



**SPC BENCHMARK 1™  
FULL DISCLOSURE REPORT**

**SUN MICROSYSTEMS, INC.  
SUN STORAGE 6180 ARRAY**

**SPC-1 V1.11**

**Submitted for Review: October 9, 2009**

**Submission Identifier: A00084**

**Revised: August 4, 2010**

**First Edition – October 2009**

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## AUDIT CERTIFICATION



Leah Schoeb  
Sun Microsystems, Inc.  
AUS08  
5300 Riata Park Court  
Austin, TX 78721

October 9, 2009

The SPC Benchmark 1™ results listed below for the Sun Storage 6180 Array were produced in compliance with the SPC Benchmark 1™ 1.11 Remote Audit requirements.

SPC Benchmark 1™ 1.11 Results	
Tested Storage Configuration (TSC) Name:	
Sun Storage 6180 Array	
Metric	Reported Result
SPC-1 IOPS™	26,090.03
SPC-1 Price-Performance	\$4.70/SPC-1 IOPS™
Total ASU Capacity	5,145.060 GB
Data Protection Level	Protected ( <i>Mirroring</i> )
Total TSC Price (including three-year maintenance)	\$122,623

The following SPC Benchmark 1™ Remote Audit requirements were reviewed and found compliant with 1.11 of the SPC Benchmark 1™ specification:

- ♦ A Letter of Good Faith, signed by a senior executive.
- ♦ The following Data Repository storage items, based on information supplied by Sun Microsystems, Inc.:
  - ✓ 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.
- ♦ An appropriate diagram of the Benchmark Configuration (BC)/Tested Storage Configuration (TSC).

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650.556.9384

**AUDIT CERTIFICATION** (CONT.)

Sun Storage 6180 Array  
SPC-1 Audit Certification

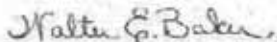
Page 2

- 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, based on information supplied by Sun Microsystems, Inc.:
  - ✓ The type of 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 Sun Microsystems, Inc. for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4 and 5 of the SPC-1 Benchmark Specification:
  - ✓ Data Persistence Test
  - ✓ Sustainability Test Phase
  - ✓ IOPS Test Phase
  - ✓ Response Time Ramp Test Phase
  - ✓ Repeatability Test
- There were no differences between the Tested Storage Configuration (TSC) used for the benchmark and Priced Storage.
- 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  
SPC Auditor

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## **LETTER OF GOOD FAITH**



Sun Microsystems, Inc.  
18 Network Circle, Menlo Park, CA 94025

Date: 9/14/09

From: Lisa Sieker

To: Walter Baker

Subject: SPC-1 Letter of Good Faith for the Sun Storagetek® 6180 Array

Sun Microsystems Inc. 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 V1.10.1 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:

A handwritten signature in black ink, appearing to read "Lisa Sieker".

---

Lisa Sieker  
Vice President, Systems Marketing

## **EXECUTIVE SUMMARY**

### **Test Sponsor and Contact Information**

<b>Test Sponsor and Contact Information</b>	
<b>Test Sponsor Primary Contact</b>	Sun Microsystems, Inc. – <a href="http://www.sun.com">http://www.sun.com</a> Steven A. Johnson – <a href="mailto:steven.a.johnson@oracle.com">steven.a.johnson@oracle.com</a> 500 Eldorado Blvd. UBRM05-194 Broomfield, CO 80021 Phone: (303) 272-9476 FAX: (303) 272-4886
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<b>Auditor</b>	Storage Performance Council – <a href="http://www.storageperformance.org">http://www.storageperformance.org</a> Walter E. Baker – <a href="mailto:AuditService@StoragePerformance.org">AuditService@StoragePerformance.org</a> 643 Bair Island Road, Suite 103 Redwood City, CA 94063 Phone: (650) 556-9384 FAX: (650) 556-9385

### **Revision Information and Key Dates**

<b>Revision Information and Key Dates</b>	
<b>SPC-1 Specification revision number</b>	V1.11
<b>SPC-1 Workload Generator revision number</b>	V2.1.0
<b>Date Results were first used publicly</b>	October 9, 2009
<b>Date the FDR was submitted to the SPC</b>	October 9, 2009
<b>Date revised FDR was submitted to the SPC</b> Revised Total TSP Price and SPC-1 Price-Performance ( <i>page 11</i> ) Revised pricing ( <i>page 14</i> ) Revised TSC/Priced Storage Configuration differences ( <i>page 14</i> ) Revised Priced Storage Configuration component table ( <i>page 15</i> ) Revised Host System and TSC component table ( <i>page 18</i> ) ( <i>revisions highlighted in red on the above pages</i> )	August 4, 2010
<b>Date the priced storage configuration is available for shipment to customers</b>	currently available
<b>Date the TSC completed audit certification</b>	October 8, 2009

## Tested Storage Product (TSP) Description

The Sun Storage 6180 Array is a modular, rack mountable and scalable array designed specifically to grow with your applications, lowering acquisition and expansion costs. The NEBS Level-3 certified Sun Storage 6180 Array offers 8 gigabits-per-second (Gb/sec) Fibre Channel (FC) host interfaces designed for both direct attached and SAN attached storage. The system features a fully redundant architecture with drive intermixing (FC or SATA-II disk drives) in the same drive enclosure, leverages the existing Common Storage Modules (CSM200) expansion trays for primary and secondary storage requirements. With redundant components, automated path failover and extensive online configuration, re-configuration, dynamic expansion and maintenance capabilities, the Sun Storage 6180 Array is designed to ensure your data is available 24x7x365.

## Summary of Results

SPC-1 Results	
Tested Storage Configuration (TSC) Name: Sun Storage 6180 Array	
Metric	Reported Result
SPC-1 IOPS™	26,090.03
SPC-1 Price-Performance	\$4.37/SPC-1 IOPS™
Total ASU Capacity	5,145.060 GB
Data Protection Level	Protected ( <i>Mirroring</i> )
Total TSC Price (including three-year maintenance)	\$114,042

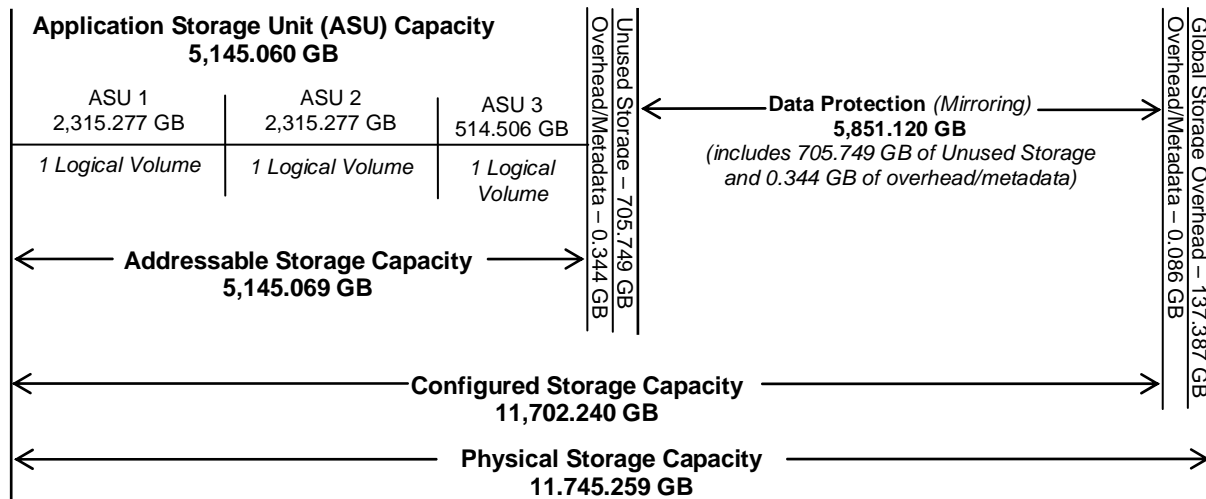
**SPC-1 IOPS™** represents the maximum I/O Request Throughput at the 100% load point.

**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	43.81%
Protected Application Utilization	87.61%
Unused Storage Ratio	12.02%

**Application Utilization:** Total ASU Capacity (5,145.060 GB) divided by Physical Storage Capacity (11,745.259 GB)

**Protected Application Utilization:** (Total ASU Capacity (5,145.060 GB) plus total Data Protection Capacity (5,851.120GB) minus unused Data Protection Capacity (705.749 GB)) divided by Physical Storage Capacity (GB)

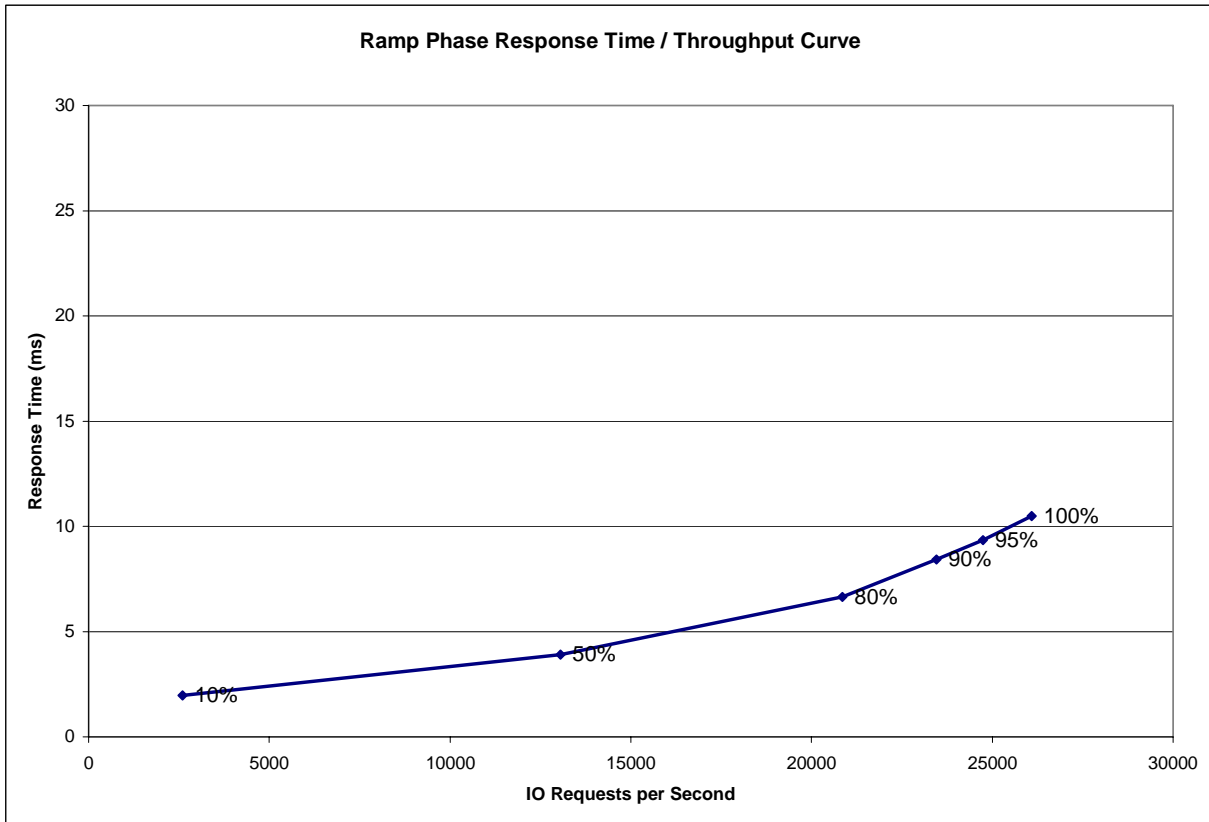
**Unused Storage Ratio:** Total Unused Capacity (1,411.507 GB) divided by Physical Storage Capacity (11,745.259 GB) and may not exceed 45%.

Detailed information for the various storage capacities and utilizations is available on pages 20-21 in the Full Disclosure Report.

### 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
<b>I/O Request Throughput</b>	2,602.65	13,053.24	20,850.35	23,457.23	24,747.16	26,090.03
<b>Average Response Time (ms):</b>						
All ASUs	1.97	3.91	6.64	8.44	9.35	10.49
ASU-1	2.63	5.09	8.13	9.95	10.82	11.91
ASU-2	2.40	5.20	11.59	16.58	19.09	21.99
ASU-3	0.38	0.83	1.32	1.65	1.98	2.45
Reads	4.47	8.71	14.92	18.97	20.82	23.02
Writes	0.34	0.78	1.26	1.57	1.89	2.33

## Priced Storage Configuration Pricing

Part Number	Description	Quantity	US List	Total	discount	Ave. Price
TB6180R11A2-0	Sun Storage 6180 array with 4GB cache and 4 * FC host ports, Rack-Ready Controller Tray - Diskless Chassis, 0GB, 0 drives; Includes: 2 * 2GB-cache memory FC RAID Controller cards, 2 * redundant AC power supplies and cooling fans, 2 * FC ports for expansion trays and 4 * 8 Gb/s host ports with shortwave SFPs, 2 * 5M fibre optic cables, 2 * 6M ethernet cables and management software. RoHS-5.	1	\$23,995	\$23,995	38%	\$14,877
XTCCSM2R01A0C2336Z	RoHS-5, Sun StorageTek (tm) CSM200, Rack-Ready Expansion Tray, 336GB, 16 * 146GB 15Krpm 4Gb FC-AL Drives, 2 * I/O Modules, 2 * redundant AC power supplies and cooling fans, 2 * FC ports for expansions, 4 * shortwave SFPs with 2 * LC-LC FC cables. (Standard Configuration)	4	\$29,915	\$119,660	38%	\$74,189
XTC-FC1CF-146G15K	RoHS-6, Sun StorageTek (tm) 6140 array / CSM200, 146GB 15Krpm FC-AL drive	16	\$1,495	\$23,920	38%	\$14,830
X9733A-Z	5M LC-LC Fiber Optic cable	2	\$80	\$160	38%	\$99
SG-XPCIE1FC-QF8-Z	Qlogic single port QLE25620 with SFPs	4	\$1,249	\$4,996	38%	\$3,098
IWU-61804G4P-24-3G	3-yr Gold Service Maintainance for controller tray	1	\$3,689	\$3,689	38%	\$2,287
	- 7/24 coverage					
	- 4 hour resonse time					
IWU-STCSM2-24-3G	- 4 hour resolution					
	3-yr Gold Service Maintainance for CSM200 expansion tray	4	\$1,880	\$7,520	38%	\$4,662
	- 7/24 coverage					
	- 4 hr response time					
	- 4 hour resolution					
				\$183,939		\$114,042

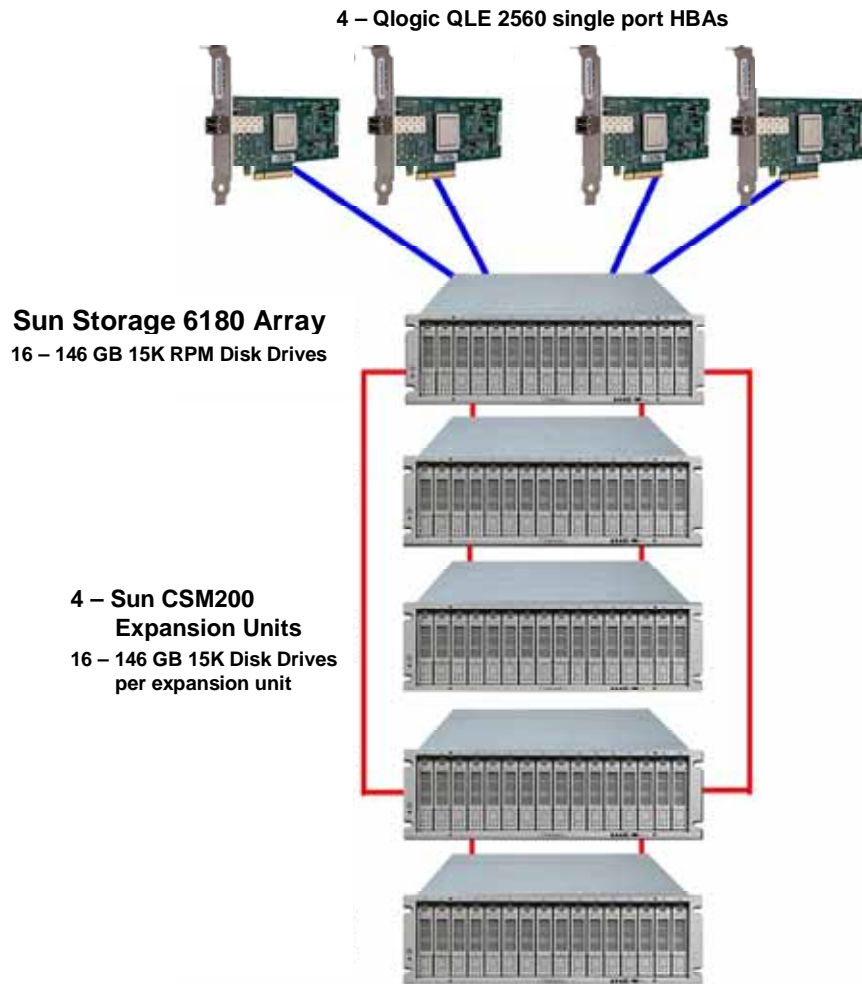
## Differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration

The differences between the TSC and Priced Storage Configuration consisted of the following:

- TSC was configured with 8 host ports (4 standard, 4 optional) of which only the 4 standard host ports were used in the audited measurements. The 4 optional host ports, included in the TSC, were not included in the Priced Storage Configuration.
- The TSC was configured with twenty 4 Gbps SFPs, of which sixteen were used. The Priced Storage Configuration included only the required sixteen SFPs.

