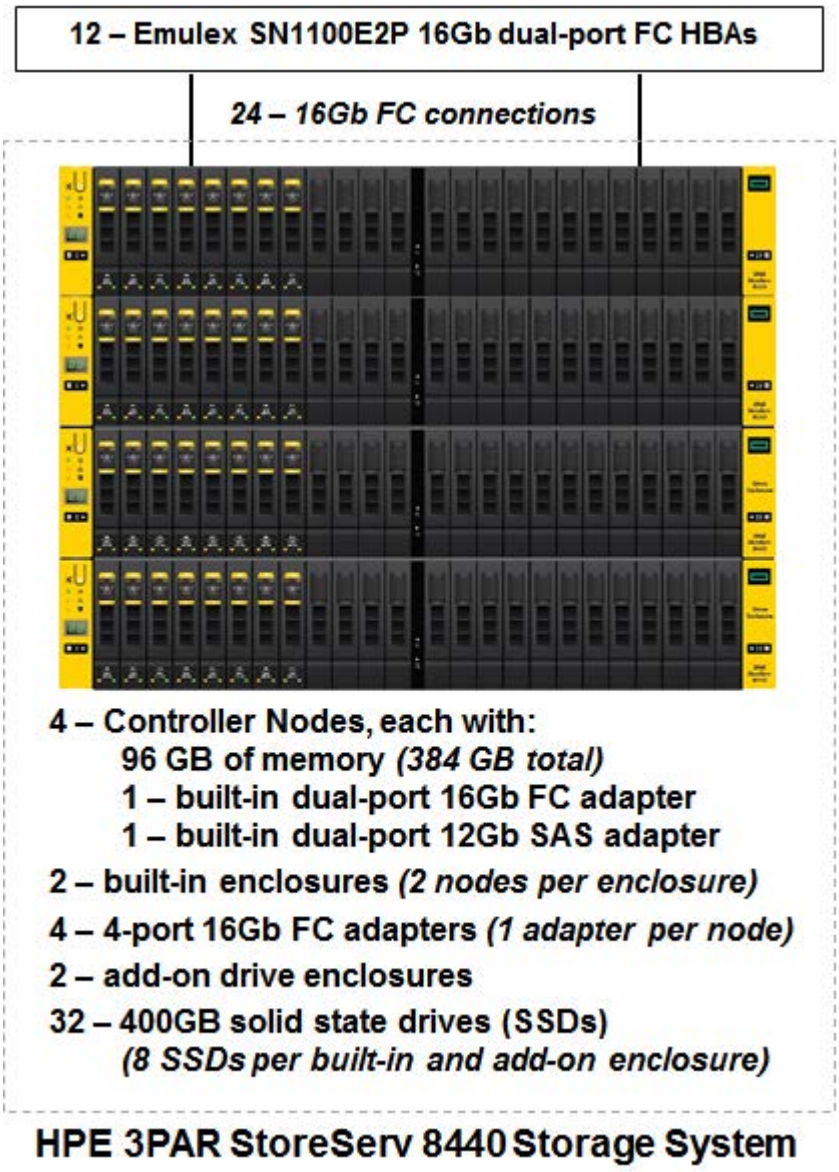
Differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration

The HPE 3PAR StoreServ 8440 uses the same controllers as the HPE 3PAR StoreServ 8450.

The HPE 3PAR StoreServ 8440 Priced Storage Configuration differs from the HPE 3PAR StoreServ 8450 Tested Storage Configuration as follows:

- The factory programmed BIOS model identifier is set to the value representing the HPE 3PAR StoreServ 8440 model.
- The HPE 3PAR StoreServ 8440 optionally supports HDD storage devices and the HPE 3PAR StoreServ 8450 does not.

Priced Storage Configuration Diagram



Priced Storage Configuration Components

Priced Storage Configuration
12 – Emulex SN1100E2P 16Gb dual-port FC HBAs
HPE 3PAR StoreServ 8440 Storage System 4 – Controller Nodes, each with 96 GB of memory *(384 GB total)* 1 – built-in dual-port 16Gb FC adapter *(4 adapters total)* *(2 ports per node, 8 ports total and used)* 1 – built-in dual-port 12 Gb SAS adapter *(4 adapters total)* *(2 ports per node, 8 ports total and used)*
2 – built-in enclosures *(2 nodes per enclosure)*
4 – 4-port 16Gb FC adapters *(1 adapter per node)* *(4 ports per node, 16 ports total and used)*
2 – add-on drive enclosures
32 – 400 GB solid state drive (SSDs) *(8 SSDs per built-in and add-on enclosure)*

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 22 (*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.

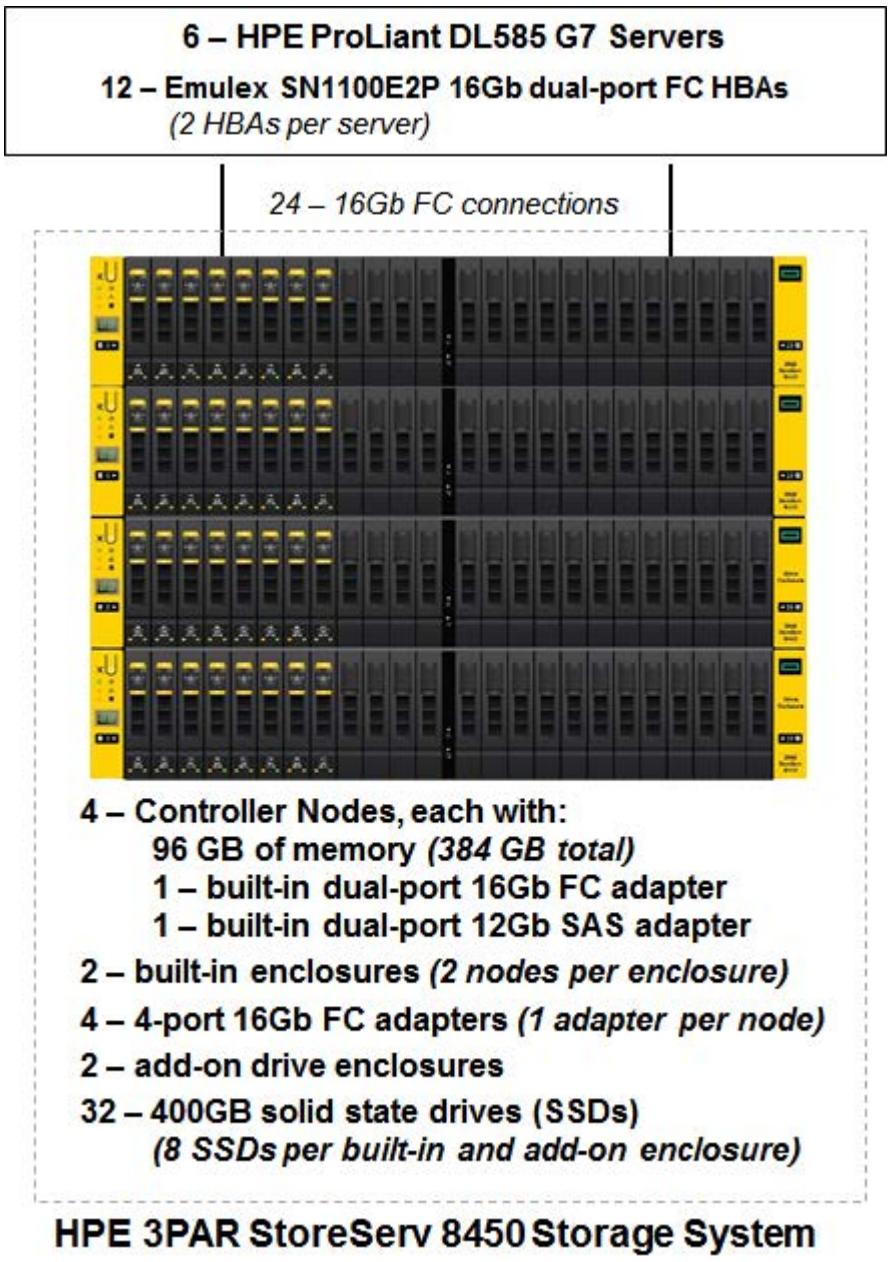
Host System(s) and Tested Storage Configuration (TSC) Table of Components

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 23 (*Host System and Tested Storage Configuration Components*).

Benchmark Configuration/Tested Storage Configuration Diagram



Host System and Tested Storage Configuration Components

Host Systems
2 – HPE ProLiant DL585 G7 Servers, each with 4 – AMD Opteron 6386 SE 2.8 GHz processors each with 16 cores, 16 MB L3 cache 256 GB main memory Red Hat Enterprise Linux 6.6 *(2.6.32-504.el6.x86_64)*
Priced Storage Configuration
12 – Emulex SN1100E2P 16Gb dual-port FC HBAs
HPE 3PAR StoreServ 8450 Storage System 4 – Controller Nodes, each with 96 GB of memory *(384 GB total)* 1 – built-in dual-port 16Gb FC adapter *(4 adapters total)* *(2 ports per node, 8 ports total and used)* 1 – built-in dual-port 12 Gb SAS adapter *(4 adapters total)* *(2 ports per node, 8 ports total and used)*
2 – built-in enclosures *(2 nodes per enclosure)*
4 – 4-port 16Gb FC adapters *(1 adapter per node)* *(4 ports per node, 16 ports total and used)*
2 – add-on drive enclosures
32 – 400 GB solid state drive (SSDs) *(8 SSDs per built-in and add-on enclosure)*

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 66 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 67 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 79.

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 79.

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 62 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 13,002.875 GB distributed over 32 solid state devices (SSDs) each with a formatted capacity of 406.340 GB. There was 0 GB (0%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 255.412 GB (1.96%) of the Physical Storage Capacity. There was 148.176 GB (1.16%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 97.67% of the Addressable Storage Capacity resulting in 125.807 GB (2.33%) of Unused Storage within the Addressable Storage Capacity. The Data Protection *(Mirroring)* capacity was 5,394.479 GB of which 5,267.598 GB was utilized. The total Unused Storage capacity was 399.790 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.

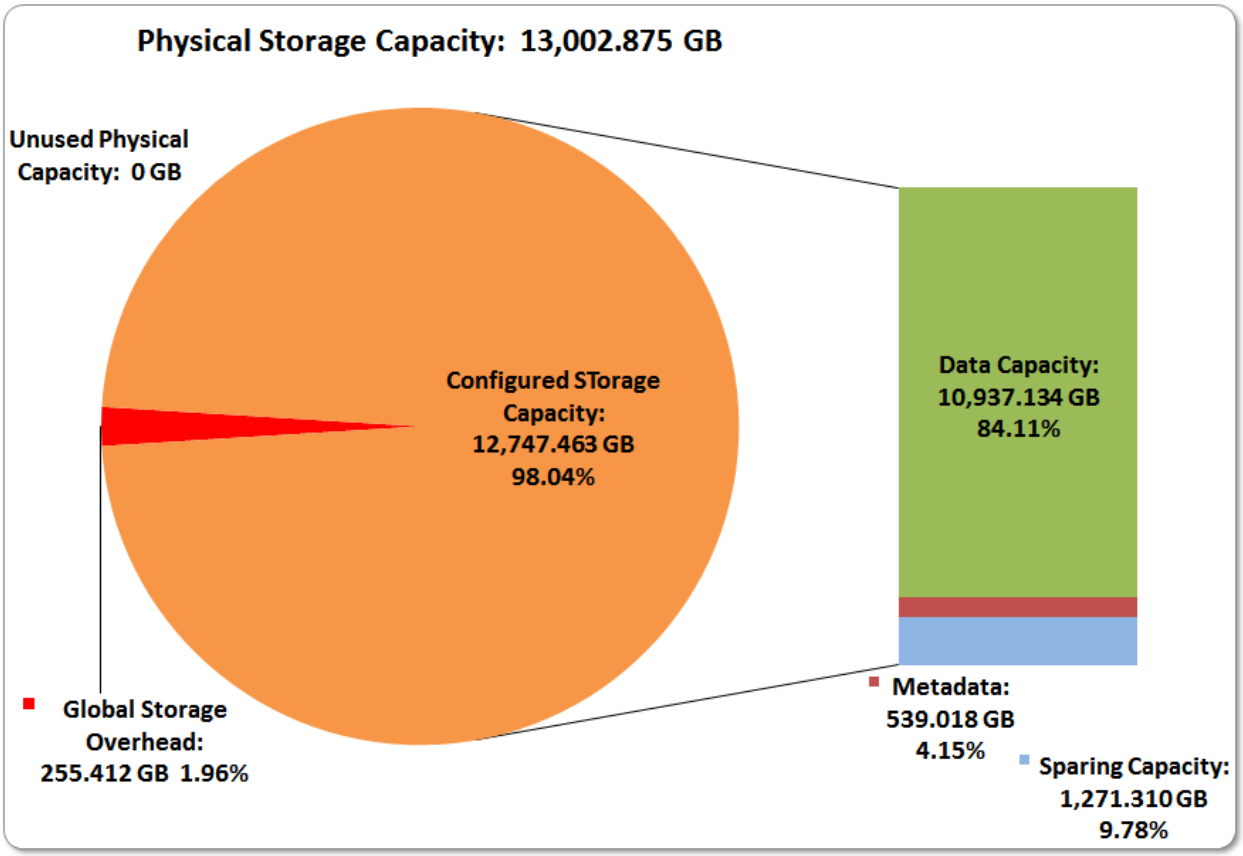
SPC-1 Storage Capacities

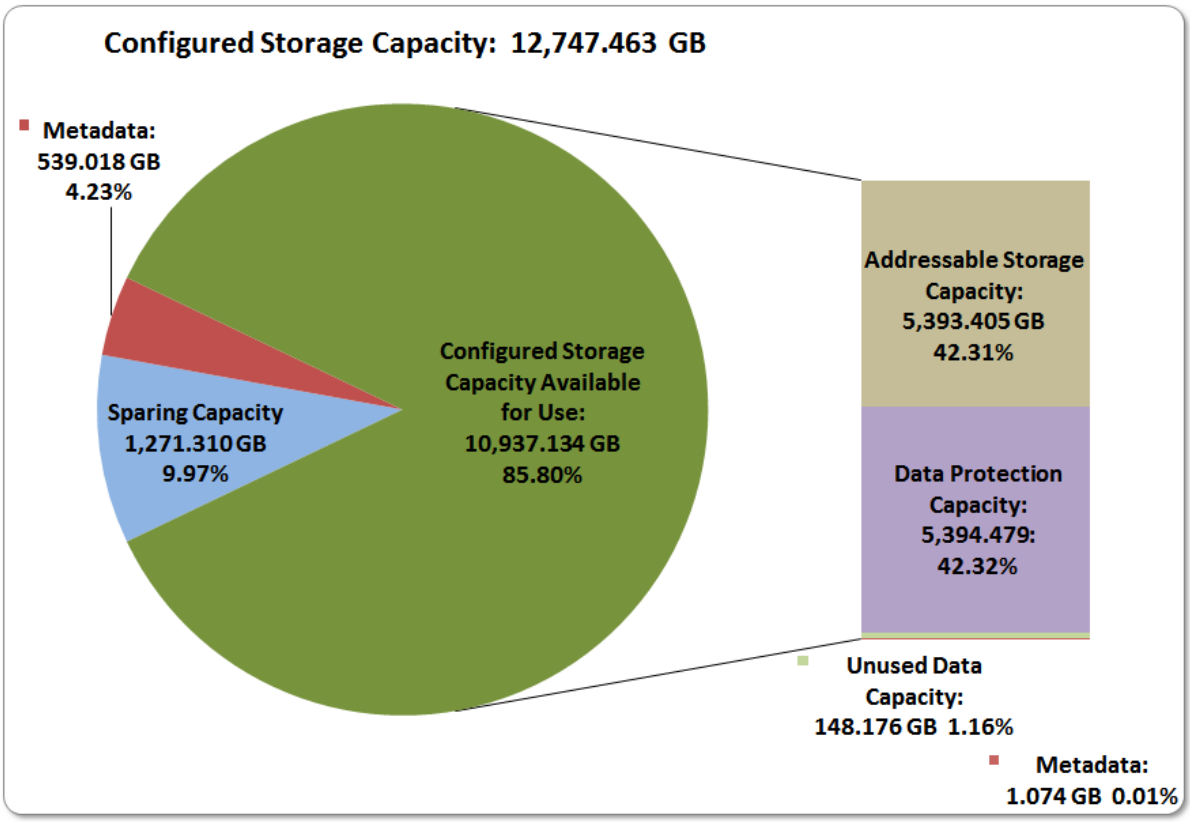
Storage Hierarchy Component	Units	Capacity
Total ASU Capacity	Gigabytes (GB)	5,267.598
Addressable Storage Capacity	Gigabytes (GB)	5,393.406
Configured Storage Capacity	Gigabytes (GB)	12,747.463
Physical Storage Capacity	Gigabytes (GB)	13,002.875
Data Protection *(Mirroring)*	Gigabytes (GB)	5,394.479
Required Storage *(metadata)*	Gigabytes (GB)	540.092
Global Storage Overhead	Gigabytes (GB)	255.412
Total Unused Storage	Gigabytes (GB)	399.790

SPC-1 Storage Hierarchy Ratios

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	96.67%	41.32%	40.51%
Required for Data Protection *(Mirroring)*		42.32%	41.49%
Addressable Storage Capacity		42.31%	41.48%
Required Storage *(metadata)*		4.24%	4.15%
Configured Storage Capacity			96.04%
Global Storage Overhead			1.96%
Unused Storage:			
Addressable	2.33%		
Configured		1.16%	
Physical			0.00%

