SPC BENCHMARK 1™
FULL DISCLOSURE REPORT

HUAWEI TECHNOLOGIES CO., LTD.
HUAWEI OCEANSTOR DORADO5100

SPC-1 V1.12

Submitted for Review: August 13, 2012
Submission Identifier: A00119

First Edition – August 2012

Trademarks

SPC Benchmark-1, SPC-1, SPC-1 IOPS, SPC-1 LRT and SPC-1 Price-Performance are trademarks of the Storage Performance Council. Huawei, the Huawei logo and OceanStor are trademarks or registered trademarks of Huawei Technologies Co., Ltd. in the United States and other countries. All other brands, trademarks, and product names are the property of their respective owners.

Table of Contents

AUDIT CERTIFICATION

Eric He
Huawei Technologies Co., Ltd.
Tianchen Road 88#
Chengdu, Sichuan, P.R. China 611711

August 8, 2012

The SPC Benchmark 1™ Reported Data listed below for the Huawei OceanStor Dorado5100 was produced in compliance with the SPC Benchmark 1™ v1.12 Remote Audit requirements.

SPC Benchmark 1™ v1.12 Reported Data	
Tested Storage Product (TSP) Name: Huawei OceanStor Dorado5100	
Metric	**Reported Result**
SPC-1 IOPS™	600,052.49
SPC-1 Price-Performance	$0.81/SPC-1 IOPS™
Total ASU Capacity	6,442.451 GB
Data Protection Level	Protected *(Mirroring)*
Total TSC Price (including three-year maintenance)	$488,617.00

The following SPC Benchmark 1™ Remote Audit requirements were reviewed and found compliant with 1.12 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 Huawei Technologies Co., Ltd.:
  - ✓ 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.
- An appropriate diagram of the Benchmark Configuration (BC)/Tested Storage Configuration (TSC).

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

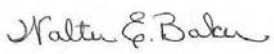
AUDIT CERTIFICATION *(CONT.)*

- 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 Huawei Technologies Co., Ltd.:
  - ✓ The type of each Host System 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 Test Results Files and resultant Summary Results Files received from Huawei Technologies Co., Ltd. for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4 and 5 of the SPC-1 Benchmark Specification:
  - ✓ Data Persistence Test
  - ✓ Sustainability Test Phase
  - ✓ IOPS Test Phase
  - ✓ Response Time Ramp Test Phase
  - ✓ Repeatability Test
- There were no differences between the Tested Storage Configuration and Priced Storage Configuration.
- The submitted pricing information met all of the requirements and constraints of Clause 8 of the SPC-1 Benchmark Specification.
- The Full Disclosure Report (FDR) met all of the requirements in Clause 9 of the SPC-1 Benchmark Specification.
- This successfully audited SPC measurement is not subject to an SPC Confidential Review.

Audit Notes:

Due to limitations of SPC-1 Persistence Test functionality, the Test could not be executed at the required level of 3,000 BSUs on the Tested Storage Configuration. The SPC-2 Persistence Test could not be substituted because SPC-2 is not currently supported on Red Hat Enterprise Linux. A level of 1,500 BSUs was used for the SPC-1 Persistence Test, which, in my opinion, was a sufficient BSU level for this configuration to successfully complete the objectives of the test.

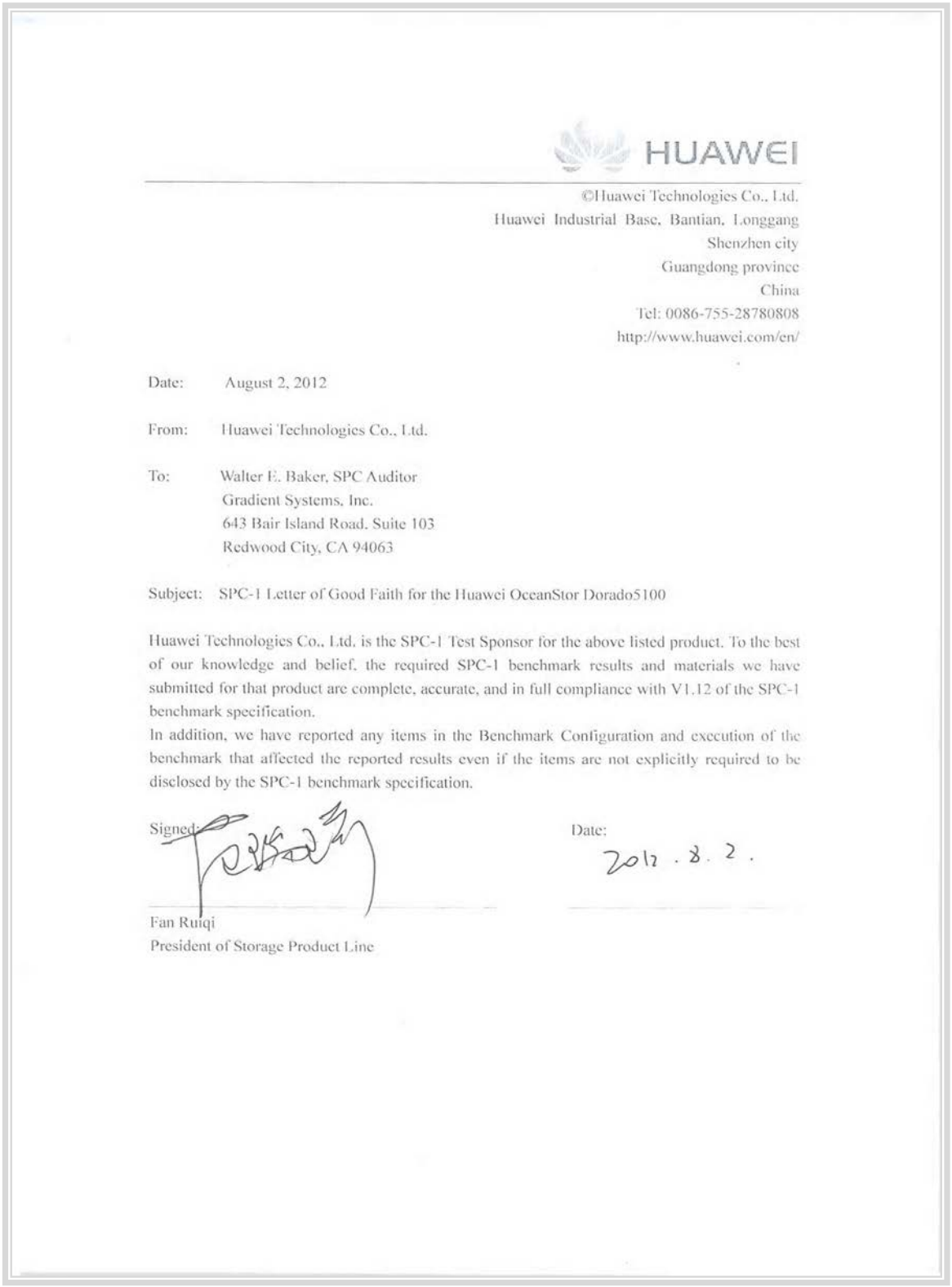
Respectfully,



Walter E. Baker
SPC Auditor

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

LETTER OF GOOD FAITH



HUAWEI

©Huawei Technologies Co., Ltd.
Huawei Industrial Base, Bantian, Longgang
Shenzhen city
Guangdong province
China
Tel: 0086-755-28780808
http://www.huawei.com/en/

Date: August 2, 2012

From: Huawei Technologies Co., Ltd.

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

Subject: SPC-1 Letter of Good Faith for the Huawei OceanStor Dorado5100

Huawei Technologies Co., Ltd. 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 V1.12 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: 2012.8.2.

Fan Ruiqi
President of Storage Product Line

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact	Huawei Technologies Co., Ltd. – http://www.huawei.com/en/ Eric He – eric.heji@huawei.com Tianchen Road 88# Chengdu, Sichuan, P.R. China 611711 Phone: 86 28 62905595 FAX: 86 28 62905793
Test Sponsor Alternate Contact	Huawei Technologies Co., Ltd. – http://www.huawei.com/en/ Jarvis Wang – wangyaohui@huawei.com Tianchen Road 88# Chengdu, Sichuan, P.R. China 611711 Phone: 86 28 62905639 FAX: 86 28 62905793
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	V1.12
SPC-1 Workload Generator revision number	V2.3.0
Date Results were first used publicly	August 13, 2012
Date the FDR was submitted to the SPC	August 13, 2012
Date the Priced Storage Configuration is available for shipment to customers	currently available
Date the TSC completed audit certification	August 9, 2012

Tested Storage Product (TSP) Description

Huawei OceanStor Dorado5100 is a SAN storage system using all solid-state technology, it is designed to eliminate IO bottlenecks, and accelerate mission-critical applications by reducing latency. The exclusive features of Dorado5100, for example solid-state architecture, Active- Active dual-controller, and hot-swappable modules, make the quick and highly available SAN deployment possible. Dorado5100 is the best choice for promoting business efficiency.

Summary of Results

SPC-1 Reported Data	
Tested Storage Product (TSP) Name: Huawei OceanStor Dorado5100	
Metric	**Reported Result**
SPC-1 IOPS™	600,052.49
SPC-1 Price-Performance™	$0.81/SPC-1 IOPS™
Total ASU Capacity	6,442.451 GB
Data Protection Level	Protected *(Mirroring)*
Total TSC Price (including three-year maintenance)	$488,617.00

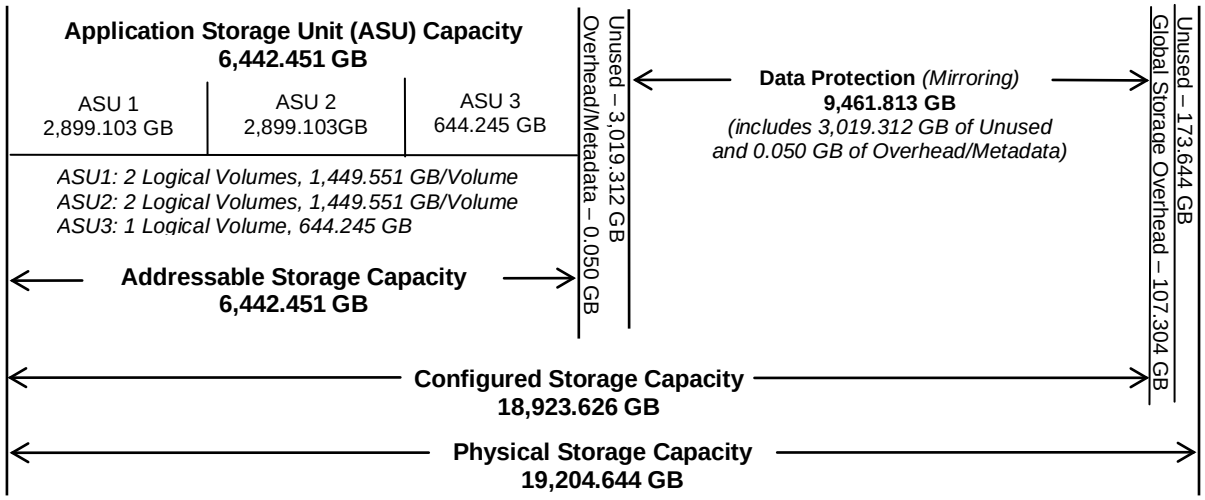
SPC-1 IOPS™ represents the maximum I/O Request Throughput at the 100% load point.

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

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

Storage Capacities, Relationships, and Utilization

The following diagram 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.



SPC-1 Storage Capacity Utilization	
Application Utilization	33.55%
Protected Application Utilization	67.09%
Unused Storage Ratio	32.35%

Application Utilization: Total ASU Capacity *(6,442.451 GB)* divided by Physical Storage Capacity *(19,204.644 GB)*

Protected Application Utilization: Total ASU Capacity *(6,442.451 GB)* plus total Data Protection Capacity *(9,461.813 GB)* minus unused Data Protection Capacity *(3,019.312 GB)* divided by Physical Storage Capacity *(19,204.644 GB)*

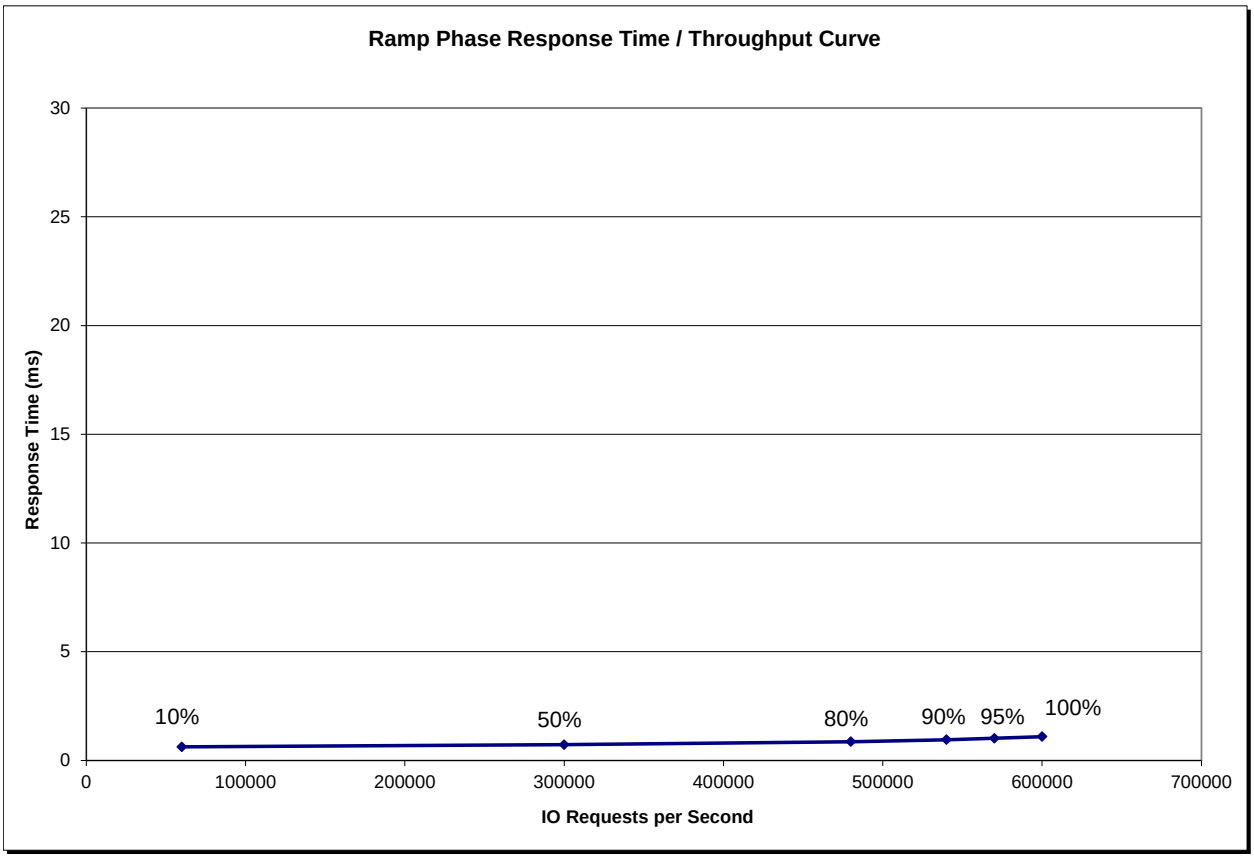
Unused Storage Ratio: Total Unused Capacity *(6,212.268 GB)* divided by Physical Storage Capacity *(19,204.644 GB)* and may not exceed 45%.

Detailed information for the various storage capacities and utilizations is available on pages 21-22.