The above differences, if applied to the TSC, would not have a negative impact on the reported SPC-1 performance.

### Priced Storage Configuration Diagram



### Priced Storage Configuration Components

<b>Priced Storage Configuration:</b>
4 – Qlogic QLE2560 single port HBAs
<b>SC-1/SC-2: Sun Storage 6180 Array</b> 2 – dual-active controllers with: 2 GB cache per controller (4 GB total) 2 – 8 Gb Fibre Channel front-end connections per controller (4 total, 4 used) 4 – 8 Gb shortwave SFPs 4 – 5m LC-LC fibre optic cables 4 – 4 Gb Fibre Channel backend connection (4 used)
4 – Sun CSM200 expansion unit each with 4 shortwave SFPs (4 Gb) and 2 LC-LC fibre optic cables
80 – 146 GB 15K RPM 15K.6 disk drives (16 in controller unit, 16 per expansion unit)

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 17 (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 TSC did not utilize network storage.

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

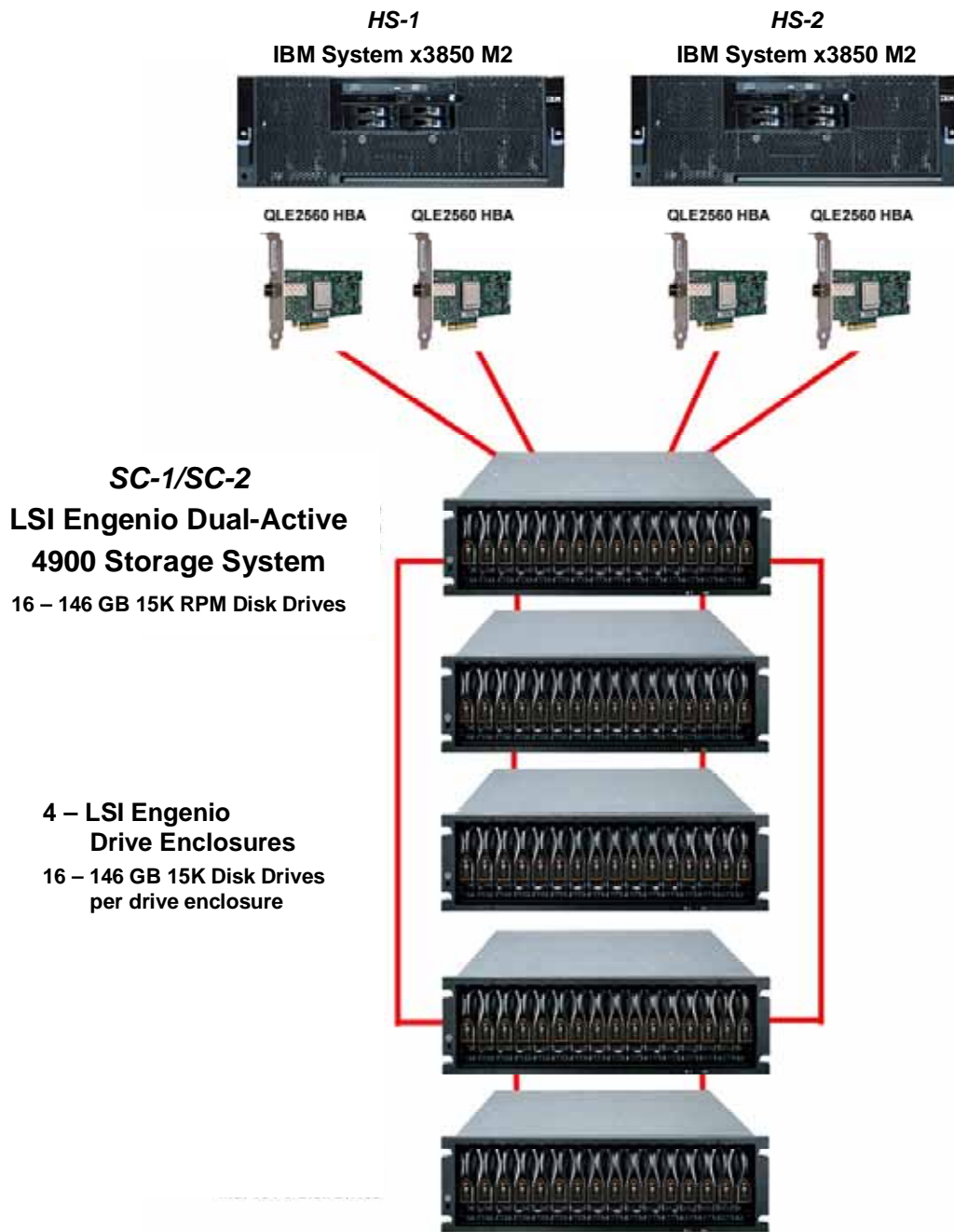
#### *Clause 9.4.3.4.3*

*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 18 (*Host System(s) and Tested Storage Configuration Components*).



### Benchmark Configuration/Tested Storage Configuration Diagram



### Host System(s) and Tested Storage Configuration Components

Host System:	Tested Storage Configuration (TSC):
<b>HS-1/HS-2: IBM System x3850 M2, each with</b> 1 – 2.4 GHz Quad Xeon Processor with 8 MB L2 cache/CPU 8 GB main memory Windows Server 2003 Enterprise Edition with SP2 PCIe WG	4 – Qlogic QLE2560 HBAs <b>SC-1/SC-2: LSI Engenio 4900 Storage System</b> 2 – LSI 4988 FCdual-active controllers with: 2 GB cache per controller 4 – 8 Gb FC Host connections per controller (8 total, 4 used – 2 per controller) 8 – 8 Gb shortwave SFPs 4 – 5m LC-LC fibre optic cables 4 – 4 Gb shortwave SFPs 4 – 4 Gb FC drive connections (4 used) 4 – LSI Engenio FC4600 drive enclosures each with 4 shortwave SFPs (4 Gb) and 2 LC-LC fibre optic cables 80 – 146 GB 15K RPM FC 15K.6 disk drives (16 in the controller unit and 16 per drive 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 62 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 63 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 67.

## 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 58 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)	5,145.060
Addressable Storage Capacity	Gigabytes (GB)	5,145.069
Configured Storage Capacity	Gigabytes (GB)	11,702.240
Physical Storage Capacity	Gigabytes (GB)	11,745.259
Data Protection ( <i>Mirroring</i> )	Gigabytes (GB)	5,851.120
Required Storage ( <i>overhead/metadata</i> )	Gigabytes (GB)	0.429
Global Storage Overhead	Gigabytes (GB)	42.933
Total Unused Storage	Gigabytes (GB)	1,411.507

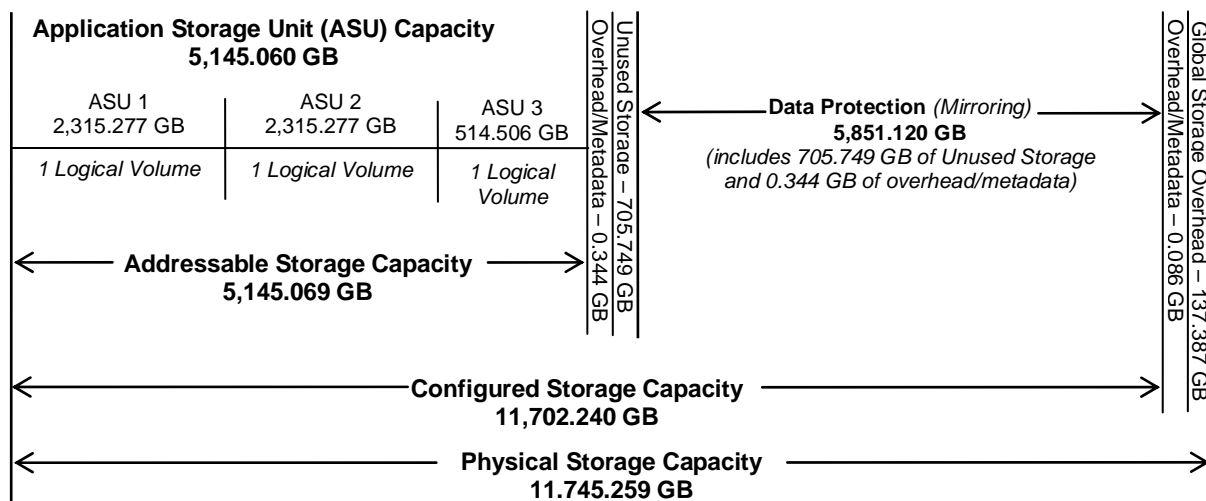
### SPC-1 Storage Hierarchy Ratios

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	43.97%	43.81%
Required for Data Protection ( <i>Mirrored</i> )		50.00%	49.82%
Addressable Storage Capacity		43.97%	43.81%
Required Storage		0.004%	0.004%
Configured Storage Capacity			99.63%
Global Storage Overhead			0.37%
Unused Storage:			
Addressable	0.00%		
Configured		12.06%	
Physical			0.00%

The Physical Storage Capacity consisted of 11,745.259 GB distributed over 80 disk drives each with a formatted capacity of 146.816 GB. There was 0.00 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 42.933 GB (0.37%) of Physical Storage Capacity. There was 1,411.498 GB (12.06%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 100% of the Addressable Storage Capacity resulting in 0.00 GB (0.00%) of Unused Storage within the Addressable Storage Capacity. The Data Protection (*mirroring*) capacity was 5,851.120 GB of which 5,145.069 GB was utilized. The total Unused Storage was 1,411.507 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 (2,315.277 GB)	ASU-2 (2,315.277 GB)	ASU-3 (514.506 GB)
1 Logical Volume 2,315.281 GB per Logical Volume (2,315.277 GB used per Logical Volume)	1 Logical Volume 2,315.281 GB per Logical Volume (2,315.277 GB used per Logical Volume)	1 Logical Volume 514.507 GB per Logical Volume (514.506 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%.

<b>SPC-1 Storage Capacity Utilization</b>	
Application Utilization	43.81%
Protected Application Utilization	87.61%
Unused Storage Ratio	12.02%

## **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 59 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 68.

## Sustainability Test Results File

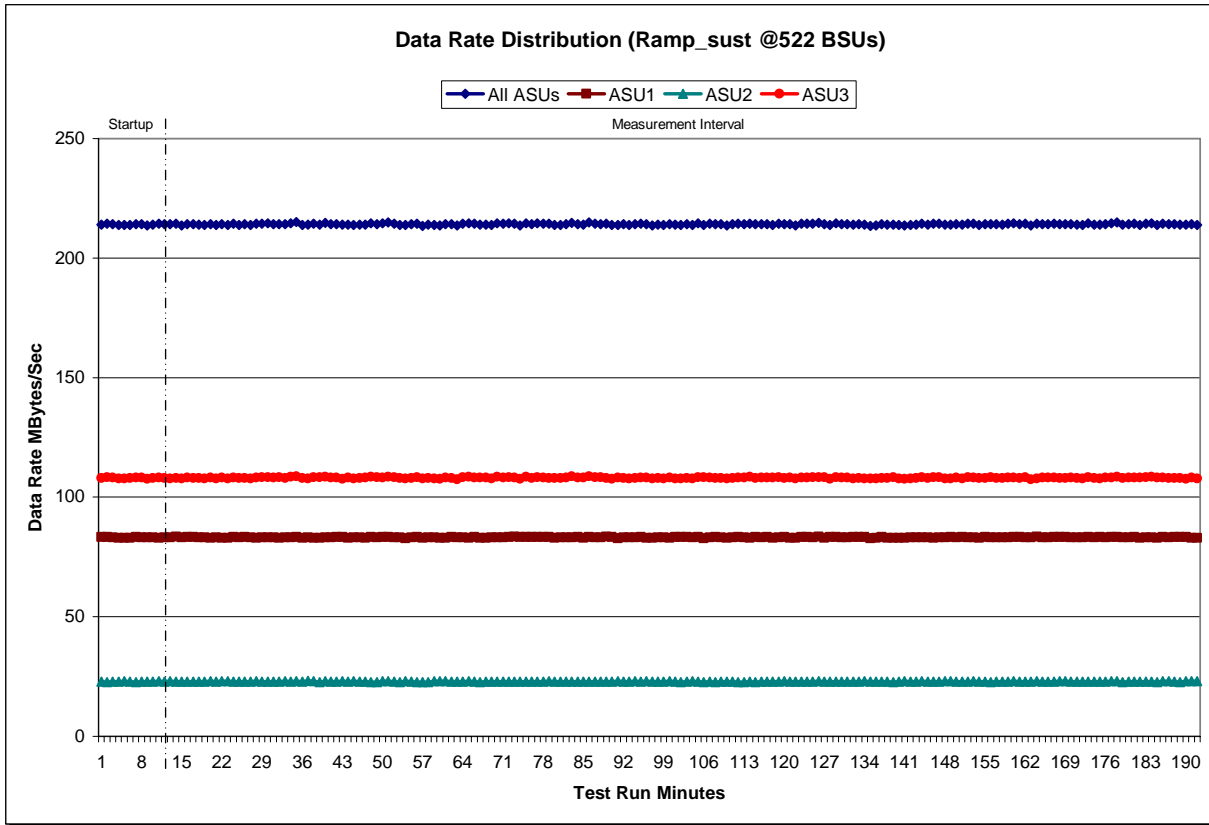
A link to the test results file generated from the Sustainability Test Run is listed below.

