



**SPC BENCHMARK 1™  
FULL DISCLOSURE REPORT**

**SUN MICROSYSTEMS, INC.  
SUN STORAGE J4400 ARRAY**

**SPC-1 V1.10.1**

**Submitted for Review: July 7, 2008  
Submission Identifier: A00068**

**First Edition – July 2008**

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## AUDIT CERTIFICATION



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

July 7, 2008

The SPC Benchmark 1™ results listed below for the Sun Storage J4400 Array were produced in compliance with the SPC Benchmark 1™ V1.10.1 Remote Audit requirements.

SPC Benchmark 1™ V1.10.1 Results	
Tested Storage Configuration (TSC) Name: Sun Storage J4400 Array	
Metric	Reported Result
SPC-1 IOPS™	7,201.32
SPC-1 Price-Performance	\$1.73/SPC-1 IOPS™
Total ASU Capacity	2,194,000 GB
Data Protection Level	Unprotected
Total TSC Price (including three-year maintenance)	\$12,446

The following SPC Benchmark 1™ Remote Audit requirements were reviewed and found compliant with V1.10.1 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).
- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters that were changed from default values.

Storage Performance Council  
643 Bair Island Road, Suite 103  
Redwood City, CA 94062  
[AuditService@storageperformance.org](mailto:AuditService@storageperformance.org)  
650.556.9384

**AUDIT CERTIFICATION** (CONT.)

Sun Storage J4400 Array  
SPC-1 Audit Certification

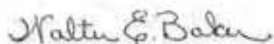
Page 2

- 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 the Host System.
  - ✓ The TSC boundary within the 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 Configuration.
- The submitted pricing information met all of the requirements and constraints of Clause 8 of the SPC-1 Benchmark Specification.
- The Full Disclosure Report (FDR) met all of the requirements in Clause 9 of the SPC-1 Benchmark Specification.
- This successfully audited SPC measurement is not subject to an SPC Confidential Review.

**Audit Notes:**

There were no audit notes or exceptions.

Respectfully,



Walter E. Baker  
SPC Auditor

Storage Performance Council  
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Redwood City, CA 94062  
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**LETTER OF GOOD FAITH**

Sun Microsystems, Inc.  
Mailstop USCA11-203  
4140 Network Circle  
Santa Clara, CA 95054



Date: 6/3/08

From: Ronald Melanson

To: Walter Baker

Subject: SPC-1 Letter of Good Faith for the Sun Storage J4400

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 cursive script, appearing to read "Ronald Melanson", written over a horizontal line.

Ronald Melanson  
Vice President, System Group Quality Office



## **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> Leah Schoeb – <a href="mailto:leah.schoeb@sun.com">leah.schoeb@sun.com</a> 5300 Riata Park Court AUS08 Austin, TX 78721 Phone: (877) 319-0457 FAX: (512) 266-2523
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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>	V1.10.1
<b>SPC-1 Workload Generator revision number</b>	V2.00.04a
<b>Date Results were first used publicly</b>	July 7, 2008
<b>Date the FDR was submitted to the SPC</b>	July 7, 2008
<b>Date the TSC is available for shipment to customers</b>	July 8, 2008
<b>Date the TSC completed audit certification</b>	July 7, 2008

### **Tested Storage Product (TSP) Description**

The Sun Storage J4400 array offers bulk SAS/SATA JBOD storage with double the storage density, twice the connectivity, and higher availability at half the price per gigabyte. Plus, you also get the groundbreaking ZFS file system included at no extra charge. ZFS automates common administrative tasks, protects data from corruption, and provides unlimited scalability.