SPC-1 Storage Capacity Charts




Configured Storage Capacity: 12,747.463 GB
Metadata:
539.018 GB
4.23%
Sparing Capacity
1,271.310 GB
9.97%
Configured Storage Capacity Available for Use:
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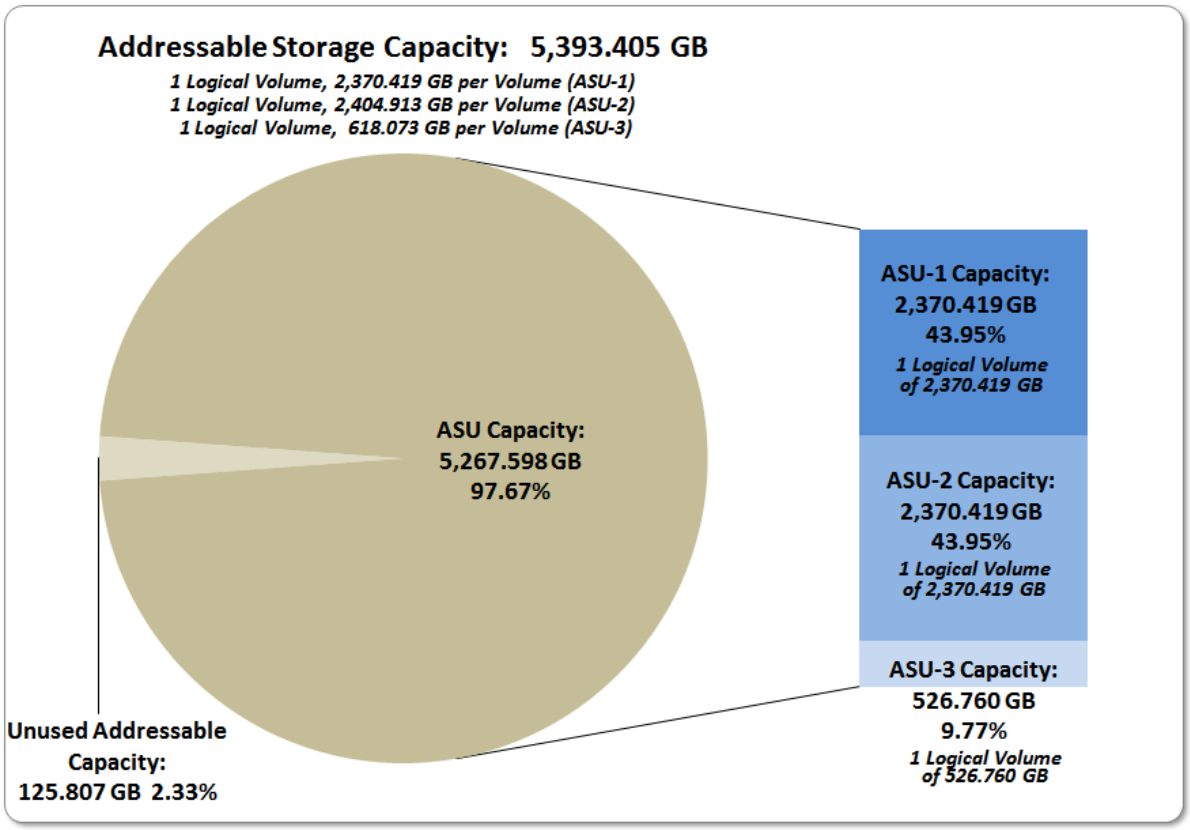
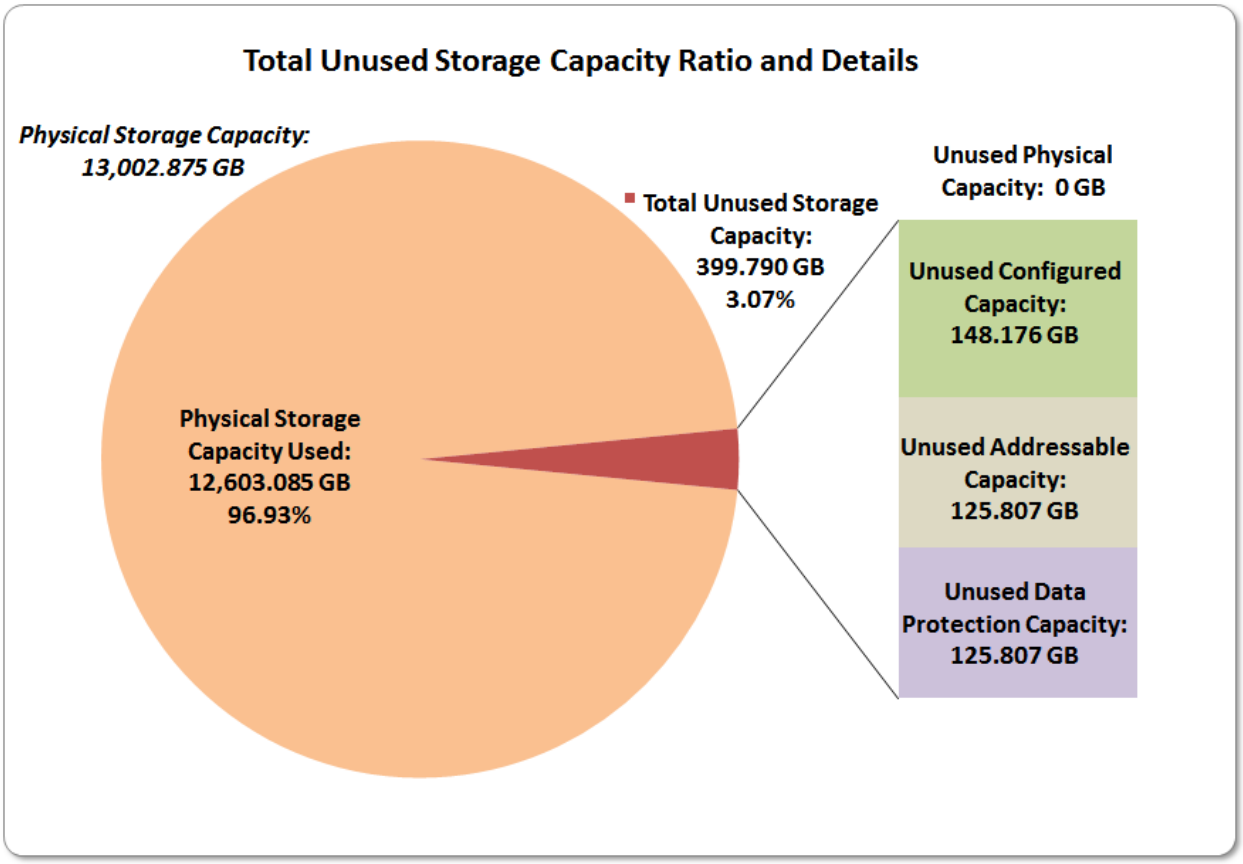

Addressable Storage Capacity: 5,393.405 GB
1 Logical Volume, 2,370.419 GB per Volume (ASU-1)
1 Logical Volume, 2,404.913 GB per Volume (ASU-2)
1 Logical Volume, 618.073 GB per Volume (ASU-3)
ASU Capacity:
5,267.598 GB
97.67%
Unused Addressable Capacity:
125.807 GB 2.33%
ASU-1 Capacity:
2,370.419 GB
43.95%
1 Logical Volume of 2,370.419 GB
ASU-2 Capacity:
2,370.419 GB
43.95%
1 Logical Volume of 2,370.419 GB
ASU-3 Capacity:
526.760 GB
9.77%
1 Logical Volume of 526.760 GB



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	40.51%
Protected Application Utilization	81.03%
Unused Storage Ratio	3.07%

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 (2,370.419 GB)
1 Logical Volume 2,370.419 GB per Logical Volume (2,370.419 GB used per Logical Volume)
ASU-2 (2,370.419 GB)
1 Logical Volume 2,404.913 GB per Logical Volume (2,370.419 GB used per Logical Volume)
ASU-3 (526.760 GB)
1 Logical Volume 618.073GB per Logical Volume (526.760 GB used per Logical Volume)

The Data Protection Level used for all Logical Volumes was **Protected 2** using ***Mirroring*** as described on page 12. 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 62 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 81.