[Sustainability Test Results File](#)



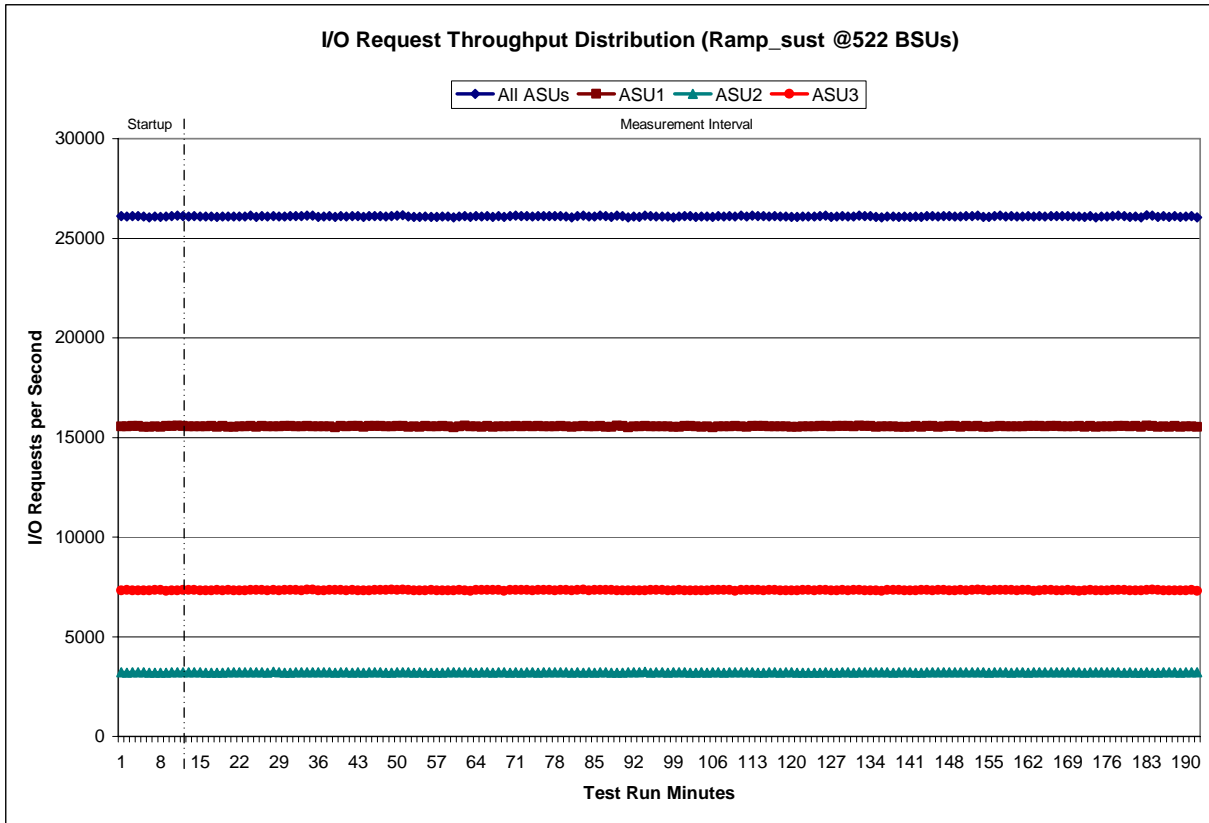


### Sustainability – Data Rate Distribution Graph



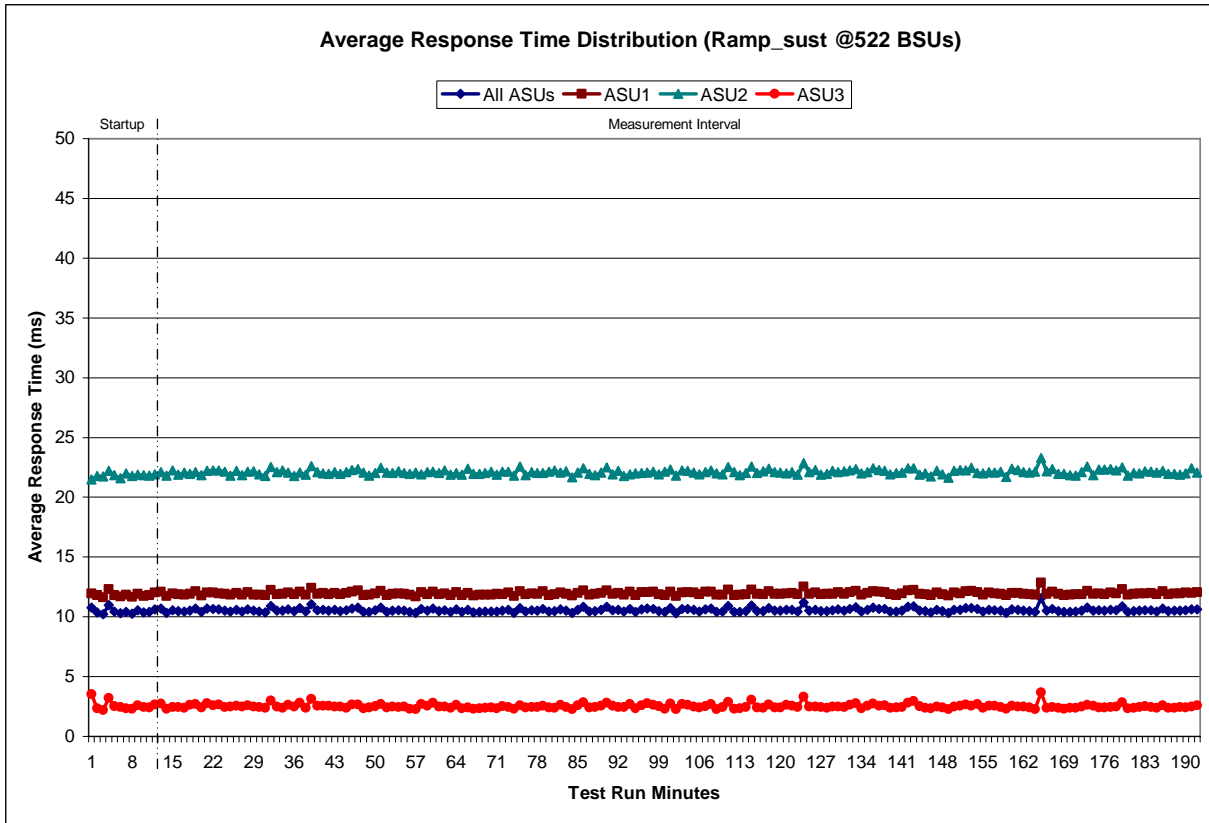


### Sustainability – I/O Request Throughput Distribution Graph





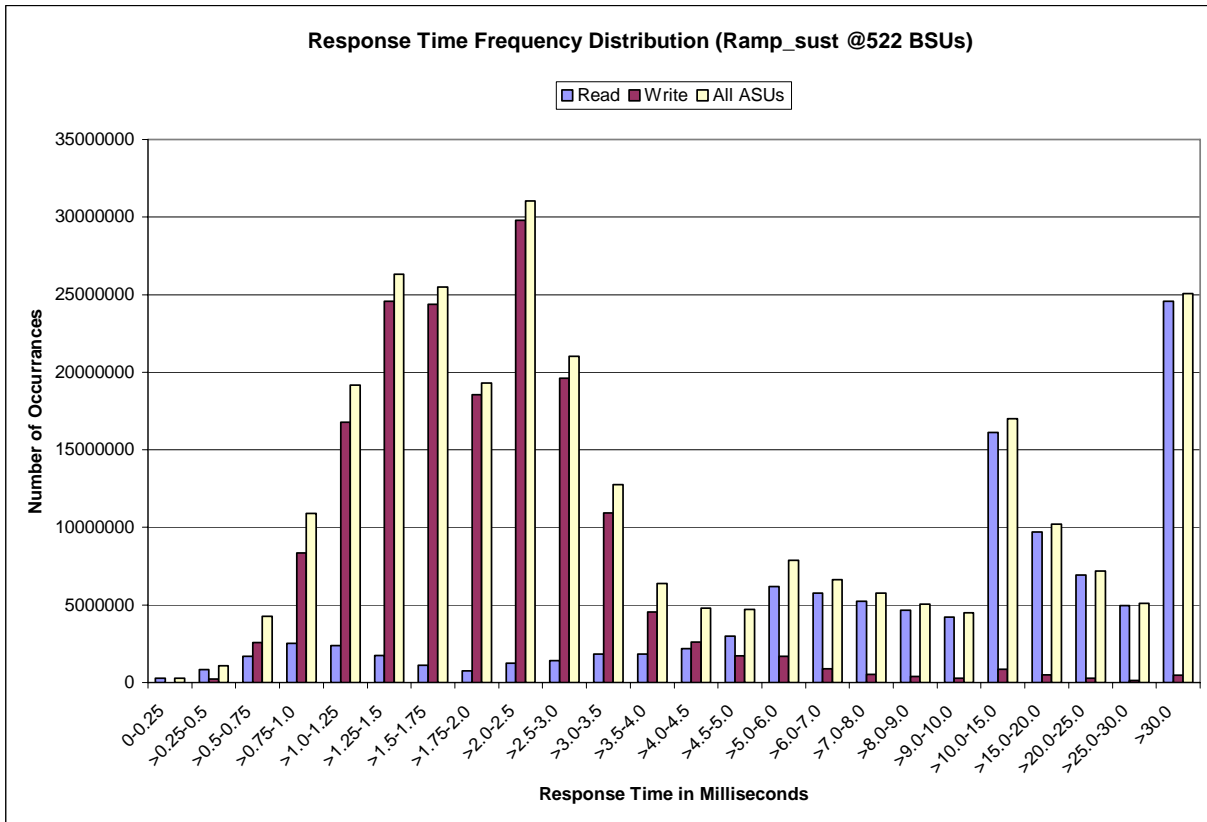
### Sustainability – Average Response Time (ms) Distribution Graph



**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	270,717	844,528	1,684,965	2,535,344	2,375,647	1,743,458	1,108,872	737,460
Write	124	235,570	2,587,088	8,355,737	16,774,601	24,582,652	24,367,548	18,566,934
All ASUs	270,841	1,080,098	4,272,053	10,891,081	19,150,248	26,326,110	25,476,420	19,304,394
ASU1	251,958	899,549	2,775,597	6,276,119	10,003,690	12,655,007	11,516,391	8,466,033
ASU2	18,877	137,626	751,158	1,663,208	2,531,338	3,104,289	2,767,306	2,007,725
ASU3	6	42,923	745,298	2,951,754	6,615,220	10,566,814	11,192,723	8,830,636
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	1,251,629	1,425,546	1,827,392	1,843,759	2,185,705	2,993,629	6,176,743	5,764,842
Write	29,779,881	19,600,525	10,932,019	4,534,690	2,600,109	1,723,760	1,699,539	875,686
All ASUs	31,031,510	21,026,071	12,759,411	6,378,449	4,785,814	4,717,389	7,876,282	6,640,528
ASU1	13,343,450	9,034,462	5,858,795	3,441,688	3,041,023	3,454,560	6,364,086	5,608,959
ASU2	3,076,646	1,946,568	1,099,342	511,109	361,294	350,565	623,097	584,128
ASU3	14,611,414	10,045,041	5,801,274	2,425,652	1,383,497	912,264	889,099	447,441
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	5,237,896	4,672,554	4,226,255	16,118,201	9,695,407	6,925,400	4,956,980	24,581,509
Write	531,754	386,158	277,702	870,226	504,281	264,265	138,481	477,380
All ASUs	5,769,650	5,058,712	4,503,957	16,988,427	10,199,688	7,189,665	5,095,461	25,058,889
ASU1	4,956,960	4,351,287	3,907,485	14,617,901	8,652,864	6,049,295	4,255,587	18,200,566
ASU2	543,210	514,217	458,285	1,940,339	1,294,644	1,004,519	768,266	6,616,454
ASU3	269,480	193,208	138,187	430,187	252,180	135,851	71,608	241,869

**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	0.350	0.2809	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.004	0.001	0.003	0.001	0.006	0.003	0.004	0.001



## 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 68.

## IOPS Test Results File

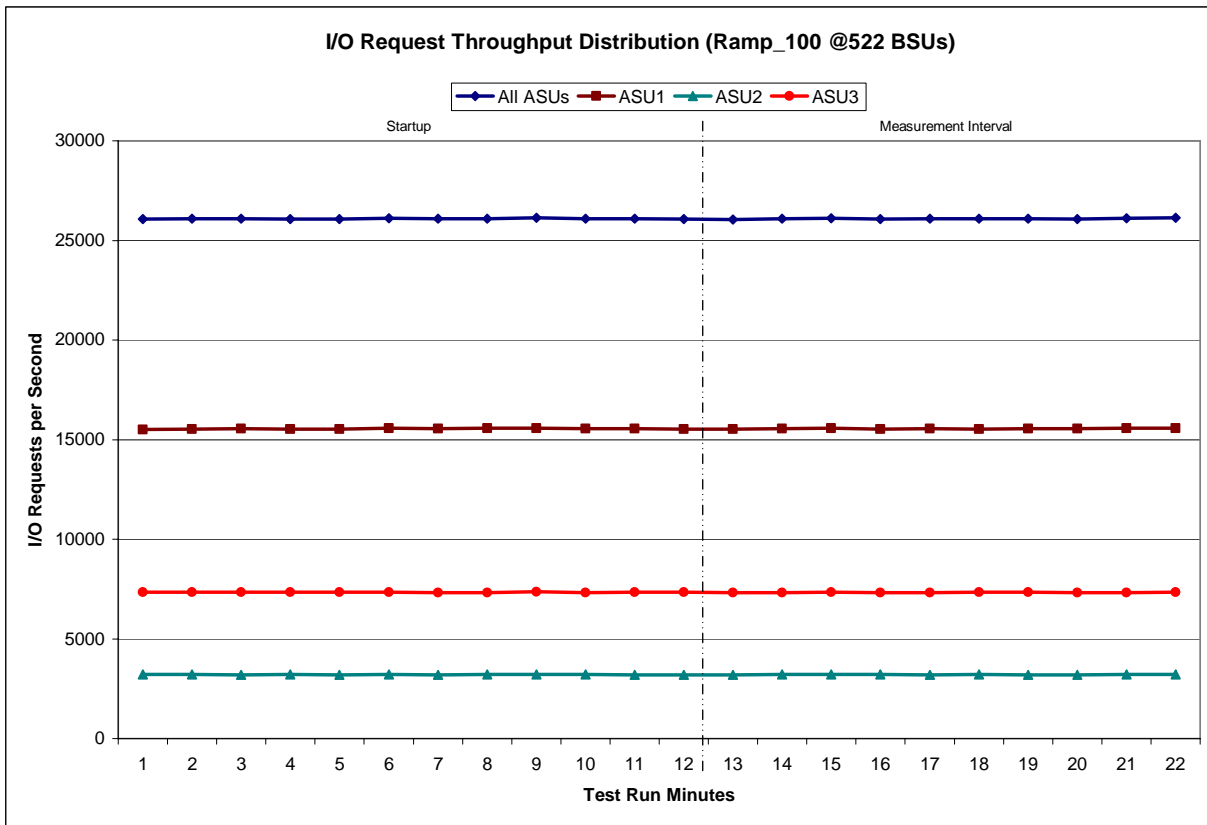
A link to the test results file generated from the IOPS Test Run is listed below.

[IOPS Test Results File](#)

**IOPS Test Run – I/O Request Throughput Distribution Data**

522 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	0:22:36	0:34:37	0-11	0:12:01
Measurement Interval	0:34:37	0:44:37	12-21	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	26,066.25	15,510.48	3,211.07	7,344.70
1	26,081.82	15,537.68	3,208.32	7,335.82
2	26,095.23	15,554.77	3,195.32	7,345.15
3	26,078.30	15,529.95	3,211.93	7,336.42
4	26,072.97	15,528.70	3,198.37	7,345.90
5	26,113.88	15,565.60	3,214.00	7,334.28
6	26,088.33	15,553.65	3,205.25	7,329.43
7	26,100.17	15,569.93	3,214.55	7,315.68
8	26,127.88	15,564.48	3,208.67	7,354.73
9	26,096.32	15,553.60	3,215.03	7,327.68
10	26,082.60	15,545.92	3,203.62	7,333.07
11	26,076.67	15,532.35	3,206.72	7,337.60
12	26,057.25	15,532.77	3,196.97	7,327.52
13	26,091.77	15,555.02	3,208.58	7,328.17
14	26,106.67	15,563.48	3,208.08	7,335.10
15	26,072.48	15,534.90	3,212.02	7,325.57
16	26,079.97	15,541.22	3,206.67	7,332.08
17	26,094.73	15,532.90	3,214.22	7,347.62
18	26,088.73	15,557.62	3,196.82	7,334.30
19	26,067.55	15,547.90	3,189.92	7,329.73
20	26,114.05	15,569.38	3,213.08	7,331.58
21	26,127.10	15,569.90	3,223.12	7,334.08
Average	26,090.03	15,550.51	3,206.95	7,332.58