### Summary of Results

SPC-1 Results	
Tested Storage Configuration (TSC) Name: Sun Storage J4400 Array	
Metric	Reported Result
SPC-1 IOPS™	7,201.32
SPC-1 Price-Performance	\$1.73/SPC-1 IOPS™
Total ASU Capacity	2,194.000 GB
Data Protection Level	Unprotected
Total TSC Price (including three-year maintenance)	\$12,446

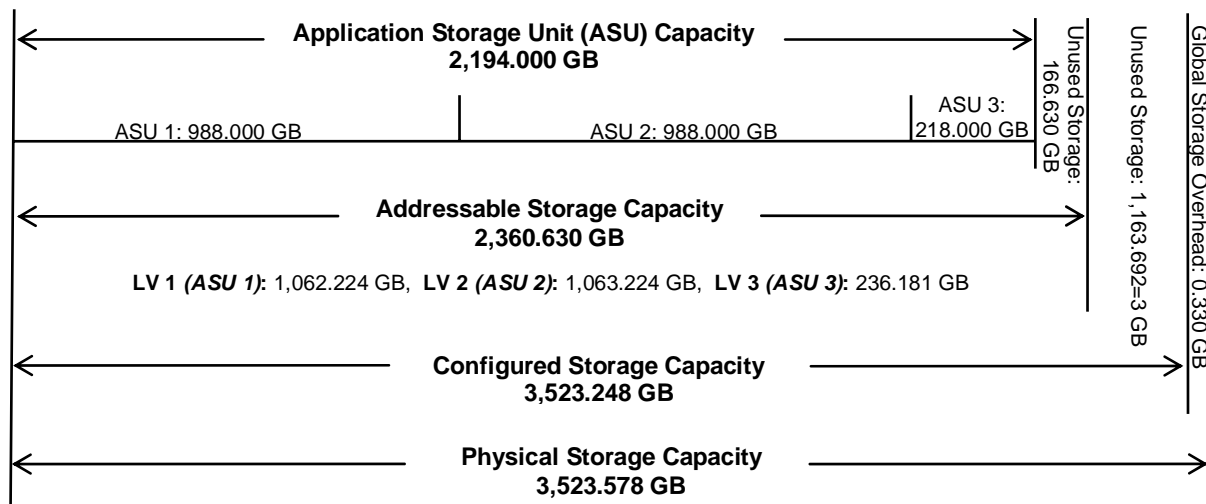
**SPC-1 IOPS™** represents the maximum I/O Request Throughput at the 100% load point.

**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 “Unprotected” provides no data protection.

### Storage Capacities and Relationships

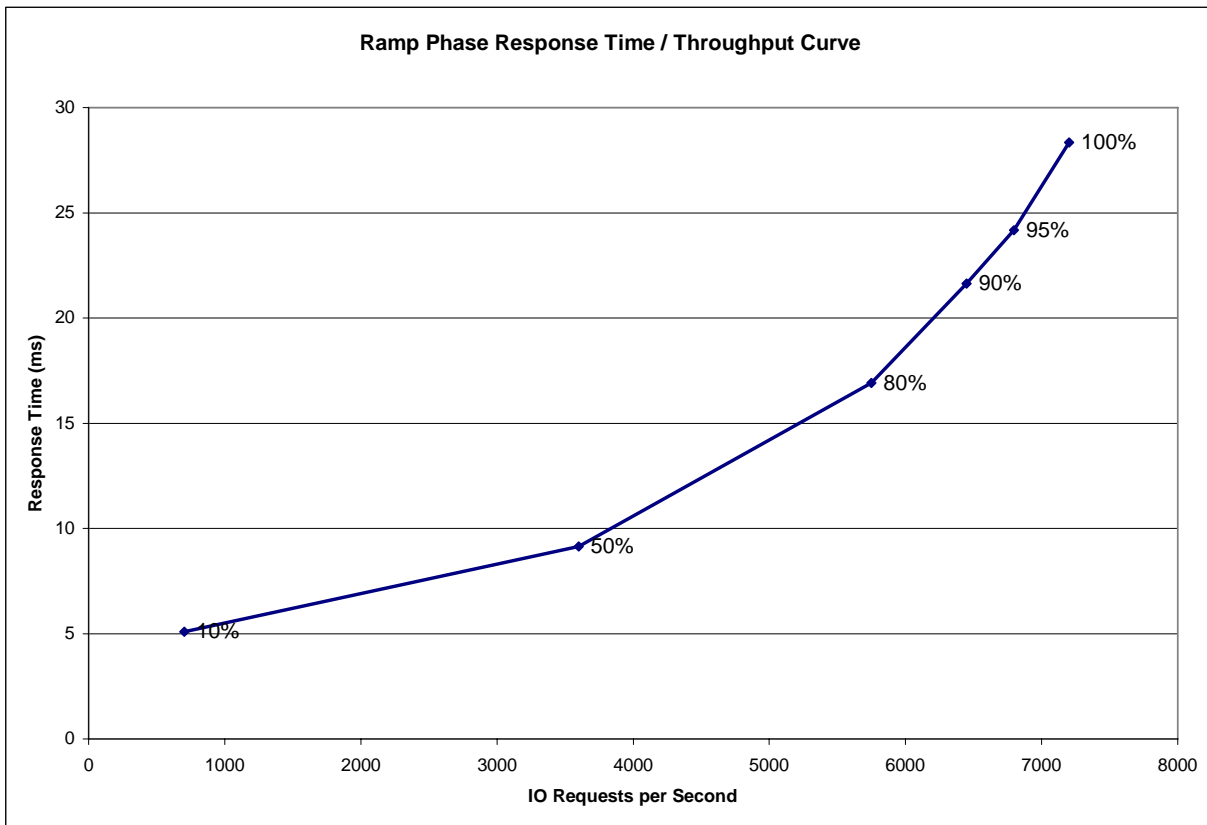
The following diagram documents the various storage capacities, used in this benchmark, and their relationships.