Sustainability Test Results File

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

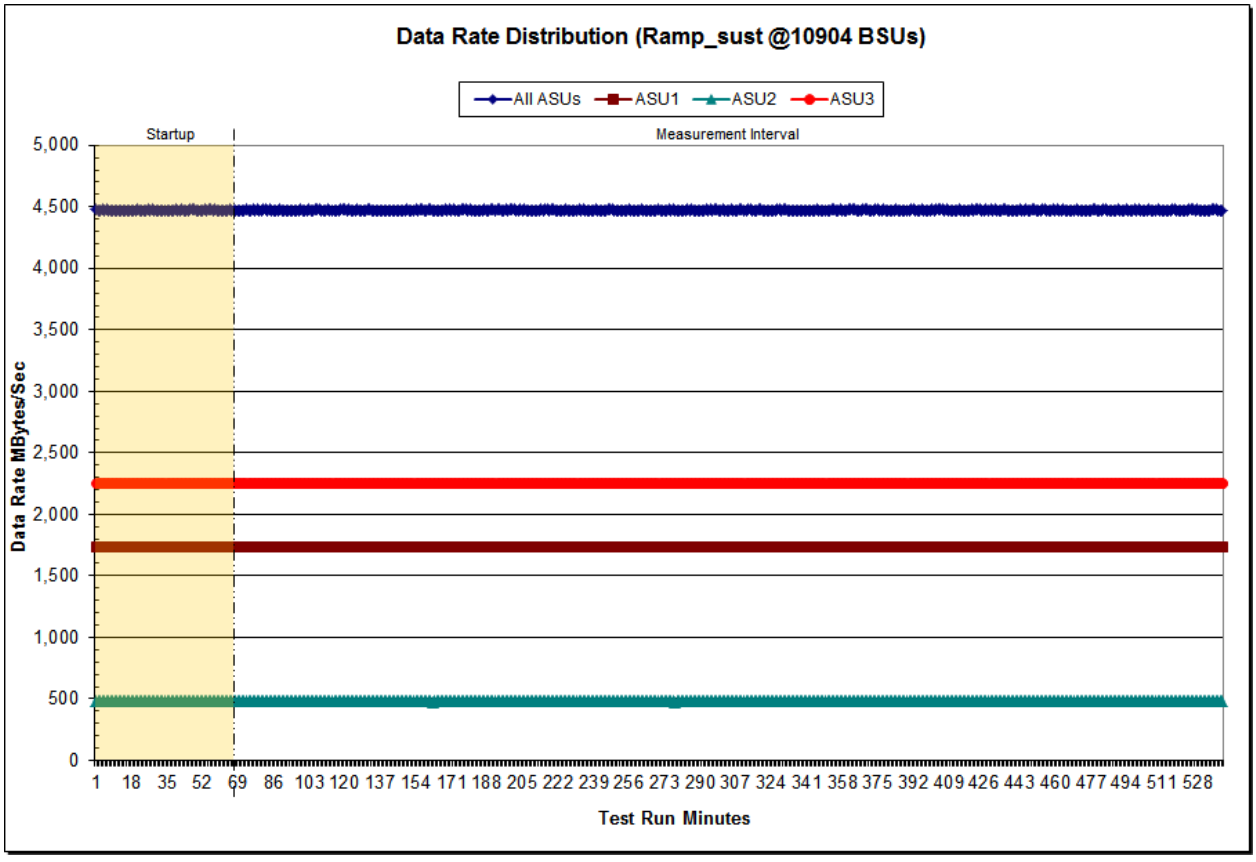
Sustainability Test Results File

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

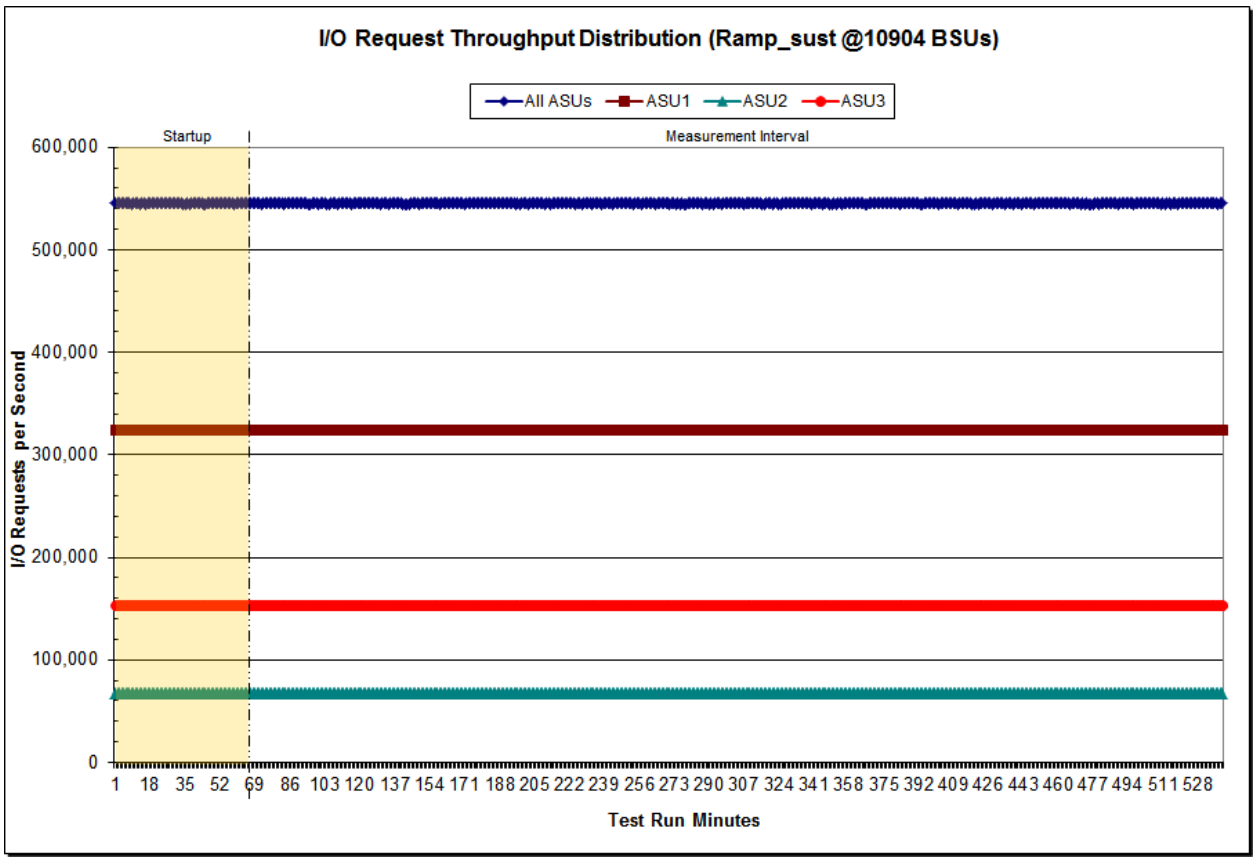


Sustainability – I/O Request Throughput Distribution Data

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

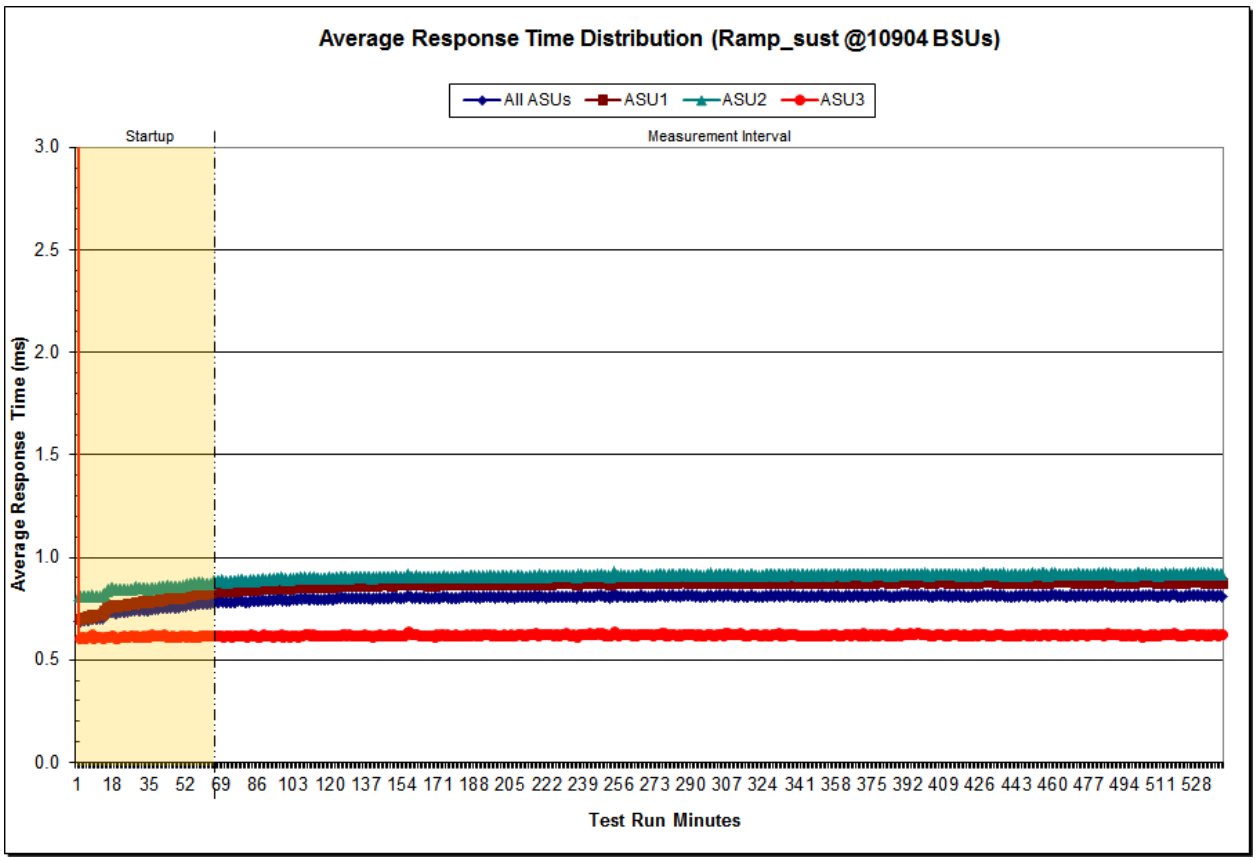


Sustainability – Average Response Time (ms) Distribution Data

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



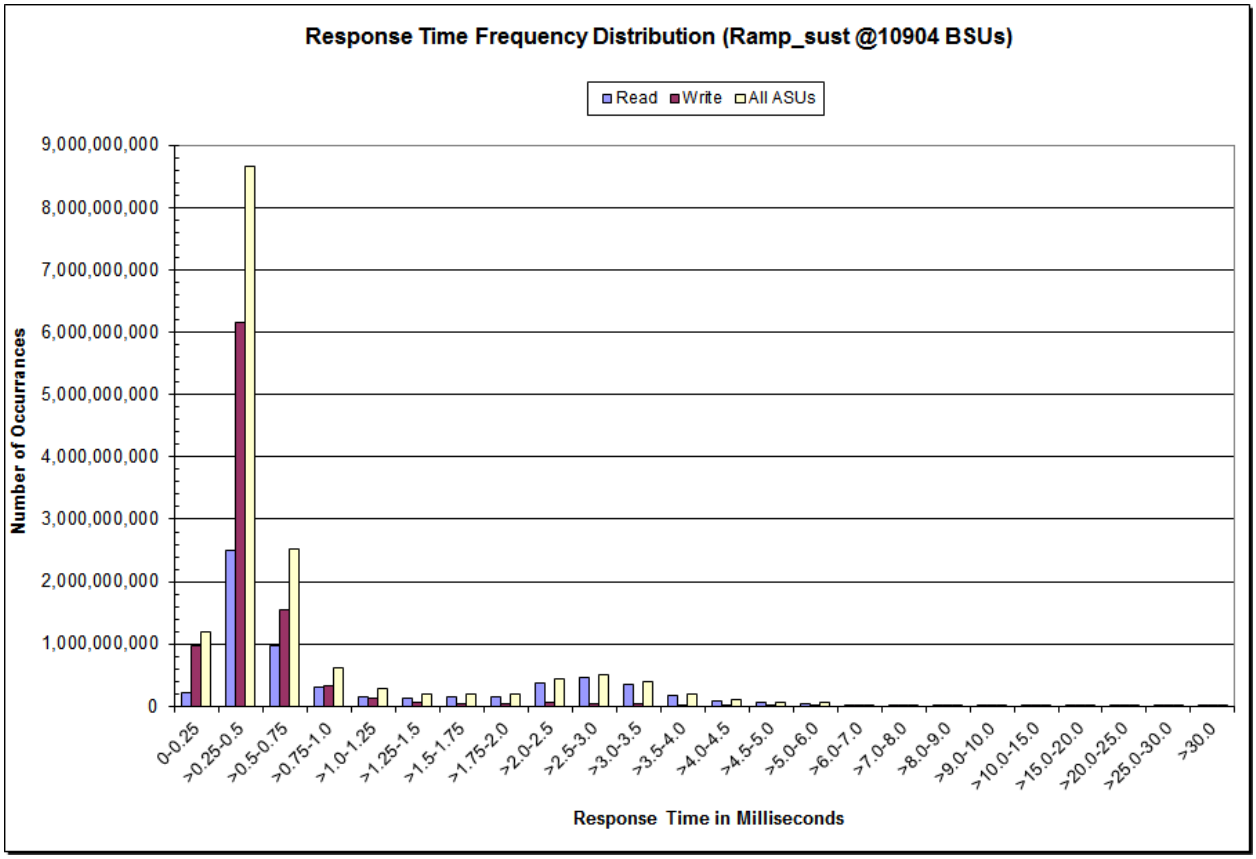
Sustainability – Response Time Frequency Distribution Data

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	208,792,687	2,508,126,399	971,061,139	299,007,344	154,739,111	136,791,698	145,758,977	161,383,885
Write	979,439,689	6,150,048,910	1,551,643,485	328,639,498	125,127,611	69,413,676	43,518,577	32,976,069
All ASUs	1,188,232,376	8,658,175,309	2,522,704,624	627,646,842	279,866,722	206,205,374	189,277,554	194,359,954
ASU1	803,175,672	4,945,796,608	1,344,541,212	344,021,609	161,742,312	130,898,742	131,202,083	141,299,544
ASU2	159,773,606	1,013,266,040	273,398,084	70,201,796	32,822,695	26,261,922	26,288,638	28,540,586
ASU3	225,283,098	2,699,112,661	904,765,328	213,423,437	85,301,715	49,044,710	31,786,833	24,519,824

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	382,006,744	460,465,818	361,140,299	178,997,519	95,851,425	52,191,802	49,272,482	17,766,723
Write	52,915,143	36,734,044	30,054,575	24,383,235	20,070,967	15,840,317	20,289,102	10,741,483
All ASUs	434,921,887	497,199,862	391,194,874	203,380,754	115,922,392	68,032,119	69,561,584	28,508,206
ASU1	327,566,761	386,333,357	299,127,989	148,675,106	80,612,462	44,622,547	42,851,964	15,918,257
ASU2	67,505,641	82,652,309	68,532,467	35,457,004	19,379,851	10,713,815	10,309,288	3,838,235
ASU3	39,849,485	28,214,196	23,534,418	19,248,644	15,930,079	12,695,757	16,400,332	8,751,714

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	5,870,359	1,716,467	632,812	749,806	117,172	52,202	8,893	3,023
Write	6,131,758	3,711,458	2,304,449	3,929,032	844,476	283,368	128,295	135,348
All ASUs	12,002,117	5,427,925	2,937,261	4,678,838	961,648	335,570	137,188	138,371
ASU1	5,628,346	1,944,910	856,725	1,179,670	209,366	79,533	24,430	19,847
ASU2	1,376,365	454,738	192,049	257,070	44,934	16,949	5,307	4,445
ASU3	4,997,406	3,028,277	1,888,487	3,242,098	707,348	239,088	107,451	114,079

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 81.

IOPS Test Results File

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

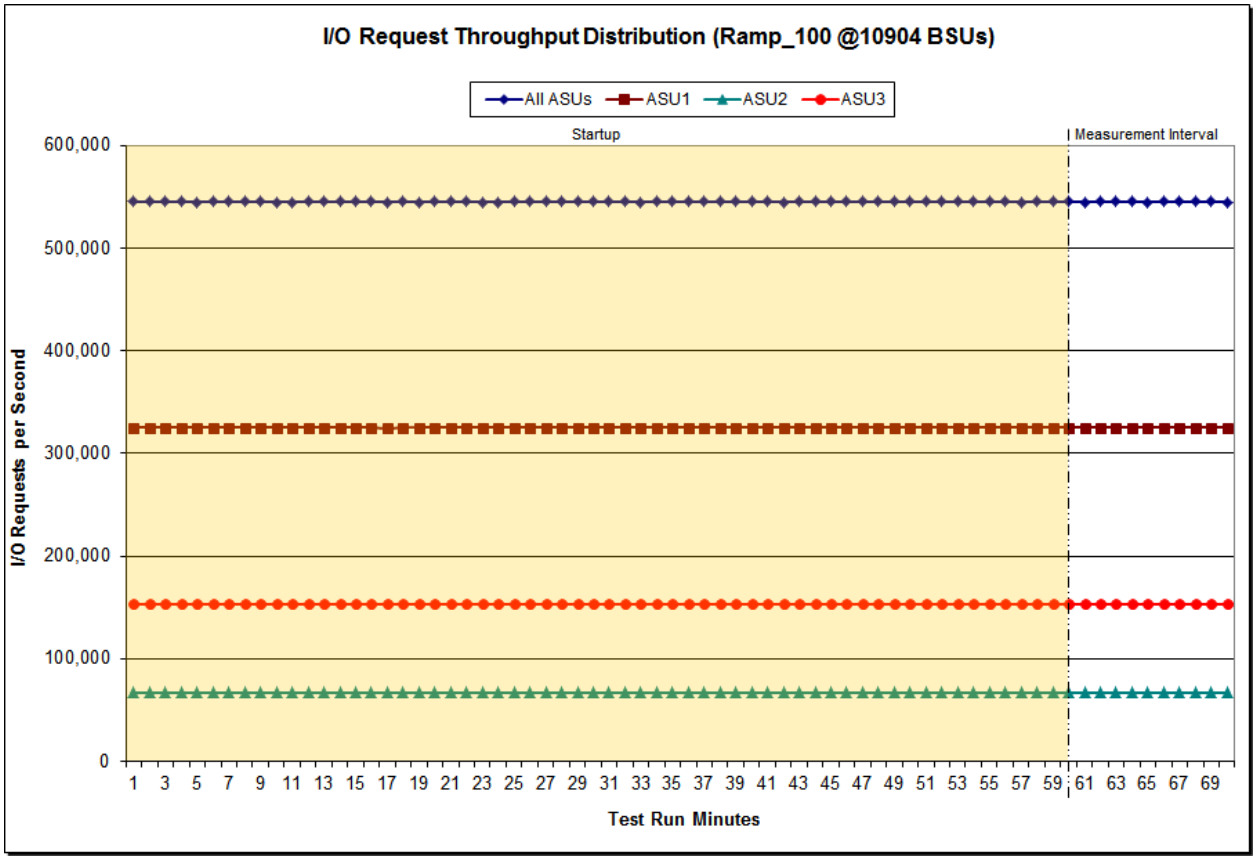
IOPS Test Results File

IOPS Test Run – I/O Request Throughput Distribution Data

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

I/O Request Throughput Distribution Data Table

IOPS Test Run – I/O Request Throughput Distribution Graph

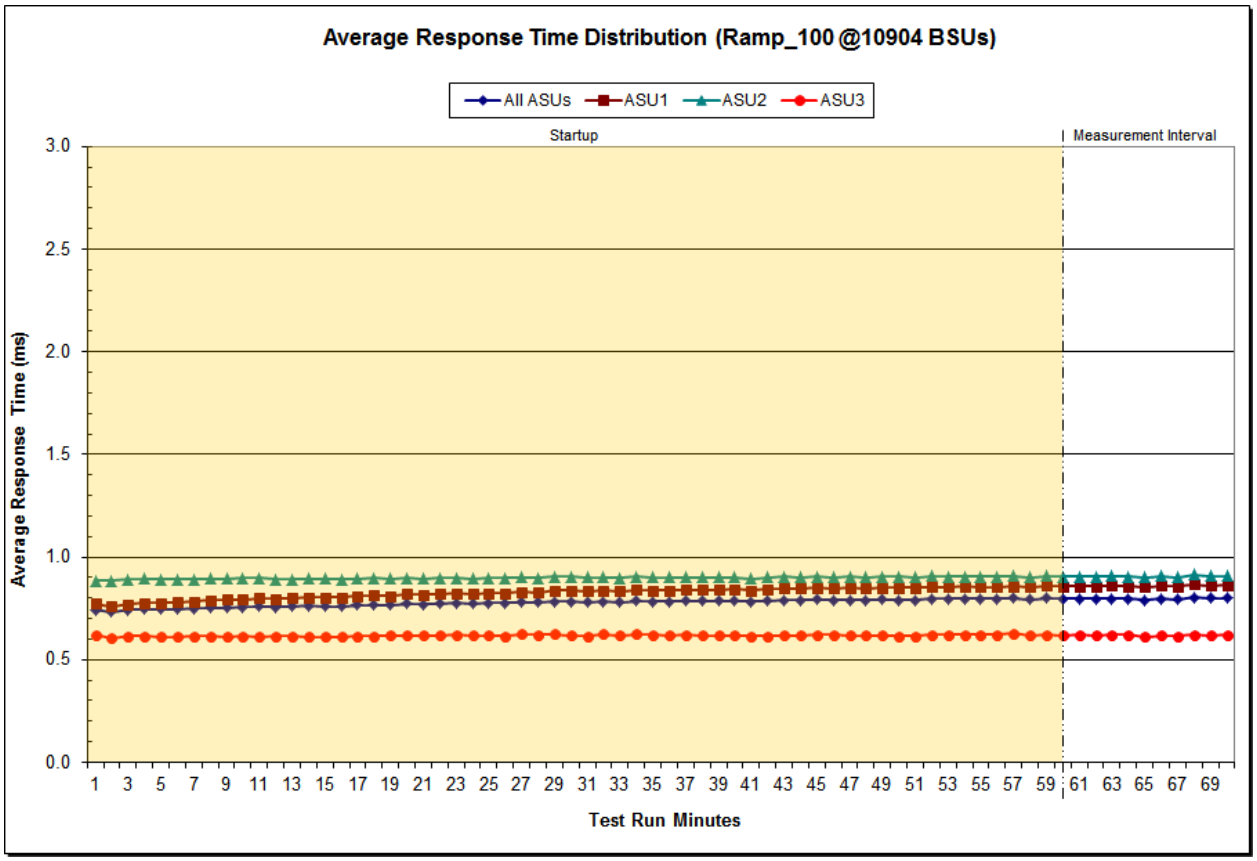


IOPS Test Run – Average Response Time (ms) Distribution Data

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

Average Response Distribution Data Table

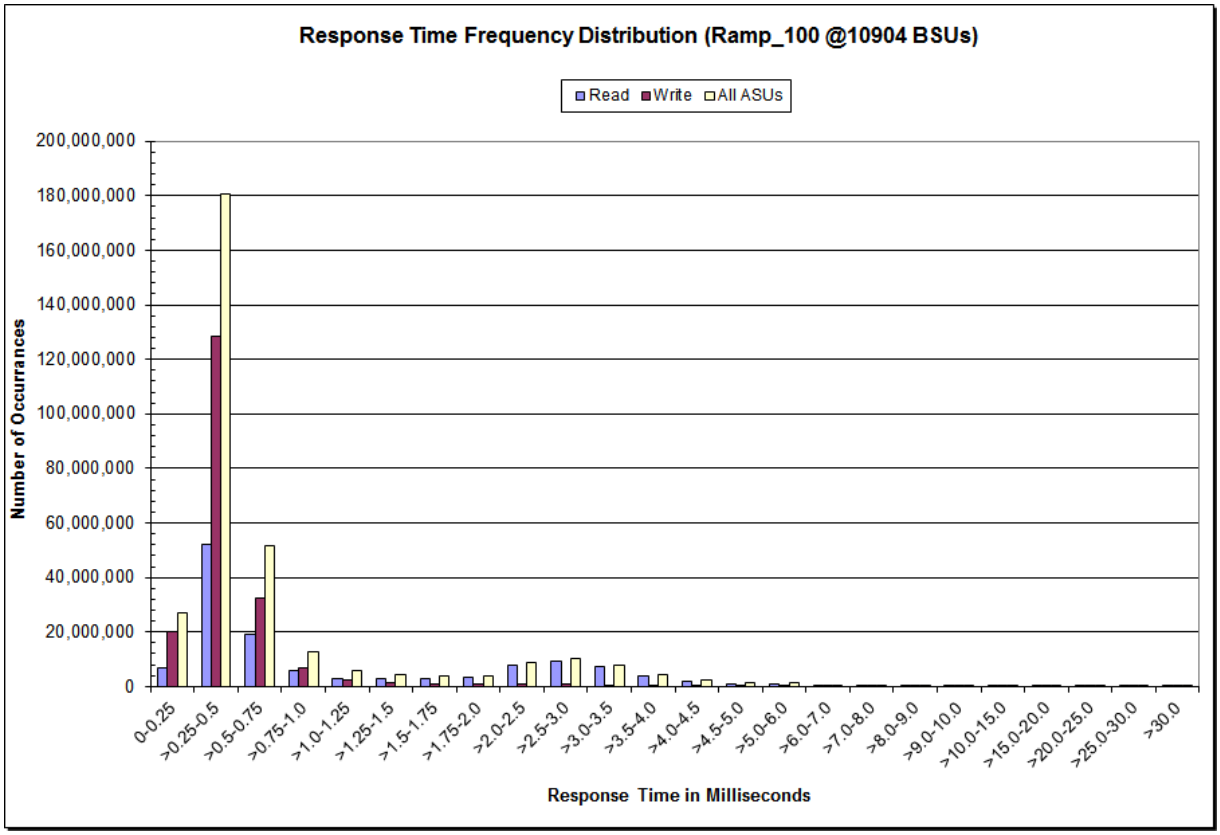
IOPS Test Run – Average Response Time (ms) Distribution Graph



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	6,833,139	52,188,166	19,352,427	5,898,777	3,088,897	2,745,985	2,935,301	3,253,111
Write	20,309,592	128,346,147	32,308,569	6,831,835	2,607,101	1,436,430	894,116	677,687
All ASUs	27,142,731	180,534,313	51,660,996	12,730,612	5,695,998	4,182,415	3,829,417	3,930,798
ASU1	19,076,242	103,030,355	27,158,458	6,852,568	3,237,912	2,619,663	2,627,651	2,832,344
ASU2	3,410,813	21,175,656	5,637,488	1,433,592	679,181	546,747	547,871	594,086
ASU3	4,655,676	56,328,302	18,865,050	4,444,452	1,778,905	1,016,005	653,895	504,368
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	7,686,372	9,281,638	7,299,881	3,666,481	2,005,865	1,129,843	1,083,597	379,595
Write	1,094,142	751,446	614,739	496,582	409,772	322,344	409,847	214,154
All ASUs	8,780,514	10,033,084	7,914,620	4,163,063	2,415,637	1,452,187	1,493,444	593,749
ASU1	6,561,913	7,759,428	6,025,828	3,037,054	1,686,067	966,309	941,681	338,464
ASU2	1,393,272	1,695,130	1,406,902	733,326	403,871	227,024	220,133	80,989
ASU3	825,329	578,526	481,890	392,683	325,699	258,854	331,630	174,296
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	122,465	36,689	14,030	17,709	3,650	1,445	124	37
Write	121,111	74,198	46,486	79,399	17,393	5,450	2,179	2,199
All ASUs	243,576	110,887	60,516	97,108	21,043	6,895	2,303	2,236
ASU1	116,627	41,217	18,678	27,123	5,908	1,950	367	309
ASU2	28,544	9,521	4,267	5,896	1,304	416	78	76
ASU3	98,405	60,149	37,571	64,089	13,831	4,529	1,858	1,851

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
327,098,142	327,095,906	2,236

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	0.2100	0.0180	0.0700	0.0350	0.2809
COV	0.001	0.000	0.001	0.000	0.000	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 16.