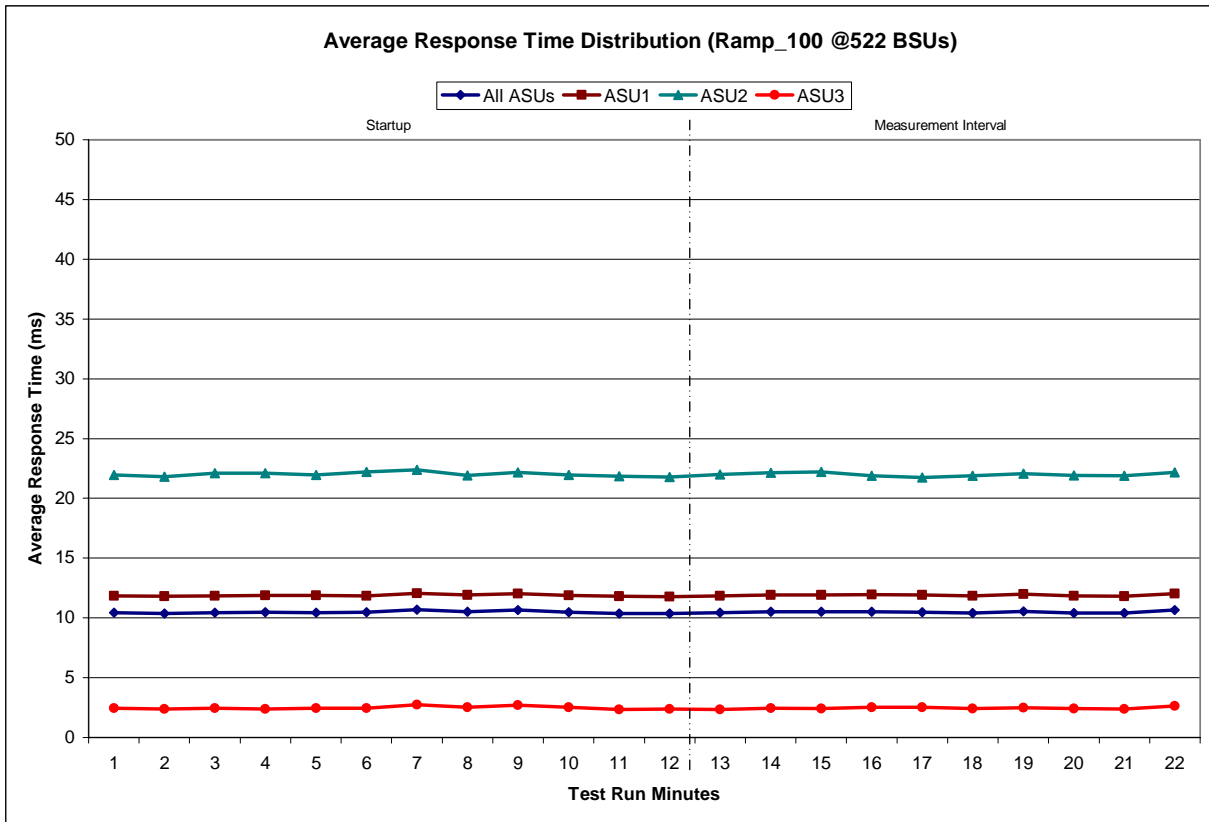
**IOPS Test Run – I/O Request Throughput Distribution Graph**



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

522 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	0:22:36	0:34:37	0-11	0:12:01
Measurement Interval	0:34:37	0:44:37	12-21	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	10.44	11.84	21.96	2.44
1	10.38	11.79	21.80	2.38
2	10.45	11.83	22.09	2.45
3	10.47	11.87	22.11	2.39
4	10.45	11.87	21.95	2.46
5	10.49	11.85	22.21	2.45
6	10.70	12.05	22.39	2.73
7	10.51	11.91	21.91	2.52
8	10.64	12.01	22.19	2.72
9	10.49	11.88	21.96	2.51
10	10.37	11.80	21.86	2.33
11	10.36	11.77	21.79	2.39
12	10.43	11.86	22.00	2.34
13	10.51	11.91	22.14	2.46
14	10.52	11.92	22.20	2.42
15	10.52	11.94	21.90	2.52
16	10.48	11.93	21.74	2.51
17	10.42	11.83	21.88	2.40
18	10.56	11.99	22.07	2.50
19	10.41	11.83	21.92	2.39
20	10.39	11.80	21.88	2.37
21	10.64	12.04	22.17	2.62
Average	10.49	11.91	21.99	2.45

**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	15340	47,844	87,828	141,701	136,233	100,583	62,651	40,413
Write	3	11,219	120,048	404,107	881,298	1,369,464	1,396,704	1,052,517
All ASUs	15343	59,063	207,876	545,808	1,017,531	1,470,047	1,459,355	1,092,930
ASU1	14308	50,117	136,974	320,637	539,712	712,423	662,638	479,977
ASU2	1035	7,038	37,225	85,864	136,910	175,065	158,488	113,690
ASU3	0	1,908	33,677	139,307	340,909	582,559	638,229	499,263

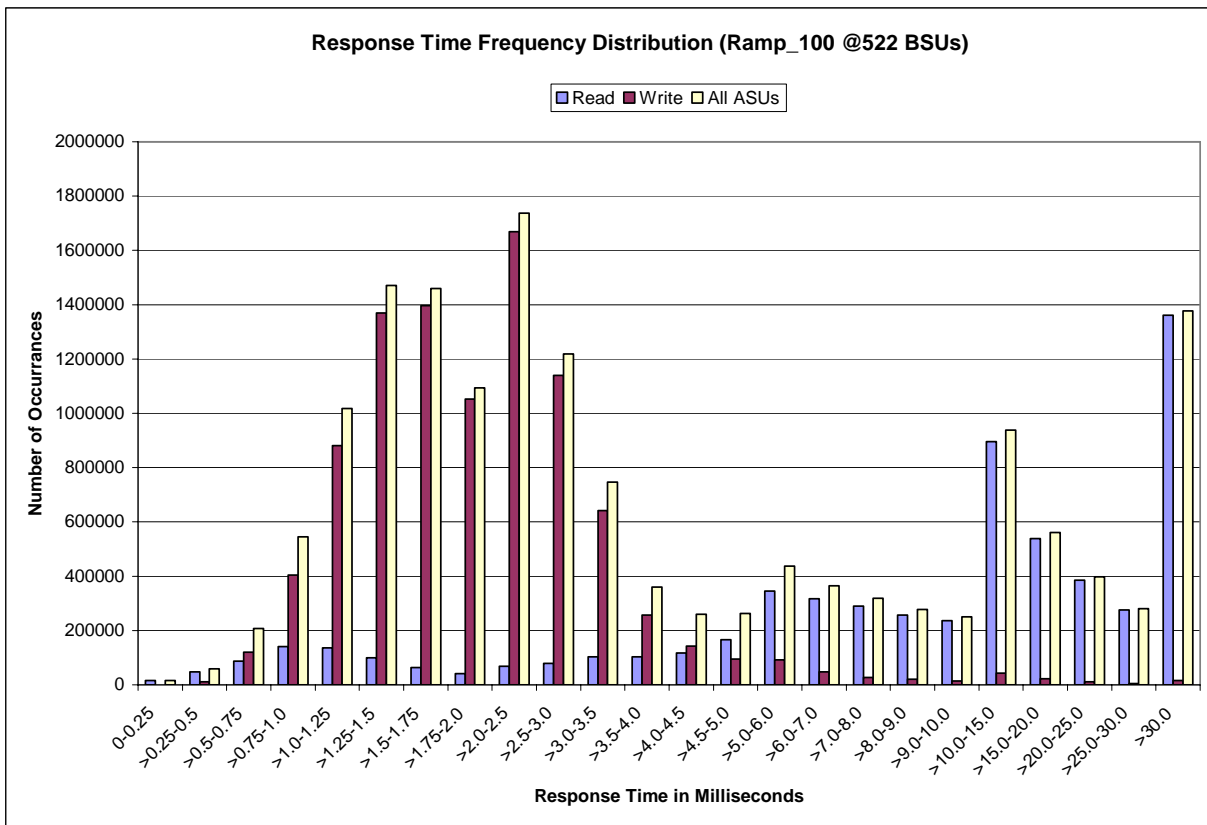
  

Response Time (ms)	>2.0-2.5	>2.5-3.0	>3.0-3.5	>3.5-4.0	>4.0-4.5	>4.5-5.0	>5.0-6.0	>6.0-7.0
Read	67,421	79,041	103,775	102,365	117,406	167,184	345,704	316,852
Write	1,668,851	1,140,069	642,531	257,350	141,887	95,295	91,587	47,266
All ASUs	1,736,272	1,219,110	746,306	359,715	259,293	262,479	437,291	364,118
ASU1	746,081	521,682	340,325	192,430	163,696	192,590	354,953	308,115
ASU2	172,842	112,670	64,212	28,621	19,365	19,308	34,477	31,724
ASU3	817,349	584,758	341,769	138,664	76,232	50,581	47,861	24,279

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	290,645	257,059	235,800	895,693	538,765	385,438	275,005	1,361,234
Write	27,525	20,553	14,573	42,968	22,963	11,767	5,345	15,883
All ASUs	318,170	277,612	250,373	938,661	561,728	397,205	280,350	1,377,117
ASU1	274,339	239,236	217,788	810,073	478,851	335,254	234,780	1,003,167
ASU2	29,766	28,297	25,320	107,096	71,205	55,687	42,676	365,509
ASU3	14,065	10,079	7,265	21,492	11,672	6,264	2,894	8,441

**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
15,653,753	14,276,636	1,377,117

### 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
<b>IM</b>	<b>0.0350</b>	<b>0.2810</b>	<b>0.0700</b>	<b>0.2100</b>	<b>0.0180</b>	<b>0.0700</b>	<b>0.0350</b>	<b>0.2810</b>
MIM	0.0349	0.2811	0.0699	0.2101	0.0180	0.0700	0.0350	0.2810
COV	0.005	0.001	0.005	0.002	0.007	0.004	0.005	0.001

## 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 68.

## 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**

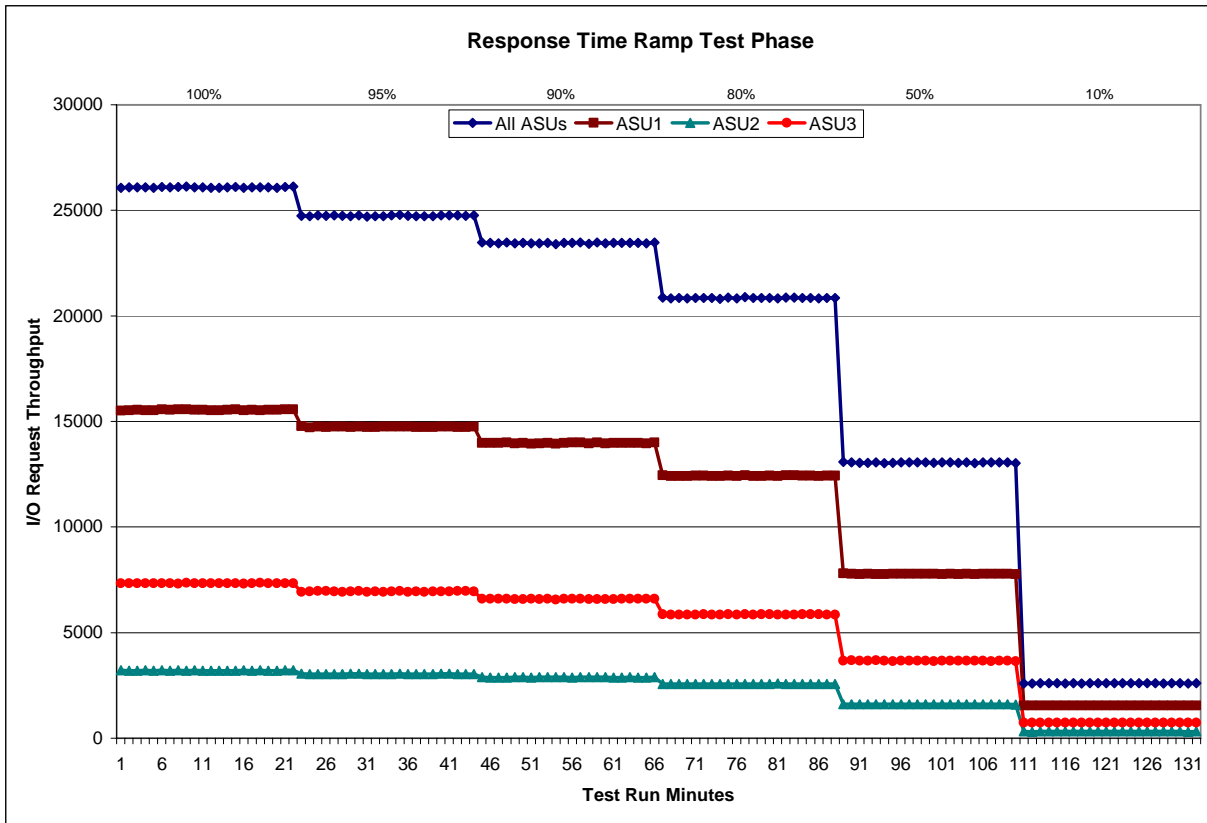
The five Test Runs that comprise the Response Time Ramp Phase are executed at 95%, 90%, 80%, 50%, and 10% of the Business Scaling Unit (BSU) load level used to produce the SPC-1 IOPS™ primary metric. The 100% BSU load level is included in the following Response Time Ramp data tables and graphs for completeness.

100% Load Level - 522 BSUs					95% Load Level - 495 BSUs				
Start	Stop	Interval	Duration		Start	Stop	Interval	Duration	
<b>Start-Up/Ramp-Up</b>					<b>Start-Up/Ramp-Up</b>				
0:22:36 0:34:37 0-11 0:12:01					0:44:40 0:56:41 0-11 0:12:01				
<b>Measurement Interval</b>					<b>Measurement Interval</b>				
0:34:37 0:44:37 12=21 0:10:00					0:56:41 1:06:41 12=21 0:10:00				
<i>(60 second intervals)</i>					<i>(60 second intervals)</i>				
	<b>All ASUs</b>	<b>ASU-1</b>	<b>ASU-2</b>	<b>ASU-3</b>		<b>All ASUs</b>	<b>ASU-1</b>	<b>ASU-2</b>	<b>ASU-3</b>
0	26,066.25	15,510.48	3,211.07	7,344.70	0	24,735.22	14,765.78	3,047.52	6,921.92
1	26,081.82	15,537.68	3,208.32	7,335.82	1	24,713.10	14,718.07	3,043.00	6,952.03
2	26,095.23	15,554.77	3,195.32	7,345.15	2	24,758.05	14,755.42	3,040.43	6,962.20
3	26,078.30	15,529.95	3,211.93	7,336.42	3	24,739.20	14,734.20	3,044.77	6,960.23
4	26,072.97	15,528.70	3,198.37	7,345.90	4	24,756.67	14,762.53	3,040.58	6,953.55
5	26,113.88	15,565.60	3,214.00	7,334.28	5	24,734.27	14,757.93	3,042.92	6,933.42
6	26,088.33	15,553.65	3,205.25	7,329.43	6	24,719.35	14,729.08	3,047.85	6,942.42
7	26,100.17	15,569.93	3,214.55	7,315.68	7	24,768.90	14,758.02	3,048.83	6,962.05
8	26,127.88	15,564.48	3,208.67	7,354.73	8	24,709.32	14,736.55	3,036.02	6,936.75
9	26,096.32	15,553.60	3,215.03	7,327.68	9	24,722.93	14,726.22	3,038.55	6,958.17
10	26,082.60	15,545.92	3,203.62	7,333.07	10	24,727.33	14,747.72	3,043.25	6,936.37
11	26,076.67	15,532.35	3,206.72	7,337.60	11	24,756.32	14,759.37	3,042.70	6,954.25
12	26,057.25	15,532.77	3,196.97	7,327.52	12	24,781.78	14,761.72	3,055.88	6,964.18
13	26,091.77	15,555.02	3,208.58	7,328.17	13	24,733.42	14,760.92	3,043.70	6,928.80
14	26,106.67	15,563.48	3,208.08	7,335.10	14	24,728.38	14,727.00	3,044.72	6,956.67
15	26,072.48	15,534.90	3,212.02	7,325.57	15	24,721.97	14,742.62	3,041.55	6,937.80
16	26,079.97	15,541.22	3,206.67	7,332.08	16	24,717.47	14,741.97	3,035.65	6,939.85
17	26,094.73	15,532.90	3,214.22	7,347.62	17	24,756.57	14,749.27	3,049.10	6,958.20
18	26,088.73	15,557.62	3,196.82	7,334.30	18	24,763.75	14,753.50	3,051.20	6,959.05
19	26,067.55	15,547.90	3,189.92	7,329.73	19	24,762.45	14,741.63	3,045.70	6,975.12
20	26,114.05	15,569.38	3,213.08	7,331.58	20	24,744.88	14,739.08	3,045.47	6,960.33
21	26,127.10	15,569.90	3,223.12	7,334.08	21	24,760.97	14,759.98	3,041.25	6,959.73
<b>Average</b>	26,090.03	15,550.51	3,206.95	7,332.58	<b>Average</b>	24,747.16	14,747.77	3,045.42	6,953.97
90% Load Level - 469 BSUs					80% Load Level - 417 BSUs				
Start	Stop	Interval	Duration		Start	Stop	Interval	Duration	
<b>Start-Up/Ramp-Up</b>					<b>Start-Up/Ramp-Up</b>				
1:06:44 1:18:45 0-11 0:12:01					1:28:49 1:40:50 0-11 0:12:01				
<b>Measurement Interval</b>					<b>Measurement Interval</b>				
1:18:45 1:28:45 12=21 0:10:00					1:40:50 1:50:50 12=21 0:10:00				
<i>(60 second intervals)</i>					<i>(60 second intervals)</i>				
	<b>All ASUs</b>	<b>ASU-1</b>	<b>ASU-2</b>	<b>ASU-3</b>		<b>All ASUs</b>	<b>ASU-1</b>	<b>ASU-2</b>	<b>ASU-3</b>
0	23,474.78	13,984.72	2,884.68	6,605.38	0	20,862.20	12,443.05	2,558.70	5,860.45
1	23,453.00	13,980.00	2,877.70	6,595.30	1	20,835.53	12,418.85	2,567.23	5,849.45
2	23,446.38	13,972.27	2,878.85	6,595.27	2	20,842.45	12,416.03	2,567.43	5,858.98
3	23,471.62	14,003.03	2,870.97	6,597.62	3	20,838.70	12,420.60	2,568.72	5,849.38
4	23,430.05	13,964.78	2,888.60	6,576.67	4	20,848.22	12,429.97	2,569.93	5,848.32
5	23,456.18	13,980.77	2,887.70	6,587.72	5	20,859.18	12,427.02	2,572.28	5,859.88
6	23,431.25	13,947.90	2,875.73	6,607.62	6	20,839.93	12,421.45	2,569.47	5,849.02
7	23,444.52	13,970.57	2,888.45	6,585.50	7	20,814.03	12,407.88	2,563.32	5,842.83
8	23,461.25	13,978.58	2,889.35	6,593.32	8	20,863.30	12,436.60	2,562.33	5,864.37
9	23,403.08	13,945.20	2,888.68	6,569.20	9	20,819.90	12,414.12	2,562.43	5,843.35
10	23,465.23	13,980.40	2,884.30	6,600.53	10	20,885.22	12,457.77	2,562.82	5,864.63
11	23,464.80	13,991.82	2,875.42	6,597.57	11	20,840.77	12,421.08	2,564.30	5,855.38
12	23,480.73	13,996.12	2,891.43	6,593.18	12	20,847.48	12,414.00	2,572.22	5,861.27
13	23,424.65	13,960.92	2,890.38	6,573.35	13	20,854.92	12,429.52	2,561.23	5,864.17
14	23,481.68	13,999.48	2,895.90	6,586.30	14	20,833.27	12,410.97	2,579.65	5,842.65
15	23,432.97	13,969.37	2,884.58	6,579.02	15	20,873.37	12,455.37	2,559.77	5,858.23
16	23,453.77	13,980.05	2,881.33	6,592.38	16	20,863.85	12,447.45	2,559.95	5,856.45
17	23,461.60	13,974.05	2,882.83	6,604.72	17	20,848.25	12,422.30	2,566.23	5,859.72
18	23,455.52	13,971.17	2,885.00	6,599.35	18	20,851.10	12,424.48	2,563.37	5,863.25
19	23,462.62	13,977.13	2,883.23	6,602.25	19	20,830.93	12,410.55	2,559.30	5,861.08
20	23,441.63	13,961.72	2,883.30	6,596.62	20	20,846.45	12,424.35	2,574.18	5,847.92
21	23,477.12	13,991.23	2,886.38	6,599.50	21	20,853.90	12,436.68	2,558.80	5,858.42
<b>Average</b>	23,457.23	13,978.12	2,886.44	6,592.67	<b>Average</b>	20,850.35	12,427.57	2,565.47	5,857.32