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	59,995.56	300,013.97	480,006.68	540,030.87	570,021.13	600,052.49
Average Response Time (ms):						
All ASUs	0.62	0.72	0.86	0.95	1.02	1.09
ASU-1	0.66	0.76	0.91	1.01	1.08	1.16
ASU-2	0.78	0.91	1.07	1.19	1.28	1.37
ASU-3	0.49	0.57	0.66	0.73	0.77	0.82
Reads	0.57	0.69	0.87	0.97	1.04	1.11
Writes	0.66	0.74	0.85	0.94	1.01	1.08

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

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

Priced Storage Configuration Pricing

Part Number	Description	Quantity	Unit Price	Total Price
STTZ14SPES	OceanStor Dorado5100 High Performance Solid State Storage System Controller Enclosure(AC,1000000 IOPS,8GBps Bandwidth,8*8G FC Front-End Port,4*4*6G SAS Back-End Port,with HS HSSD Controller System Software,SPE61C0200)	1	16,214.00	16,214.00
LPU2S6	2*24Gbps SAS-wide I/O modules(Total 2 ports)	6	1,020.00	6,120.00
LPU4F8	4*8Gbps Fibre Channel I/O modules(Total 4 ports)	2	866.00	1,732.00
STTZ06DAE24	High Performance Solid State Storage System Disk Enclosure-4.8TB(2U,AC,24*200GB SLC,with HS SAS in Band Management Software,DAE12425U2)	4	89,873.00	359,492.00
SS-OP-D-LC-M-3	Patchcord,DLC/PC-DLC/PC,Multimode,2mm Parallel,3m	8	11.00	88.00
LIC-Dorado-ISM02	HS Integrated Storage Manager-Device Management License for Dorado	1	4,557.00	4,557.00
QLE2562-CK	QLogic Dual Port 8Gb Fibre Channel to PCI Express Host Bus Adapter (QLE2562-CK)	4	2,598.00	10,392.00
mini-SAS-1	Purchased Cable,MiniSAS Cable,28AWG,Key246,1m	8	38	304.00
Product Total				***398,899.00***
Total Service 3-year Hi-Care Premier Support service				89,718.00
Grand Total				**488,617.00**

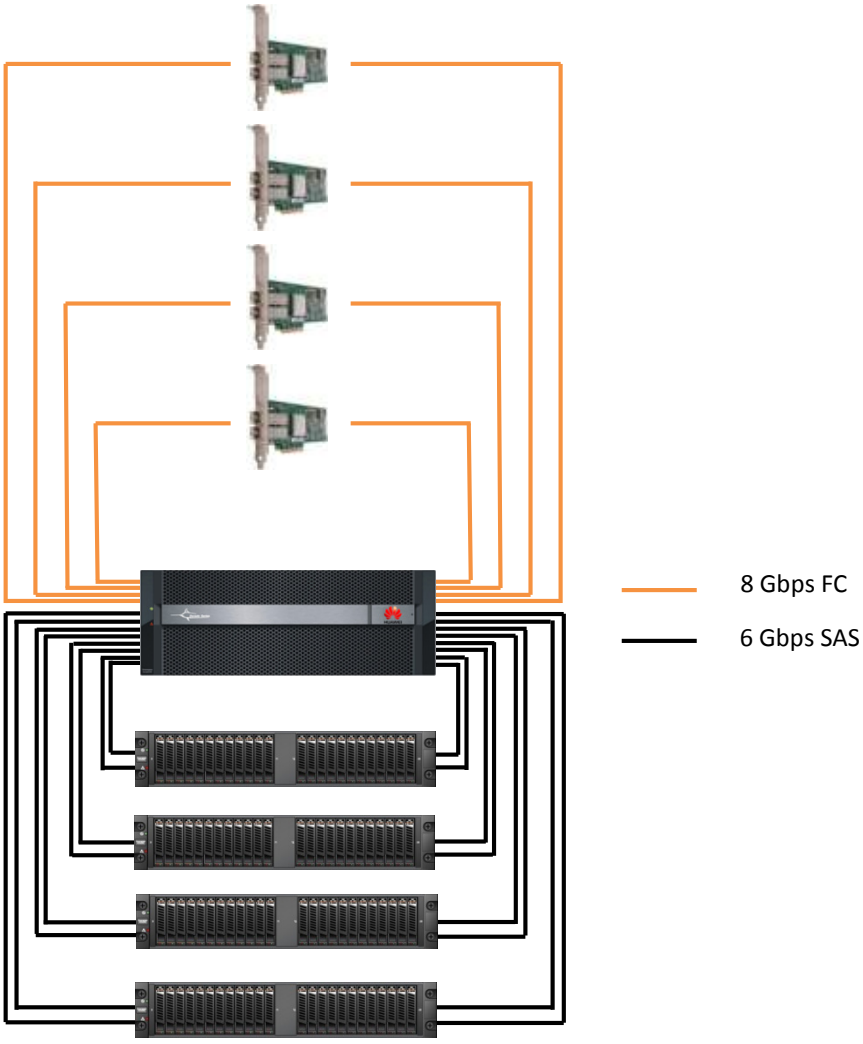
The above pricing includes hardware maintenance and software support for three years, 7 days per week, 24 hours per day. The hardware maintenance and software support provides the following:

- Acknowledgement of new and existing problems with 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.

Huawei Technologies Co., Ltd. only sells its products to third-party resellers, who in turn, sell those products to U.S. customers. The above pricing, which also includes the required three-year maintenance and support, was obtained from one of those third-party resellers. See page 71 *("Appendix F: Third-Party Quotation")* for a copy of the third-party reseller quotation.

Priced Storage Configuration Diagram

4 - QLogic dual-ported QLE 2562 FC HBAs



Huawei OceanStor Dorado5100

2 - Active-Active controllers

48 GB per controller (96 GB total)

2 – FC 4-port 8 Gbps I/O module per controller

4 – 4x6 Gbps SAS-wide I/O modules per controller

4 –Disk Enclosures

24 – 200 GB Solid State Disks (SSDs) per enclosure (96 total)

Priced Storage Configuration Components

Priced Storage Configuration:
4 – QLogic dual-ported QLE2562 FC HBAs
Huawei OceanStor Dorado5100 **2 – Active-Active controllers** 48 GB cache per controller *(96 total)* 2 – FC, 4-port, 8 Gbps I/O modules per controller *(4 total)* 8 – 8Gbps FC front-end ports per controller *(16 total, 8 used)* 16 – 8 Gbps SFPs 4 – 4x6 Gbps SAS-wide I/O modules per controller *(8 total)* 8 – 4x6 Gbps SAS-wide backend connections per controller *(16 total and used)*
4 –Disk Enclosures
96 – 200 GB Solid State Disks (SSDs) *(24 SSDs per Disk 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 18 *(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 Benchmark Configuration (BC)/Tested Storage Configuration (TSC) was configured with local storage and, as such, did not employ a storage network.

Host System 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). Table 9-10 specifies the content, format, and appearance of the table.

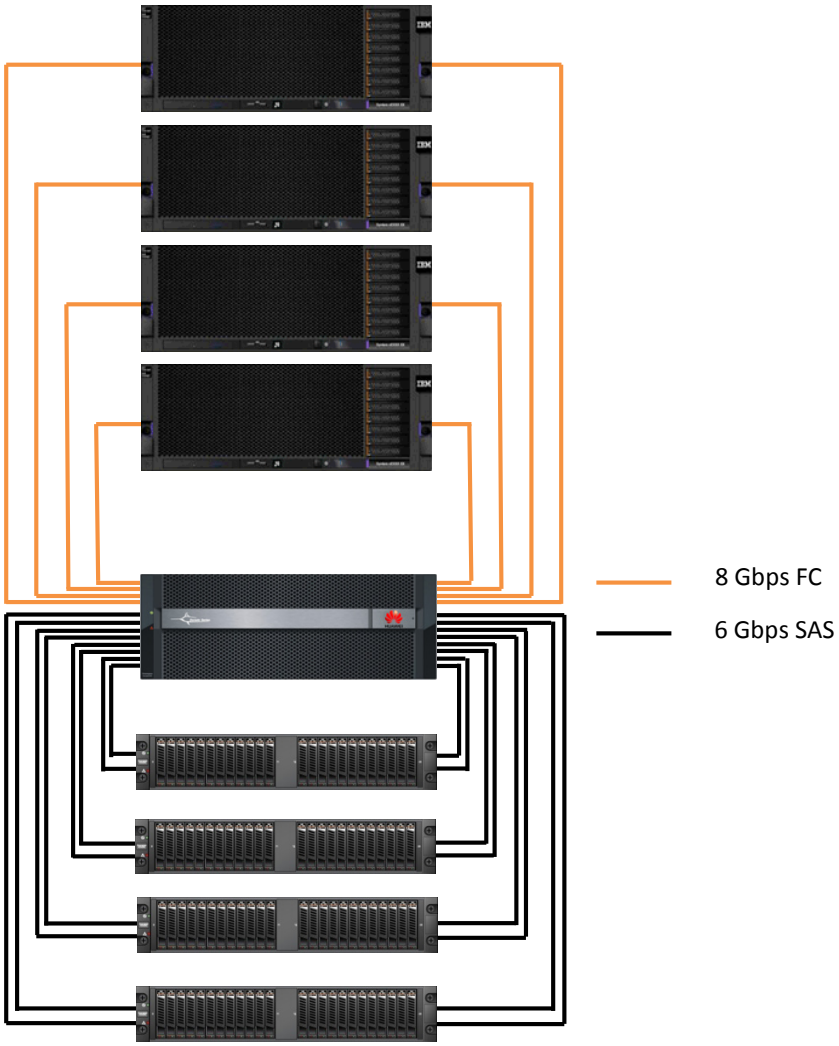
The Host System and TSC table of components may be found on page 19 *(Host Systems and Tested Storage Configuration Components).*

Benchmark Configuration/Tested Storage Configuration Diagram

4 – IBM System X3850 X5

4 - QLogic dual-ported QLE 2562 FC HBA

1 – HBA per Host System



Huawei OceanStor Dorado5100

2 - Active-Active controllers

48 GB per controller (96 GB total)

2 – FC 4-port 8 Gbps I/O module per controller

4 – 4x6 Gbps SAS-wide I/O modules per controller

4 –Disk Enclosures

24 – 200 GB Solid State Disks (SSDs) per enclosure (96 total)

Host Systems and Tested Storage Configuration Components

Host Systems:	Tested Storage Configuration (TSC):
4 – IBM System X3850 X5 servers each server with: 2 – Intel Xeon 6 core 2.67 GHz X7542 processors with 18 MB L3 cache 64 GB main memory Red Hat Enterprise Linux 5.5 x86_64 PCIe	4 – QLogic dual-ported QLE2562 FC HBAs
	Huawei OceanStor Dorado5100 **2 – Active-Active controllers** 48 GB cache per controller *(96 total)* 2 – FC, 4-port 8 Gbps I/O modules per controller *(4 total)* 8 – 8Gbps FC front-end ports per controller *(16 total, 8 used)* 16 – 8 Gbps SFPs 4 – 4x6 Gbps SAS-wide I/O modules per controller *(8 total)* 8 – 4x6 Gbps SAS-wide backend connections per controller *(16 total and used)*
	4 –Disk Enclosures
	96 – 200 GB Solid State Disks (SSDs) *(24 SSDs per Disk 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 60 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 61 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 68.

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 56 contains definitions of terms specific to the SPC-1 Data Repository.

Storage Capacities and Relationships

Clause 9.4.3.6.1

Two tables and an illustration documenting the storage capacities and relationships of the SPC-1 Storage Hierarchy (Clause 2.1) shall be included in the FDR.

SPC-1 Storage Capacities

SPC-1 Storage Capacities		
Storage Hierarchy Component	**Units**	**Capacity**
Total ASU Capacity	Gigabytes (GB)	6,442.451
Addressable Storage Capacity	Gigabytes (GB)	6,442.451
Configured Storage Capacity	Gigabytes (GB)	18,923.626
Physical Storage Capacity	Gigabytes (GB)	19,204.644
Data Protection *(Mirroring)*	Gigabytes (GB)	9,461.813
Required Storage *(overhead/metadata)*	Gigabytes (GB)	0.050
Global Storage Overhead	Gigabytes (GB)	173.644
Total Unused Storage	Gigabytes (GB)	6,212.268

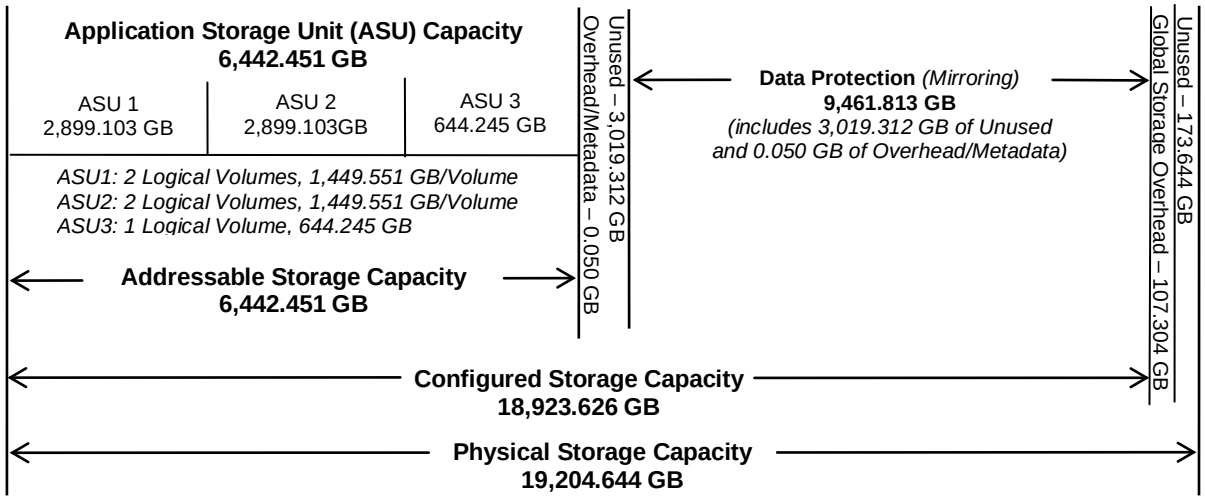
SPC-1 Storage Hierarchy Ratios

	Addressable Storage Capacity	**Configured Storage Capacity**	**Physical Storage Capacity**
Total ASU Capacity	100.00%	34.04%	33.55%
Required for Data Protection *(Mirroring)*		50.00%	49.27%
Addressable Storage Capacity		34.04%	33.55%
Required Storage *(overhead/metadata)*		0.00%	0.00%
Configured Storage Capacity			98.54%
Global Storage Overhead			0.56%
Unused Storage:			
Addressable	0.00%		
Configured		31.95%	
Physical			0.90%

The Physical Storage Capacity consisted of 19,204.644 GB distributed over 96 solid state storage devices, each with a formatted capacity of 200.048 GB. There was 173.64 GB (0.90%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 173.644 GB (0.56%) of the Physical Storage Capacity. There was 6,038.623 GB (31.91%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 100% of the Addressable Storage Capacity resulting in 0.000 GB (0.00%) of Unused Storage within the Addressable Storage Capacity. The Data Protection *(Mirroring)* capacity was 9,461.813 GB of which 6,442.451 GB was utilized. The total Unused Storage capacity was 6,212.268 GB.

SPC-1 Storage Capacities and Relationships Illustration

The various storage capacities configured in the benchmark result are illustrated below *(not to scale)*.



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 (2,899.103 GB)	**ASU-2 (2,899.103 GB)**	**ASU-3 (644.245 GB)**
2 Logical Volumes 1,449.551 GB per Logical Volume (1,449.551 GB used per Logical Volume)	2 Logical Volumes 1,449.551 GB per Logical Volume (1,449.551 GB used per Logical Volume)	1 Logical Volume 644.245 GB per Logical Volume (644.245 GB used per Logical Volume)

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

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	33.55%
Protected Application Utilization	67.09%
Unused Storage Ratio	32.35%

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. "SPC-1 Test Execution Definitions" on page 57 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.

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 three (3) 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 9.4.3.7.1

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 69.