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 81.

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

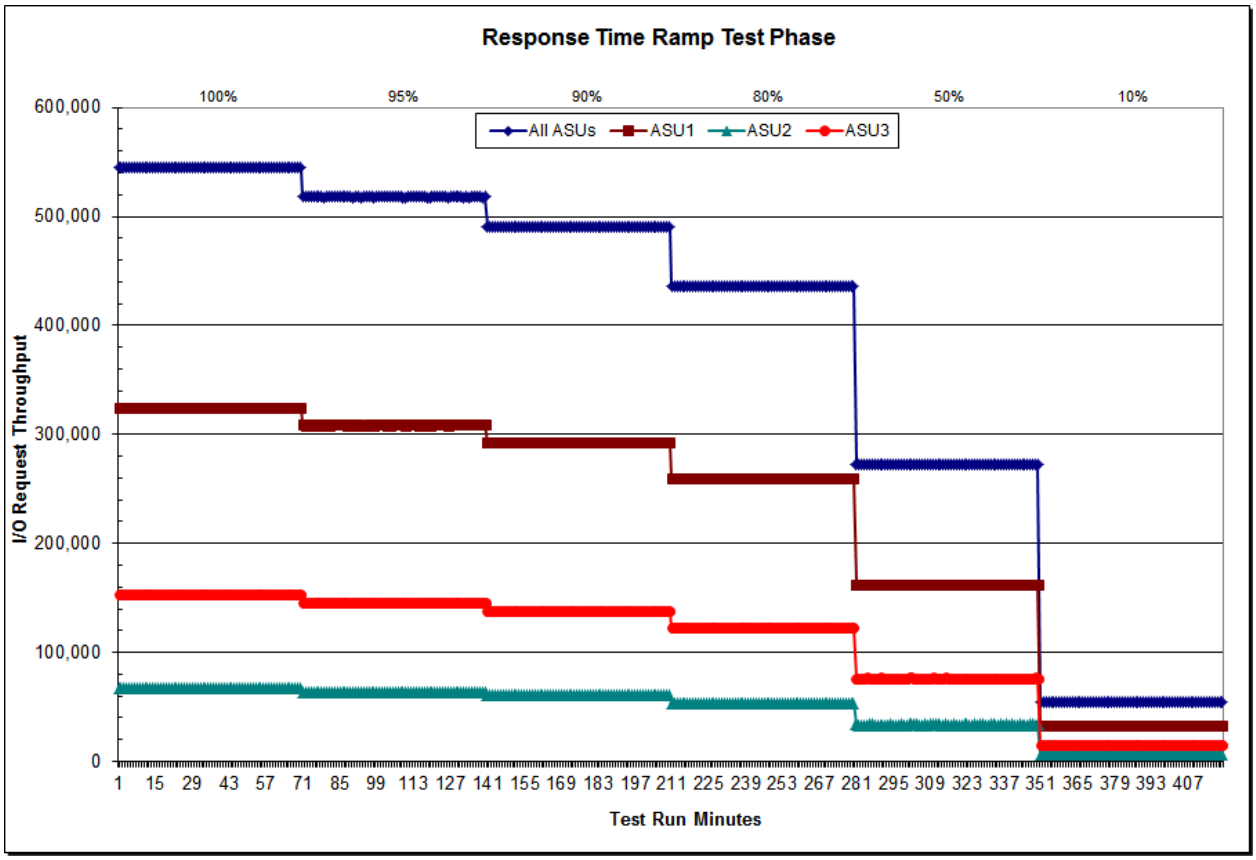
Response Time Ramp Distribution (IOPS) Data

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.

The Response Time Ramp Distribution Data table is not embedded in this document due to its size. The table is available via the following URL:

Response Time Ramp Distribution Data Table

Response Time Ramp Distribution (IOPS) Graph

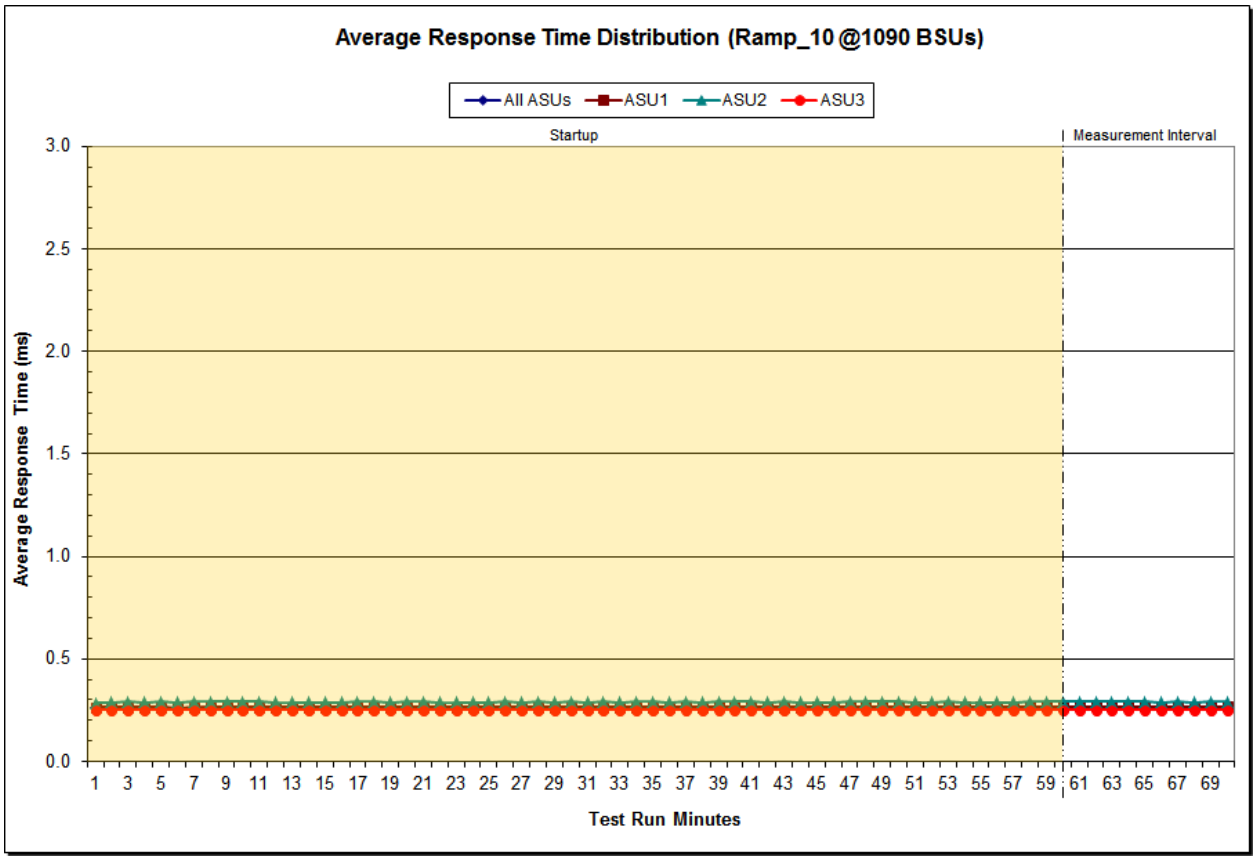


SPC-1 LRT™ Average Response Time (ms) Distribution Data

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

Average Response Time Distribution Data Table

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								
COV								

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 81.

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	***545,164.29***
Repeatability Test Phase 1	545,208.72
Repeatability Test Phase 2	545,200.03

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	***0.27***
Repeatability Test Phase 1	0.27
Repeatability Test Phase 2	0.27

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)

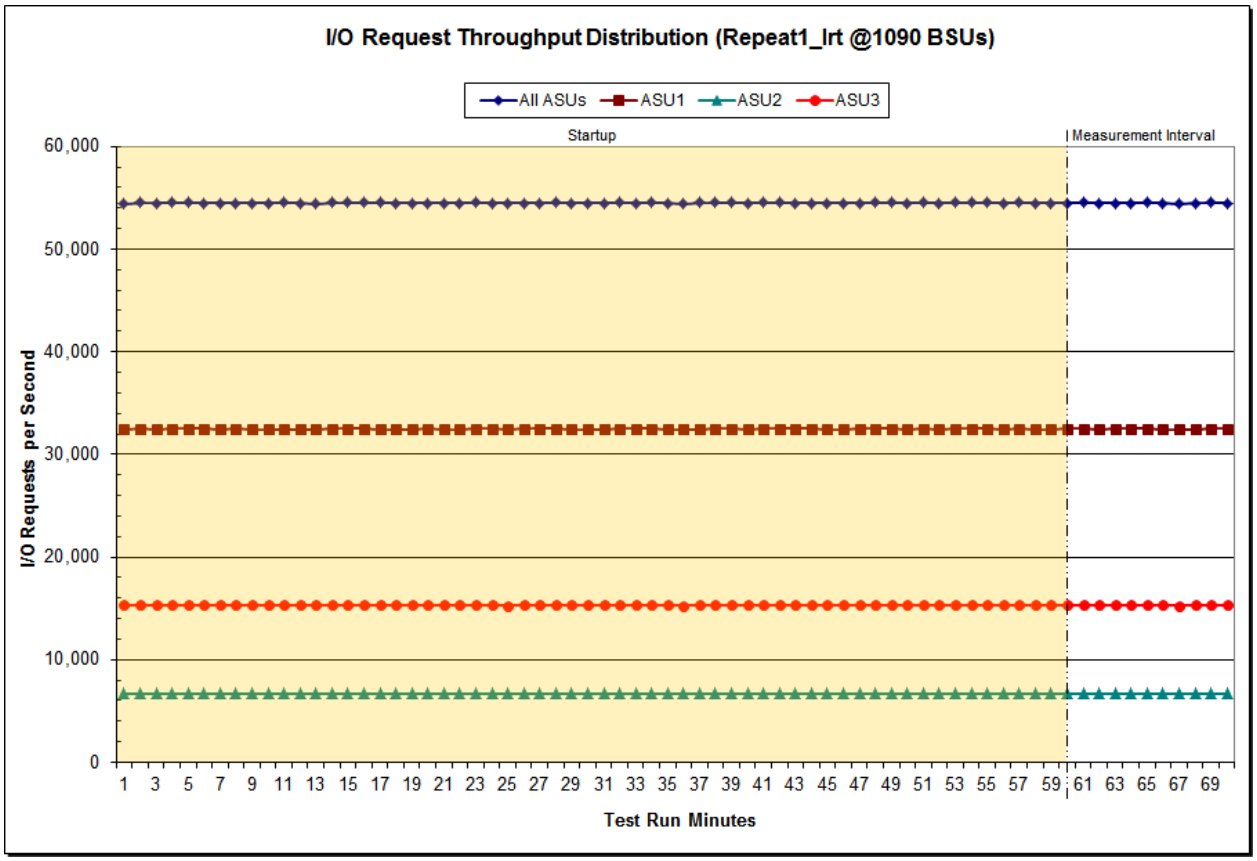
Repeatability Test Phase 2, Test Run 2 (IOPS)

Repeatability 1 LRT – I/O Request Throughput Distribution Data

The Repeatability 1 LRT – I/O Request Throughput Distribution Data table is not embedded in this document due to its size. The table is available via the following URL:

Repeatability 1 LRT – I/O Request Throughput Distribution Data Table

Repeatability 1 LRT – I/O Request Throughput Distribution Graph

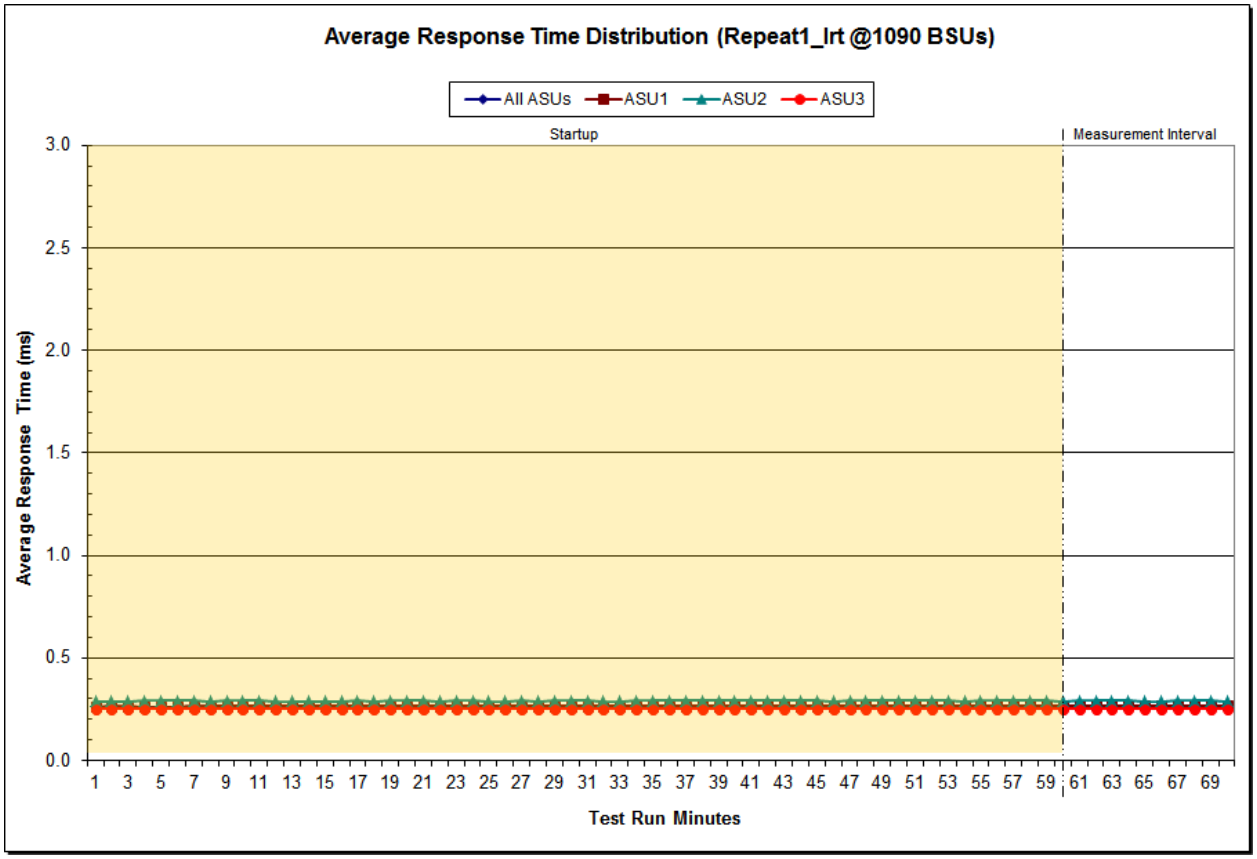


Repeatability 1 LRT –Average Response Time (ms) Distribution Data

The Repeatability 1 LRT – Average Response Time Distribution Data table is not embedded in this document due to its size. The table is available via the following URL:

Repeatability 1 LRT – Average Response Time Distribution Data Table

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

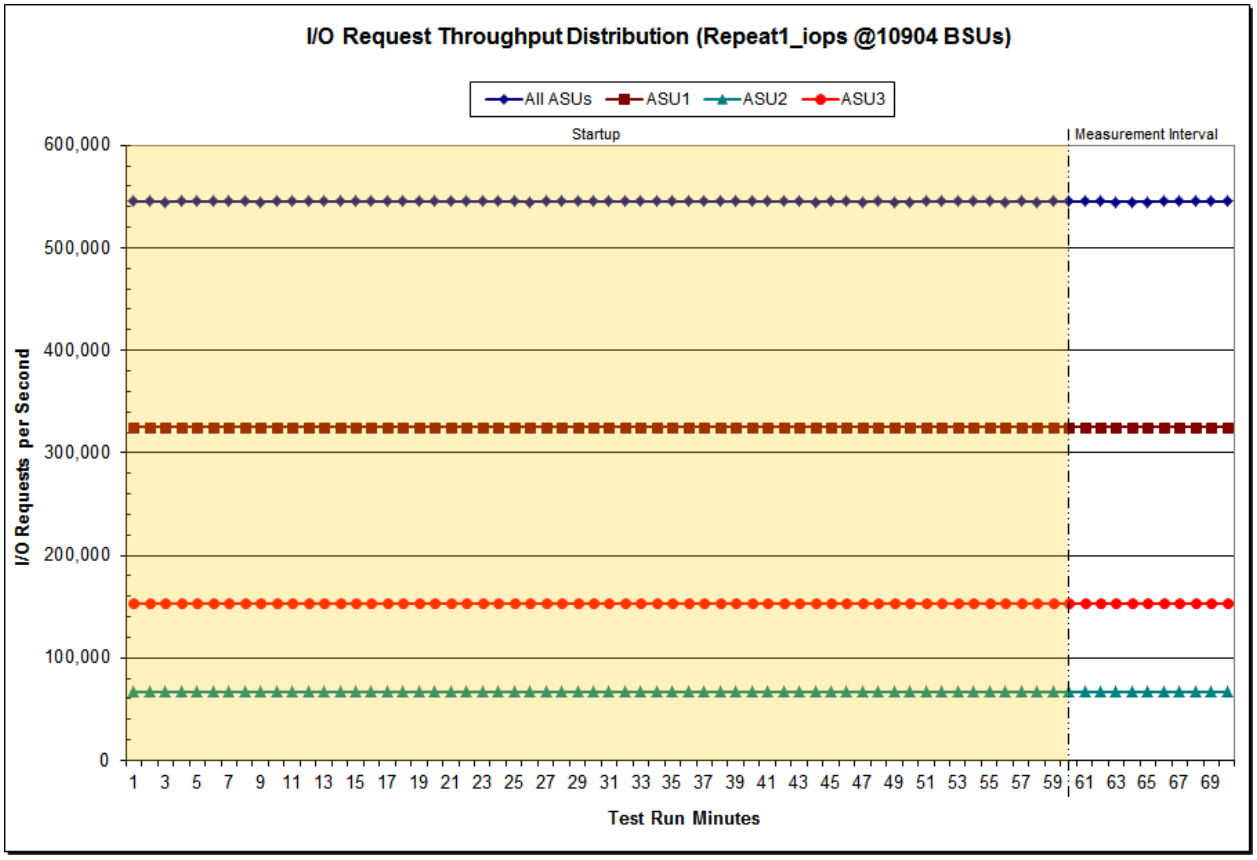


Repeatability 1 IOPS – I/O Request Throughput Distribution Data

The Repeatability 1 IOPS – I/O Request Throughput Distribution Data table is not embedded in this document due to its size. The table is available via the following URL:

Repeatability 1 IOPS – I/O Request Throughput Distribution Data Table

Repeatability 1 IOPS – I/O Request Throughput Distribution Graph

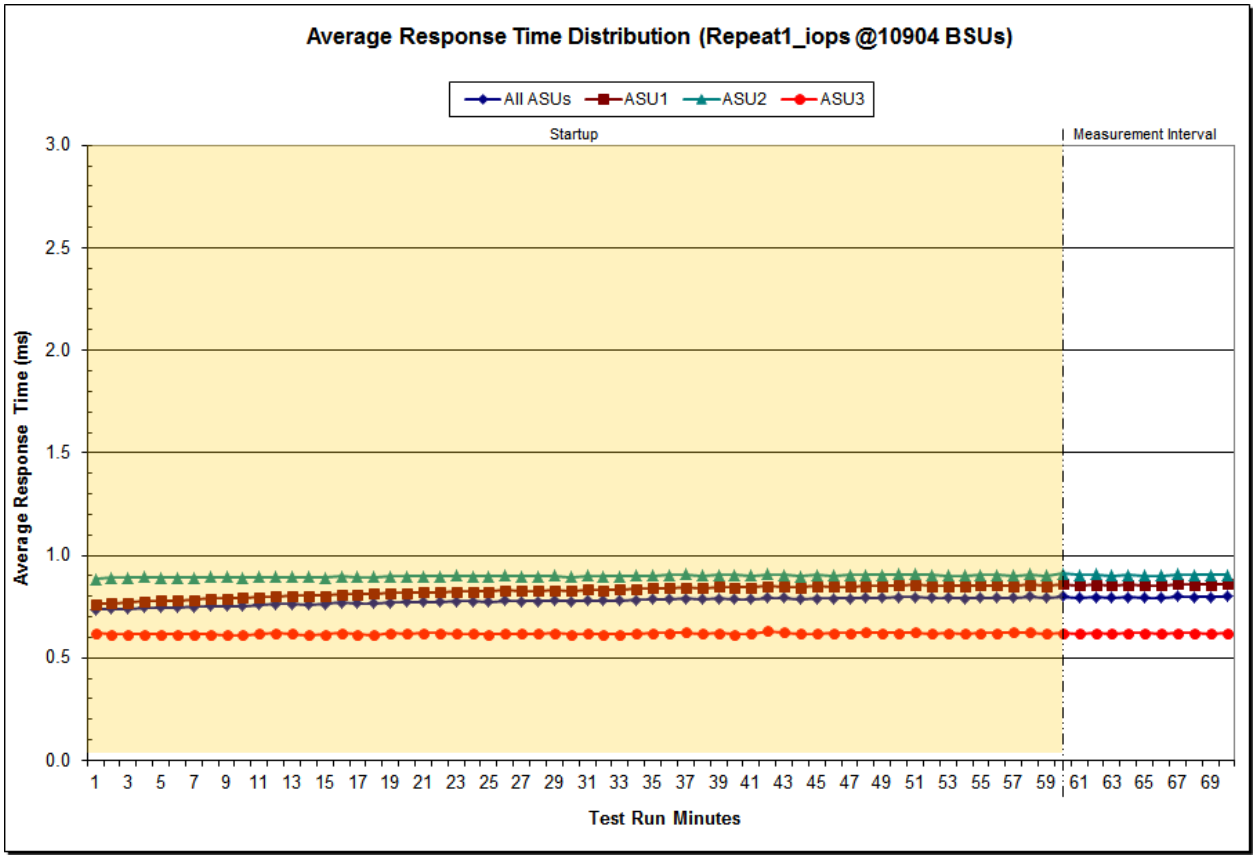


Repeatability 1 IOPS –Average Response Time (ms) Distribution Data

The Repeatability 1 IOPS – Average Response Time Distribution Data table is not embedded in this document due to its size. The table is available via the following URL:

Repeatability 1 IOPS – Average Response Time Distribution Data Table

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

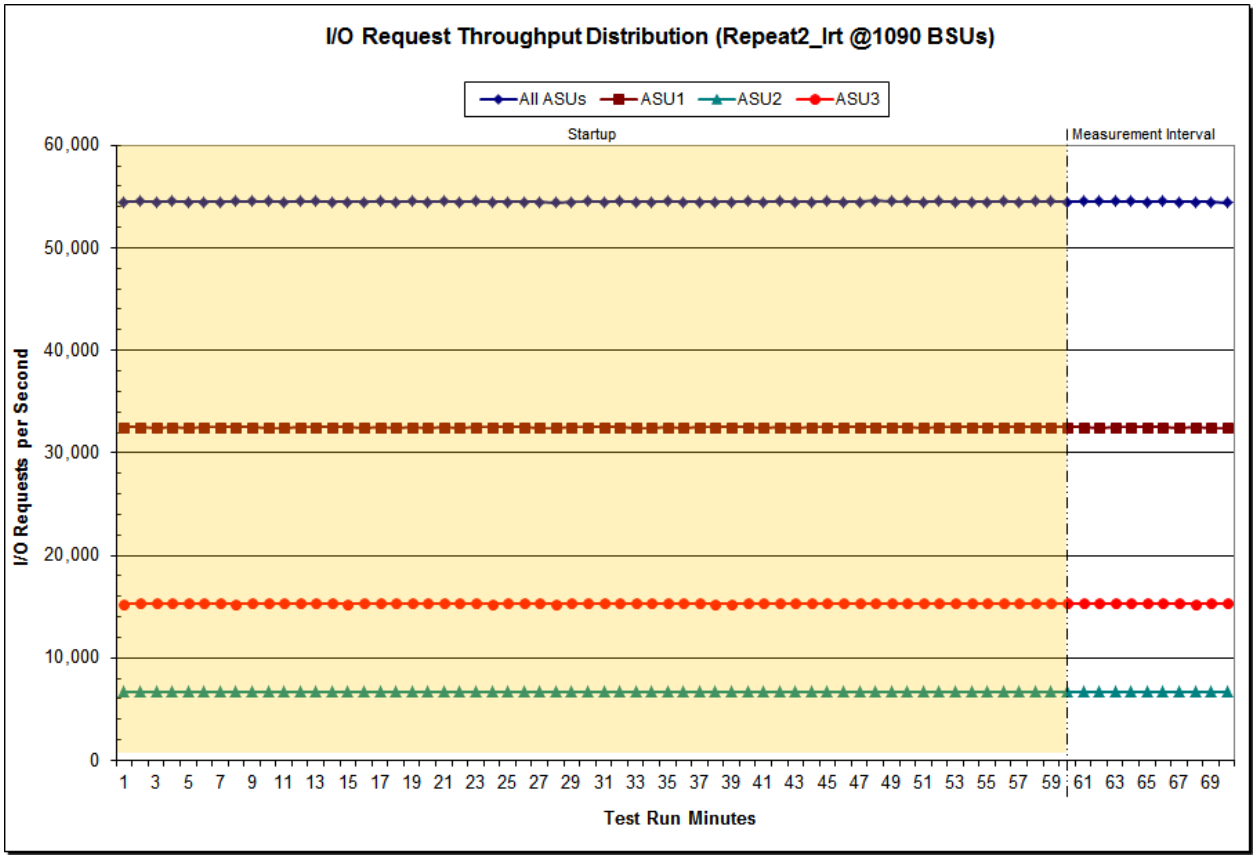


Repeatability 2 LRT – I/O Request Throughput Distribution Data

The Repeatability 2 LRT – I/O Request Throughput Distribution Data table is not embedded in this document due to its size. The table is available via the following URL:

Repeatability 2 LRT – I/O Request Throughput Distribution Data Table

Repeatability 2 LRT – I/O Request Throughput Distribution Graph

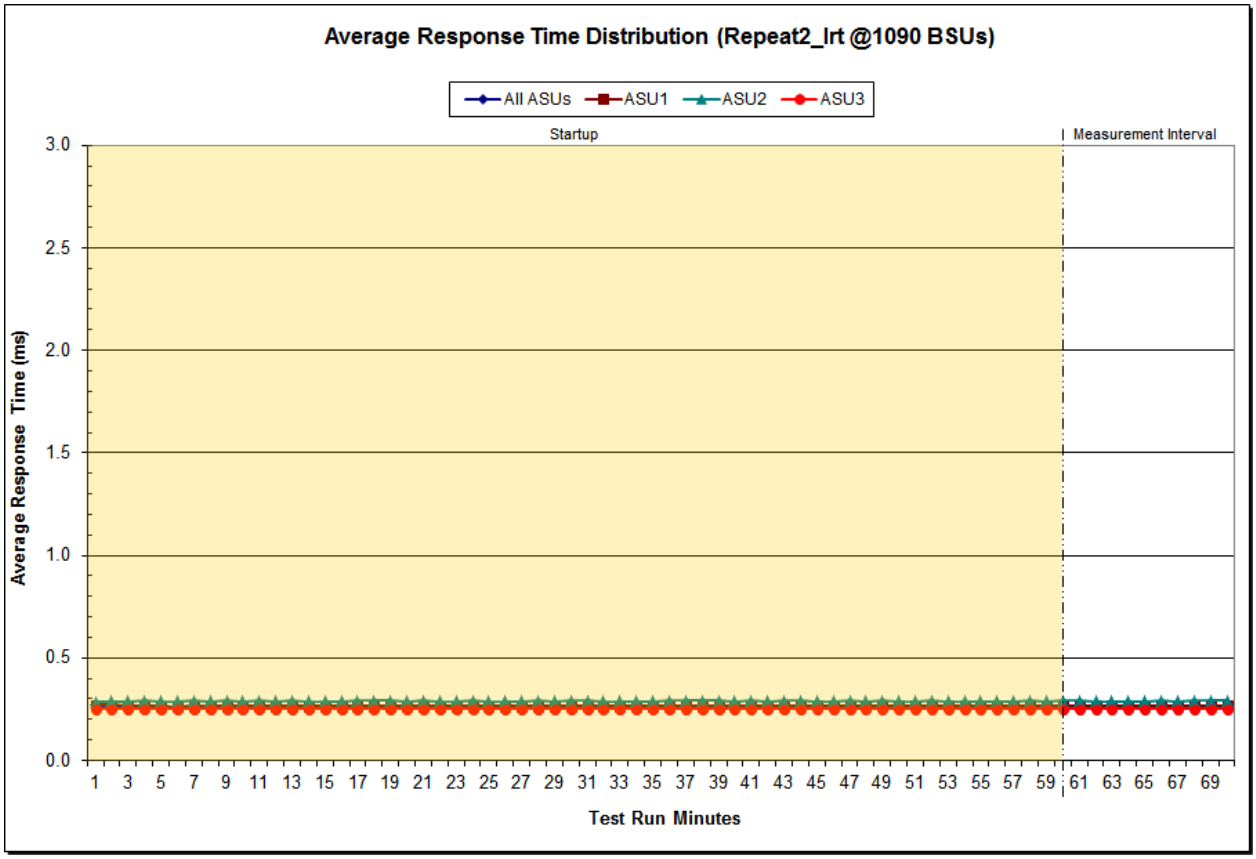


Repeatability 2 LRT –Average Response Time (ms) Distribution Data

The Repeatability 1 LRT – Average Response Time Distribution Data table is not embedded in this document due to its size. The table is available via the following URL:

Repeatability 2 LRT – Average Response Time Distribution Data Table

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

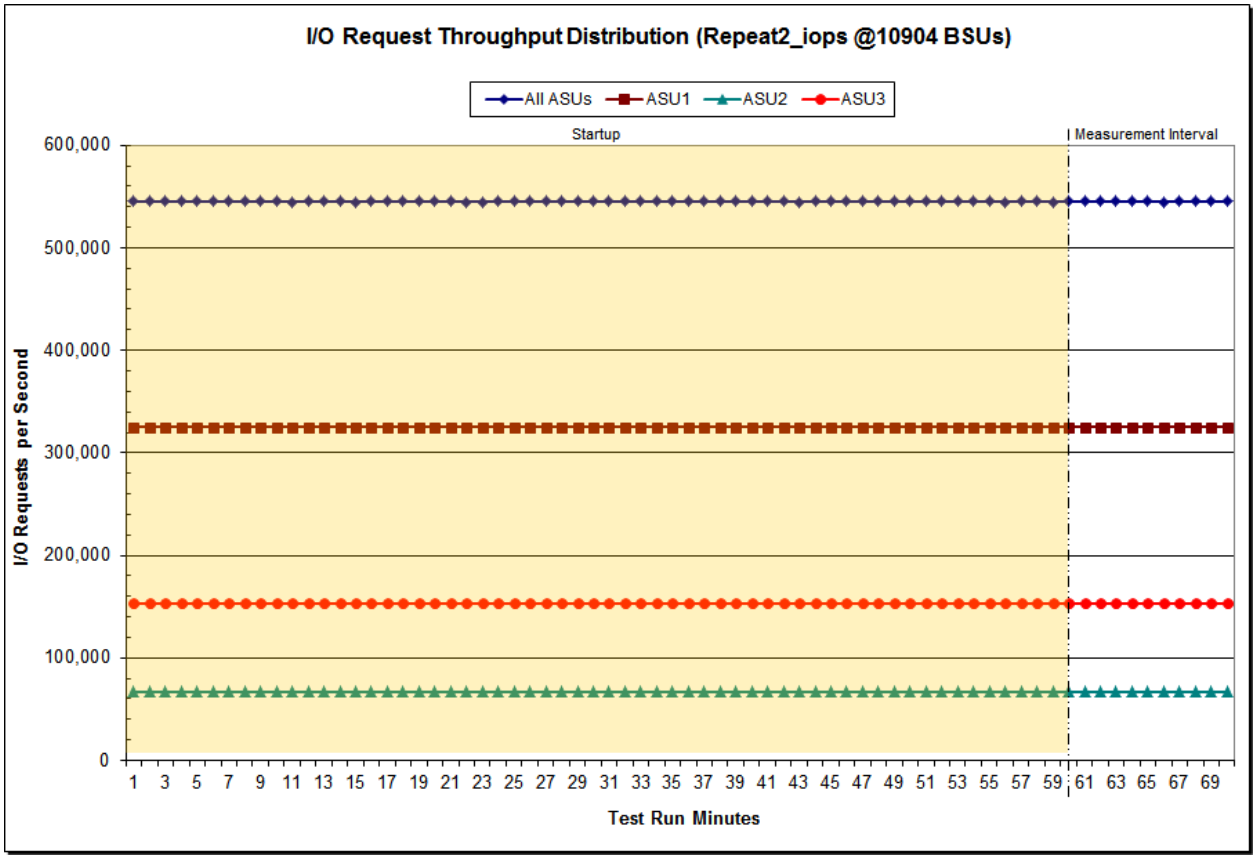


Repeatability 2 IOPS – I/O Request Throughput Distribution Data

The Repeatability 2 IOPS – I/O Request Throughput Distribution Data table is not embedded in this document due to its size. The table is available via the following URL:

Repeatability 2 IOPS – I/O Request Throughput Distribution Data Table

Repeatability 2 IOPS – I/O Request Throughput Distribution Graph

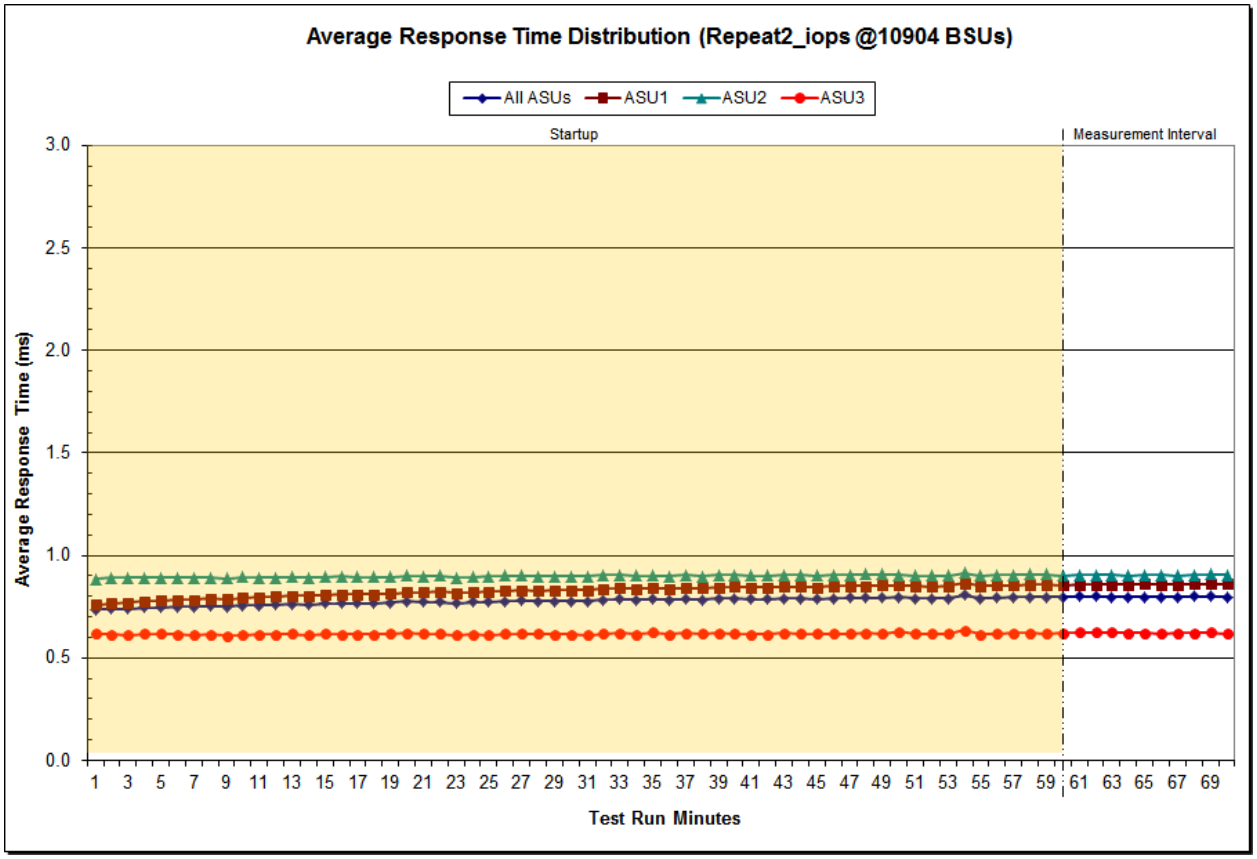


Repeatability 2 IOPS –Average Response Time (ms) Distribution Data

The Repeatability 2 IOPS – Average Response Time Distribution Data table is not embedded in this document due to its size. The table is available via the following URL:

Repeatability 2 IOPS – Average Response Time Distribution Data Table

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	0.0701	0.2099	0.0180	0.0700	0.0350	0.2809
COV	0.003	0.000	0.002	0.001	0.003	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	0.2100	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

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	0.2808	0.0700	0.2100	0.0180	0.0700	0.0350	0.2811
COV	0.004	0.001	0.001	0.001	0.003	0.002	0.003	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	0.000	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 81.

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	175,283,168
Total Number of Logical Blocks Verified	124,640,976
Total Number of Logical Blocks that Failed Verification	0
Time Duration for Writing Test Logical Blocks	10 minutes
Size in bytes of each Logical Block	512
Number of Failed I/O Requests in the process of the Test	0

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 HPE 3PAR StoreServ 8440 Storage System 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 17.

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 17.

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 Remote Audit of the HPE 3PAR StoreServ 8440 Storage System.

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.

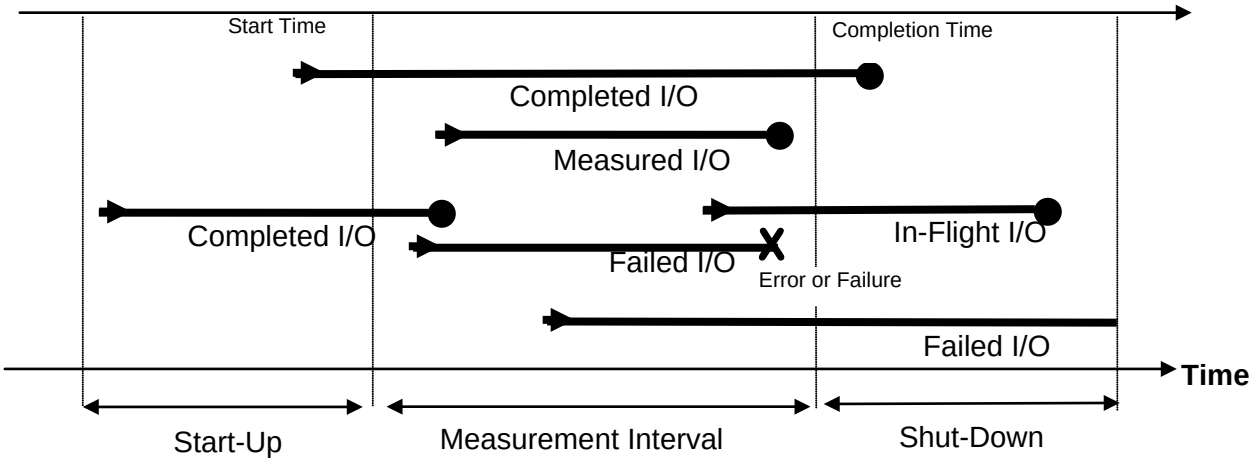
Steady State: The consistent and sustainable throughput of the TSC. During this period the load presented to the TSC by the Workload Generator is constant.

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

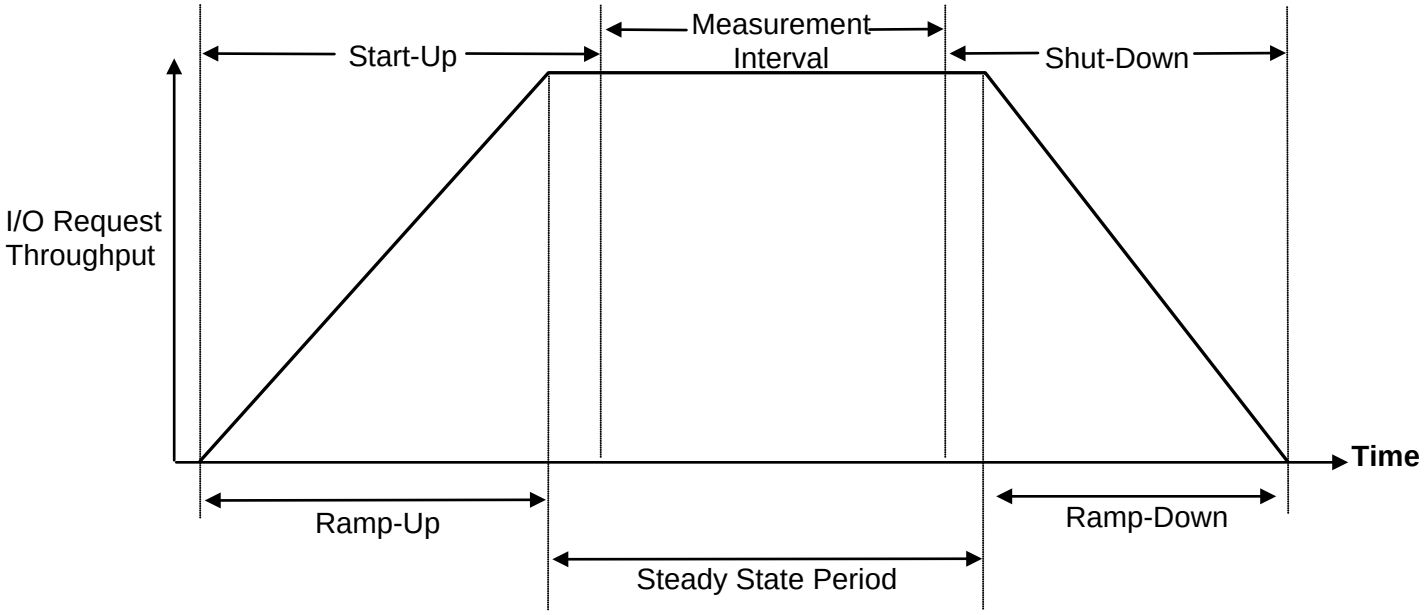
Test Run: The execution of SPC-1 for the purpose of producing or supporting an SPC-1 test result. SPC-1 Test Runs may have a finite and measured Ramp-Up period, Start-Up period, Shut-Down period, and Ramp-Down period as illustrated in the "SPC-1 Test Run Components" below. All SPC-1 Test Runs shall have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

The following customer tunable parameters and options were changed from their default values on each of the Host Systems for this benchmark. The **Set Customer Tunable Options and Parameters** section of *"Appendix C: Tested Storage Configuration (TSC) Creation"* documents how those parameters and options were changed.

- The HBA queue depth was set to 128 per device
- The default **cfq** scheduler was changed to **noop** scheduler.
- The RHEL ramdisk image was rebuilt and each Host System rebooted so that the above changes would be in effect.

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

Customer-Ready Configuration

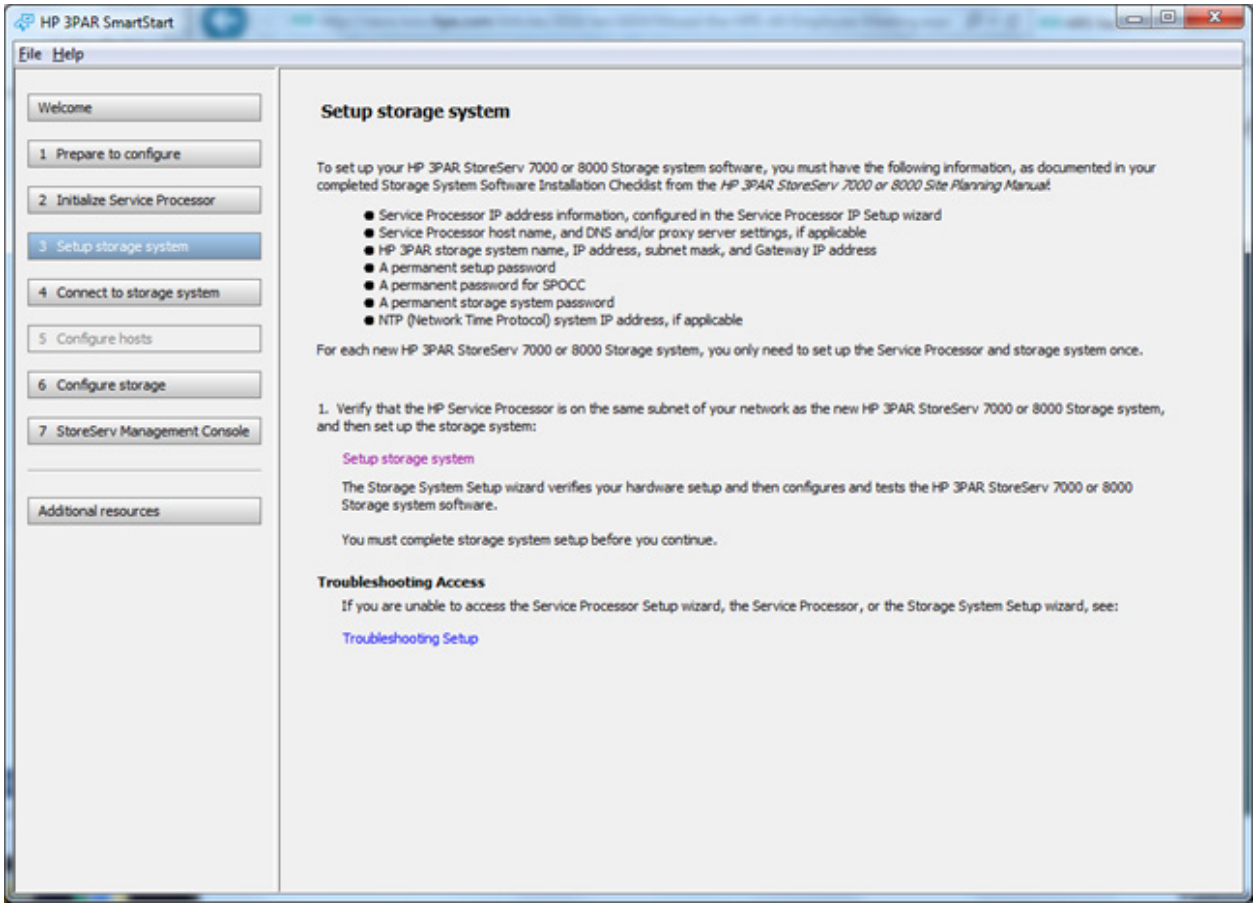
The HPE 3PAR StoreServ 8000 series is customer installable. As part of that installation process, the customer will execute an HPE wizard that guides them in configuring the storage array. This will result in the storage system self-configuring and self-provisioning the appropriate available, spare and metadata capacities based upon the number and capacity of storage devices in the configuration.

A QuickStart guide and a complimentary online video are available to provide clear instruction for a successful customer installation.

The remainder of this section documents that customer installation process.

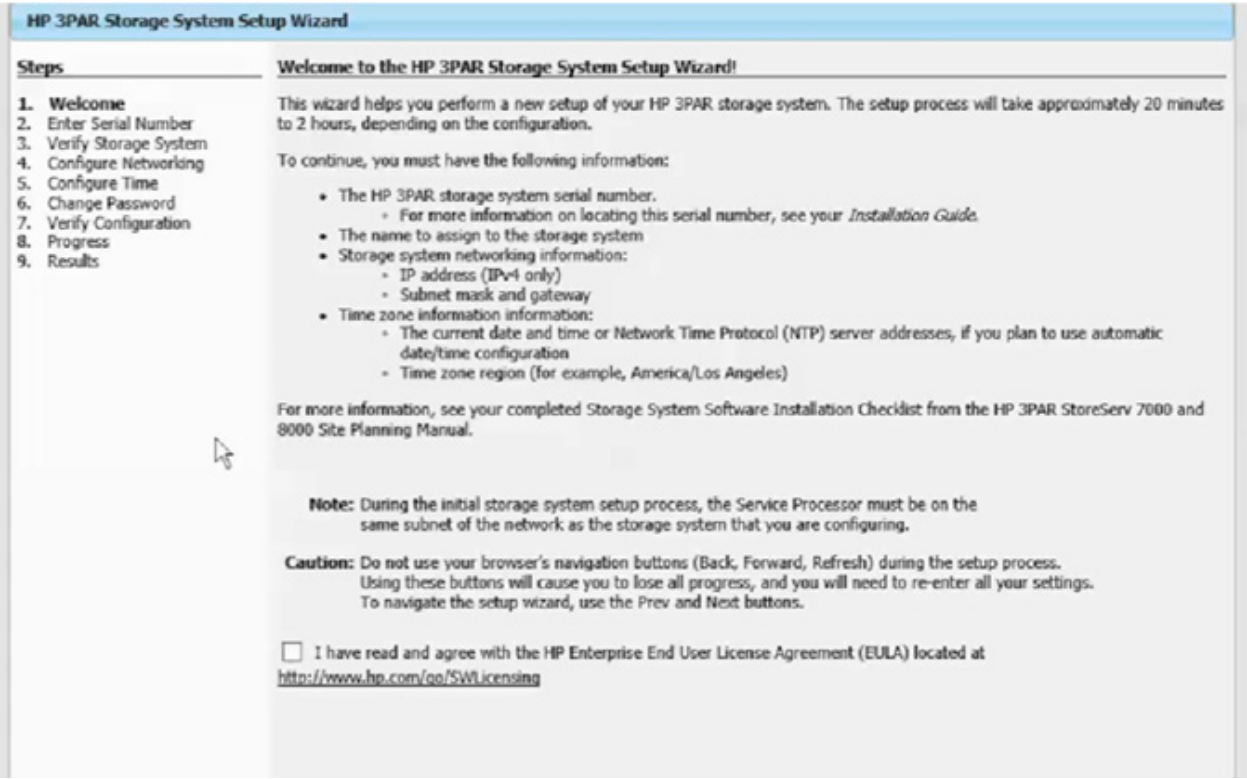
Install the HPE wizard on any Windows server that is on the same network as the HPE 3PAR StoreServ 8450 Storage System.