**Response Time Ramp Distribution (IOPS) Data (cont.)**

50% Load Level - 261 BSUs					10% Load Level - 52 BSUs				
Start	Stop	Interval	Duration		Start	Stop	Interval	Duration	
Start-Up/Ramp-Up					Start-Up/Ramp-Up				
2:02:54					2:24:58				
2:12:54					2:34:58				
12=21					12=21				
0:10:00					0:10:00				
Measurement Interval					Measurement Interval				
(60 second intervals)					(60 second intervals)				
All ASUs	ASU-1	ASU-2	ASU-3		All ASUs	ASU-1	ASU-2	ASU-3	
0	13,074.35	7,796.58	1,604.63	3,673.13	0	2,593.93	1,544.48	320.05	729.40
1	13,063.05	7,776.27	1,608.07	3,678.72	1	2,598.03	1,554.63	315.32	728.08
2	13,039.85	7,771.88	1,604.78	3,663.18	2	2,604.83	1,549.25	318.38	737.20
3	13,051.47	7,775.73	1,603.67	3,672.07	3	2,607.72	1,553.60	319.23	734.88
4	13,064.37	7,772.40	1,605.17	3,686.80	4	2,604.25	1,554.13	318.97	731.15
5	13,022.63	7,761.62	1,601.75	3,659.27	5	2,592.18	1,545.57	318.62	728.00
6	13,041.93	7,779.60	1,608.05	3,654.28	6	2,606.37	1,548.53	321.48	736.35
7	13,067.03	7,782.05	1,608.97	3,676.02	7	2,593.28	1,546.10	316.70	730.48
8	13,072.72	7,789.17	1,611.35	3,672.20	8	2,599.95	1,549.42	317.97	732.57
9	13,068.55	7,776.83	1,618.43	3,673.28	9	2,606.83	1,555.52	318.47	732.85
10	13,073.10	7,787.58	1,614.60	3,670.92	10	2,600.02	1,551.43	320.07	728.52
11	13,043.63	7,779.43	1,607.95	3,656.25	11	2,602.65	1,545.93	322.12	734.60
12	13,056.63	7,771.82	1,606.32	3,678.50	12	2,602.80	1,552.08	320.90	729.82
13	13,066.33	7,789.93	1,606.55	3,669.85	13	2,603.70	1,556.93	319.13	727.63
14	13,047.85	7,774.48	1,602.40	3,670.97	14	2,600.10	1,552.52	320.07	727.52
15	13,067.83	7,778.17	1,611.13	3,678.53	15	2,601.03	1,554.85	319.32	726.87
16	13,032.42	7,761.00	1,604.00	3,667.42	16	2,612.42	1,554.20	320.72	737.50
17	13,069.18	7,788.20	1,610.18	3,670.80	17	2,595.57	1,543.88	321.37	730.32
18	13,054.45	7,793.43	1,606.42	3,654.60	18	2,614.87	1,558.42	320.58	735.87
19	13,062.43	7,792.98	1,608.23	3,661.22	19	2,603.45	1,551.25	319.20	733.00
20	13,058.10	7,779.67	1,618.02	3,660.42	20	2,592.47	1,543.98	314.78	733.70
21	13,017.20	7,774.82	1,597.15	3,645.23	21	2,600.07	1,546.62	320.43	733.02
Average	13,053.24	7,780.45	1,607.04	3,665.75	Average	2,602.65	1,551.47	319.65	731.52

**Response Time Ramp Distribution (IOPS) Graph**

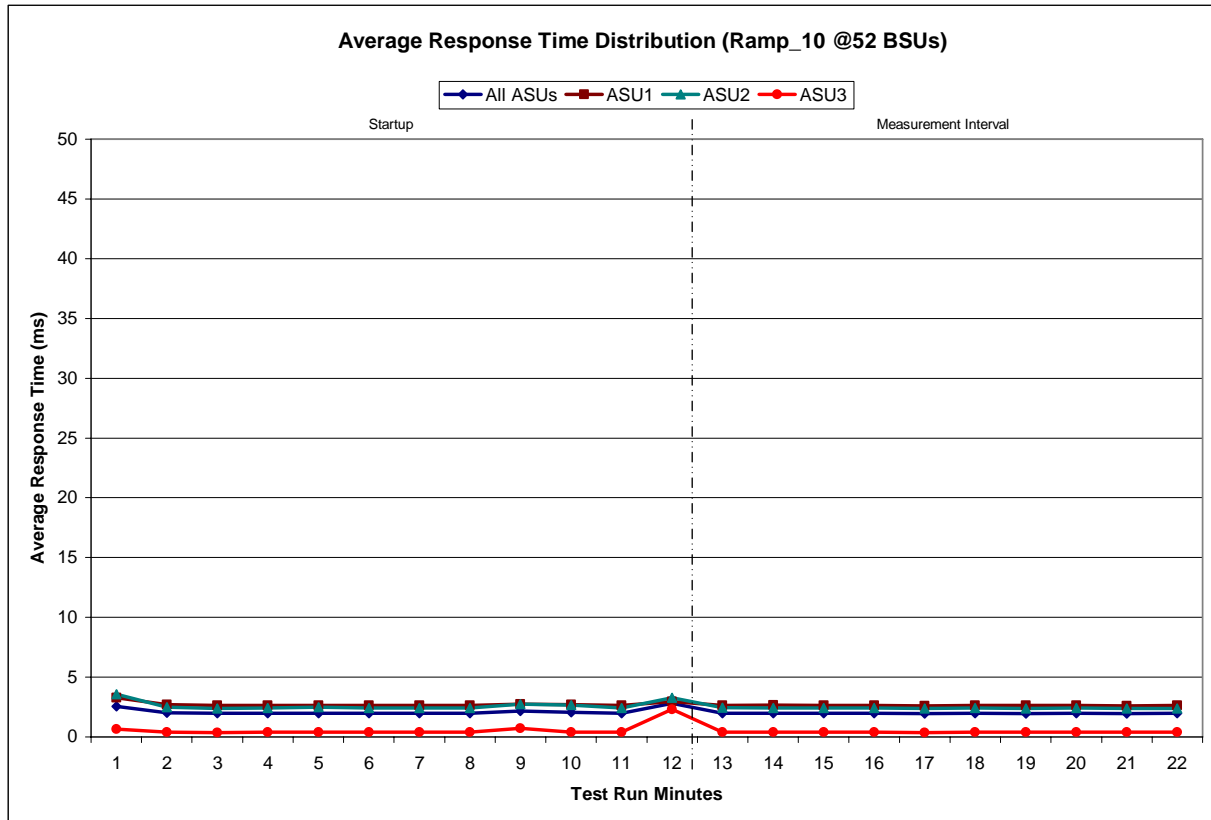




**SPC-1 LRT™ Average Response Time (ms) Distribution Data**

52 BSUs Start-Up/Ramp-Up Measurement Interval	Start	Stop	Interval	Duration
	2:12:57	2:24:58	0-11	0:12:01
	2:24:58	2:34:58	12-21	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	2.56	3.27	3.56	0.64
1	2.03	2.71	2.49	0.38
2	1.96	2.63	2.39	0.38
3	1.97	2.63	2.40	0.38
4	1.98	2.64	2.47	0.38
5	1.98	2.64	2.40	0.38
6	1.98	2.64	2.40	0.39
7	1.98	2.64	2.41	0.40
8	2.17	2.75	2.72	0.72
9	2.05	2.70	2.68	0.40
10	1.97	2.62	2.39	0.40
11	2.82	2.96	3.28	2.30
12	1.97	2.62	2.43	0.39
13	1.99	2.66	2.43	0.39
14	1.97	2.63	2.41	0.38
15	1.98	2.64	2.42	0.38
16	1.95	2.61	2.38	0.38
17	1.98	2.65	2.42	0.38
18	1.95	2.61	2.37	0.38
19	1.98	2.65	2.41	0.38
20	1.94	2.59	2.39	0.39
21	1.98	2.64	2.38	0.39
Average	1.97	2.63	2.40	0.38

**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	0.2812	0.0702	0.2097	0.0179	0.0700	0.0350	0.2811
COV	0.007	0.005	0.006	0.005	0.014	0.010	0.017	0.004

## Repeatability Test

### Clause 5.4.5

*The Repeatability Test demonstrates the repeatability and reproducibility of the SPC-1 IOPS™ primary metric and 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 68.

### 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™
<i>Primary Metrics</i>	<b>26,090.03</b>
Repeatability Test Phase 1	26,091.65
Repeatability Test Phase 2	26,090.05

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 be greater than 95% of the reported SPC-1 IOPS™ Primary Metric.

	SPC-1 LRT™
<i>Primary Metrics</i>	<b>1.97 ms</b>
Repeatability Test Phase 1	1.98 ms
Repeatability Test Phase 2	1.98 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)..

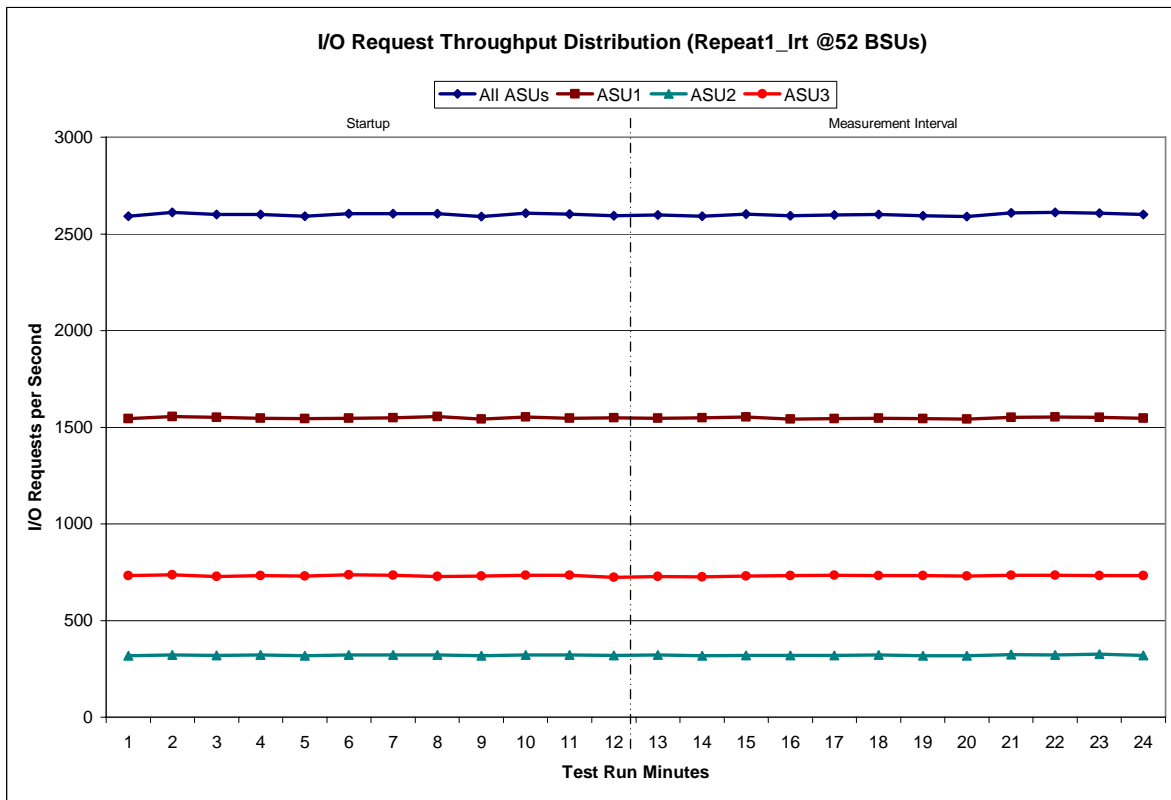
A link to the test result file generated from each Repeatability Test Run is listed below.