Sustainability Test Results File

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

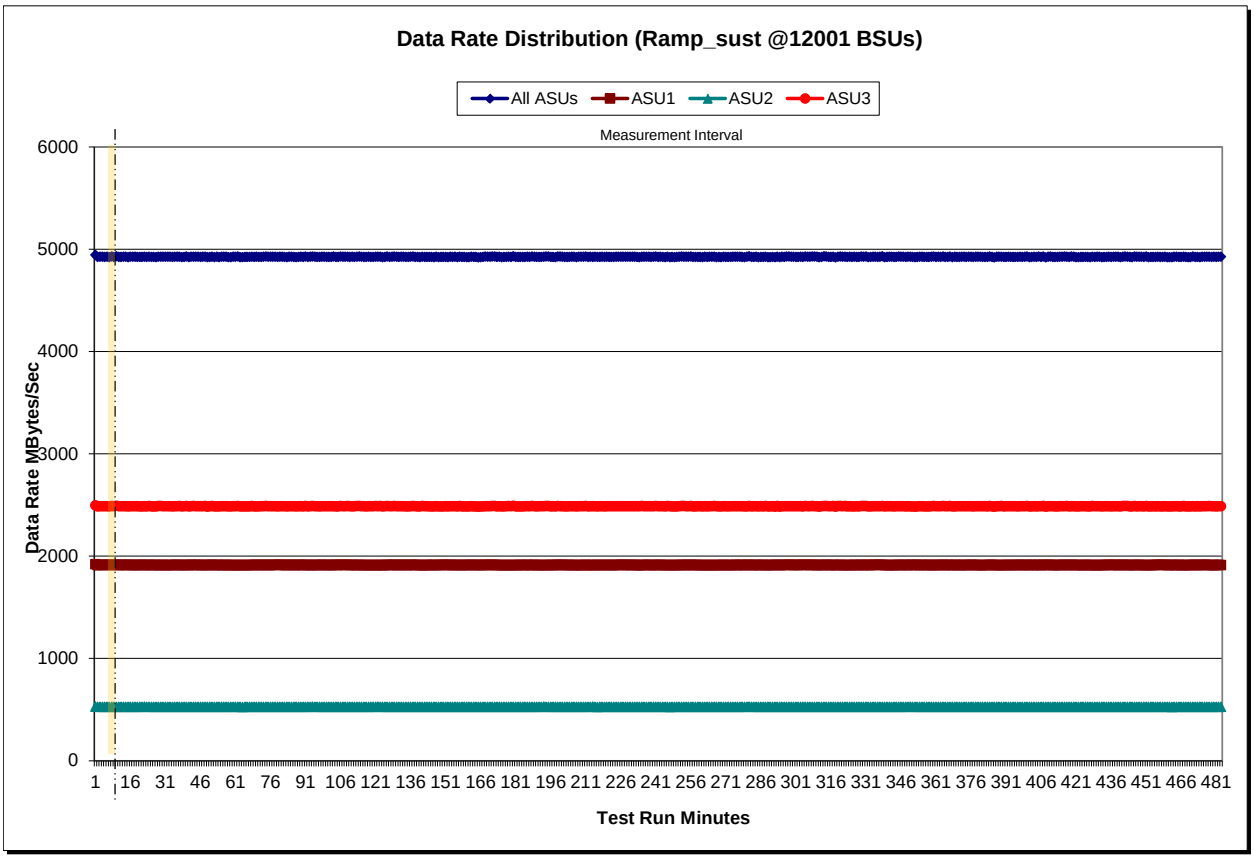
Sustainability Test Results File

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

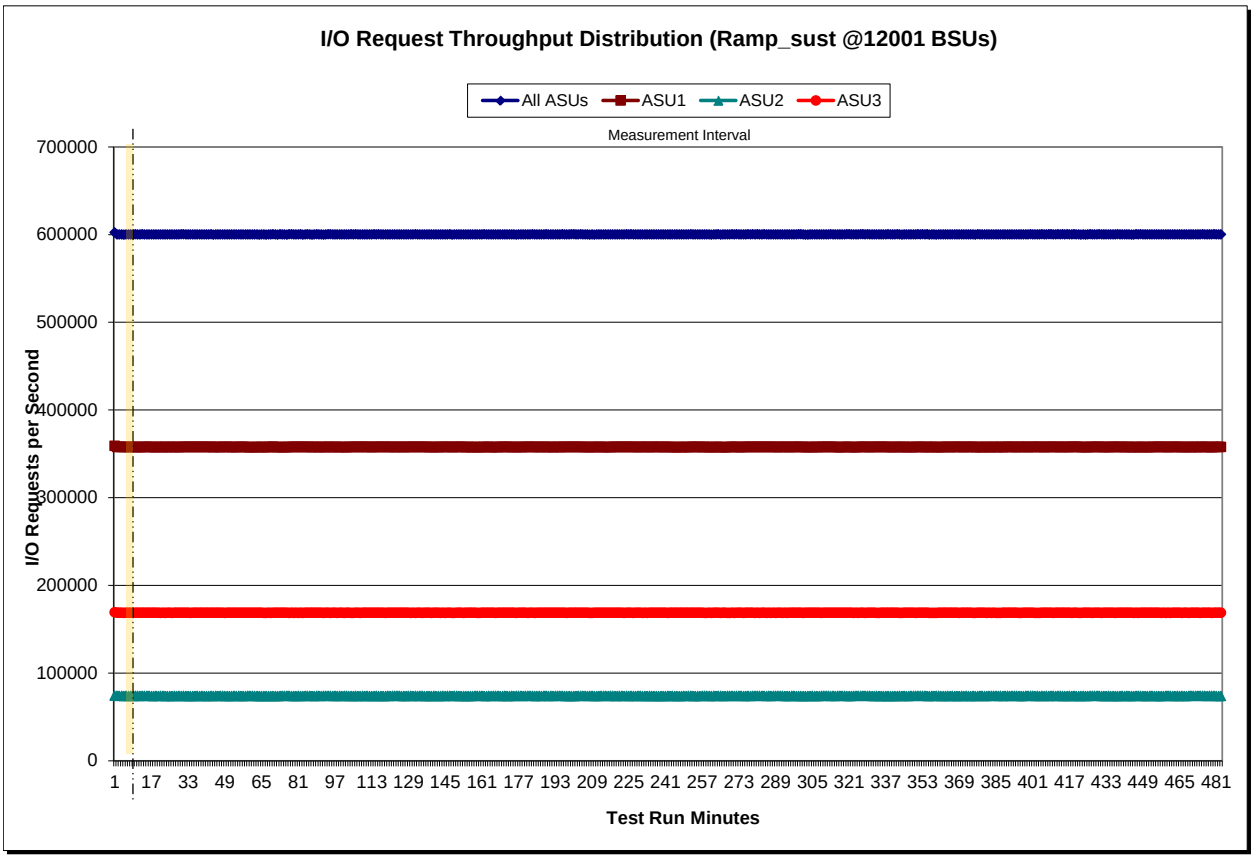


Sustainability – I/O Request Throughput Distribution Data

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

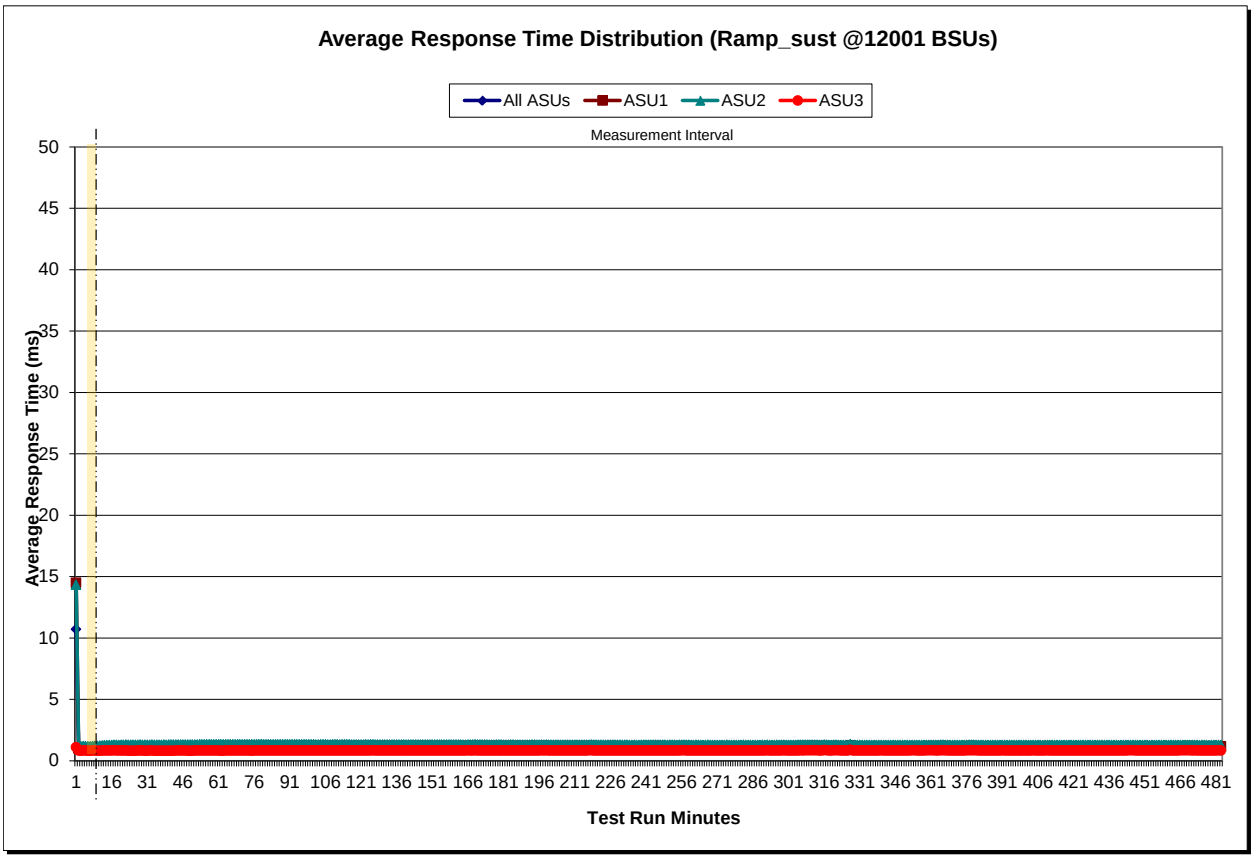


Sustainability – Average Response Time (ms) Distribution Data

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

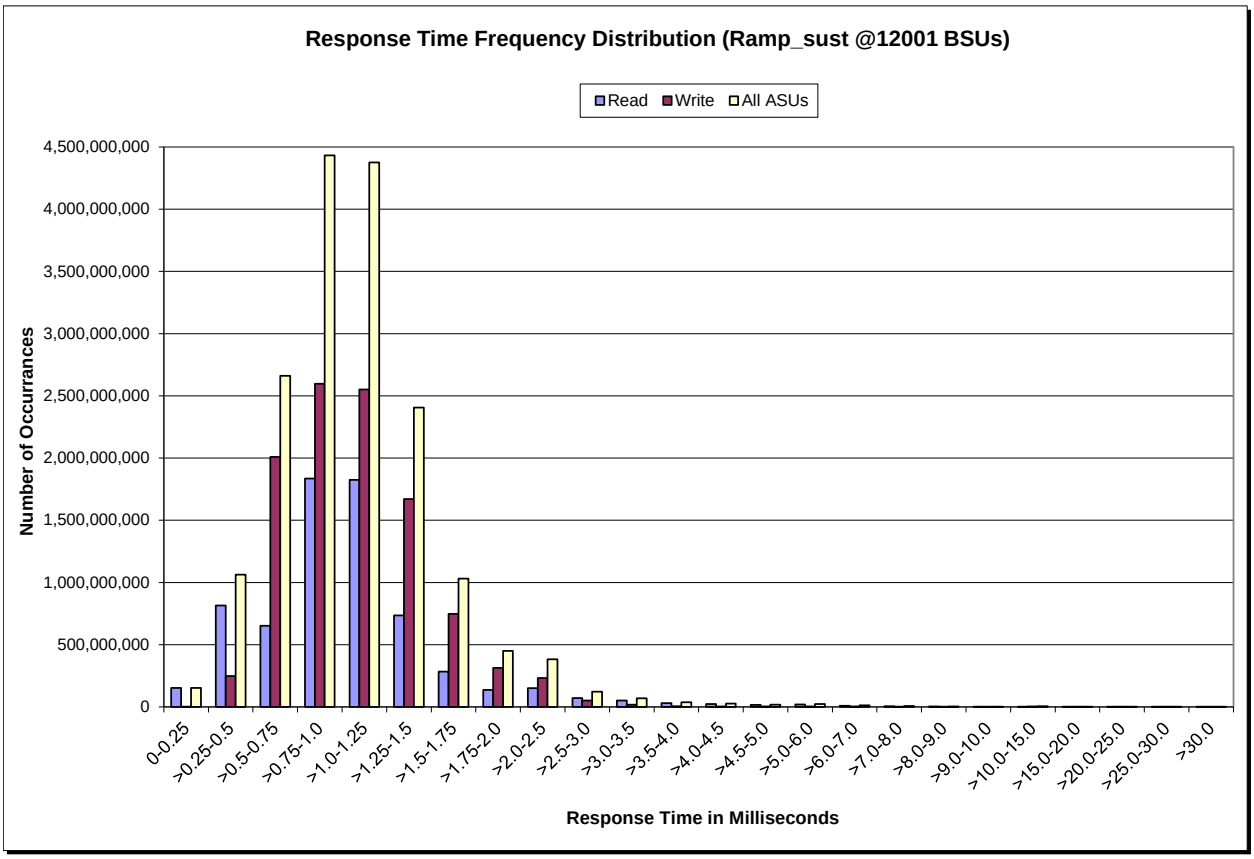
Sustainability – Average Response Time (ms) Distribution Graph



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	151,756,396	814,833,585	651,741,360	1,835,777,315	1,824,474,419	735,156,948	283,215,187	135,815,511
Write	717	247,865,946	2,008,309,942	2,597,370,937	2,550,302,170	1,670,729,029	747,516,819	313,355,469
All ASUs	151,757,113	1,062,699,531	2,660,051,302	4,433,148,252	4,374,776,589	2,405,885,977	1,030,732,006	449,170,980
ASU1	147,902,352	793,474,643	648,839,768	2,231,082,293	2,968,572,813	1,803,762,888	802,870,478	353,873,482
ASU2	3,854,044	21,477,670	96,078,680	471,874,540	673,171,525	427,534,605	195,842,113	88,705,451
ASU3	717	247,747,218	1,915,132,854	1,730,191,419	733,032,251	174,588,484	32,019,415	6,592,047
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	151,221,465	70,029,935	51,223,635	30,997,531	23,134,597	15,564,930	19,046,746	9,420,028
Write	232,199,361	51,529,953	17,602,437	6,037,616	3,932,953	3,006,575	4,104,985	3,015,850
All ASUs	383,420,826	121,559,888	68,826,072	37,035,147	27,067,550	18,571,505	23,151,731	12,435,878
ASU1	302,117,834	94,501,614	52,644,850	28,016,312	20,083,958	13,513,114	16,908,272	8,588,413
ASU2	78,249,511	25,587,258	14,876,738	8,110,420	5,783,214	3,898,418	4,779,829	2,395,947
ASU3	3,053,481	1,471,016	1,304,484	908,415	1,200,378	1,159,973	1,463,630	1,451,518
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	5,163,853	2,819,704	1,500,868	2,047,919	368,711	206,634	97,826	84,236
Write	1,982,258	1,382,157	1,058,959	2,834,173	1,003,963	389,678	178,772	151,180
All ASUs	7,146,111	4,201,861	2,559,827	4,882,092	1,372,674	596,312	276,598	235,416
ASU1	4,971,528	2,727,357	1,540,415	2,481,450	642,213	369,874	184,733	153,116
ASU2	1,343,130	726,736	403,987	622,692	150,373	86,119	43,398	35,560
ASU3	831,453	747,768	615,425	1,777,950	580,088	140,319	48,467	46,740

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 5.3.13.2

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 5.3.13.3

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 9.4.3.7.2

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 69.

IOPS Test Results File

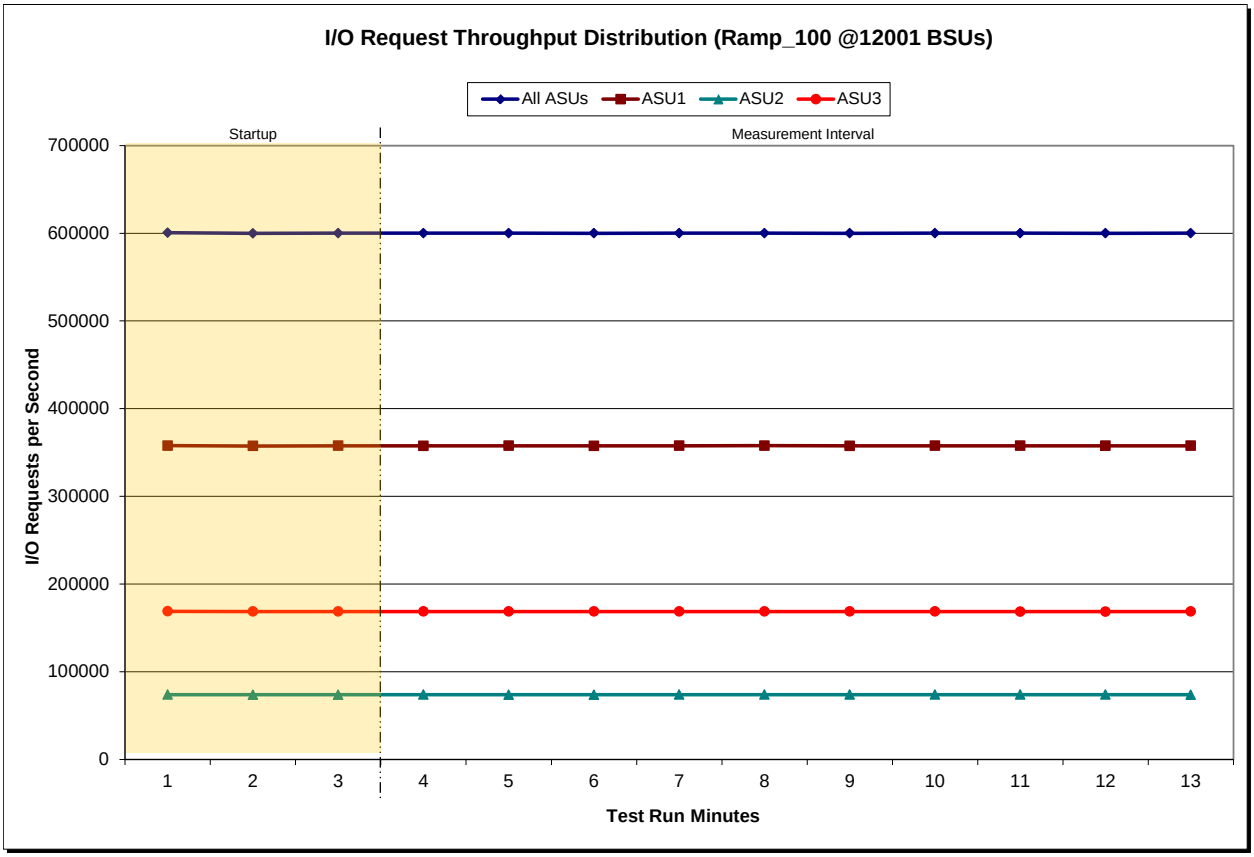
A link to the test results file generated from the IOPS Test Run is listed below.