### 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>	701.67	3,600.51	5,749.02	6,447.36	6,798.19	7,201.32
<b>Average Response Time (ms):</b>						
All ASUs	5.09	9.14	16.90	21.63	24.17	28.34
ASU-1	4.91	8.27	13.63	16.78	18.37	21.01
ASU-2	5.45	10.96	26.27	36.35	41.92	50.68
ASU-3	5.29	10.19	19.75	25.46	28.69	34.12
Reads	4.40	7.47	12.24	15.02	16.61	19.02
Writes	5.53	10.23	19.94	25.94	29.09	34.42

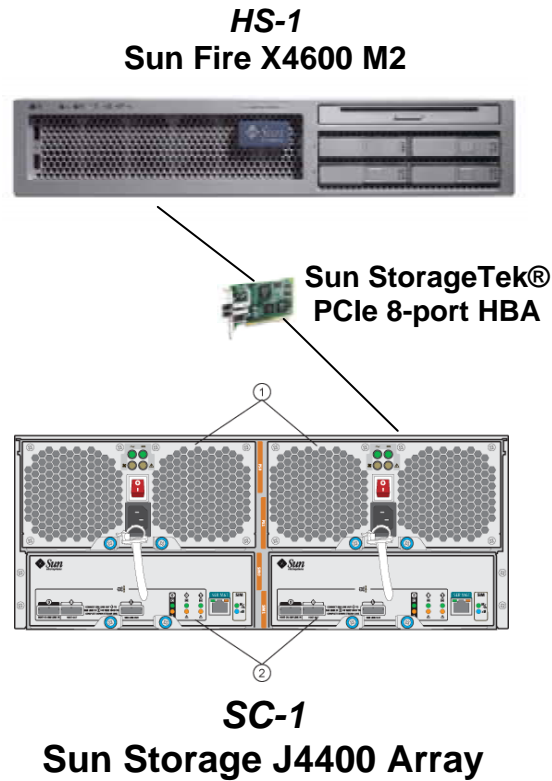
### Tested Storage Configuration Pricing (*Priced Storage Configuration*)

Part Number	Description	Quantity	US List	Total	discount	Ave. Price
XTA4400R00A10DISK	Sun Storage J4400 Rack Ready JBOD Chassis, No drives, dual AC power supplies, dual fan module, rail kit, single SAS I/O module, One .5M SAS cable, RoHS-5.	1	\$3,525.00	\$3,525	22%	\$2,750
XTA-4400-IOM	One three-port SAS I/O module for Storage J4400, One .5M SAS cable.	1	\$600	\$600	22%	\$468
XTA-SS1NJ-146G15K	RoHS-6. Internal 146GB 15K SAS HDD, 3.5" x 1" drive with bracket for J4200 and J4400.	24	\$399	\$9,576	22%	\$7,469
XTA-4200-2URK-19U	Sun Storage J4400 4U universal rack rail kit; RoHS-5	1	\$175	\$175	22%	\$137
SG-XPCIE8SAS-E-Z	Sun StorageTek (TM) PCIe SAS Host Bus Adapter, 8 port, RoHS 6 compliant	1	\$550	\$550	22%	\$429
IWU-STJ4400-24-3G	Controller unit upgrade 3 year Gold Service Maintenance	1	\$2,131.27	\$2,131	44%	\$1,194
	- 7/24 coverage					
	- 4 hr response time					
	- 4 hour resolution					
<b>Total</b>				<b>\$16,557</b>		<b>\$12,446</b>