- [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**

52 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:35:04	2:47:04	0-11	0:12:00
Measurement Interval	2:47:04	2:59:04	12-23	0:12:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	2,592.83	1,543.20	317.90	731.73
1	2,611.58	1,554.53	321.17	735.88
2	2,599.77	1,550.37	320.47	728.93
3	2,599.77	1,546.87	321.18	731.72
4	2,592.65	1,545.25	318.30	729.10
5	2,604.77	1,547.07	322.25	735.45
6	2,603.73	1,548.45	321.57	733.72
7	2,604.13	1,554.53	320.80	728.80
8	2,589.35	1,541.88	318.48	728.98
9	2,606.77	1,552.15	321.18	733.43
10	2,602.18	1,546.08	322.18	733.92
11	2,593.95	1,549.02	320.67	724.27
12	2,598.63	1,547.12	322.60	728.92
13	2,591.70	1,548.43	317.05	726.22
14	2,601.90	1,552.77	319.45	729.68
15	2,594.35	1,542.77	319.85	731.73
16	2,598.15	1,543.48	319.40	735.27
17	2,601.45	1,546.55	322.30	732.60
18	2,594.37	1,543.45	318.45	732.47
19	2,588.98	1,541.73	317.15	730.10
20	2,608.23	1,550.33	323.50	734.40
21	2,610.73	1,553.52	322.77	734.45
22	2,607.48	1,550.38	325.68	731.42
23	2,600.68	1,547.37	320.13	733.18
Average	2,599.72	1,547.33	320.69	731.70

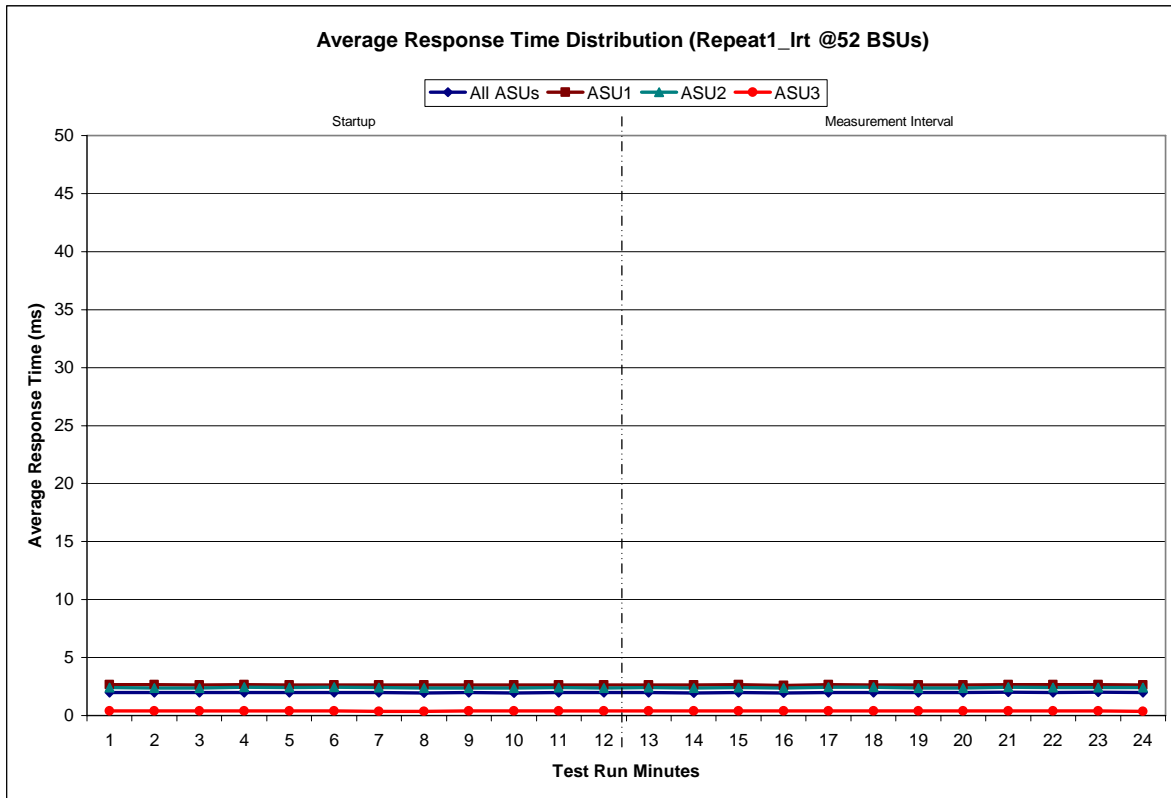
**Repeatability 1 LRT - I/O Request Throughput Distribution Graph**



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

52 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:35:04	2:47:04	0-11	0:12:00
Measurement Interval	2:47:04	2:59:04	12-23	0:12:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	1.98	2.65	2.41	0.39
1	1.99	2.65	2.39	0.40
2	1.97	2.63	2.38	0.40
3	1.99	2.65	2.46	0.39
4	1.97	2.62	2.41	0.39
5	1.98	2.65	2.45	0.38
6	1.97	2.64	2.40	0.38
7	1.96	2.62	2.37	0.38
8	1.97	2.63	2.39	0.38
9	1.96	2.62	2.37	0.38
10	1.97	2.64	2.43	0.38
11	1.97	2.62	2.37	0.38
12	1.98	2.64	2.41	0.39
13	1.96	2.62	2.36	0.39
14	1.99	2.65	2.42	0.39
15	1.96	2.61	2.37	0.40
16	1.99	2.65	2.44	0.40
17	1.97	2.62	2.43	0.39
18	1.96	2.62	2.39	0.39
19	1.97	2.63	2.39	0.38
20	2.00	2.68	2.45	0.38
21	1.99	2.66	2.40	0.38
22	2.00	2.68	2.42	0.38
23	1.96	2.62	2.41	0.38
Average	1.98	2.64	2.41	0.39

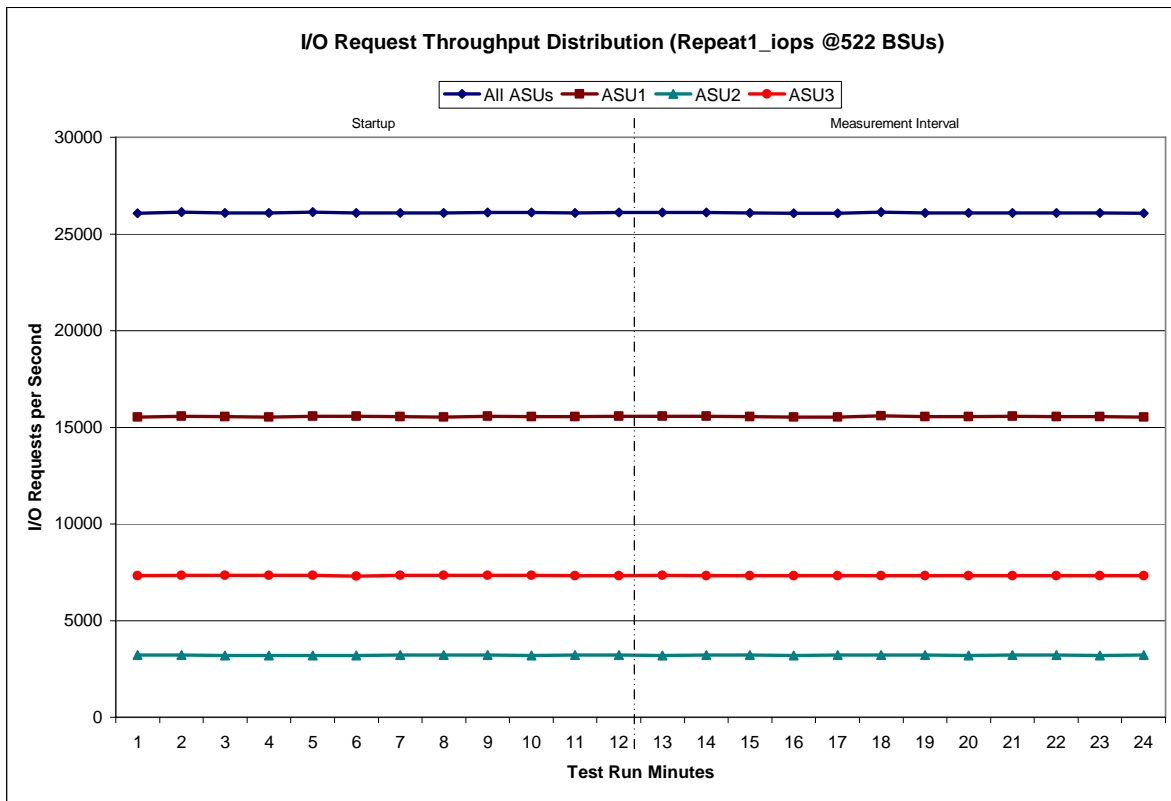
**Repeatability 1 LRT –Average Response Time (ms) Distribution Graph**



**Repeatability 1 IOPS - I/O Request Throughput Distribution Data**

522 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:59:08	3:11:09	0-11	0:12:01
Measurement Interval	3:11:09	3:23:09	12-23	0:12:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	26,070.35	15,524.15	3,222.88	7,323.32
1	26,135.67	15,576.38	3,223.65	7,335.63
2	26,092.33	15,548.72	3,202.38	7,341.23
3	26,082.20	15,538.18	3,195.48	7,348.53
4	26,128.67	15,568.23	3,206.63	7,353.80
5	26,087.28	15,572.70	3,206.73	7,307.85
6	26,096.30	15,543.37	3,217.13	7,335.80
7	26,086.27	15,535.10	3,214.30	7,336.87
8	26,114.48	15,569.08	3,211.53	7,333.87
9	26,106.95	15,557.50	3,206.58	7,342.87
10	26,080.60	15,541.80	3,215.87	7,322.93
11	26,110.88	15,575.60	3,209.53	7,325.75
12	26,117.43	15,562.03	3,204.07	7,351.33
13	26,118.00	15,576.33	3,211.03	7,330.63
14	26,090.27	15,557.05	3,214.15	7,319.07
15	26,062.87	15,535.25	3,206.43	7,321.18
16	26,062.47	15,520.95	3,211.23	7,330.28
17	26,128.88	15,591.85	3,210.52	7,326.52
18	26,082.90	15,549.83	3,214.82	7,318.25
19	26,088.00	15,560.68	3,202.73	7,324.58
20	26,099.50	15,571.40	3,211.90	7,316.20
21	26,091.03	15,555.93	3,214.82	7,320.28
22	26,081.52	15,551.18	3,199.23	7,331.10
23	26,076.95	15,522.37	3,222.17	7,332.42
Average	26,091.65	15,554.57	3,210.26	7,326.82

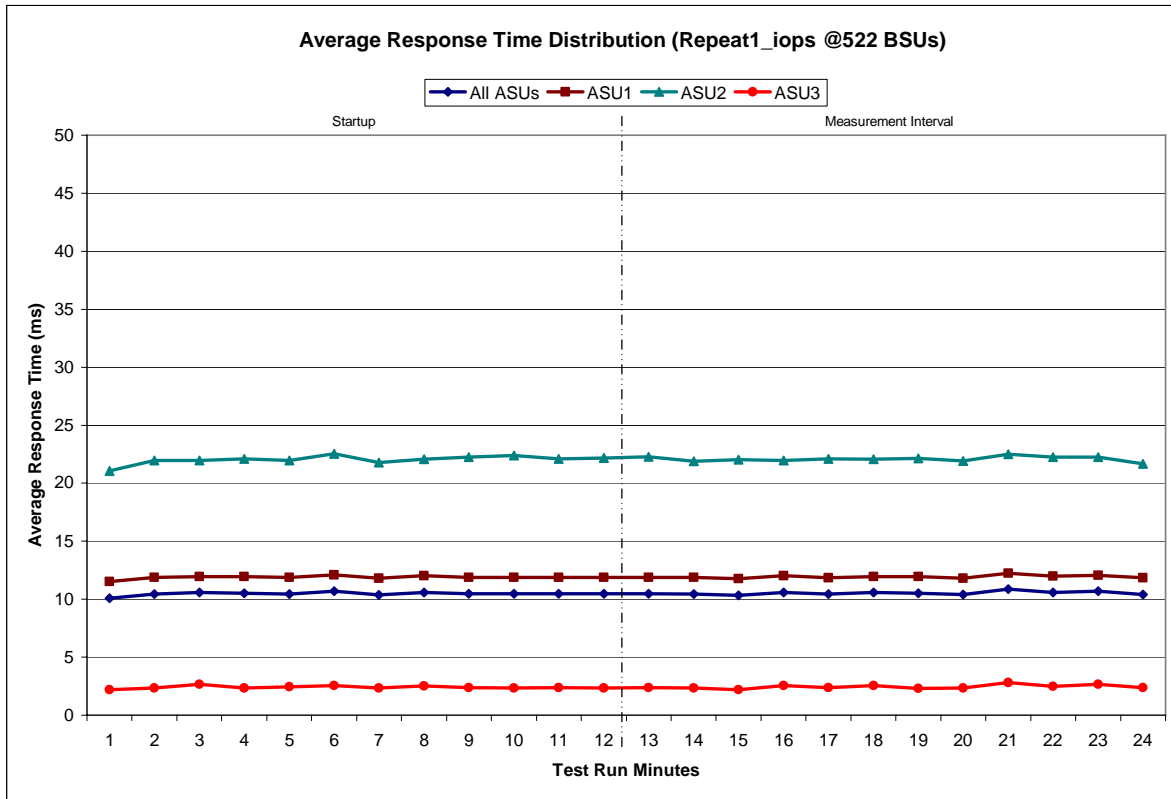
**Repeatability 1 IOPS - I/O Request Throughput Distribution Graph**



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

522 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:59:08	3:11:09	0-11	0:12:01
Measurement Interval	3:11:09	3:23:09	12-23	0:12:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	10.09	11.53	21.06	2.21
1	10.45	11.88	21.95	2.34
2	10.58	11.97	21.97	2.66
3	10.50	11.96	22.09	2.35
4	10.45	11.87	21.94	2.45
5	10.69	12.08	22.52	2.54
6	10.37	11.80	21.79	2.34
7	10.59	12.03	22.08	2.53
8	10.48	11.87	22.25	2.38
9	10.49	11.88	22.40	2.34
10	10.47	11.87	22.11	2.39
11	10.47	11.89	22.17	2.34
12	10.49	11.89	22.29	2.37
13	10.43	11.88	21.89	2.33
14	10.35	11.77	22.02	2.19
15	10.57	12.01	21.96	2.54
16	10.45	11.86	22.11	2.37
17	10.57	11.96	22.08	2.54
18	10.50	11.94	22.14	2.31
19	10.39	11.81	21.94	2.32
20	10.85	12.23	22.49	2.82
21	10.57	11.97	22.24	2.47
22	10.68	12.07	22.23	2.67
23	10.39	11.83	21.65	2.39
Average	10.52	11.94	22.09	2.44

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

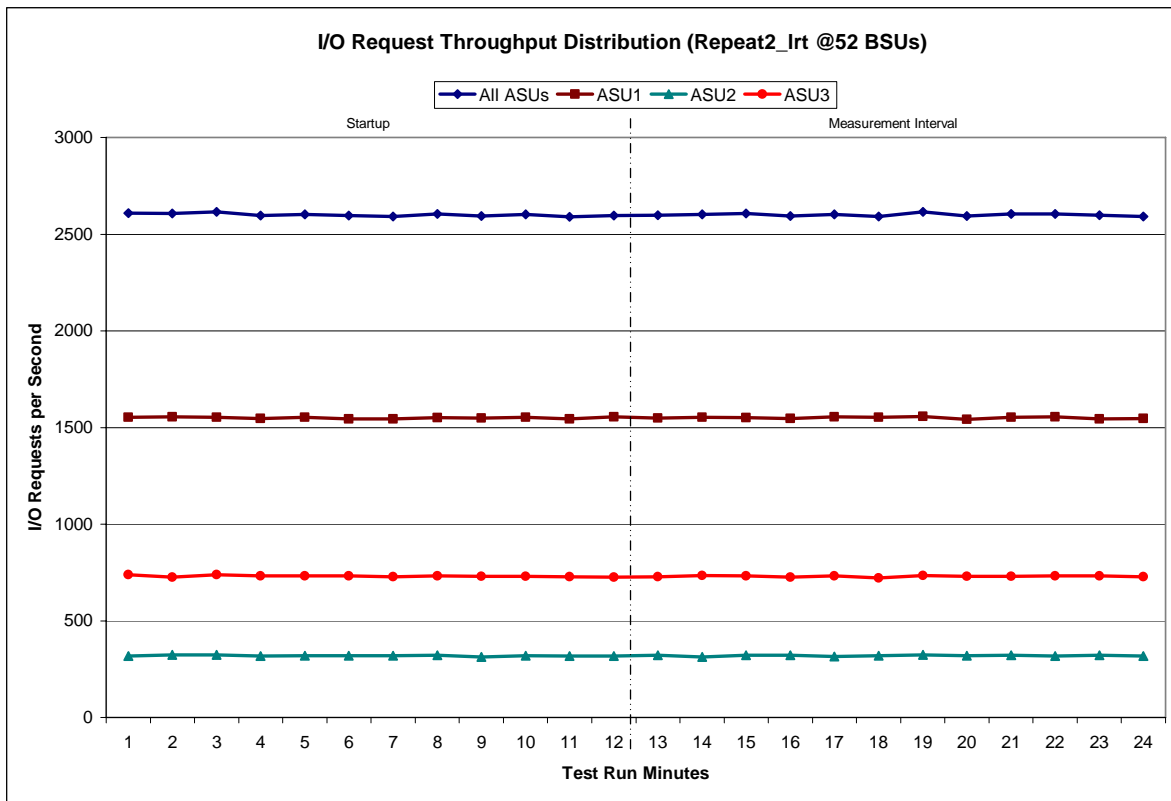




**Repeatability 2 LRT – I/O Request Throughput Distribution Data**

52 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	3:23:15	3:35:15	0-11	0:12:00
Measurement Interval	3:35:15	3:47:15	12-23	0:12:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	2,608.48	1,553.27	317.28	737.93
1	2,606.53	1,555.68	324.10	726.75
2	2,614.92	1,553.13	323.38	738.40
3	2,596.90	1,546.78	317.17	732.95
4	2,603.18	1,553.12	318.88	731.18
5	2,596.57	1,544.53	320.50	731.53
6	2,591.18	1,545.23	319.02	726.93
7	2,604.25	1,550.60	321.43	732.22
8	2,592.97	1,548.87	313.58	730.52
9	2,602.78	1,552.08	319.60	731.10
10	2,589.55	1,544.62	316.85	728.08
11	2,596.52	1,554.07	317.58	724.87
12	2,598.22	1,548.43	322.37	727.42
13	2,601.52	1,553.53	313.12	734.87
14	2,606.02	1,550.37	322.73	732.92
15	2,593.62	1,546.87	321.73	725.02
16	2,603.07	1,554.88	315.80	732.38
17	2,592.43	1,551.85	318.72	721.87
18	2,615.70	1,558.07	323.18	734.45
19	2,594.57	1,543.07	320.72	730.78
20	2,604.77	1,552.73	322.73	729.30
21	2,605.22	1,555.33	318.27	731.62
22	2,598.33	1,544.87	322.03	731.43
23	2,591.47	1,546.70	317.20	727.57
Average	2,600.41	1,550.56	319.88	729.97