IOPS Test Results File

IOPS Test Run – I/O Request Throughput Distribution Data

12,001 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	5:57:17	6:00:18	0-2	0:03:01
Measurement Interval	6:00:18	6:10:18	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	600,542.10	357,840.58	73,849.13	168,852.38
1	599,878.32	357,437.58	73,791.93	168,648.80
2	600,090.88	357,688.37	73,763.32	168,639.20
3	600,045.82	357,580.40	73,813.65	168,651.77
4	600,040.97	357,656.07	73,765.70	168,619.20
5	600,017.22	357,574.12	73,804.37	168,638.73
6	600,113.05	357,614.10	73,830.85	168,668.10
7	600,135.45	357,722.50	73,837.82	168,575.13
8	599,990.48	357,537.00	73,845.77	168,607.72
9	600,076.13	357,647.23	73,820.38	168,608.52
10	600,044.08	357,696.72	73,816.17	168,531.20
11	599,986.55	357,623.10	73,846.47	168,516.98
12	600,075.15	357,614.05	73,808.65	168,652.45
Average	***600,052.49***	***357,626.53***	***73,818.98***	***168,606.98***

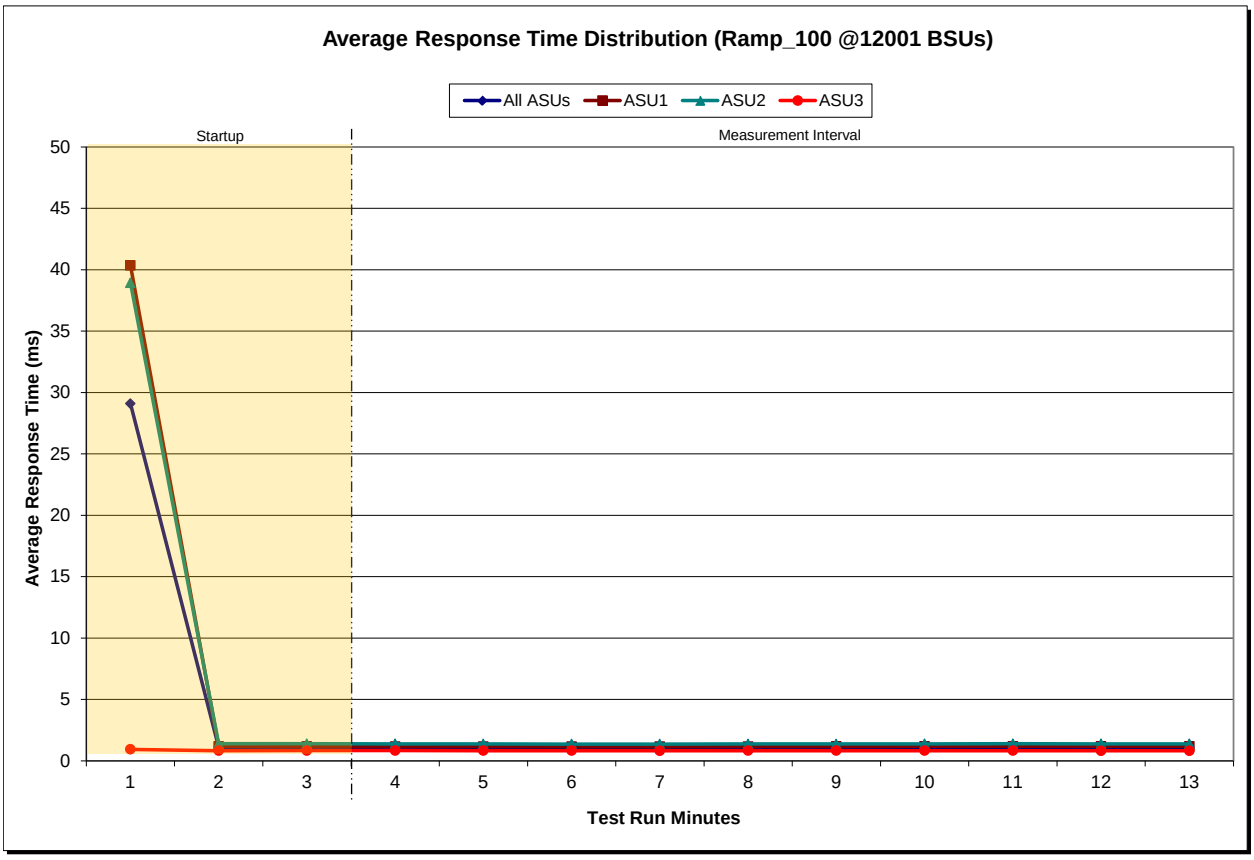
IOPS Test Run – I/O Request Throughput Distribution Graph



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

12,001 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	5:57:17	6:00:18	0-2	0:03:01
Measurement Interval	6:00:18	6:10:18	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	29.09	40.34	38.92	0.93
1	1.10	1.17	1.39	0.82
2	1.10	1.17	1.39	0.83
3	1.09	1.16	1.38	0.83
4	1.09	1.15	1.37	0.83
5	1.08	1.15	1.36	0.82
6	1.08	1.15	1.36	0.82
7	1.09	1.16	1.37	0.82
8	1.09	1.17	1.37	0.82
9	1.10	1.17	1.38	0.82
10	1.10	1.18	1.39	0.82
11	1.10	1.18	1.38	0.82
12	1.10	1.18	1.38	0.82
Average	***1.09***	***1.16***	***1.37***	***0.82***

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



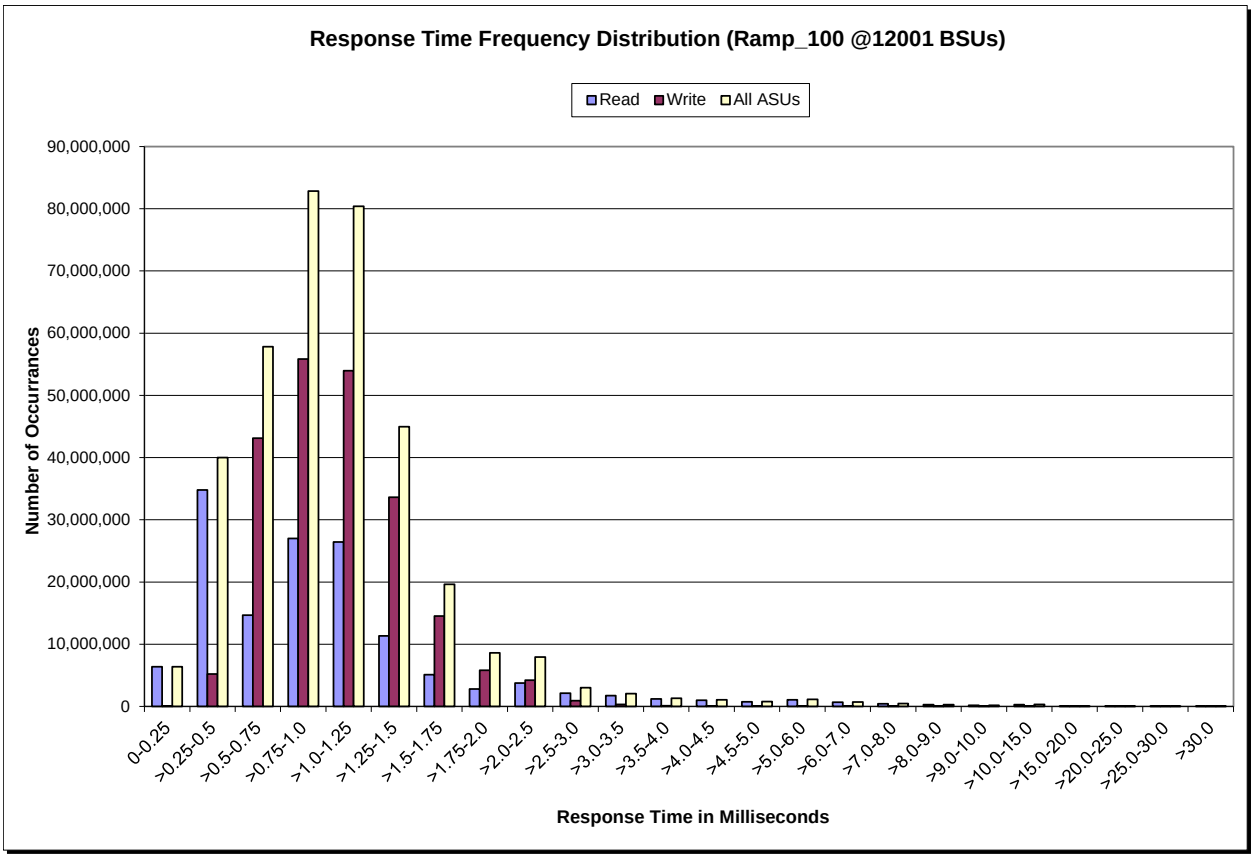
IOPS Test Run – Response Time Frequency Distribution Data

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	6,394,190	34,790,460	14,677,742	27,012,302	26,441,870	11,347,046	5,096,538	2,814,817
Write	12	5,196,870	43,127,102	55,838,162	53,949,196	33,622,788	14,533,113	5,803,679
All ASUs	6,394,202	39,987,330	57,804,844	82,850,464	80,391,066	44,969,834	19,629,651	8,618,496
ASU1	6,272,568	34,115,801	14,865,892	36,944,179	52,070,029	33,279,404	15,230,750	6,784,784
ASU2	121,622	678,436	2,112,862	9,784,096	13,600,353	8,402,219	3,824,370	1,720,038
ASU3	12	5,193,093	40,826,090	36,122,189	14,720,684	3,288,211	574,531	113,674

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	3,740,581	2,109,346	1,732,004	1,217,091	980,157	736,335	1,060,326	664,442
Write	4,203,923	916,810	306,798	104,517	75,008	56,885	84,820	56,673
All ASUs	7,944,504	3,026,156	2,038,802	1,321,608	1,055,165	793,220	1,145,146	721,115
ASU1	6,263,606	2,358,474	1,576,381	1,018,529	803,677	602,204	868,098	543,812
ASU2	1,621,679	637,048	437,732	286,102	225,796	169,447	244,737	151,979
ASU3	59,219	30,634	24,689	16,977	25,692	21,569	32,311	25,324

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	423,542	270,288	171,505	275,699	31,976	6,097	1,962	1,571
Write	35,251	24,746	19,049	49,856	15,593	6,709	3,024	2,438
All ASUs	458,793	295,034	190,554	325,555	47,569	12,806	4,986	4,009
ASU1	346,102	219,492	140,156	228,231	29,189	8,161	3,361	2,664
ASU2	96,901	61,400	39,129	63,704	8,098	2,062	822	681
ASU3	15,790	14,142	11,269	33,620	10,282	2,583	803	664

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
360,030,909	360,026,900	4,009

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 5.3.13.2

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 5.3.13.3

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 – 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 13.

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 9.4.3.7.3

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 69.

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 tables and graphs for completeness.

100% Load Level - 12,001 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	5:57:17	6:00:18	0-2	0:03:01
Measurement Interval	6:00:18	6:10:18	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	600,542.10	357,840.58	73,849.13	168,852.38
1	599,878.32	357,437.58	73,791.93	168,648.80
2	600,090.88	357,688.37	73,763.32	168,639.20
3	600,045.82	357,580.40	73,813.65	168,651.77
4	600,040.97	357,656.07	73,765.70	168,619.20
5	600,017.22	357,574.12	73,804.37	168,638.73
6	600,113.05	357,614.10	73,830.85	168,668.10
7	600,135.45	357,722.50	73,837.82	168,575.13
8	599,990.48	357,537.00	73,845.77	168,607.72
9	600,076.13	357,647.23	73,820.38	168,608.52
10	600,044.08	357,696.72	73,816.17	168,531.20
11	599,986.55	357,623.10	73,846.47	168,516.98
12	600,075.15	357,614.05	73,808.65	168,652.45
Average	***600,052.49***	***357,626.53***	***73,818.98***	***168,606.98***

95% Load Level - 11,400 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	6:11:56	6:14:57	0-2	0:03:01
Measurement Interval	6:14:57	6:24:57	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	570,364.72	339,897.60	70,187.92	160,279.20
1	570,045.65	339,805.03	70,099.47	160,141.15
2	570,029.80	339,751.23	70,100.07	160,178.50
3	569,950.43	339,638.37	70,083.62	160,228.45
4	569,994.77	339,726.20	70,038.50	160,230.07
5	570,101.25	339,876.88	70,140.17	160,084.20
6	570,009.90	339,754.02	70,072.57	160,183.32
7	569,886.18	339,744.62	70,088.83	160,052.73
8	570,021.20	339,692.48	70,121.27	160,207.45
9	570,113.18	339,770.28	70,084.38	160,258.52
10	570,177.43	339,804.95	70,121.52	160,250.97
11	570,113.47	339,834.38	70,075.15	160,203.93
12	569,843.47	339,615.80	70,092.98	160,134.68
Average	***570,021.13***	***339,745.80***	***70,091.90***	***160,183.43***

90% Load Level - 10,800 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	6:26:28	6:29:29	0-2	0:03:01
Measurement Interval	6:29:29	6:39:29	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	540,417.65	322,162.33	66,419.80	151,835.52
1	540,150.13	321,955.95	66,423.77	151,770.42
2	540,024.92	321,919.25	66,391.88	151,713.78
3	539,971.05	321,804.50	66,409.80	151,756.75
4	540,084.98	321,838.52	66,447.20	151,799.27
5	540,079.87	321,877.58	66,477.95	151,724.33
6	539,751.42	321,700.32	66,389.22	151,661.88
7	540,145.58	321,931.30	66,486.77	151,727.52
8	540,116.38	321,825.10	66,407.83	151,883.45
9	539,885.82	321,832.05	66,378.35	151,675.42
10	540,169.28	321,915.75	66,417.22	151,836.32
11	539,998.80	321,873.68	66,439.23	151,685.88
12	540,105.47	321,916.93	66,452.57	151,735.97
Average	***540,030.87***	***321,851.57***	***66,430.61***	***151,748.68***

80% Load Level - 9,600 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	6:40:51	6:43:52	0-2	0:03:01
Measurement Interval	6:43:52	6:53:52	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	480,287.13	286,242.13	59,086.55	134,958.45
1	480,007.42	286,131.28	59,061.48	134,814.65
2	479,993.22	286,168.10	58,997.12	134,828.00
3	480,032.78	286,075.15	59,035.00	134,922.63
4	480,125.75	286,117.07	59,109.32	134,899.37
5	479,977.75	286,109.12	58,970.45	134,898.18
6	479,992.50	286,071.32	59,037.33	134,883.85
7	479,885.10	286,044.15	59,028.93	134,812.02
8	480,095.75	286,157.83	59,026.83	134,911.08
9	479,985.47	286,015.03	59,053.23	134,917.20
10	479,922.52	286,018.68	59,029.93	134,873.90
11	480,026.83	286,086.05	59,068.32	134,872.47
12	480,022.35	286,147.95	59,037.22	134,837.18
Average	***480,006.68***	***286,084.24***	***59,039.66***	***134,882.79***

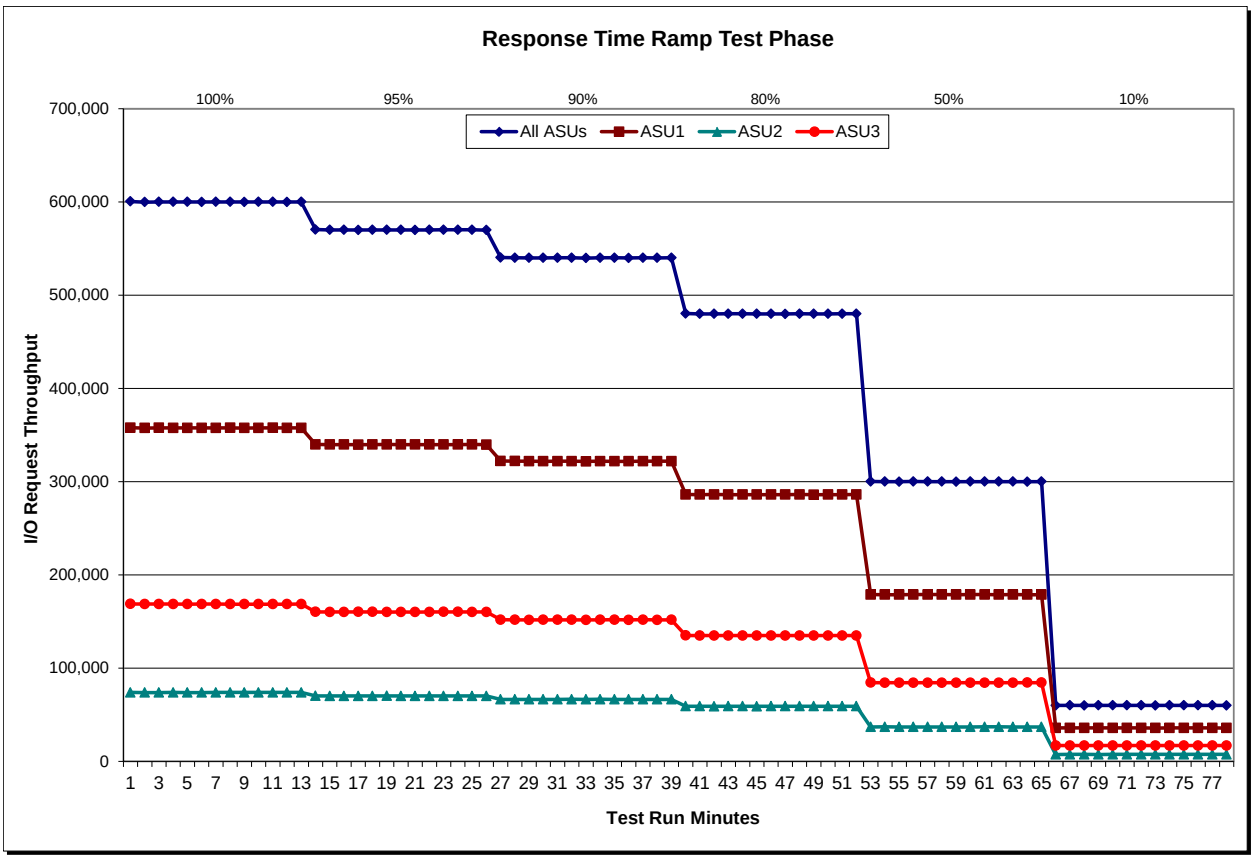
50% Load Level - 6,000 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	6:54:49	6:57:50	0-2	0:03:01
Measurement Interval	6:57:50	7:07:50	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	300,086.70	178,858.55	36,889.15	84,339.00
1	299,976.42	178,768.62	36,926.83	84,280.97
2	299,915.40	178,767.48	36,873.02	84,274.90
3	300,111.38	178,883.67	36,908.53	84,319.18
4	300,030.57	178,815.00	36,910.88	84,304.68
5	300,048.32	178,856.10	36,901.07	84,291.15
6	299,853.25	178,701.98	36,890.98	84,260.28
7	300,047.92	178,823.65	36,916.45	84,307.82
8	300,034.18	178,809.27	36,921.35	84,303.57
9	300,029.32	178,773.65	36,949.28	84,306.38
10	299,969.65	178,830.32	36,912.80	84,226.53
11	299,954.93	178,678.65	36,903.78	84,372.50
12	300,060.15	178,783.67	36,917.20	84,359.28
Average	***300,013.97***	***178,795.60***	***36,913.23***	***84,305.14***