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

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

**Benchmark Configuration/Tested Storage Configuration Diagram**



**Benchmark Configuration/Tested Storage Configuration Components**

Host System:	Tested Storage Configuration (TSC):
<b>UID=HS-1</b> Sun Fire X4600 M2	1 – Sun StorageTek PCI Express SAS 8-Channel HBA
4 – 2.6 GHz dual core AMD Opteron™ Processor 8222, 1 MB L2	<b>UID=SC-1:</b> <b>Sun Storage J4400</b>
15.5 GB main memory	3 – 3 Gb/s “x4 wide” SAS ports available 1 port used
MS Windows Server 2003 Enterprise x64 with Service Pack 2	24 – 146 GB, 15K RPM Seagate SAS disk drives
PCIe	
WG	

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 9.2.4.4.1*

*A one page Benchmark Configuration (BC)/Tested Storage Configuration (TSC) diagram shall be included in the Executive Summary...*

The Benchmark Configuration (BC)/Tested Storage Configuration (TSC) is illustrated on page 13 (*Benchmark Configuration/Tested Storage Configuration Diagram*).

### **Storage Network Configuration**

#### *Clause 9.2.4.4.1*

...

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 9.2.4.4.2.*

#### *Clause 9.2.4.4.2*

*If a storage network was configured as a part of the Tested Storage Configuration and the Benchmark Configuration diagram described in Clause 9.2.4.4.1 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), including the network configuration, is illustrated on page 13 (*Benchmark Configuration/Tested Storage Configuration Diagram*).

### **Host System Configuration**

#### *Clause 9.2.4.4.3*

*The FDR shall minimally contain, for each Host System running the Workload Generator, a listing of the following:*

1. *Number and type of CPUs.*
2. *Main memory capacity.*
3. *Cache memory capacity.*
4. *Number and type of disk controllers or Host Bus Adapters.*

The details of the Host System configuration may be found on page 13 (*Benchmark Configuration/Tested Storage Configuration Diagram*).

## Customer Tunable Parameters and Options

### Clause 9.2.4.5.1

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 57 contains the customer tunable parameters and options that have been altered from their default values for this benchmark.

## Tested Storage Configuration (TSC) Description

### Clause 9.2.4.5.2

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 58 contains the detailed information that describes how to create and configure the logical TSC.

## SPC-1 Workload Generator Storage Configuration

### Clause 9.2.4.5.3

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 60.

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

### Storage Capacities and Relationships

#### Clause 9.2.4.6.1

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)	2,194.000
Addressable Storage Capacity	Gigabytes (GB)	2,360.630
Configured Storage Capacity	Gigabytes (GB)	3,523.248
Physical Storage Capacity	Gigabytes (GB)	3,523.578
Data Protection ( <i>Unprotected</i> )	Gigabytes (GB)	0.000
Required Storage ( <i>spares/overhead</i> )	Gigabytes (GB)	0.000
Global Storage Overhead	Gigabytes (GB)	0.330
Total Unused Storage	Gigabytes (GB)	1,329.323