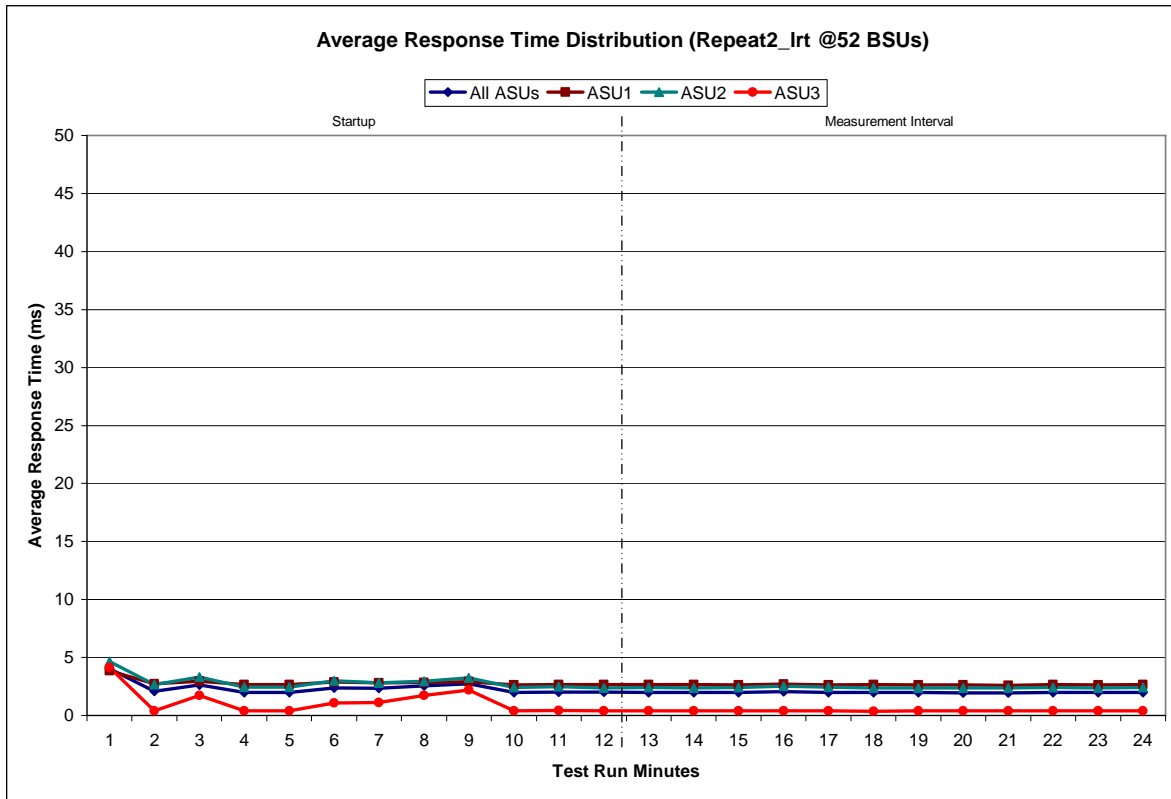
**Repeatability 2 LRT – I/O Request Throughput Distribution Graph**



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

52 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	3:23:15	3:35:15	0-11	0:12:00
Measurement Interval	3:35:15	3:47:15	12-23	0:12:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	4.03	3.86	4.65	4.12
1	2.07	2.74	2.65	0.38
2	2.64	2.93	3.29	1.74
3	1.99	2.66	2.45	0.38
4	1.99	2.66	2.46	0.38
5	2.39	2.89	2.98	1.08
6	2.33	2.81	2.80	1.12
7	2.56	2.86	2.97	1.74
8	2.75	2.90	3.25	2.21
9	1.97	2.62	2.39	0.39
10	2.01	2.66	2.48	0.42
11	2.00	2.66	2.39	0.40
12	1.99	2.65	2.40	0.39
13	1.98	2.65	2.38	0.40
14	1.98	2.64	2.41	0.39
15	2.04	2.71	2.52	0.39
16	1.96	2.62	2.43	0.38
17	1.98	2.65	2.39	0.38
18	1.97	2.63	2.39	0.38
19	1.96	2.62	2.39	0.38
20	1.94	2.59	2.36	0.38
21	1.98	2.65	2.43	0.38
22	1.97	2.64	2.38	0.38
23	1.99	2.65	2.42	0.39
Average	1.98	2.64	2.41	0.38

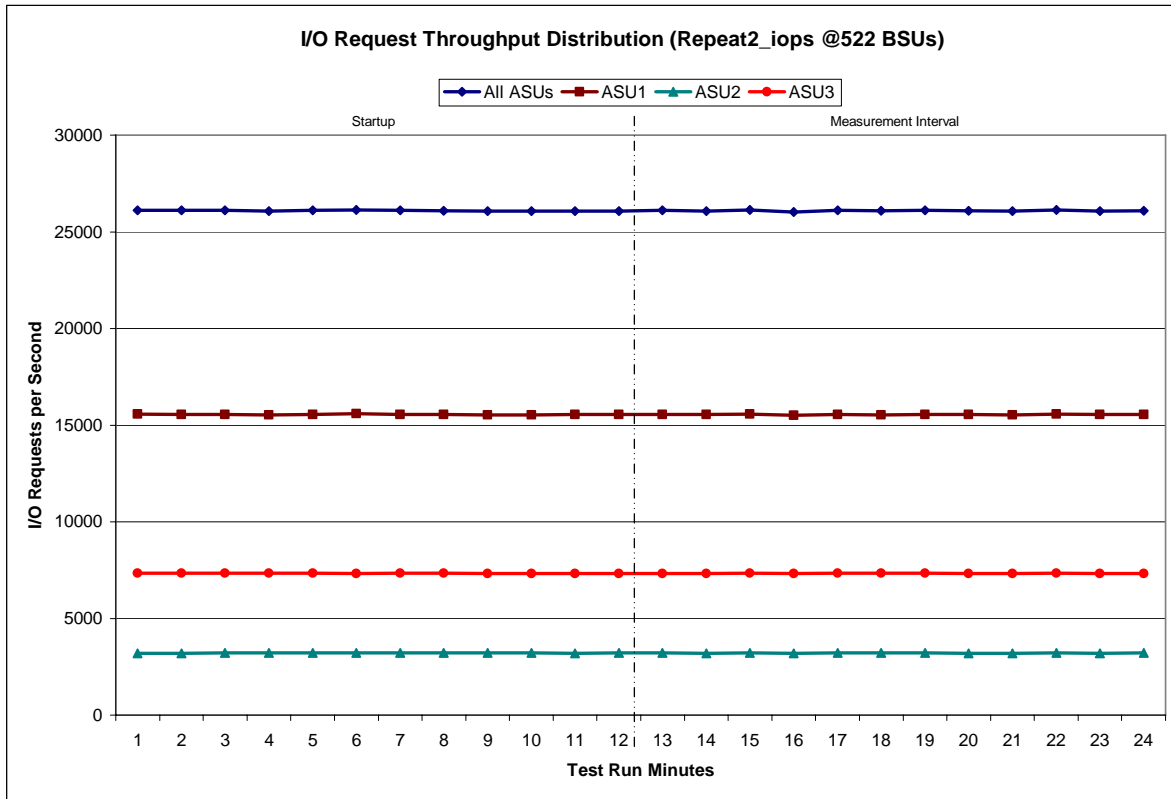
**Repeatability 2 LRT –Average Response Time (ms) Distribution Graph**



**Repeatability 2 IOPS - I/O Request Throughput Distribution Data**

522 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	3:47:19	3:59:20	0-11	0:12:01
Measurement Interval	3:59:20	4:11:20	12-23	0:12:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	26,105.25	15,568.83	3,202.68	7,333.73
1	26,106.10	15,559.13	3,205.92	7,341.05
2	26,113.20	15,559.10	3,214.75	7,339.35
3	26,074.17	15,525.95	3,211.33	7,336.88
4	26,120.85	15,557.80	3,219.60	7,343.45
5	26,132.03	15,596.08	3,220.37	7,315.58
6	26,111.62	15,560.95	3,216.78	7,333.88
7	26,095.07	15,545.60	3,210.88	7,338.58
8	26,061.97	15,532.17	3,208.55	7,321.25
9	26,076.78	15,535.48	3,211.90	7,329.40
10	26,076.10	15,558.03	3,201.43	7,316.63
11	26,078.62	15,556.65	3,210.92	7,311.05
12	26,105.20	15,552.18	3,220.92	7,332.10
13	26,076.50	15,544.18	3,202.12	7,330.20
14	26,135.58	15,568.03	3,216.87	7,350.68
15	26,030.02	15,507.82	3,201.52	7,320.68
16	26,108.38	15,544.75	3,219.08	7,344.55
17	26,085.97	15,539.58	3,209.27	7,337.12
18	26,104.08	15,551.60	3,216.25	7,336.23
19	26,084.72	15,551.85	3,205.72	7,327.15
20	26,063.02	15,537.32	3,206.98	7,318.72
21	26,128.68	15,572.02	3,212.48	7,344.18
22	26,076.98	15,554.22	3,205.72	7,317.05
23	26,081.43	15,555.43	3,213.68	7,312.32
Average	26,090.05	15,548.25	3,210.88	7,330.92

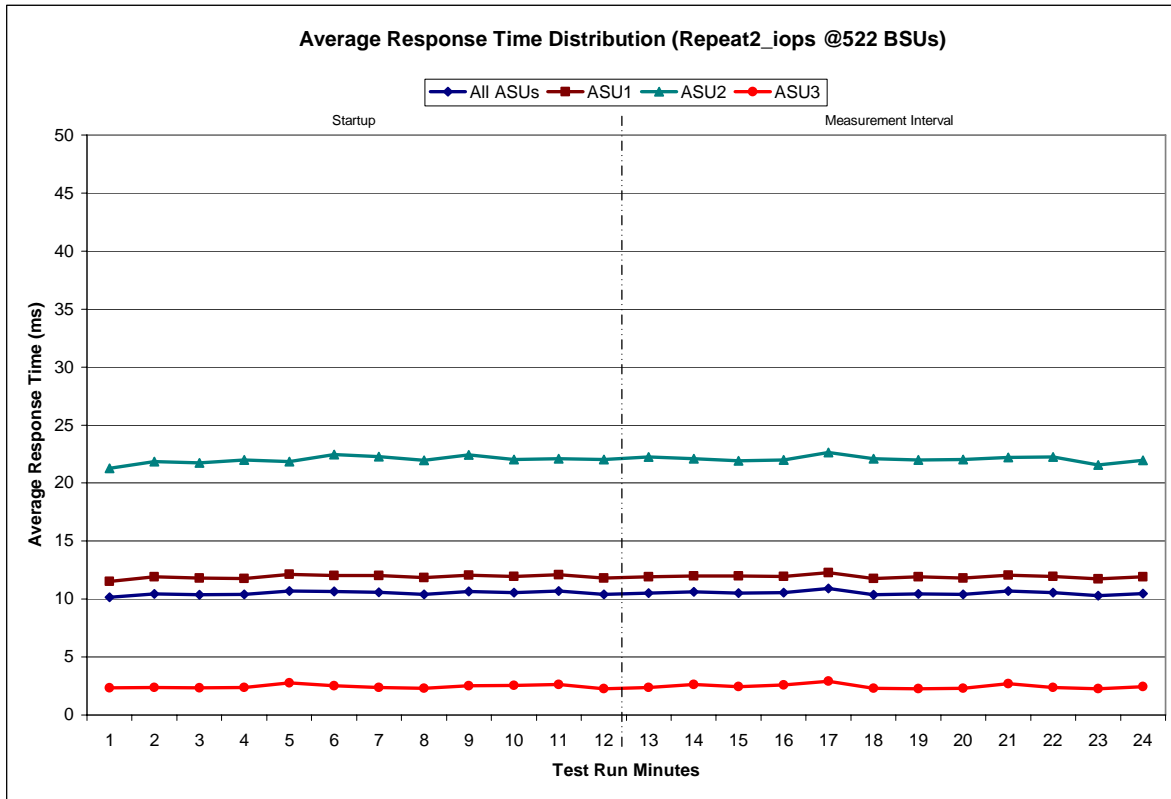
**Repeatability 2 IOPS - I/O Request Throughput Distribution Graph**



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

522 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	3:47:19	3:59:20	0-11	0:12:01
Measurement Interval	3:59:20	4:11:20	12-23	0:12:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	10.14	11.53	21.26	2.33
1	10.44	11.90	21.84	2.36
2	10.36	11.80	21.74	2.33
3	10.39	11.78	21.99	2.37
4	10.69	12.12	21.85	2.76
5	10.64	12.01	22.45	2.52
6	10.57	12.02	22.29	2.38
7	10.39	11.83	21.94	2.29
8	10.65	12.04	22.42	2.52
9	10.56	11.97	22.04	2.55
10	10.67	12.10	22.11	2.64
11	10.41	11.82	22.04	2.28
12	10.52	11.93	22.24	2.38
13	10.61	11.99	22.11	2.64
14	10.53	11.99	21.94	2.44
15	10.56	11.96	22.01	2.61
16	10.91	12.26	22.64	2.92
17	10.38	11.78	22.11	2.29
18	10.44	11.91	21.98	2.27
19	10.40	11.82	22.04	2.30
20	10.67	12.05	22.20	2.70
21	10.53	11.96	22.24	2.39
22	10.29	11.74	21.57	2.27
23	10.49	11.90	21.96	2.44
Average	10.53	11.94	22.09	2.47

**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
<b>IM</b>	<b>0.0350</b>	<b>0.2810</b>	<b>0.0700</b>	<b>0.2100</b>	<b>0.0180</b>	<b>0.0700</b>	<b>0.0350</b>	<b>0.2810</b>
MIM	0.0348	0.2805	0.0702	0.2097	0.0181	0.0702	0.0350	0.2815
COV	0.010	0.003	0.008	0.005	0.014	0.009	0.010	0.003

**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
<b>IM</b>	<b>0.0350</b>	<b>0.2810</b>	<b>0.0700</b>	<b>0.2100</b>	<b>0.0180</b>	<b>0.0700</b>	<b>0.0350</b>	<b>0.2810</b>
MIM	0.0351	0.2811	0.0700	0.2100	0.0180	0.0700	0.0351	0.2808
COV	0.005	0.001	0.003	0.002	0.004	0.003	0.004	0.001

**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
<b>IM</b>	<b>0.0350</b>	<b>0.2810</b>	<b>0.0700</b>	<b>0.2100</b>	<b>0.0180</b>	<b>0.0700</b>	<b>0.0350</b>	<b>0.2810</b>
MIM	0.0350	0.2818	0.0696	0.2098	0.0182	0.0700	0.0348	0.2807
COV	0.014	0.004	0.007	0.005	0.024	0.013	0.012	0.004

**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
<i>IM</i>	<i>0.0350</i>	<i>0.2810</i>	<i>0.0700</i>	<i>0.2100</i>	<i>0.0180</i>	<i>0.0700</i>	<i>0.0350</i>	<i>0.2810</i>
MIM	0.0350	0.2811	0.0700	0.2099	0.0180	0.0700	0.0350	0.2810
COV	0.004	0.001	0.003	0.002	0.005	0.002	0.003	0.001

## 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 68.

## 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

<b>Data Persistence Test Results</b>	
Data Persistence Test Run Number: 1	
Total Number of Logical Blocks Written	60,386,976
Total Number of Logical Blocks Verified	53,459,280
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 Sun Storage 6180 Array 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 differenced 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 Sun Storage 6180 Array .

## **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 gibibyte (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.