10% Load Level - 1,200 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:08:13	7:11:14	0-2	0:03:01
Measurement Interval	7:11:14	7:21:14	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	59,960.05	35,738.92	7,360.45	16,860.68
1	59,987.98	35,747.63	7,374.90	16,865.45
2	59,962.77	35,738.38	7,370.93	16,853.45
3	59,973.78	35,745.88	7,361.77	16,866.13
4	59,981.27	35,752.80	7,378.18	16,850.28
5	60,001.20	35,738.58	7,378.80	16,883.82
6	60,034.67	35,775.97	7,382.15	16,876.55
7	59,933.27	35,734.60	7,369.72	16,828.95
8	59,995.12	35,762.83	7,374.05	16,858.23
9	60,065.77	35,794.35	7,388.18	16,883.23
10	60,008.27	35,752.50	7,390.57	16,865.20
11	60,002.70	35,757.48	7,366.43	16,878.78
12	59,959.55	35,726.25	7,375.38	16,857.92
Average	***59,995.56***	***35,754.13***	***7,376.52***	***16,864.91***

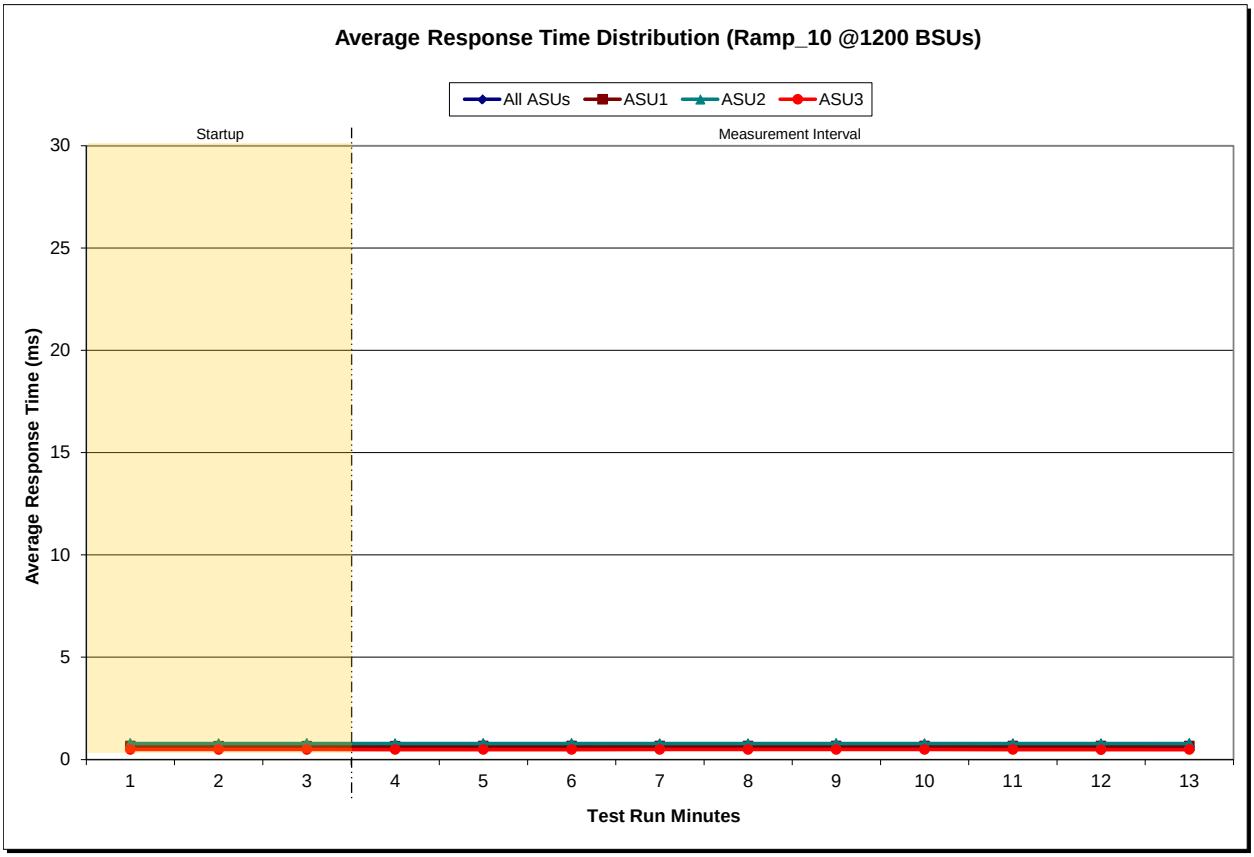
Response Time Ramp Distribution (IOPS) Graph



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

1,200 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:08:13	7:11:14	0-2	0:03:01
Measurement Interval	7:11:14	7:21:14	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.62	0.66	0.79	0.49
1	0.62	0.65	0.78	0.49
2	0.62	0.65	0.78	0.49
3	0.62	0.65	0.78	0.48
4	0.62	0.66	0.78	0.49
5	0.62	0.66	0.79	0.48
6	0.62	0.66	0.78	0.49
7	0.62	0.65	0.78	0.49
8	0.63	0.66	0.78	0.49
9	0.62	0.65	0.78	0.49
10	0.62	0.66	0.78	0.49
11	0.62	0.65	0.78	0.48
12	0.63	0.66	0.78	0.48
Average	***0.62***	***0.66***	***0.78***	***0.49***

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 5.3.13.2

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 5.3.13.3

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	0.0701	0.2099	0.0180	0.0700	0.0349	0.2811
COV	0.003	0.001	0.002	0.001	0.004	0.003	0.003	0.001

Repeatability Test

Clause 5.4.5

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

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

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

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

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

Clause 9.4.3.7.4

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 69.

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	***600,052.49***
Repeatability Test Phase 1	600,061.29
Repeatability Test Phase 2	599,990.50

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	***0.62 ms***
Repeatability Test Phase 1	0.62 ms
Repeatability Test Phase 2	0.62 ms

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

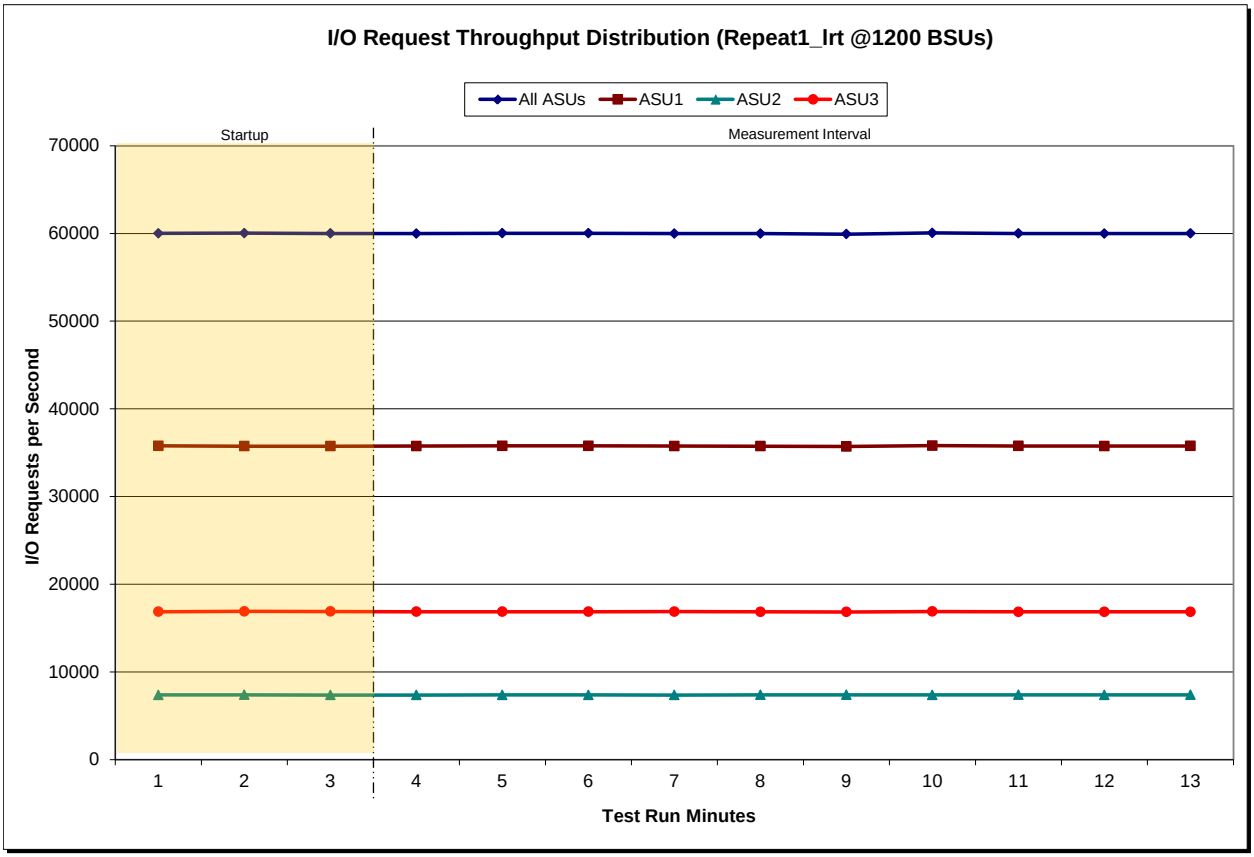
A link to the test result file generated from each Repeatability Test Run is listed below.

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

1,200 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:21:51	7:24:51	0-2	0:03:00
Measurement Interval	7:24:51	7:34:51	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	60,011.75	35,772.35	7,373.38	16,866.02
1	60,033.10	35,745.47	7,386.47	16,901.17
2	59,992.22	35,744.70	7,365.25	16,882.27
3	59,988.13	35,756.95	7,367.35	16,863.83
4	60,018.75	35,774.23	7,375.38	16,869.13
5	60,021.73	35,778.22	7,375.73	16,867.78
6	59,989.13	35,752.33	7,360.92	16,875.88
7	59,977.88	35,739.65	7,383.57	16,854.67
8	59,926.13	35,700.53	7,392.42	16,833.18
9	60,058.92	35,798.08	7,377.25	16,883.58
10	59,993.20	35,761.12	7,382.48	16,849.60
11	59,980.92	35,750.40	7,377.58	16,852.93
12	59,994.33	35,762.98	7,381.72	16,849.63
Average	***59,994.91***	***35,757.45***	***7,377.44***	***16,860.02***

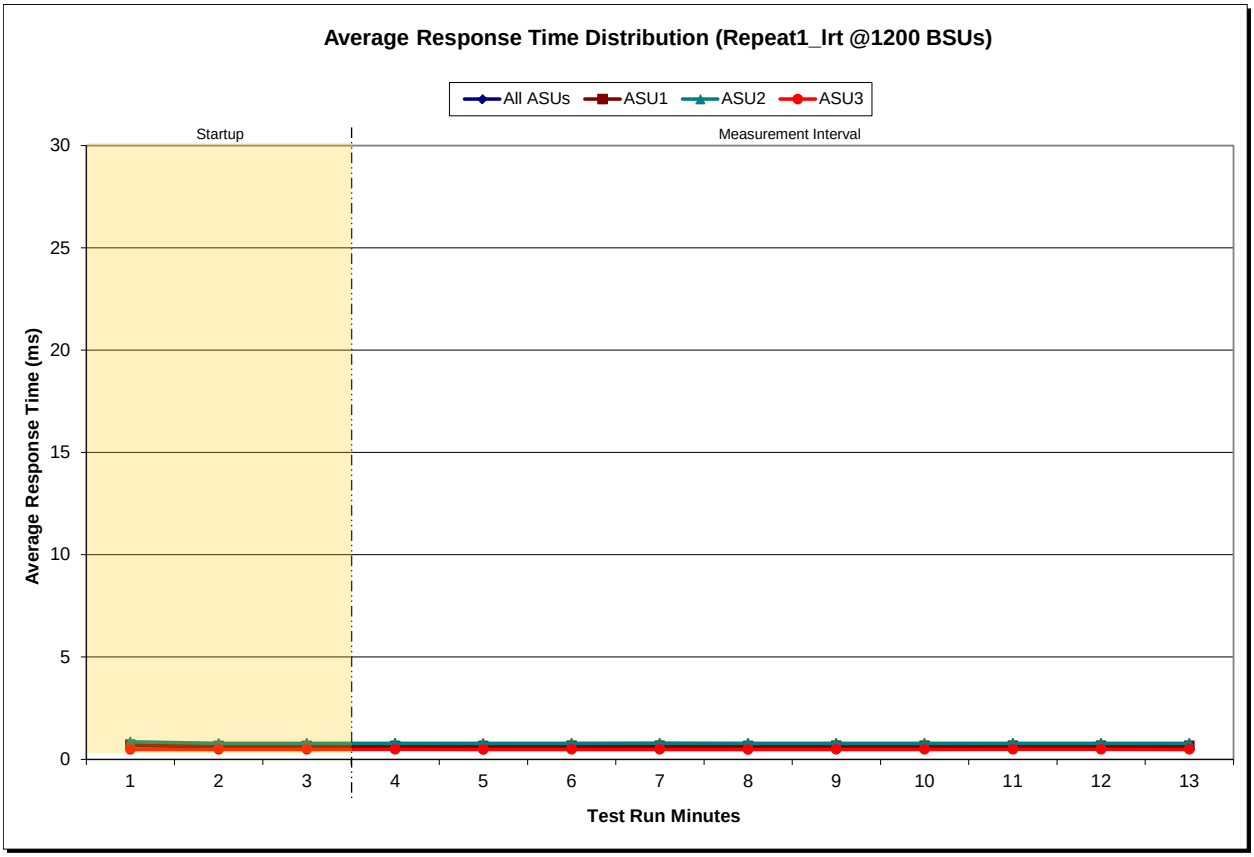
Repeatability 1 LRT – I/O Request Throughput Distribution Graph



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

1,200 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:21:51	7:24:51	0-2	0:03:00
Measurement Interval	7:24:51	7:34:51	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.67	0.71	0.86	0.49
1	0.62	0.65	0.78	0.49
2	0.62	0.65	0.78	0.48
3	0.62	0.65	0.78	0.49
4	0.62	0.65	0.78	0.48
5	0.62	0.66	0.79	0.49
6	0.62	0.66	0.79	0.48
7	0.62	0.65	0.78	0.48
8	0.62	0.66	0.79	0.48
9	0.62	0.66	0.79	0.48
10	0.62	0.66	0.79	0.49
11	0.62	0.65	0.78	0.49
12	0.62	0.65	0.78	0.48
Average	***0.62***	***0.65***	***0.78***	***0.48***