After installation on an appropriate Windows server, start the HPE wizard and select **option 3** to setup the storage system.



The Welcome screen will then appear, as illustrated below. That screen lists the information the customer needs to have in order to configure the storage system: IP address, password, and HPE 3PAR StoreServ serial number.

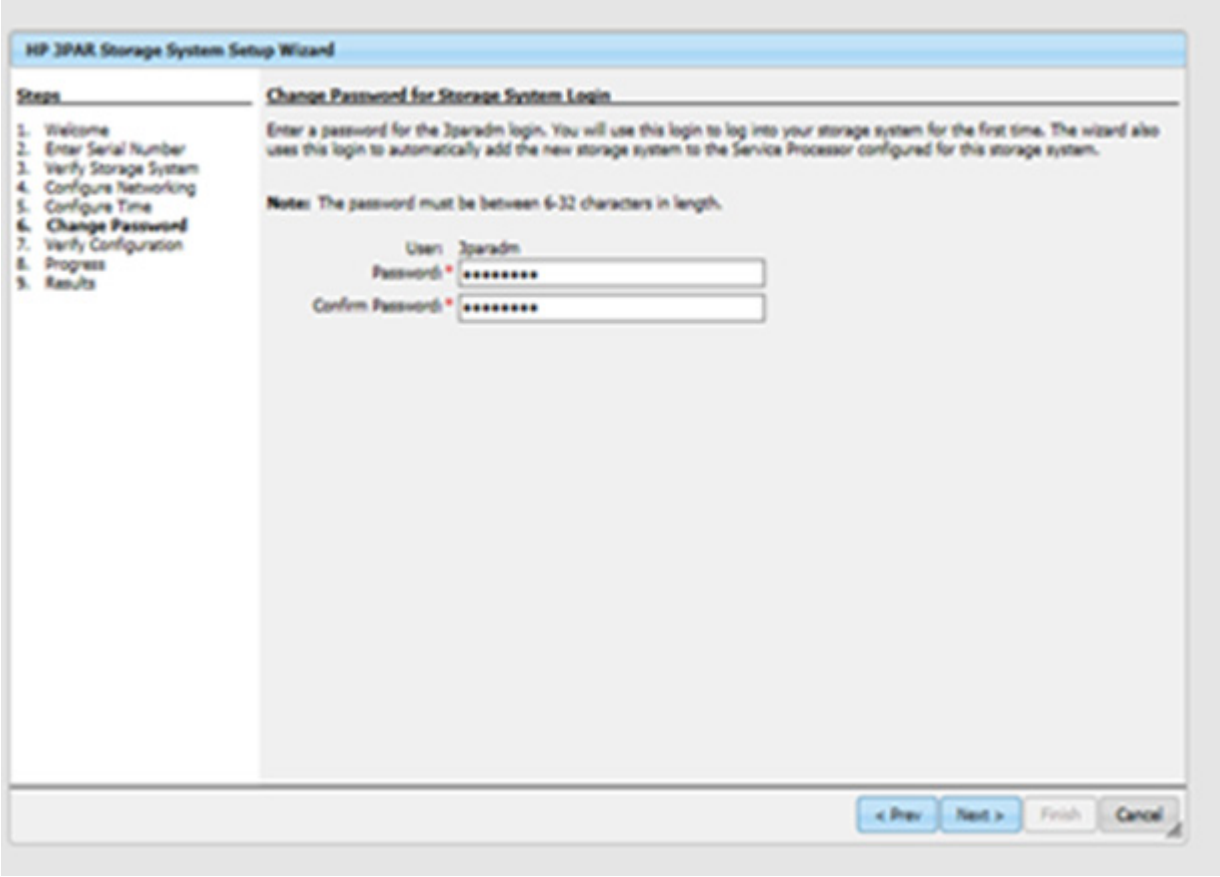
Check the license agreement box to move to the next screen.



There are five screens that will follow the Welcome screen. The steps for the screens are listed on the left panel of each screen.

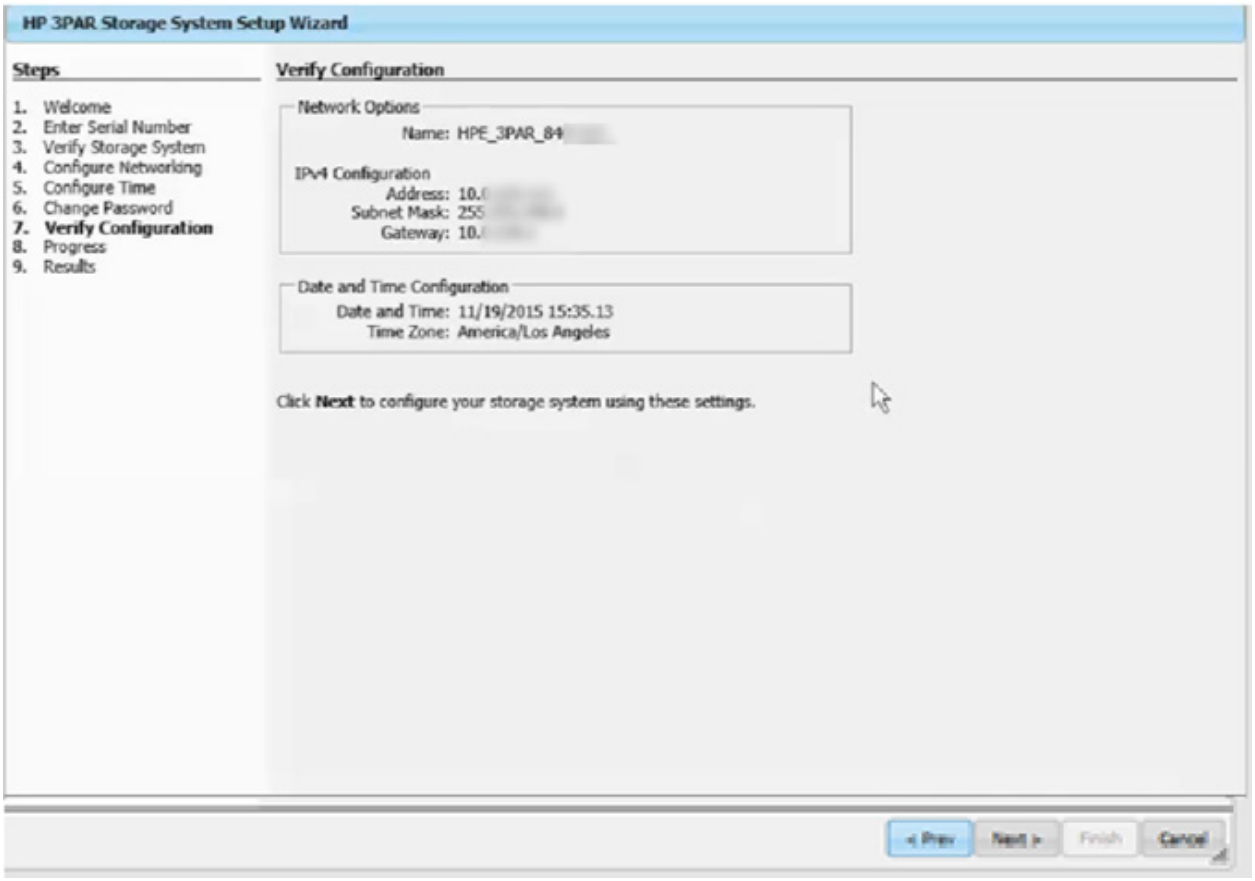
- On the first screen, enter the 3PAR StoreServ serial number.
- On the second screen, verify the model number of the system is correct. In this case 8450.
- On the third screen, enter a user selected storage array name and the IP address information.
- On the fourth screen, enter the time option.
- On the fifth screen *(shown below)*, enter the password and confirmation.

On each screen, enter **Next** to move to the next screen.



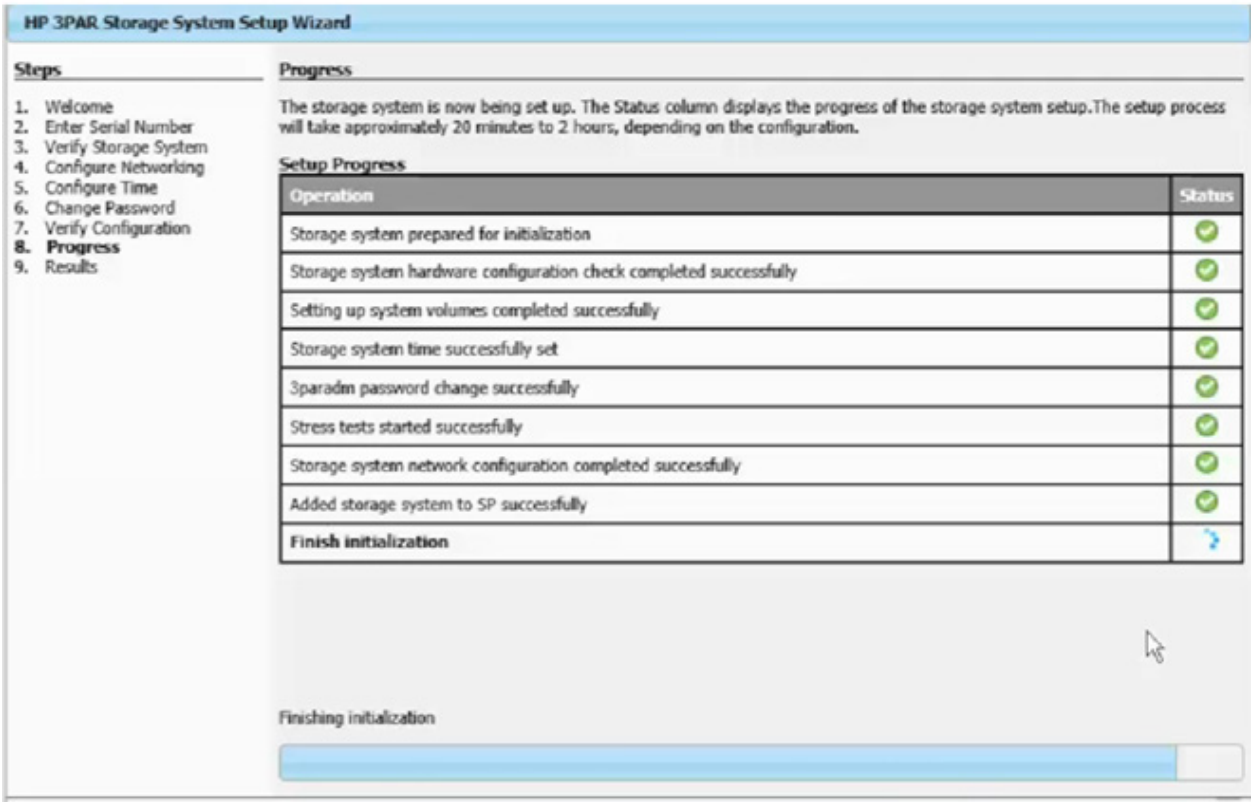
The **Verify Configuration** screen will appear after the password screen and contains the array name, IP information, and time configuration information entered in the previous screens.

If that information is correct, click on **Next** and the system will begin configuring the storage system.



The **Progress** screen is then displayed. The system will automatically execute the steps of configuring and provisioning the appropriate available, spare and metadata capacities based upon the number and capacity of storage devices in the configuration.

When this completes, the last screen is displayed.



When the configuring and provisioning process completes, which may take from 20 minutes to 2 hours as the **Progress** screen will indicate, the last screen appears denoting the system is ready to use.

Clicking **Finish** will exit the HPE wizard.

Front-End Port Configuration – Create Hosts

The script, **SPC1_buildhosts**, executed from a command window on the StoreServ 8450, created the paths *(hosts)* for all ports of each Host System used *(24 ports, 4 per Host System)*.

Create the Array Physical Volumes

The script, **SPC1_buildvols**, executed from a command window on the StoreServ 8450, does the following:

- Creates 64 physical volumes *(24 for ASU-1, 16 for ASU-2, and 24 for ASU-3)*.
- Exports the physical volumes to the Host System ports.

Create the SPC-1 Logical Volumes using the Logical Volume Manager (LVM)

- Reboot the Master Host System *(host21)* so the array physical volumes are visible.
- On the Master Host System, execute the script, **makethepvs**, to create 64 LVM physical volumes, one for each of the 64 array physical volume.
- On the Master Host System, execute the script, **makethevgs**, to create the three volume groups **vg1**, **vg2** and **vg3** for ASU-1, ASU-2, and ASU-3 respectively. The LVM physical volumes created from the array physical volumes *(asu1.*)* for ASU-1 are used in **vg1**. The LVM physical volumes created from the array physical volumes *(asu2.*)* for ASU-2 are used in **vg2**. The LVM physical volumes created from the array physical volumes *(asu3.*)* for ASU-3 are used in **vg3**.
- On the Master Host System, execute the script, **makethelvs**, to create one logical volume for each volume group to use as ASU-1, ASU-2, and ASU-3.
- Reboot the remaining Host Systems so the logical volumes are visible to those Host Systems.

Set Customer Tunable Options and Parameters

The following customer tunable parameters were changed on each Host System:

- Edit and save **/etc/modprobe.d/lpfc.conf**, as follows, to change the HBA default queue length.
  -> cd /etc/modprobe.d
  -> vi lpfc.conf
  options lpfc lpfc_lun_queue_depth=128
- Edit and save **/etc/grub.conf**, as follows, to change the default Linux scheduler.
  -> vi /etc/grub.conf
  elevator = noop *(added at the end of the kernel line)*
- Rebuild the RHEL ramdisk image and reboot each Host System, as follows, so that the above changes will be in effect:
  -> uname –a
  -> dracut -v -f /boot/initramfs-2.6.32-504.el6.x86_64.img 2.6.32-504.el6.x86_64
  -> reboot

Referenced Scripts

SPC1_buildhosts

```
createhost  d13-n0 1000C4346B20C4CC
createhost  d13-n1 1000C4346B20E428
createhost  d13-n2 1000C4346B20C4CD
createhost  d13-n3 1000C4346B20E429
createhost  d14-n0 1000C4346B2094A8
createhost  d14-n1 1000C4346B2094DC
createhost  d14-n2 1000C4346B2094A9
createhost  d14-n3 1000C4346B2094DD
createhost  d20-n0 1000C4346B2026BE
createhost  d20-n1 1000C4346B2026B2
createhost  d20-n2 1000C4346B2026BF
createhost  d20-n3 1000C4346B2026B3
createhost  d21-n0 1000C4346B205672
createhost  d21-n1 1000C4346B2046AE
createhost  d21-n2 1000C4346B205673
createhost  d21-n3 1000C4346B2046AF
createhost  d03-n0 1000C4346B20E488
createhost  d03-n1 1000C4346B20E4EC
createhost  d03-n2 1000C4346B20E489
createhost  d03-n3 1000C4346B20E4ED
createhost  d04-n0 1000C4346B203514
createhost  d04-n1 1000C4346B201534
createhost  d04-n2 1000C4346B203515
createhost  d04-n3 1000C4346B201535
```