### SPC-1 Storage Hierarchy Ratios

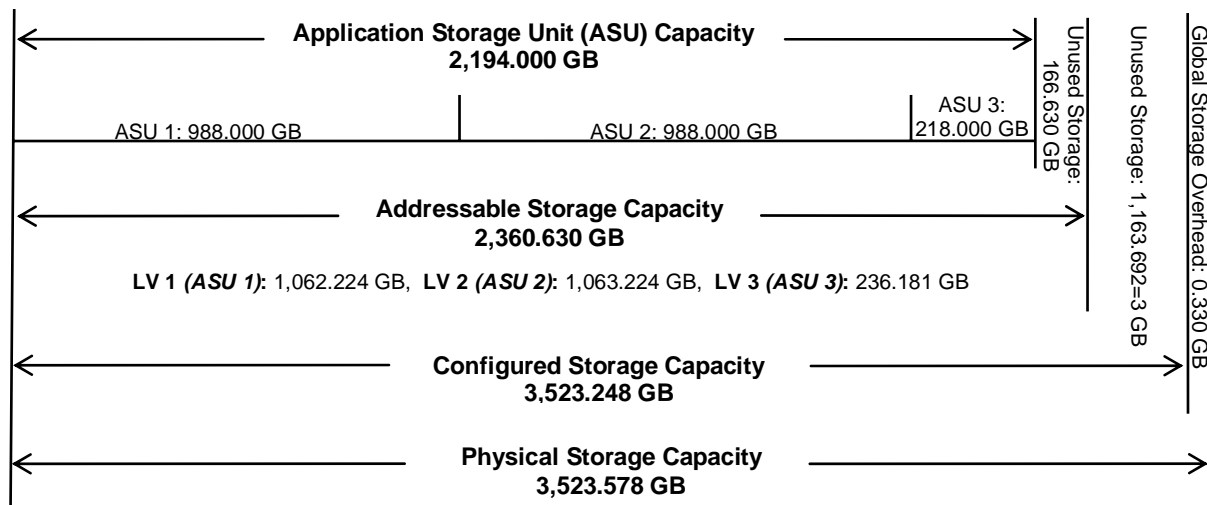
	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
<b>Total ASU Capacity</b>	92.94%	62.27%	62.27%
<b>Required for Data Protection (<i>Unprotected</i>)</b>		0.00%	0.00%
<b>Addressable Storage Capacity</b>		67.00%	67.00%
<b>Required Storage</b>		0.00%	0.00%
<b>Configured Storage Capacity</b>			99.99%
<b>Global Storage Overhead</b>			0.01%
<b>Unused Storage:</b>			
<b>Addressable</b>	7.06%		
<b>Configured</b>		33.00%	
<b>Physical</b>			0.00%



The Physical Storage Capacity consisted of 3,523.578 GB distributed over 24 disk drives each with a formatted capacity of 146.816 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 0.330 GB (0.01%) of Physical Storage Capacity. There was 1,162.693 GB (33.00%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 92.94% of the Addressable Storage Capacity resulting in 166.630 GB (7.06%) of Unused Storage within the Addressable Storage Capacity.

**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 9.2.4.6.2*

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 (988.000 GB)	ASU-2 (988.000 GB)	ASU-3 (218.000 GB)
1 Logical Volume 1,062.224 GB per Logical Volume (988.000 GB used per Logical Volume)	1 Logical Volume 1,062.224 GB per Logical Volume (988.000 GB used per Logical Volume)	1 Logical Volume 236.181 GB per Logical Volume (218.000 GB used per Logical Volume)

The Data Protection Level used for all Logical Volumes was “Unprotected” as described on page 10. See “ASU Configuration” in the [IOPS Test Results File](#) for more detailed configuration information.

## **SPC-1 BENCHMARK EXECUTION RESULTS**

This portion of the Full Disclosure Report documents the results of the various SPC-1 Tests, Test Phases, and Test Runs. “SPC-1 Test Execution Definitions” on page 54 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 9.2.4.7.1

*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 61.