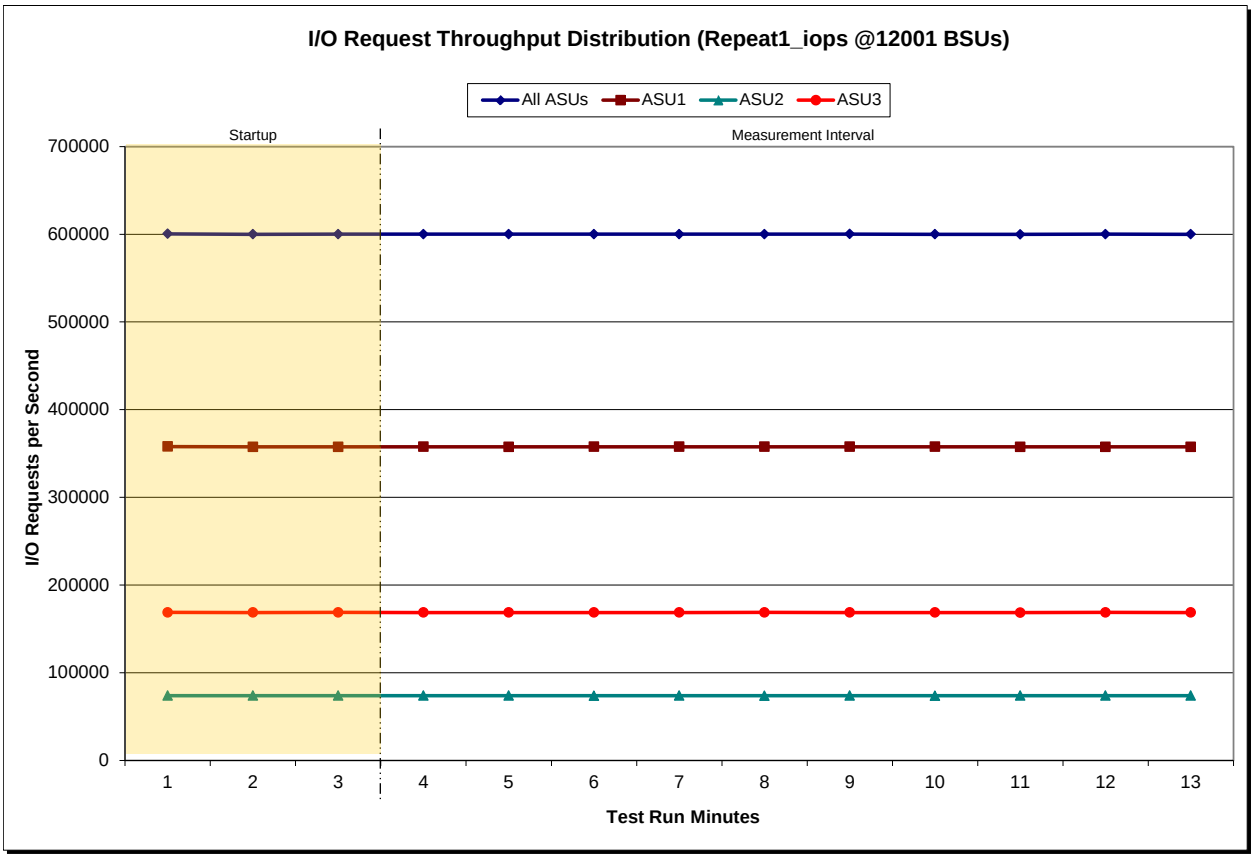
Repeatability 1 LRT –Average Response Time (ms) Distribution Graph



Repeatability 1 IOPS – I/O Request Throughput Distribution Data

12,001 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:36:37	7:39:38	0-2	0:03:01
Measurement Interval	7:39:38	7:49:38	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	600,513.72	357,925.43	73,859.58	168,728.70
1	600,005.75	357,557.73	73,870.15	168,577.87
2	600,116.47	357,585.48	73,833.20	168,697.78
3	600,122.23	357,652.32	73,841.83	168,628.08
4	600,072.95	357,568.90	73,866.02	168,638.03
5	600,054.52	357,657.28	73,722.17	168,675.07
6	600,080.93	357,593.17	73,850.47	168,637.30
7	600,109.87	357,628.05	73,753.90	168,727.92
8	600,184.37	357,681.80	73,832.87	168,669.70
9	599,954.42	357,639.12	73,721.83	168,593.47
10	599,893.88	357,511.42	73,838.03	168,544.43
11	600,128.52	357,521.58	73,872.63	168,734.30
12	600,011.20	357,572.28	73,810.00	168,628.92
Average	***600,061.29***	***357,602.59***	***73,810.98***	***168,647.72***

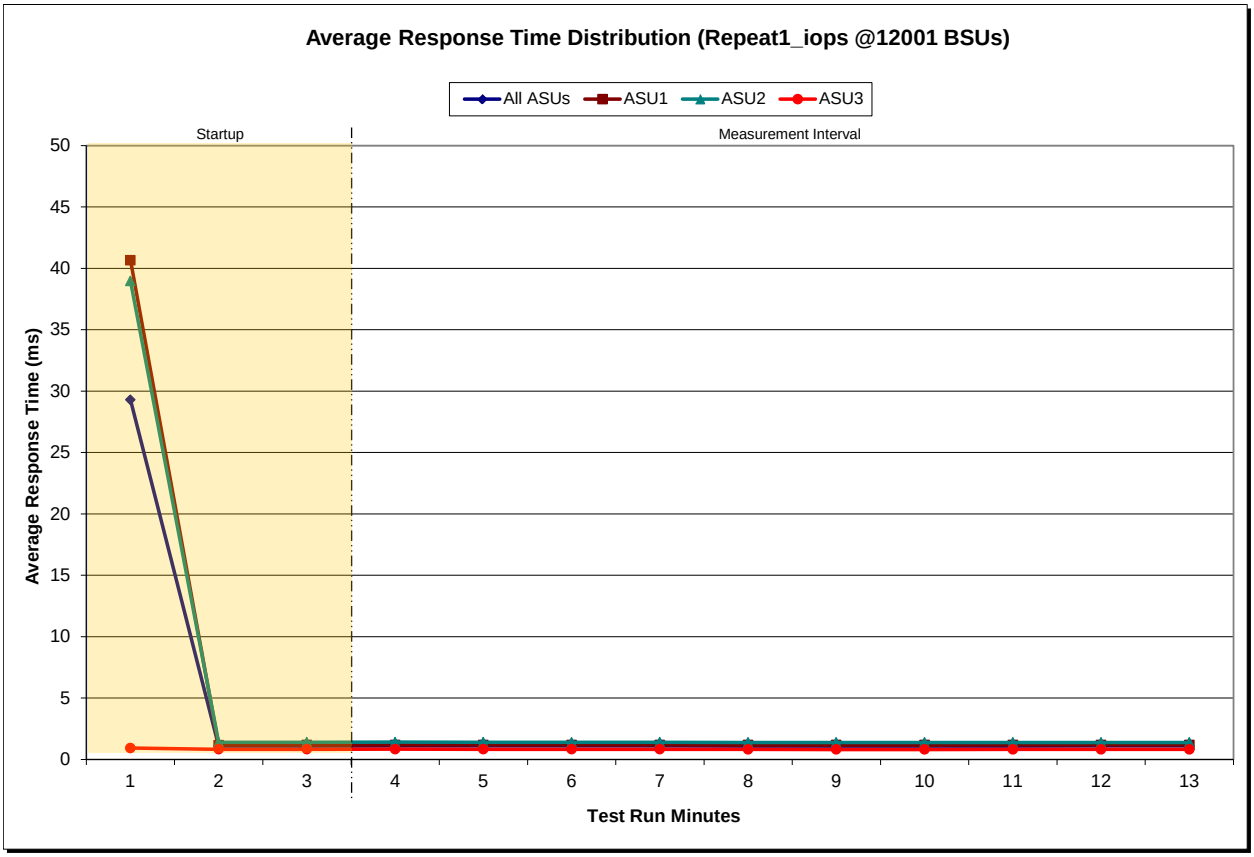
Repeatability 1 IOPS – I/O Request Throughput Distribution Graph



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

12,001 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:36:37	7:39:38	0-2	0:03:01
Measurement Interval	7:39:38	7:49:38	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	29.28	40.65	38.96	0.92
1	1.09	1.16	1.39	0.82
2	1.10	1.16	1.40	0.82
3	1.11	1.18	1.41	0.83
4	1.10	1.17	1.40	0.82
5	1.10	1.17	1.39	0.82
6	1.10	1.18	1.39	0.82
7	1.09	1.17	1.38	0.81
8	1.09	1.17	1.38	0.81
9	1.09	1.17	1.38	0.81
10	1.10	1.17	1.38	0.81
11	1.10	1.18	1.38	0.81
12	1.10	1.18	1.38	0.81
Average	***1.10***	***1.17***	***1.39***	***0.82***

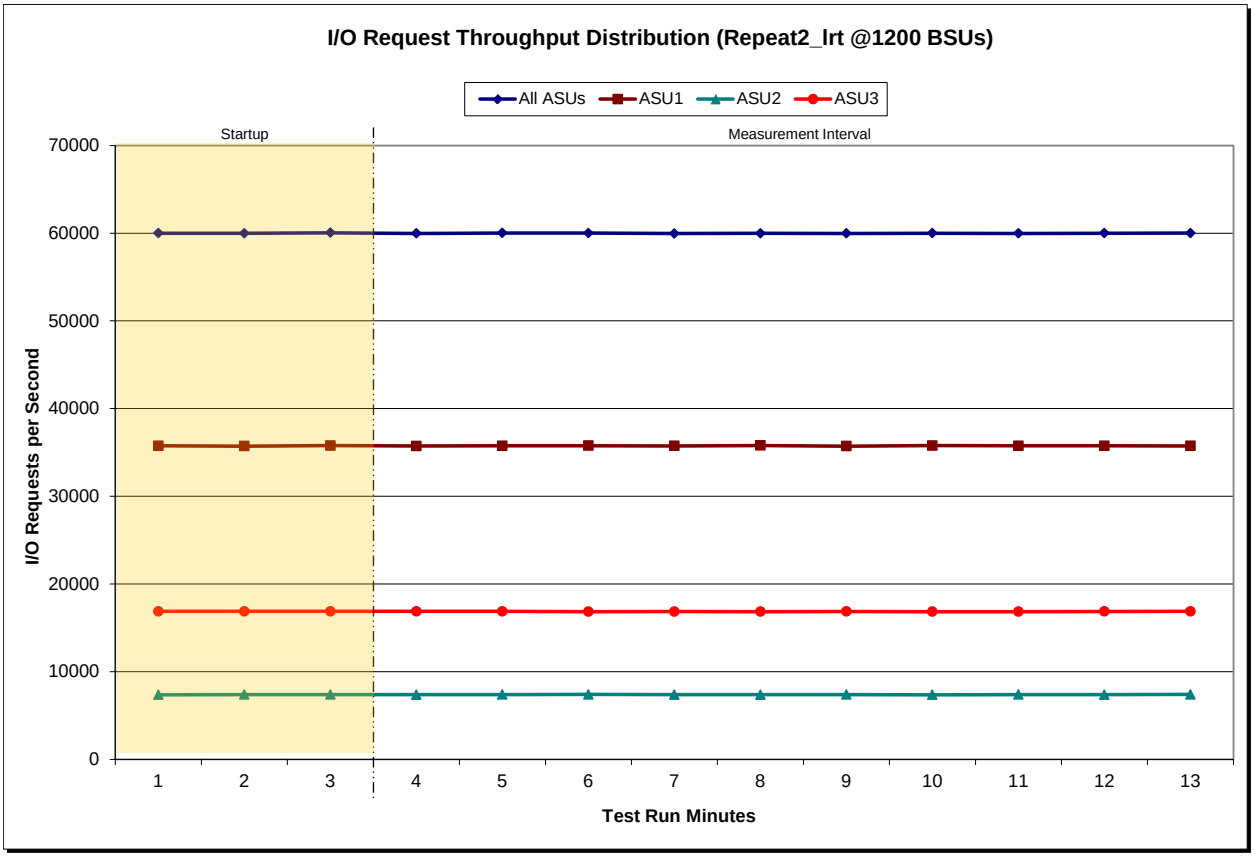
Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph



Repeatability 2 LRT – I/O Request Throughput Distribution Data

1,200 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:50:14	7:53:14	0-2	0:03:00
Measurement Interval	7:53:14	8:03:14	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	59,994.18	35,753.43	7,366.90	16,873.85
1	59,986.35	35,720.57	7,389.75	16,876.03
2	60,042.72	35,781.07	7,385.88	16,875.77
3	59,971.45	35,724.37	7,370.38	16,876.70
4	60,017.73	35,748.52	7,389.07	16,880.15
5	60,005.98	35,768.63	7,394.35	16,843.00
6	59,962.02	35,739.83	7,376.18	16,846.00
7	59,989.77	35,784.58	7,370.12	16,835.07
8	59,969.27	35,719.88	7,391.45	16,857.93
9	59,991.22	35,784.15	7,366.02	16,841.05
10	59,977.08	35,756.67	7,383.05	16,837.37
11	59,993.57	35,755.95	7,375.73	16,861.88
12	60,012.13	35,743.13	7,397.97	16,871.03
Average	***59,989.02***	***35,752.57***	***7,381.43***	***16,855.02***

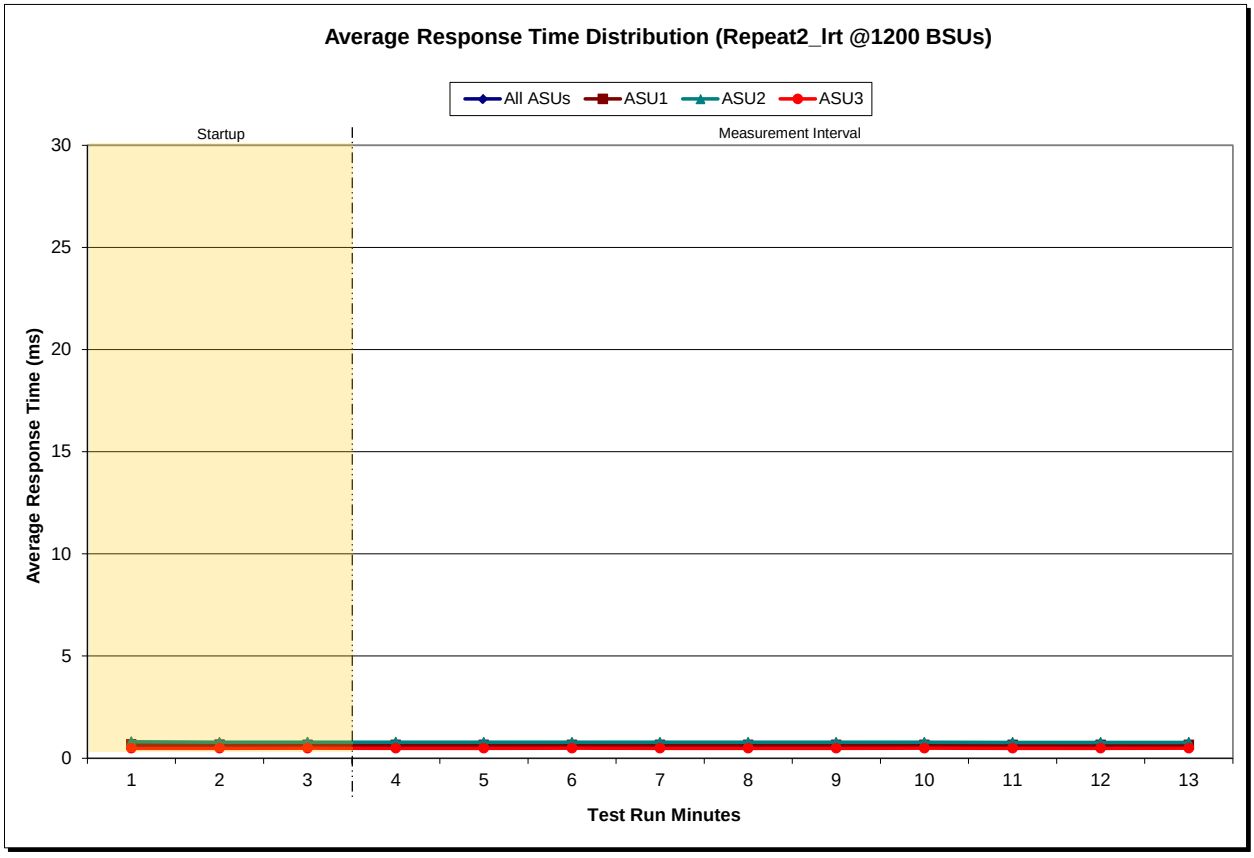
Repeatability 2 LRT – I/O Request Throughput Distribution Graph



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

1,200 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:50:14	7:53:14	0-2	0:03:00
Measurement Interval	7:53:14	8:03:14	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.63	0.67	0.81	0.48
1	0.62	0.65	0.78	0.48
2	0.62	0.65	0.78	0.49
3	0.62	0.65	0.78	0.49
4	0.62	0.65	0.78	0.49
5	0.62	0.65	0.78	0.49
6	0.62	0.65	0.78	0.48
7	0.62	0.65	0.78	0.48
8	0.62	0.65	0.78	0.48
9	0.62	0.65	0.78	0.49
10	0.62	0.65	0.77	0.48
11	0.62	0.65	0.78	0.48
12	0.62	0.65	0.78	0.49
Average	***0.62***	***0.65***	***0.78***	***0.48***