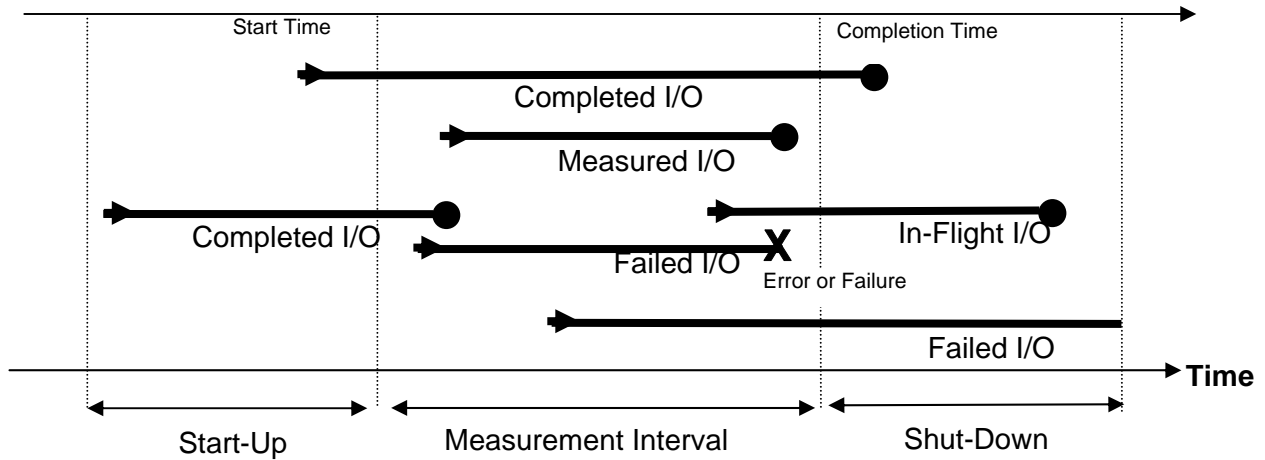
**Test:** A collection of Test Phases and or Test Runs sharing a common objective.

**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

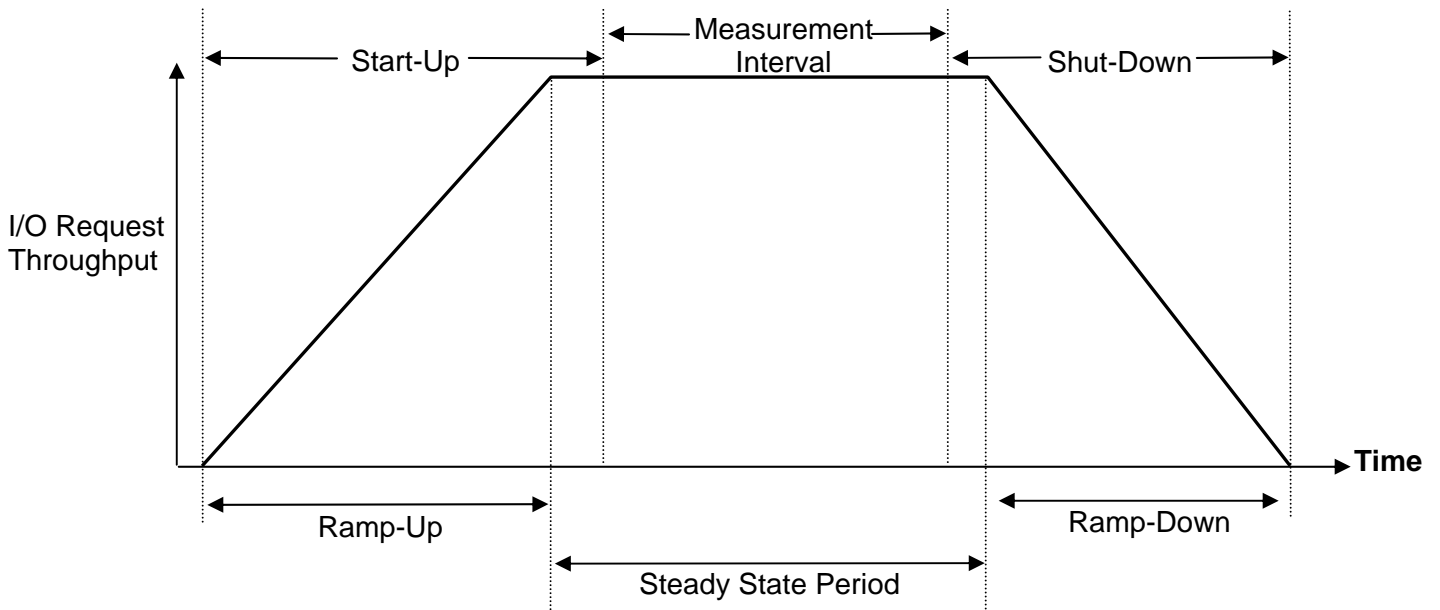
period, Shut-Down period, and Ramp-Down period as illustrated in the “SPC-1 Test Run Components” below. All SPC-1 Test Runs shall have a Steady State period and a Measurement Interval.

**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**

### **Windows 2003 Registry Changes**

HKEY\_LOCAL\_MACHINE\SYSTEM\CurrentControlSet\Services\ql2300\Device\MaximumSGList=0xf  
f

HKEY\_LOCAL\_MACHINE\SYSTEM\CurrentControlSet\Services\ql2300\Device\NumberOfRequests=  
0xfe

HKEY\_LOCAL\_MACHINE\SYSTEM\CurrentControlSet\Services\ql2300\Parameters\Device\Driver  
Parameter: UseSameNN=1

HKEY\_LOCAL\_MACHINE\SYSTEM\CurrentControlSet\Services\ql2300\Start=1

### **Storage Array Cache Block Size**

**CacheBlockSize:** changed from default of 4 KB to new value of 16 KB

### **RDAC Failover Options**

Host Region	Offset	Default	New Value
3	0x24	1	0
9	0x24	1	0
10	0x24	1	0
11	0x24	1	0
12	0x24	1	0
13	0x24	1	0
14	0x24	1	0

### **Host Bus Adapter Options**

The table below lists the Host Bus Adapter BIOS options that were changed from their default values.

<b>Host Bus Adapter Settings</b>		
Item	Default	New Value
<b>Adapter Settings:</b>		
Fibre Channel Tape Support	Enabled	Disabled
<b>Advanced Adapter Settings:</b>		
Execution Throttle	16	1020
LUNs per Target	8	128
Port Down Retry Count	8	30

## **APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION**

The storage management utility, **SANtricity**, was used to create eight volume groups on the storage subsystem, each volume group contains a RAID1 (mirrored) volume. All eight RAID1 volumes are visible by both of the attached hosts. The steps that follow are required to define the Host Access and TSC configuration.

1. Use **Simplicity** to create a host of type **“Windows 2000/Server 2003 Non-Clustered”**, name the hosts **“bm3850e”** and **“bm3850f”**. Specify the HBA Host Ports that correspond to the connected hosts. Select **“No, This host will NOT share access to the same volumes with other hosts.”** for each.
2. Remove the Access Volume’s Host-to-Volume Mapping.
3. Create Volumes using the **Simplicity** script, **“create8\_5plus5vols.script”**, listed below. Requires all preexisting volumes and volume groups be deleted from array.

The steps that follow are required to define the Windows partitions, volumes, and stripe sets that will be used by the SPC-1 benchmark and are executed on either of the hosts.

1. Execute the following command to create a 32 MiB partition at the front of each volume:  

```
FOR /L %n in (1,1,8) DO diskpar -s %n < diskparResponse.txt
```

where **diskparResponse.txt** is a text file listed below.
2. Convert all of the storage system volumes to Dynamic Disks using the Windows Disk Administrator.
3. Using Disk Administrator, execute the following steps:
  - a. Create a Windows Striped (RAID 0) volume using all eight 32MiB partitions.
  - b. Delete the remaining large volume on each of the Dynamic Disks.
  - c. Create a Windows Striped (RAID 0) volume for ASU 3.
  - d. Set capacity to 61334 MiB per volume, 490672 MiB total.
  - e. Select all eight volumes.
  - f. Assign drive letter “L” to the volume. Do not format the volume.
4. Repeat previous step for ASU 1.
  - a. Set capacity to 276003 MiB per volume, 2208024 MiB total.
  - b. Select all eight volumes.
  - c. Assign drive letter “M” to the volume. Do not format the volume.
5. Repeat previous step for ASU 2.
  - a. Set capacity to 276003 MiB per volume, 2208024 MiB total.
  - b. Select all eight volumes.
  - c. Assign drive letter “N” to the volume. Do not format the volume.

6. On the second Host System, import foreign disks using Disk Administrator and assign the same drive letters for the corresponding striped volumes. Do not format any volume.
7. Reboot the two Host Systems.
8. After reboot completes, start Disk Administrator on each of the two Host Systems and reactivate the Windows stripe sets as necessary.

### **create\_8\_5plus5vols.script**

```
/* SPC-1 volume creation script */
/* Matterhorn 4988 Controller */
/* 80 Drives, 8 5+5 */
/* 4 expansion trays */

create volume drives=(0,1 0,2 10,1 10,2 10,3 10,4 10,5 10,6 10,7 10,8)
RAIDLevel=1
segmentSize=128
userLabel="Vol1"
capacity=599 GB
owner=A;
set volume["Vol1"] LogicalUnitNumber=1 hostGroup=defaultGroup;

create volume drives=(0,3 0,4 10,9 10,10 10,11 10,12 10,13 10,14 10,15 10,16)
RAIDLevel=1
segmentSize=128
userLabel="Vol2"
capacity=599 GB
owner=A;
set volume["Vol2"] LogicalUnitNumber=2 hostGroup=defaultGroup;

create volume drives=(0,5 0,6 11,1 11,2 11,3 11,4 11,5 11,6 11,7 11,8)
RAIDLevel=1
segmentSize=128
userLabel="Vol3"
capacity=599 GB
owner=A;
set volume["Vol3"] LogicalUnitNumber=3 hostGroup=defaultGroup;

create volume drives=(0,7 0,8 11,9 11,10 11,11 11,12 11,13 11,14 11,15 11,16)
RAIDLevel=1
segmentSize=128
userLabel="Vol4"
capacity=599 GB
owner=A;
set volume["Vol4"] LogicalUnitNumber=4 hostGroup=defaultGroup;

create volume drives=(0,9 0,10 20,1 20,2 20,3 20,4 20,5 20,6 20,7 20,8)
RAIDLevel=1
segmentSize=128
userLabel="Vol5"
capacity=599 GB
owner=B;
set volume["Vol5"] LogicalUnitNumber=5 hostGroup=defaultGroup;

create volume drives=(0,11 0,12 20,9 20,10 20,11 20,12 20,13 20,14 20,15 20,16)
RAIDLevel=1
segmentSize=128
```



```
userLabel="Vol6"  
capacity=599 GB  
owner=B;  
set volume["Vol6"] LogicalUnitNumber=6 hostGroup=defaultGroup;  
  
create volume drives=(0,13 0,14 21,1 21,2 21,3 21,4 21,5 21,6 21,7 21,8)  
RAIDLevel=1  
segmentSize=128  
userLabel="Vol7"  
capacity=599 GB  
owner=B;  
set volume["Vol7"] LogicalUnitNumber=7 hostGroup=defaultGroup;  
  
create volume drives=(0,15 0,16 21,9 21,10 21,11 21,12 21,13 21,14 21,15 21,16)  
RAIDLevel=1  
segmentSize=128  
userLabel="Vol8"  
capacity=599 GB  
owner=B;  
set volume["Vol8"] LogicalUnitNumber=8 hostGroup=defaultGroup;  
  
set StorageArray cacheBlockSize=16;  
set storageArray cacheFlushStart=80 cacheFlushStop=80;  
set allVolumes writeCacheEnabled=True;  
set allVolumes readCacheEnabled=True;  
set allVolumes mirrorCacheEnabled=True;  
set allVolumes cacheReadPrefetch=False;  
set allVolumes mediaScanEnabled=False;  
  
/* Setup for RDAC failover environment */  
set controller[a] HostNVS RAMByte[0x00, 0x24]=0x00;  
set controller[a] HostNVS RAMByte[0x01, 0x24]=0x00;  
set controller[a] HostNVS RAMByte[0x02, 0x24]=0x00;  
set controller[a] HostNVS RAMByte[0x03, 0x24]=0x00;  
set controller[a] HostNVS RAMByte[0x04, 0x24]=0x00;  
set controller[a] HostNVS RAMByte[0x05, 0x24]=0x00;  
set controller[a] HostNVS RAMByte[0x06, 0x24]=0x00;  
set controller[a] HostNVS RAMByte[0x07, 0x24]=0x00;  
set controller[a] HostNVS RAMByte[0x08, 0x24]=0x00;  
set controller[a] HostNVS RAMByte[0x09, 0x24]=0x00;  
set controller[a] HostNVS RAMByte[0x0a, 0x24]=0x00;  
set controller[a] HostNVS RAMByte[0x0b, 0x24]=0x00;  
set controller[a] HostNVS RAMByte[0x0c, 0x24]=0x00;  
set controller[a] HostNVS RAMByte[0x0d, 0x24]=0x00;  
set controller[a] HostNVS RAMByte[0x0e, 0x24]=0x00;  
set controller[a] HostNVS RAMByte[0x0f, 0x24]=0x00;  
  
set controller[b] HostNVS RAMByte[0x00, 0x24]=0x00;  
set controller[b] HostNVS RAMByte[0x01, 0x24]=0x00;  
set controller[b] HostNVS RAMByte[0x02, 0x24]=0x00;  
set controller[b] HostNVS RAMByte[0x03, 0x24]=0x00;  
set controller[b] HostNVS RAMByte[0x04, 0x24]=0x00;  
set controller[b] HostNVS RAMByte[0x05, 0x24]=0x00;  
set controller[b] HostNVS RAMByte[0x06, 0x24]=0x00;  
set controller[b] HostNVS RAMByte[0x07, 0x24]=0x00;  
set controller[b] HostNVS RAMByte[0x08, 0x24]=0x00;  
set controller[b] HostNVS RAMByte[0x09, 0x24]=0x00;  
set controller[b] HostNVS RAMByte[0x0a, 0x24]=0x00;  
set controller[b] HostNVS RAMByte[0x0b, 0x24]=0x00;  
set controller[b] HostNVS RAMByte[0x0c, 0x24]=0x00;  
set controller[b] HostNVS RAMByte[0x0d, 0x24]=0x00;  
set controller[b] HostNVS RAMByte[0x0e, 0x24]=0x00;
```

```
set controller[b] HostNVSRAMByte[0x0f, 0x24]=0x00;
```

### **diskparResponse.txt**

```
y  
y  
65536  
613340
```

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

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.

```
* spc1_iops.cfg

javaparms="-Xmx400m -Xms400m"
host=master
slaves=(slave1,slave2)
sd=asu1_1,lun=\\.M:,size=2315277M
sd=asu2_1,lun=\\.N:,size=2315277M
sd=asu3_1,lun=\\.L:,size=514506M
```

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

```
* spc1_persist.cfg

javaparms="-Xmx400m -Xms400m"
sd=asu1_1,lun=\\.M:,size=2315277M
sd=asu2_1,lun=\\.N:,size=2315277M
sd=asu3_1,lun=\\.L:,size=514506M
```

## **APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS**

### **Primary Metrics Test, Repeatability Test, and Persistence Test Run 1**

The following script was used to execute the Primary Metrics Test (*Sustainability Test Phase, IOPS Test Phase, and Response Time Ramp Test Phase*), Repeatability Test (*Repeatability Test Phase 1 and Repeatability Test Phase 2*), and Persistence Test Run 1 in an uninterrupted sequence.

```
copy /y spc1_iops.cfg spc1.cfg
java metrics -b 522 -s 720
java repeat1 -b 522 -t 720 -s 720
java repeat2 -b 522 -t 720 -s 720
REM single host for persistence test
copy /y spc1_persist.cfg spc1.cfg
java persist1 -b 522
```

### **Persistence Test Run 2**

The following script was used to execute Persistence Test Run 2.

```
copy /y spc1_persist.cfg spc1.cfg
java persist2
```

### **Slave JVM Initiation**

Each Slave JVM on each Host System was initiated by a command and corresponding parameter file. An example of the command and corresponding parameter file appear below.

#### **Slave1.cmd**

```
java spc1 -fslavel.txt
```

#### **Slave1.txt**

```
*slavel.txt

javaparms="-Xmx400m -Xms400m"
master=172.22.201.90
host=slavel

sd=asu1_1,lun=\\.M:
sd=asu2_1,lun=\\.N:
sd=asu3_1,lun=\\.L:

eof
```