## Sustainability Test Results File

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

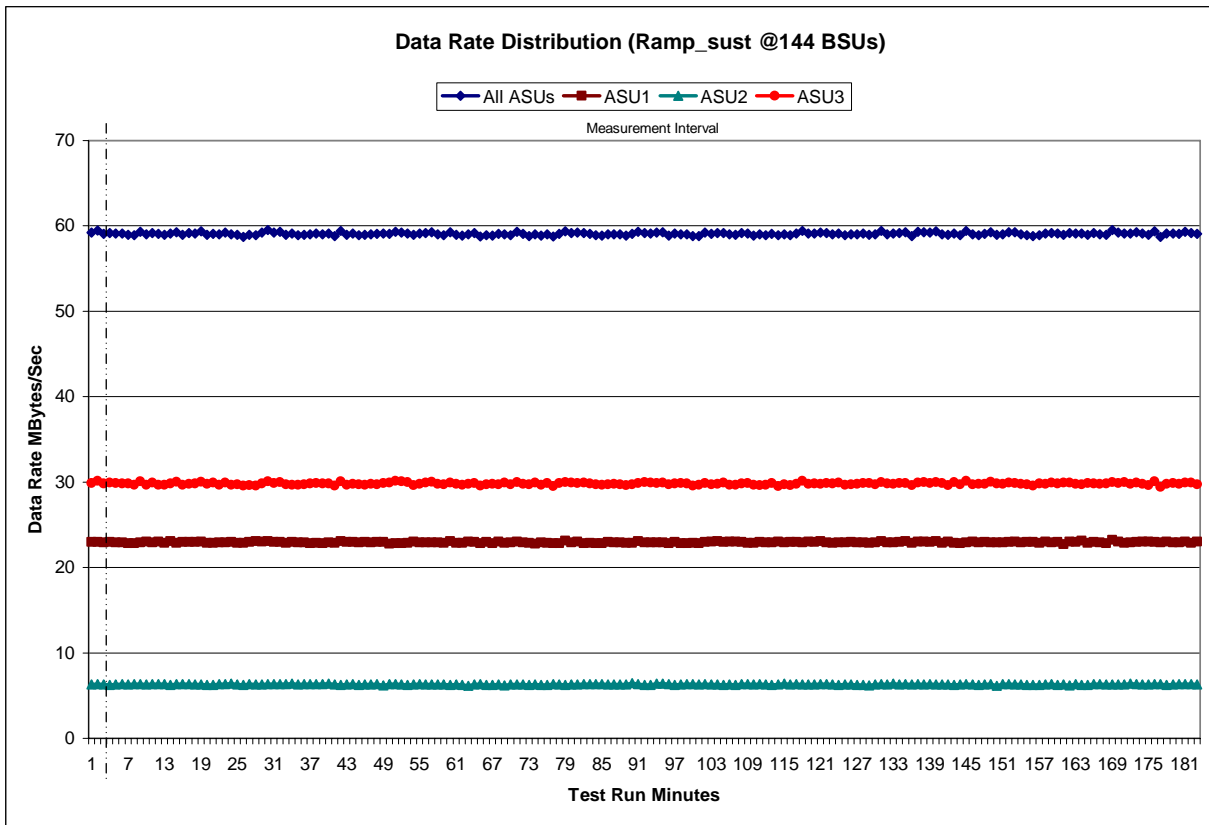
[Sustainability Test Results File](#)

**Sustainability – Data Rate Distribution Data (MB/second)**

Ramp-Up/Start-Up 21:11:19 21:14:19 0-2 0:03:00  
 Measurement Interval 21:14:19 0:14:19 3-182 3:00:00