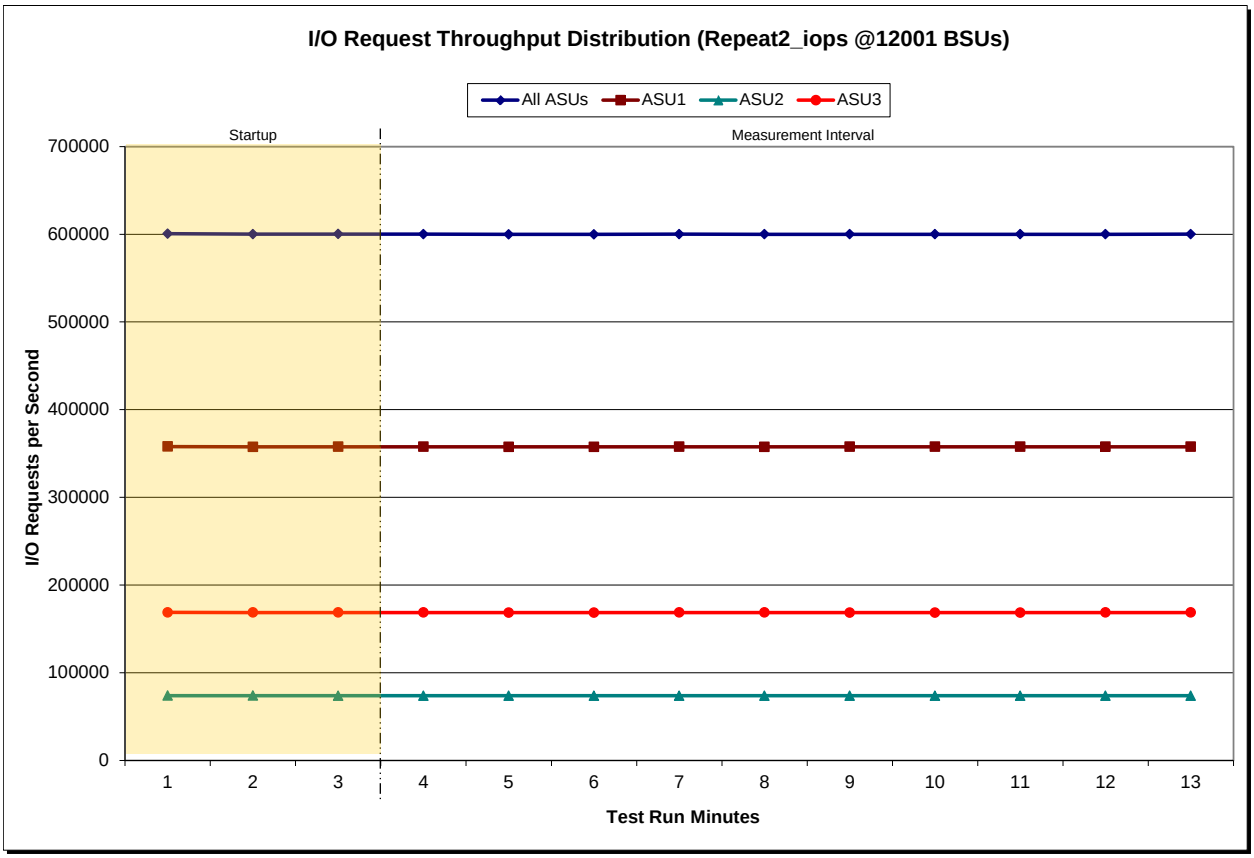
Repeatability 2 LRT –Average Response Time (ms) Distribution Graph



Repeatability 2 IOPS – I/O Request Throughput Distribution Data

1,200 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	8:04:59	8:08:00	0-2	0:03:01
Measurement Interval	8:08:00	8:18:00	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	600,573.28	357,939.87	73,856.65	168,776.77
1	600,033.72	357,589.57	73,828.70	168,615.45
2	600,171.25	357,693.07	73,798.78	168,679.40
3	600,107.60	357,668.98	73,796.30	168,642.32
4	599,891.90	357,554.27	73,782.48	168,555.15
5	599,878.17	357,545.18	73,774.52	168,558.47
6	600,090.27	357,657.78	73,800.70	168,631.78
7	599,963.80	357,579.70	73,768.07	168,616.03
8	600,016.08	357,695.38	73,788.97	168,531.73
9	599,925.37	357,625.08	73,786.92	168,513.37
10	599,971.85	357,703.55	73,717.72	168,550.58
11	599,997.10	357,632.05	73,757.08	168,607.97
12	600,062.87	357,669.20	73,779.65	168,614.02
Average	***599,990.50***	***357,633.12***	***73,775.24***	***168,582.14***

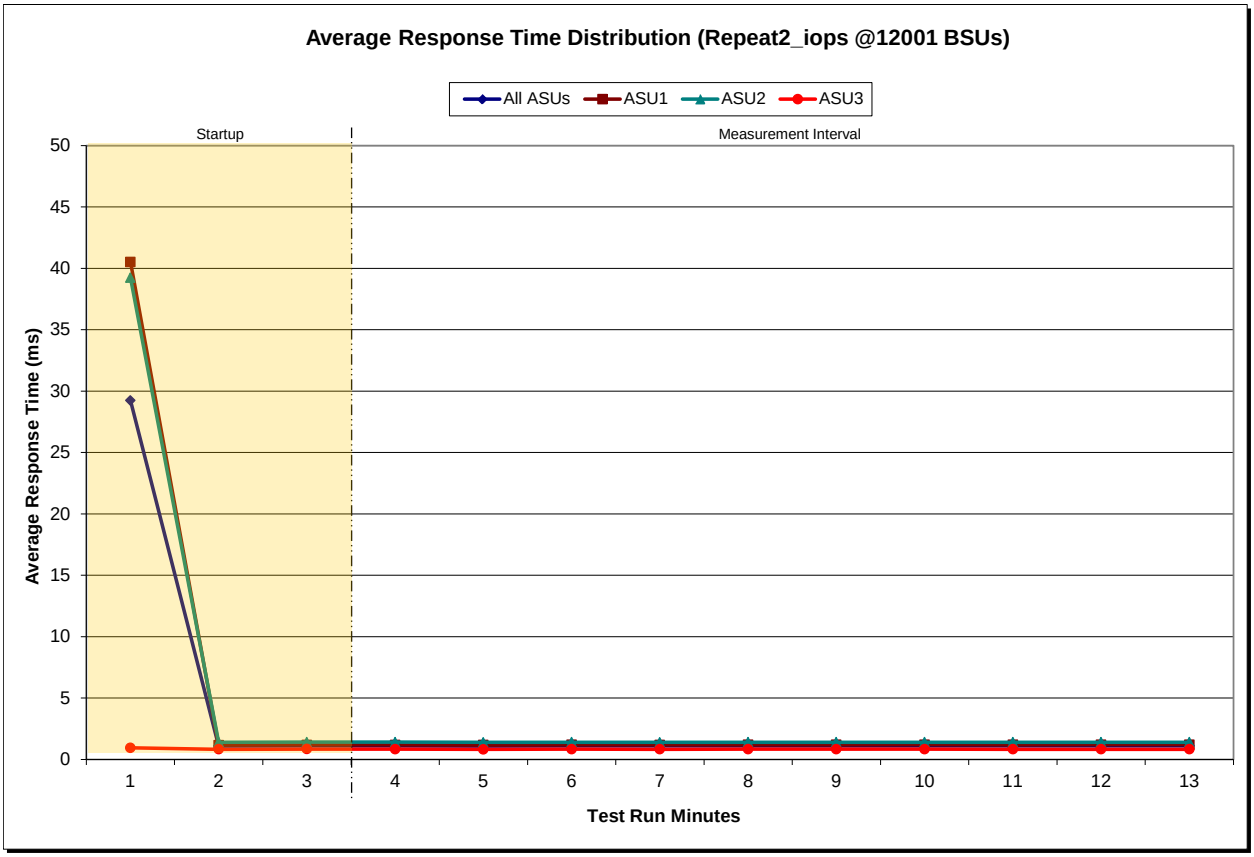
Repeatability 2 IOPS – I/O Request Throughput Distribution Graph



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

1,200 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	8:04:59	8:08:00	0-2	0:03:01
Measurement Interval	8:08:00	8:18:00	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	29.23	40.51	39.23	0.94
1	1.09	1.16	1.40	0.82
2	1.11	1.18	1.41	0.84
3	1.11	1.17	1.40	0.83
4	1.10	1.17	1.39	0.82
5	1.11	1.18	1.40	0.83
6	1.10	1.17	1.39	0.82
7	1.11	1.18	1.40	0.83
8	1.11	1.18	1.40	0.83
9	1.11	1.19	1.40	0.83
10	1.11	1.18	1.40	0.82
11	1.11	1.19	1.40	0.83
12	1.11	1.19	1.40	0.83
Average	***1.11***	***1.18***	***1.40***	***0.83***

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.*

Clauses 5.1.10 and 5.3.13.2

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 5.3.13.3

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	0.0699	0.2101	0.0180	0.0700	0.0349	0.2810
COV	0.002	0.001	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	0.2811
COV	0.001	0.000	0.001	0.000	0.001	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	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.002	0.001	0.002	0.001	0.004	0.002	0.004	0.001

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

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

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 69.

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	411,266,720
Total Number of Logical Blocks Verified	196,520,256
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 9.2.4.9

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 Huawei OceanStor Dorado5100 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 14.

TESTED STORAGE CONFIGURATION (TSC) AND PRICED STORAGE CONFIGURATION DIFFERENCES

Clause 9.4.3.3.7

The Executive Summary shall contain a pricing 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 14.

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 Huawei OceanStor Dorado5100.

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: This level will ensure data protection in the event of a single point of failure of any configured storage device. A brief description of the data protection utilized is included in the Executive Summary.

Unprotected: No claim of data protection is asserted in the event of a single point of failure.

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.

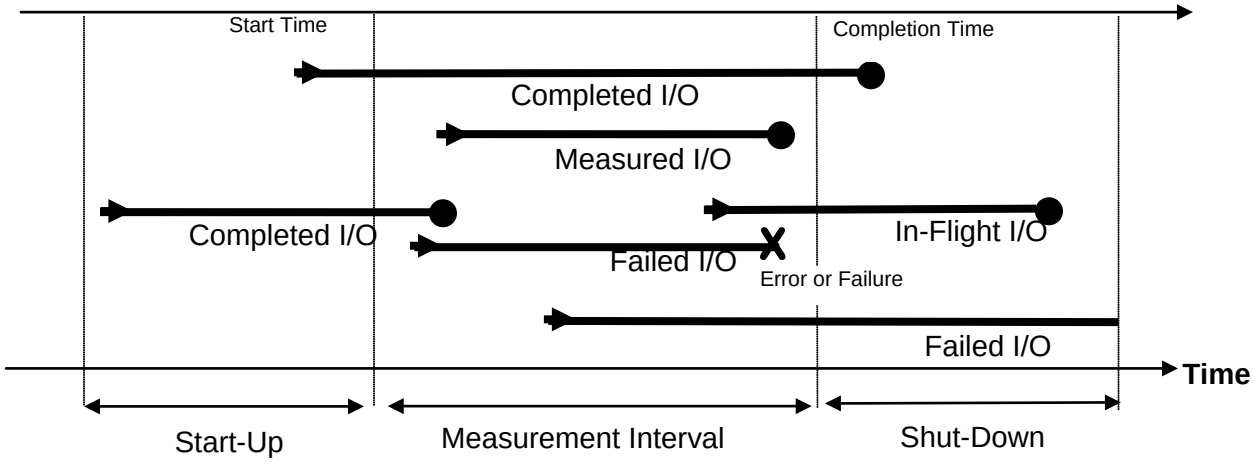
Test: A collection of Test Phases and or Test Runs sharing a common objective.

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

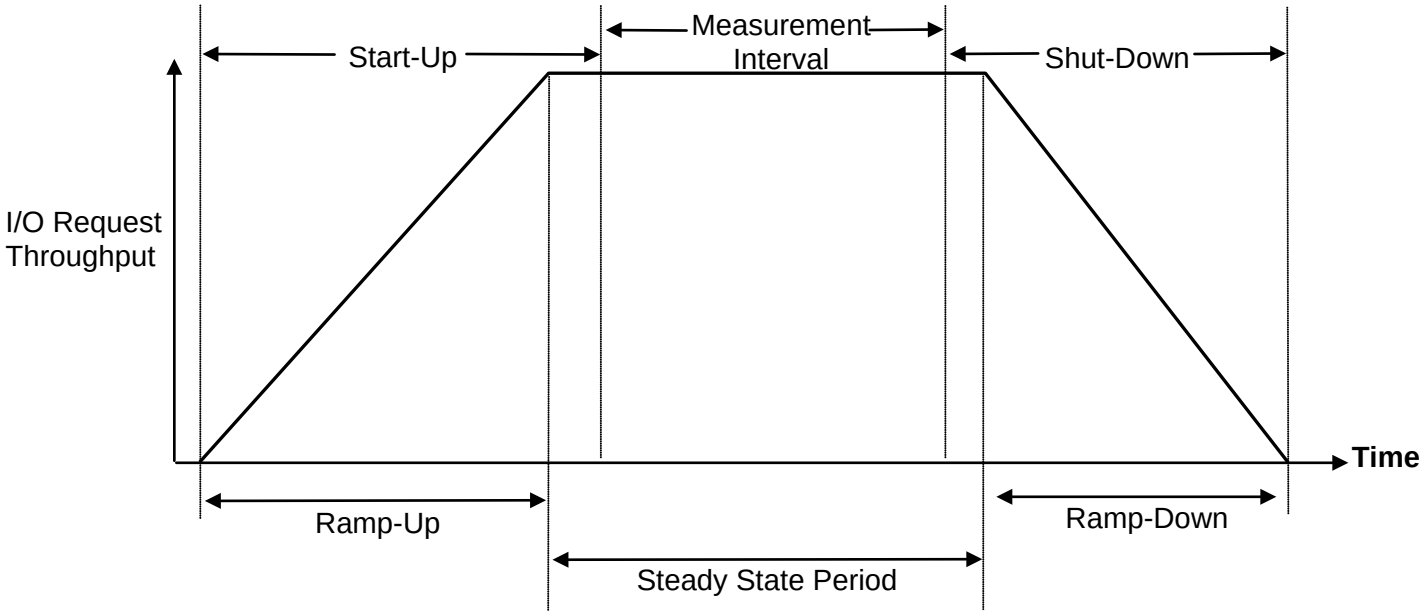
period, Shut-Down period, and Ramp-Down period as illustrated in the "SPC-1 Test Run Components" below. All SPC-1 Test Runs shall have a Steady State period and a Measurement Interval.

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

Red Hat Enterprise Linux 6.2 (64-bit)

Change the I/O scheduler to ***elevator=noop*** on each Host System, which will result in all incoming I/O requests inserted into a simple, unordered FIFO queue. This was done by adding the following parameter in **/boot/grub/grub.conf** file at the end of the kernel line on each Host System.

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

Step 1: Create Host Groups and Hosts

The **mkhostport.tcl** script on the first Host System ('Master Host System') using the ***expect*** command. That script will:

- Log into the Dorado5100 CLI and create one Host Group
- Add two Hosts to the Host Group
- Add FC WWNs connected to storage controller A to Host 0
- Add FC WWNs connected to storage controller B to Host 1

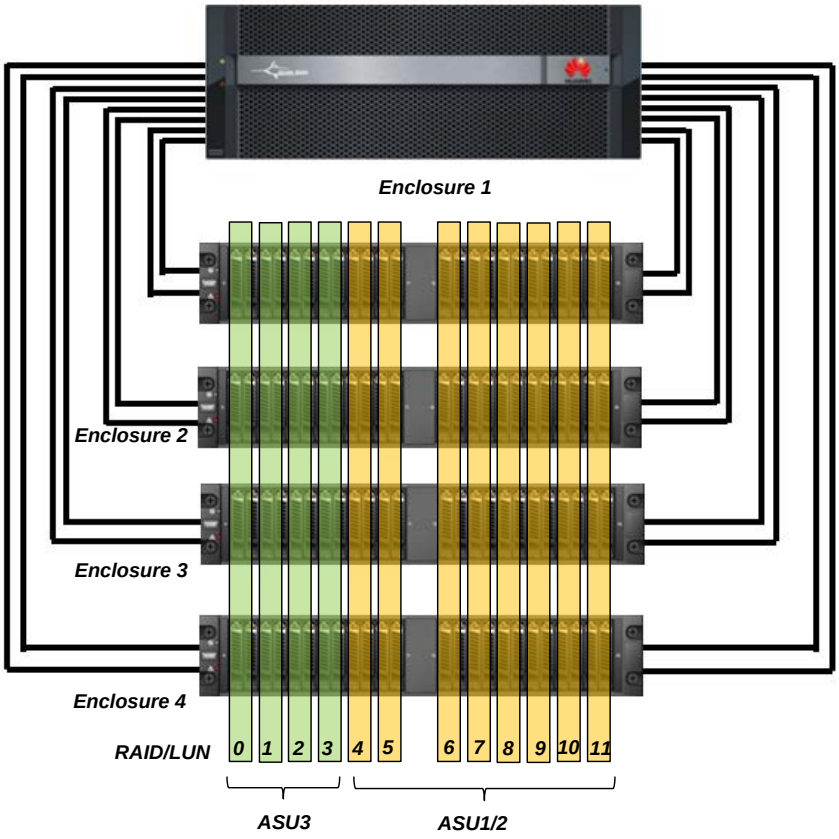
Expect *is a Unix automation and testing tool, written by Don Libes as an extension to the Tcl scripting language, for interactive applications such as telnet, ftp, passwd, fsck, rlogin, tip, ssh, and others. It uses Unix pseudo terminals to wrap up subprocesses transparently, allowing the automation of arbitrary applications that are accessed over a terminal. Expect is an open source tool can be downloaded here :* http://www.nist.gov/el/msid/expect.cfm.