SPC1_buildvols

```
createcpg -t r1 -ha mag  -p -devtype SSD  -nd 0 cpgssd0
createcpg -t r1 -ha mag  -p -devtype SSD  -nd 1 cpgssd1
createcpg -t r1 -ha mag  -p -devtype SSD  -nd 2 cpgssd2
createcpg -t r1 -ha mag  -p -devtype SSD  -nd 3 cpgssd3


j=10;
nd=0
for ll in 1 2 3 4 5 6; do
for i in `seq 1 4`;
       do
                      createvv -i $j cpgssd${nd} asu1.${j}  92G;

                            createvlun  -f  asu1.${j} $j  d13-n${nd}
                            createvlun  -f  asu1.${j} $j  d14-n${nd}
                            createvlun  -f  asu1.${j} $j  d20-n${nd}
                            createvlun  -f  asu1.${j} $j  d21-n${nd}
                            createvlun  -f  asu1.${j} $j  d03-n${nd}
                            createvlun  -f  asu1.${j} $j  d04-n${nd}


                      j=$((j+1))
                      nd=$((nd+1))
                      if (($nd>3))
                         then
                             nd=0
                      fi
       done
done



nd=0
for ll in 1 2 3 4  ; do
for i in `seq 1 4`;
       do
                      createvv -i $j cpgssd${nd} asu2.${j} 140G;

                            createvlun  -f  asu2.${j} $j  d13-n${nd}
                            createvlun  -f  asu2.${j} $j  d14-n${nd}
                            createvlun  -f  asu2.${j} $j  d20-n${nd}
                            createvlun  -f  asu2.${j} $j  d21-n${nd}
                            createvlun  -f  asu2.${j} $j  d03-n${nd}
                            createvlun  -f  asu2.${j} $j  d04-n${nd}


                      j=$((j+1))
                      nd=$((nd+1))
                      if (($nd>3))
                         then
                             nd=0
                      fi
       done
done
```

```
nd=0
for ll in 1 2 3 4 5 6; do
for i in `seq 1 4`;
       do
                       createvv -i $j cpgssd${nd} asu3.${j}  24G;

                             createvlun  -f  asu3.${j} $j  d13-n${nd}
                             createvlun  -f  asu3.${j} $j  d14-n${nd}
                             createvlun  -f  asu3.${j} $j  d20-n${nd}
                             createvlun  -f  asu3.${j} $j  d21-n${nd}
                             createvlun  -f  asu3.${j} $j  d03-n${nd}
                             createvlun  -f  asu3.${j} $j  d04-n${nd}


                       j=$((j+1))
                       nd=$((nd+1))
                       if (($nd>3))
                          then
                              nd=0
                       fi
       done
done
```

makethepvs

```
pvcreate  /dev/mapper/360002ac0000000000000000a000183bf
pvcreate  /dev/mapper/360002ac0000000000000000b000183bf
pvcreate  /dev/mapper/360002ac0000000000000000c000183bf
pvcreate  /dev/mapper/360002ac0000000000000000d000183bf
pvcreate  /dev/mapper/360002ac0000000000000000e000183bf
pvcreate  /dev/mapper/360002ac0000000000000000f000183bf
pvcreate  /dev/mapper/360002ac00000000000000010000183bf
pvcreate  /dev/mapper/360002ac00000000000000011000183bf
pvcreate  /dev/mapper/360002ac00000000000000012000183bf
pvcreate  /dev/mapper/360002ac00000000000000013000183bf
pvcreate  /dev/mapper/360002ac00000000000000014000183bf
pvcreate  /dev/mapper/360002ac00000000000000015000183bf
pvcreate  /dev/mapper/360002ac00000000000000016000183bf
pvcreate  /dev/mapper/360002ac00000000000000017000183bf
pvcreate  /dev/mapper/360002ac00000000000000018000183bf
pvcreate  /dev/mapper/360002ac00000000000000019000183bf
pvcreate  /dev/mapper/360002ac0000000000000001a000183bf
pvcreate  /dev/mapper/360002ac0000000000000001b000183bf
pvcreate  /dev/mapper/360002ac0000000000000001c000183bf
pvcreate  /dev/mapper/360002ac0000000000000001d000183bf
pvcreate  /dev/mapper/360002ac0000000000000001e000183bf
pvcreate  /dev/mapper/360002ac0000000000000001f000183bf
pvcreate  /dev/mapper/360002ac00000000000000020000183bf
pvcreate  /dev/mapper/360002ac00000000000000021000183bf
pvcreate  /dev/mapper/360002ac00000000000000022000183bf
pvcreate  /dev/mapper/360002ac00000000000000023000183bf
pvcreate  /dev/mapper/360002ac00000000000000024000183bf
pvcreate  /dev/mapper/360002ac00000000000000025000183bf
pvcreate  /dev/mapper/360002ac00000000000000026000183bf
pvcreate  /dev/mapper/360002ac00000000000000027000183bf
pvcreate  /dev/mapper/360002ac00000000000000028000183bf
pvcreate  /dev/mapper/360002ac00000000000000029000183bf
pvcreate  /dev/mapper/360002ac0000000000000002a000183bf
pvcreate  /dev/mapper/360002ac0000000000000002b000183bf
pvcreate  /dev/mapper/360002ac0000000000000002c000183bf
pvcreate  /dev/mapper/360002ac0000000000000002d000183bf
```

```
pvcreate  /dev/mapper/360002ac0000000000000002e000183bf
pvcreate  /dev/mapper/360002ac0000000000000002f000183bf
pvcreate  /dev/mapper/360002ac00000000000000030000183bf
pvcreate  /dev/mapper/360002ac00000000000000031000183bf
pvcreate  /dev/mapper/360002ac00000000000000032000183bf
pvcreate  /dev/mapper/360002ac00000000000000033000183bf
pvcreate  /dev/mapper/360002ac00000000000000034000183bf
pvcreate  /dev/mapper/360002ac00000000000000035000183bf
pvcreate  /dev/mapper/360002ac00000000000000036000183bf
pvcreate  /dev/mapper/360002ac00000000000000037000183bf
pvcreate  /dev/mapper/360002ac00000000000000038000183bf
pvcreate  /dev/mapper/360002ac00000000000000039000183bf
pvcreate  /dev/mapper/360002ac0000000000000003a000183bf
pvcreate  /dev/mapper/360002ac0000000000000003b000183bf
pvcreate  /dev/mapper/360002ac0000000000000003c000183bf
pvcreate  /dev/mapper/360002ac0000000000000003d000183bf
pvcreate  /dev/mapper/360002ac0000000000000003e000183bf
pvcreate  /dev/mapper/360002ac0000000000000003f000183bf
pvcreate  /dev/mapper/360002ac00000000000000040000183bf
pvcreate  /dev/mapper/360002ac00000000000000041000183bf
pvcreate  /dev/mapper/360002ac00000000000000042000183bf
pvcreate  /dev/mapper/360002ac00000000000000043000183bf
pvcreate  /dev/mapper/360002ac00000000000000044000183bf
pvcreate  /dev/mapper/360002ac00000000000000045000183bf
pvcreate  /dev/mapper/360002ac00000000000000046000183bf
pvcreate  /dev/mapper/360002ac00000000000000047000183bf
pvcreate  /dev/mapper/360002ac00000000000000048000183bf
pvcreate  /dev/mapper/360002ac00000000000000049000183bf
```

makethevgs

```
vgcreate vg1  /dev/mapper/360002ac0000000000000000a000183bf
/dev/mapper/360002ac0000000000000000b000183bf
/dev/mapper/360002ac0000000000000000c000183bf
/dev/mapper/360002ac0000000000000000d000183bf
/dev/mapper/360002ac0000000000000000e000183bf
/dev/mapper/360002ac0000000000000000f000183bf
/dev/mapper/360002ac00000000000000010000183bf
/dev/mapper/360002ac00000000000000011000183bf
/dev/mapper/360002ac00000000000000012000183bf
/dev/mapper/360002ac00000000000000013000183bf
/dev/mapper/360002ac00000000000000014000183bf
/dev/mapper/360002ac00000000000000015000183bf
/dev/mapper/360002ac00000000000000016000183bf
/dev/mapper/360002ac00000000000000017000183bf
/dev/mapper/360002ac00000000000000018000183bf
/dev/mapper/360002ac00000000000000019000183bf
/dev/mapper/360002ac0000000000000001a000183bf
/dev/mapper/360002ac0000000000000001b000183bf
/dev/mapper/360002ac0000000000000001c000183bf
/dev/mapper/360002ac0000000000000001d000183bf
/dev/mapper/360002ac0000000000000001e000183bf
/dev/mapper/360002ac0000000000000001f000183bf
/dev/mapper/360002ac00000000000000020000183bf
/dev/mapper/360002ac00000000000000021000183bf

vgcreate vg2  /dev/mapper/360002ac00000000000000022000183bf
/dev/mapper/360002ac00000000000000023000183bf
/dev/mapper/360002ac00000000000000024000183bf
/dev/mapper/360002ac00000000000000025000183bf
/dev/mapper/360002ac00000000000000026000183bf
/dev/mapper/360002ac00000000000000027000183bf
```

```
/dev/mapper/360002ac0000000000000028000183bf
/dev/mapper/360002ac0000000000000029000183bf
/dev/mapper/360002ac000000000000002a000183bf
/dev/mapper/360002ac000000000000002b000183bf
/dev/mapper/360002ac000000000000002c000183bf
/dev/mapper/360002ac000000000000002d000183bf
/dev/mapper/360002ac000000000000002e000183bf
/dev/mapper/360002ac000000000000002f000183bf
/dev/mapper/360002ac0000000000000030000183bf
/dev/mapper/360002ac0000000000000031000183bf

vgcreate vg3  /dev/mapper/360002ac0000000000000032000183bf
/dev/mapper/360002ac0000000000000033000183bf
/dev/mapper/360002ac0000000000000034000183bf
/dev/mapper/360002ac0000000000000035000183bf
/dev/mapper/360002ac0000000000000036000183bf
/dev/mapper/360002ac0000000000000037000183bf
/dev/mapper/360002ac0000000000000038000183bf
/dev/mapper/360002ac0000000000000039000183bf
/dev/mapper/360002ac000000000000003a000183bf
/dev/mapper/360002ac000000000000003b000183bf
/dev/mapper/360002ac000000000000003c000183bf
/dev/mapper/360002ac000000000000003d000183bf
/dev/mapper/360002ac000000000000003e000183bf
/dev/mapper/360002ac000000000000003f000183bf
/dev/mapper/360002ac0000000000000040000183bf
/dev/mapper/360002ac0000000000000041000183bf
/dev/mapper/360002ac0000000000000042000183bf
/dev/mapper/360002ac0000000000000043000183bf
/dev/mapper/360002ac0000000000000044000183bf
/dev/mapper/360002ac0000000000000045000183bf
/dev/mapper/360002ac0000000000000046000183bf
/dev/mapper/360002ac0000000000000047000183bf
/dev/mapper/360002ac0000000000000048000183bf
/dev/mapper/360002ac0000000000000049000183bf
```

makethelvs

```
lvcreate -l 100%VG -i  24  -I 128K -n asu1 vg1
lvcreate -l 100%VG -i  16  -I 128K -n asu2 vg2
lvcreate -l 100%VG -i  24  -I 128K -n asu3 vg3
```

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=asu1_1,lun=/dev/vg1/asu1,size=2370419294175,threads=1,openflags=o_direct
sd=asu2_1,lun=/dev/vg2/asu2,size=2370419294175,threads=1,openflags=o_direct
sd=asu3_1,lun=/dev/vg3/asu3,size=526759843150,threads=1,openflags=o_direct

wd=wd1,sd=asu*,rdpct=0,seek=-1,xfersize=1m
rd=prepspc,wd=wd*,iorate=max,elapsed=12000,interval=10
```

Primary Metrics and Repeatability Tests

The content of SPC-1 Workload Generator command and parameter files 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 are listed below.

```
javaparms="-Xms1024m -Xmx1024m -Xss512k"
host=master

slaves=(slave101a,slave101b,slave101c,slave101d,slave101e,slave101f,slave101g,slave1
01h,slave101i,slave101j,slave101k,slave101l,slave101m,slave101n,slave101o,slave101p,
slave101q,slave101r,slave101s,slave101t,slave102a,slave102b,slave102c,slave102d,slav
e102e,slave102f,slave102g,slave102h,slave102i,slave102j,slave102k,slave102l,slave102
m,slave102n,slave102o,slave102p,slave102q,slave102r,slave102s,slave102t,slave103a,sl
ave103b,slave103c,slave103d,slave103e,slave103f,slave103g,slave103h,slave103i,slave1
03j,slave103k,slave103l,slave103m,slave103n,slave103o,slave103p,slave103q,slave103r,
slave103s,slave103t,slave104a,slave104b,slave104c,slave104d,slave104e,slave104f,slav
e104g,slave104h,slave104i,slave104j,slave104k,slave104l,slave104m,slave104n,slave104
o,slave104p,slave104q,slave104r,slave104s,slave104t,slave105a,slave105b,slave105c,sl
ave105d,slave105e,slave105f,slave105g,slave105h,slave105i,slave105j,slave105k,slave1
05l,slave105m,slave105n,slave105o,slave105p,slave105q,slave105r,slave105s,slave105t,
slave106a,slave106b,slave106c,slave106d,slave106e,slave106f,slave106g,slave106h,slav
e106i,slave106j,slave106k,slave106l,slave106m,slave106n,slave106o,slave106p,slave106
q,slave106r,slave106s,slave106t)

sd=asu1_1,lun=/dev/vg1/asu1,size=2370419294175
sd=asu2_1,lun=/dev/vg2/asu2,size=2370419294175
sd=asu3_1,lun=/dev/vg3/asu3,size=526759843150
```

SPC-1 Persistence Test

The content of SPC-1 Workload Generator command and parameter files used in this benchmark to execute the SPC-1 Persistence Test *(read and write phases)*.

```
javaparms="-Xms1024m -Xmx1024m -Xss512k"

sd=asu1_1,lun=/dev/vg1/asu1,size=2370419294175
sd=asu2_1,lun=/dev/vg2/asu2,size=2370419294175
sd=asu3_1,lun=/dev/vg3/asu3,size=526759843150
```

Slave JVMs

Each Slave JVM was invoked with a command and parameter file similar to the example listed below. The only difference in each file was **host** parameter value, which was unique to each Slave JVM, e.g. ***slave101a…slave106t***.

```
javaparms="-Xms1024m -Xmx1024m -Xss128k"
master=dl585g7-21
host=slave101a

#  the sd=asu1_1, asu2_1, asu3_1  lines go below.  sizes must match spc1.cfg for
this config
sd=asu1_1,lun=/dev/vg1/asu1,size=2070000000000
sd=asu2_1,lun=/dev/vg2/asu2,size=2070000000000
sd=asu3_1,lun=/dev/vg3/asu3,size=460000000000
```

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

The 'master' script, **runtest**, was executed to:

- Generate the first set of storage configuration information required for audit.
- Execute the required ASU pre-fill.
- Start the required number of Slave JVMs (**startmyslaves**).
- 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)* and SPC-1 Persistence Test Run 1 *(write phase)* in an uninterrupted sequence.
- Terminate the Slave JVMs (**killmyslaves**).
- Shutdown the Tested Storage Configuration (TSC) (**shutdownarray**).

The **runpersist2** script was then invoked to execute the SPC-1 Persistence Test Run 2 *(read phase)* after completion of the required TSC power off/power on cycle. In addition, the script generated the second set of storage configuration information required for audit and copy of the system log to verify the time of the TSC power off/power on cycle.

runtest

```
if [ $# -ne 1 ]
then
    echo "Error in $0 - Invalid Argument Count"
    exit
fi

runid=$1

bsu=10904
date

# collect configuration information before run starts
# put the line in here and output should use $runid
/home/spc/spc1/getinventory start_inv.$runid

# do prefill - set for 12000 seconds but will end as soon as each VV is full
/home/vdbench/vdbench -f /home/spc/spc1/spc1_prefill
mv output output_prefill.$runid


# prepare for metrics and run it
cp /home/spc/spc1/metrics.spc1.cfg spc1.cfg


# start the slave threads on all the servers including this one
ssh dl585g7-03  "/home/spc/spc1/startmyslaves " > /dev/null &
ssh dl585g7-04  "/home/spc/spc1/startmyslaves " > /dev/null &
ssh dl585g7-13  "/home/spc/spc1/startmyslaves " > /dev/null &
ssh dl585g7-14  "/home/spc/spc1/startmyslaves " > /dev/null &
ssh dl585g7-20  "/home/spc/spc1/startmyslaves " > /dev/null &
ssh dl585g7-21  "/home/spc/spc1/startmyslaves " > /dev/null &
sleep 10

#  run the three tests back to back -- 3600 second warmup
```

```
java -Xms1536m -Xmx1536m -Xss512k metrics -b $bsu -t 28800 -s 3600
java -Xms1536m -Xmx1536m -Xss512k repeat1 -b $bsu -s 3600
java -Xms1536m -Xmx1536m -Xss512k repeat2 -b $bsu -s 3600
sleep 10

# kill off slaves on other hosts - not needed for persistence
ssh dl585g7-03 "/home/spc/spc1/killmyslaves " &
ssh dl585g7-04 "/home/spc/spc1/killmyslaves " &
ssh dl585g7-13 "/home/spc/spc1/killmyslaves " &
ssh dl585g7-14 "/home/spc/spc1/killmyslaves " &
ssh dl585g7-20 "/home/spc/spc1/killmyslaves " &
ssh dl585g7-21 "/home/spc/spc1/killmyslaves " &

sleep 120



# prepare for persistence 1 at quarter rate
cp persist1.spc1.cfg spc1.cfg


java -Xms2048m -Xmx2048m -Xss512k persist1 -b $bsu

sleep 60

# shutdown the array

/home/spc/spc1/shutdownarray
```

startmyslaves

```
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_a.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_a.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_b.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_b.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_c.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_c.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_d.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_d.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_e.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_e.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_f.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_f.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_g.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_g.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_h.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_h.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_i.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_i.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_j.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_j.output &
sleep 2
```

```
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_k.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_k.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_l.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_l.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_m.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_m.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_n.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_n.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_o.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_o.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_p.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_p.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_q.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_q.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_r.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_r.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_s.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_s.output &
sleep 2
java spc1 -f /home/spc/spc1/spc1_slavefiles/spc1sl_t.cfg -o
/home/spc/spc1/spc1_slavefiles/host21_t.output &
sleep 2
```

killmyslaves

```
pkill java
```

shutdownarray

```
#!/bin/bash
#
#

Inserv="dnoded27638"
ssh $Inserv "shutdownsys halt -f"
```

runpersist2

```
# executed after shutdown of array and total power cycle
if [ $# -ne 1 ]
then
    echo "Error in $0 - Invalid Argument Count"
    exit
fi

runid=$1

echo " system has been brought back up.  get inventory and then do persistence 2 "
date

date > /home/spc/spc1/showsysdown.$runid
echo " " >> /home/spc/spc1/showsysdown.$runid

/home/spc/spc1/showshutdown >> /home/spc/spc1/showsysdown.$runid
```

```
echo " " >> /home/spc/spc1/showsysdown.$runid
date >> /home/spc/spc1/showsysdown.$runid

/home/spc/spc1/getinventory finish_inv.$runid
java -Xms2048m -Xmx2048m -Xss512k persist2

# save off all files with runid
mv metrics metrics.$runid
mv repeatability1 repeatability1.$runid
mv repeatability2 repeatability2.$runid
mv persistence1 persistence1.$runid
mv persistence2 persistence2.$runid
mv SPCOut SPCOut.$runid
mv /share/sqaperf-active/datafiles/SPC1_Collect/SPC1_8450_inventory/start_inv.$runid
.
mv /share/sqaperf-
active/datafiles/SPC1_Collect/SPC1_8450_inventory/finish_inv.$runid .
```

APPENDIX F: THIRD-PARTY QUOTATION

HBAs