Step 2: Create RAID Groups and LUNs

The **mklun.sh** script is executed on the Master Host System, which will then invoke the **mklun.tcl** script to:

- Create 12 RAID Groups with the ***createrg*** command, which sequentially selected two storage devices from each of the four enclosures. RAID Groups 0-3 were used for ASU-3 and RAID Groups 4-11 were used for ASU-1 and ASU-2 as illustrated below.
- Create 12 LUNs *(one LUN per RAID Group)* with the ***createlun*** command, using all available capacity for each LUN.
- The ***addhostmap*** command mapped LUNs 0, 2, 4, 6, 8 and 10 *(even IDs)* to Host 1 and LUNs 1, 3, 5, 7, 9, and 11 *(odd IDs)* to Host 1.

LUNs with even IDs were scanned as **/dev/sdb** - **/dev/sdg** on the four Host Systems. LUNs with odd IDs were scanned as **/dev/sdh** - **/dev/sdm** on the four Host Systems.



Step 3: Create Volumes on Master Host System

The **mklv.sh** script is executed on the Master Host System to:

- Create twelve physical volumes, one for each block device ***(/dev/sdb - /dev/sdm)***.
- Create the volume group vg0 using four of the physical volumes.
- Create the volume group vg1 using the remaining eight physical volumes.
- Create five logical volumes, which will comprise the SPC-1 ASUs.
- Scan the physical volumes, volume groups and logical volumes on the remaining three Host Systems.

Referenced Scripts

mkhostport.tcl

```
set stor 129.22.242.3
set stor_user admin
set stor_pswd Admin@storage

# login storage

spawn ssh $stor_user@$stor

expect {
     "assword" {
           send "$stor_pswd\r"
     }
     "yes/no" {
           send "yes\r"
           expect "assword"
           send "$stor_pswd\r"
     }
}
expect ">"

set timeout 60

send "createhostgroup -n spc1\r"
expect ">"

send "addhost -group 1 -n hba_a -t 0\r"
expect ">"
send "addhost -group 1 -n hba_b -t 0\r"
expect ">"

send "addhostport -host 1 -type 1 -wwn 21000024ff3a3eb6 -n host1_b\r"
expect ">"
send "addhostport -host 1 -type 1 -wwn 21000024ff3a3a28 -n host2_b\r"
expect ">"
send "addhostport -host 1 -type 1 -wwn 21000024ff3a3d5c -n host3_b\r"
expect ">"
send "addhostport -host 1 -type 1 -wwn 21000024ff208834 -n host4_b\r"
expect ">"

send "addhostport -host 0 -type 1 -wwn 21000024ff3a3eb7 -n host1_a\r"
expect ">"
send "addhostport -host 0 -type 1 -wwn 21000024ff3a3a29 -n host2_a\r"
expect ">"
send "addhostport -host 0 -type 1 -wwn 21000024ff3a3d5d -n host3_a\r"
expect ">"
send "addhostport -host 0 -type 1 -wwn 21000024ff208835 -n host4_a\r"
expect ">"

send "exit\r"
expect "(y/n):"
send "y\r"
expect "closed"
```

mklun.sh

```
expect mklun.tcl
for host in host1 host2 host3 host4
do
  ssh $host rmmod qla2xxx
  ssh $host modprobe qla2xxx
done
```

mklun.tcl

```
set stor 129.22.242.3
set stor_user admin
set stor_pswd Admin@storage

# login storage

spawn ssh $stor_user@$stor

expect {
     "assword" {
            send "$stor_pswd\r"
     }
     "yes/no" {
            send "yes\r"
            expect "assword"
            send "$stor_pswd\r"
     }
}
expect ">"

set timeout 60

set lunid 0
set rgid 0


# create ASU3 RAIDs & LUNs

set asu3id 0

for {set d 0} { $d <= 6 } { set d [ expr $d + 2 ] } {
     set m [ expr $d + 1 ]
     send "createrg -n ASU3-$asu3id -l 10 -num 2 -list
1,$d:1,$m:2,$d:2,$m:3,$d:3,$m:4,$d:4,$m:\r"
     expect "(y/n)"
     send "y\r"
     expect ">"
     send "showrg -rg $rgid\r"
     expect ">"
     if [ expr $lunid%2 ] {
            set ctrl b
            set host 1
     } else {
            set ctrl a
            set host 0
     }
     send "createlun -rg $rgid -n ASU3-$asu3id -susize 512 -c $ctrl\r"
     set sucsses 0
     while { $sucsses == 0 } {
            expect {
```

```
                    "Error" {
                           expect ">"
                           sleep 1
                           send "createlun -rg $rgid -n ASU3-$asu3id -susize 512 -c
$ctrl\r"
                    }
                    ">" {
                           set sucsses 1
                    }
             }
      }
      send "showlun -lun $lunid\r"
      expect ">"
      send "addhostmap -host $host -devlun $lunid\r"
      set sucsses 0
      while { $sucsses == 0 } {
             expect {
                    "Error" {
                           expect ">"
                           sleep 1
                           send "addhostmap -host $host -devlun $lunid\r"
                    }
                    ">" {
                           set sucsses 1
                    }
             }
      }
      incr lunid
      incr rgid
      incr asu3id
}

# create ASU1/2 RAIDs & LUNs

set asu12id 0

for {set d 8} { $d <= 22 } { set d [ expr $d + 2 ] } {
      set m [ expr $d + 1 ]
      send "createrg -n ASU12-$asu12id -l 10 -num 2 -list
1,$d:1,$m:2,$d:2,$m:3,$d:3,$m:4,$d:4,$m:\r"
      expect "(y/n)"
      send "y\r"
      expect ">"
      send "showrg -rg $rgid\r"
      expect ">"
      if [ expr $lunid%2 ] {
             set ctrl b
             set host 1
      } else {
             set ctrl a
             set host 0
      }
      send "createlun -rg $rgid -n ASU12-$asu12id -susize 512 -c $ctrl\r"
      set sucsses 0
      while { $sucsses == 0 } {
             expect {
                    "Error" {
                           expect ">"
                           sleep 1
                           send "createlun -rg $rgid -n ASU12-$asu12id -susize 512 -c
$ctrl\r"
                    }
                    ">" {
```

```
                        set sucsses 1
                }
        }
        send "showlun -lun $lunid\r"
        expect ">"
        send "addhostmap -host $host -devlun $lunid\r"
        set sucsses 0
        while { $sucsses == 0 } {
                expect {
                "Error" {
                        expect ">"
                        sleep 1
                        send "addhostmap -host $host -devlun $lunid\r"
                }
                ">" {
                        set sucsses 1
                }
        }
        }

        incr lunid
        incr rgid
        incr asu12id
}

send "exit\r"
expect "(y/n):"
send "y\r"
expect "closed"
```

mklv.sh

```
pvcreate /dev/sdb
pvcreate /dev/sdc
pvcreate /dev/sdd
pvcreate /dev/sde
pvcreate /dev/sdf
pvcreate /dev/sdg
pvcreate /dev/sdh
pvcreate /dev/sdi
pvcreate /dev/sdj
pvcreate /dev/sdk
pvcreate /dev/sdl
pvcreate /dev/sdm
vgcreate vg0 /dev/sdb /dev/sdc /dev/sdh /dev/sdi
vgcreate vg1 /dev/sdd /dev/sde /dev/sdf /dev/sdg /dev/sdj /dev/sdk /dev/sdl /dev/sdm
lvcreate -n asu3 -i 4 -I 512 -L 600g vg0
lvcreate -n asu11 -i 8 -I 512 -L 1350g vg1
lvcreate -n asu12 -i 8 -I 512 -L 1350g vg1
lvcreate -n asu21 -i 8 -I 512 -L 1350g vg1
lvcreate -n asu22 -i 8 -I 512 -L 1350g vg1
for host in host2 host3 host4
do
  ssh $host pvscan
  ssh $host vgscan
  ssh $host lvscan
  ssh $host lvchange -ay /dev/vg0/asu3
  ssh $host lvchange -ay /dev/vg1/asu11
  ssh $host lvchange -ay /dev/vg1/asu12
  ssh $host lvchange -ay /dev/vg1/asu21
  ssh $host lvchange -ay /dev/vg1/asu22
```

```
done
```

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

Primary Metrics and Repeatability Tests

The content of SPC-1 Workload Generator command and parameter file, used in this benchmark to execute the Primary Metrics and Repeatability Tests, is listed below.

```
host=master
slaves=(slave1,slave2,slave3,slave4,slave5,slave6,slave7,slave8,slave9,slave10,slave
11,slave12,slave13,slave14,slave15,slave16,slave17,slave18,slave19,slave20,slave21,s
lave22,slave23,slave24,slave25,slave26,slave27,slave28,slave29,slave30,slave31,slave
32,slave33,slave34,slave35,slave36,slave37,slave38,slave39,slave40,slave41,slave42,s
lave43,slave44,slave45,slave46,slave47,slave48,slave49,slave50,slave51,slave52,slave
53,slave54,slave55,slave56,slave57,slave58,slave59,slave60,slave61,slave62,slave63,s
lave64,slave65,slave66,slave67,slave68,slave69,slave70,slave71,slave72,slave73,slave
74,slave75,slave76,slave77,slave78,slave79,slave80,slave81,slave82,slave83,slave84,s
lave85,slave86,slave87,slave88,slave89,slave90,slave91,slave92,slave93,slave94,slave
95,slave96,slave97,slave98,slave99,slave100,slave101,slave102,slave103,slave104,slav
e105,slave106,slave107,slave108,slave109,slave110,slave111,slave112,slave113,slave11
4,slave115,slave116,slave117,slave118,slave119,slave120,slave121,slave122,slave123,s
lave124)
sd=asu1_1,lun=/dev/vg1/asu11,size=1449551462400
sd=asu1_2,lun=/dev/vg1/asu12,size=1449551462400
sd=asu2_1,lun=/dev/vg1/asu21,size=1449551462400
sd=asu2_2,lun=/dev/vg1/asu22,size=1449551462400
sd=asu3_1,lun=/dev/vg0/asu3,size=644245094400
```

SPC-1 Persistence Test

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

```
sd=asu1_1,lun=/dev/vg1/asu11,size=1449551462400
sd=asu1_2,lun=/dev/vg1/asu12,size=1449551462400
sd=asu2_1,lun=/dev/vg1/asu21,size=1449551462400
sd=asu2_2,lun=/dev/vg1/asu22,size=1449551462400
sd=asu3_1,lun=/dev/vg0/asu3,size=644245094400
```

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. **slave1**, **slave2**, **slave3**… .

```
master=host1
host=slave1
sd=asu1_1,lun=/dev/vg1/asu11,size=1449551462400
sd=asu1_2,lun=/dev/vg1/asu12,size=1449551462400
sd=asu2_1,lun=/dev/vg1/asu21,size=1449551462400
sd=asu2_2,lun=/dev/vg1/asu22,size=1449551462400
sd=asu3_1,lun=/dev/vg0/asu3,size=644245094400
```

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

ASU Pre-Fill, Primary Metrics Test, Repeatability Test, Persistence Test Run 1, TSC power off/power on and Persistence Test Run 2

The following script was used to execute the required ASU pre-fill, 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 Persistence Test Run 1 in an uninterrupted sequence. The script pauses until the required TSC power off/power on cycle is completed then executes Persistence Test Run 2.

```
JAVA="java -Xms1024m -Xmx1024m -Xss256k"
EXEDIR=/dorado/script

expect shstorage.tcl > profile1_storage.log
date > profile1_volume.log
pvdisplay >> profile1_volume.log
vgdisplay >> profile1_volume.log
lvdisplay >> profile1_volume.log
date >> profile1_volume.log

../vdbench/vdbench -f prefilling.cfg -o prefilling

N=1
for host in host1 host2 host3 host4
do
  ssh $host rm -rf $EXEDIR/output
  ssh $host rm -rf $EXEDIR/config
  ssh $host mkdir $EXEDIR/output
  ssh $host mkdir $EXEDIR/config
  for((i=1;i<=31;i++))
  do
    echo "start slave$N on $host"
    echo "master=host1" > $EXEDIR/config/slave$N.cfg
    echo "host=slave$N" >> $EXEDIR/config/slave$N.cfg
    echo "sd=asu1_1,lun=/dev/vg1/asu11,size=1449551462400" >>
$EXEDIR/config/slave$N.cfg
    echo "sd=asu1_2,lun=/dev/vg1/asu12,size=1449551462400" >>
$EXEDIR/config/slave$N.cfg
    echo "sd=asu2_1,lun=/dev/vg1/asu21,size=1449551462400" >>
$EXEDIR/config/slave$N.cfg
    echo "sd=asu2_2,lun=/dev/vg1/asu22,size=1449551462400" >>
$EXEDIR/config/slave$N.cfg
    echo "sd=asu3_1,lun=/dev/vg0/asu3,size=644245094400" >>
$EXEDIR/config/slave$N.cfg
    scp $EXEDIR/config/slave$N.cfg $host:$EXEDIR/config/slave$N.cfg
    ssh $host "$JAVA -cp $EXEDIR/../spc1 spc1 -f $EXEDIR/config/slave$N.cfg -o
$EXEDIR/output/slave$N" > /dev/null &
    N=$[N+1]
  done
done

rm -rf spc1.cfg
cp metrics.cfg spc1.cfg

$JAVA -cp ../spc1 metrics -b 12001 -t 28800
$JAVA -cp ../spc1 repeat1 -b 12001
$JAVA -cp ../spc1 repeat2 -b 12001
```

```
for host in host1 host2 host3 host4
do
  ssh $host killall java
done

rm -rf spc1.cfg
cp persist.cfg spc1.cfg

$JAVA -cp ../spc1 persist1 -b 6000

echo "Power cycle TSC, then Enter to continue"
read

expect shstorage.tcl > profile2_storage.log
date > profile2_volume.log
pvdisplay >> profile2_volume.log
vgdisplay >> profile2_volume.log
lvdisplay >> profile2_volume.log
date >> profile2_volume.log

$JAVA -cp ../spc1 persist2
```

APPENDIX F: THIRD-PARTY QUOTATION

EVEN ENTERPRISES, INC.

Even Enterprises
12439 Magnolia Blvd. Suite# 303
N. Hollywood, CA 91607
Phone: 818-793-4403
Fax: 818-302-3344

Even Enterprises Quotation

Issued To: «Company»
«First_Name» «Last_Name»
«City», «State»
Phone: «Business_Phone»
Email: «Email»

DATE ISSUED: August 7, 2012
PAYMENT TERMS: Credit Card / Net 30 (upon approval)
Salesperson: Esti Even
Prices subject to change without notice
Prices Valid for 90 days Confidential

No.	Model	Description	Add	Unit Price ($)	Total Price ($)
1	Dorado5100 V100R001		1	398,899.00	398,899.00
1.1	Main Equipment				383,558.00
	Storage Processor Enclosure				16,214.00
	STTZ14SPES	OceanStor Dorado5100 High Performance Solid State Storage System Controller Enclosure(AC,1000000 IOPS,8GBps Bandwidth,8*8G FC Front-End Port,4*4*6G SAS Back-End Port,with HS HSSD Controller System Software,SPE61C0200)	1	16,214.00	16,214.00
	Expand Interface Module				7,852.00
	LPU2S6	2*24Gbps SAS-wide I/O modules(Total 2 ports)	6	1,020.00	6,120.00
	LPU4F8	4*8Gbps Fibre Channel I/O modules(Total 4 ports)	2	866.00	1,732.00
	Disk Enclosure				359,492.00
	STTZ06DAE24	High Performance Solid State Storage System Disk Enclosure-4.8TB(2U,AC,24*200GB SLC,with HS SAS in Band Management Software,DAE12425U2)	4	89,873.00	359,492.00
1.2	Installation Material				88.00
	SS-OP-D-LC-M-3	Patchcord,DLC/PC-DLC/PC,Multimode,2mm Parallel,3m	8	11.00	88.00
1.3	Software				4,557.00
	LIC-Dorado-ISM02	HS Integrated Storage Manager-Device Management License for Dorado	1	4,557.00	4,557.00
1.4	Third Party				10,696.00
	QLE2562-CK	QLogic Dual Port 8Gb Fibre Channel to PCI Express Host Bus Adapter (QLE2562-CK)	4	2,598.00	10,392.00
	mini-SAS-1	Purchased Cable,MiniSAS Cable,28AWG,Key246,1m	8	38	304.00
Total of Product					398,899.00
Total Service 3-year Hi-Care Premier Support service					89,718.00
Total Price					488,617.00

Notes: Hi-Care Premier Support service include: 7*24 Remote Support. Access to all new software updates.
4 Hours Parts Delivery. 4 Hours Engineer Onsite