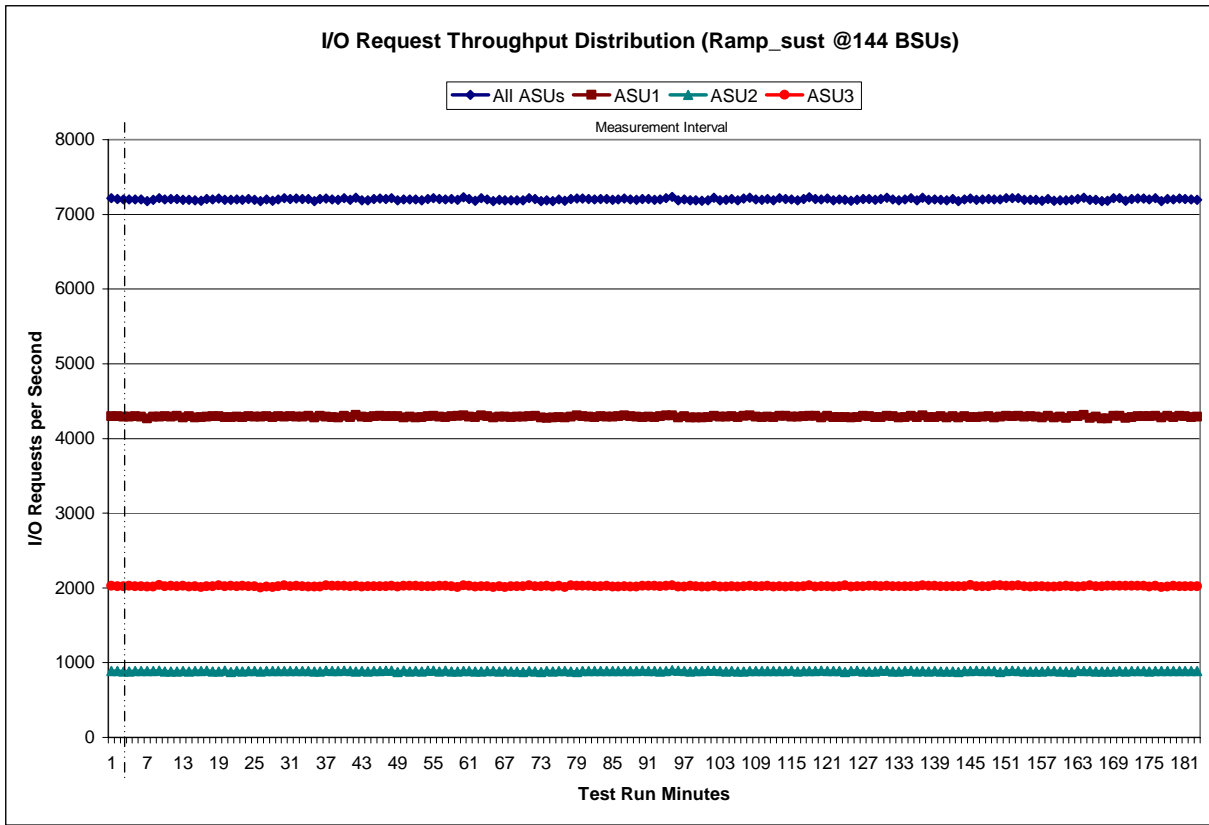
Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	59.21	22.99	6.32	29.90	63	59.15	22.99	6.30	29.86	126	59.01	22.95	6.27	29.78
1	59.47	23.00	6.35	30.12	64	58.76	22.84	6.34	29.58	127	59.12	22.95	6.27	29.91
2	59.09	22.94	6.32	29.82	65	58.93	22.96	6.25	29.72	128	58.94	22.86	6.21	29.88
3	59.17	22.96	6.27	29.94	66	58.86	22.83	6.25	29.78	129	58.99	22.95	6.29	29.75
4	59.10	22.94	6.28	29.88	67	59.05	23.04	6.28	29.73	130	59.44	23.08	6.36	30.00
5	59.14	22.95	6.34	29.85	68	59.04	22.90	6.20	29.93	131	59.03	22.91	6.31	29.81
6	58.96	22.82	6.32	29.82	69	58.93	22.93	6.28	29.72	132	59.10	22.94	6.40	29.76
7	58.90	22.83	6.36	29.71	70	59.31	23.02	6.32	29.97	133	59.17	22.97	6.31	29.89
8	59.34	22.92	6.36	30.07	71	59.05	22.94	6.31	29.79	134	59.29	23.06	6.34	29.89
9	59.03	23.01	6.32	29.69	72	58.82	22.86	6.24	29.72	135	58.79	22.88	6.28	29.63
10	59.18	22.93	6.33	29.92	73	59.00	22.77	6.30	29.93	136	59.33	23.05	6.35	29.93
11	59.07	23.04	6.34	29.69	74	58.88	22.92	6.27	29.70	137	59.28	23.01	6.29	29.98
12	58.94	22.89	6.37	29.68	75	59.02	22.89	6.26	29.87	138	59.19	22.97	6.34	29.88
13	59.13	23.08	6.24	29.81	76	58.74	22.85	6.34	29.54	139	59.37	23.10	6.30	29.97
14	59.25	22.89	6.34	30.01	77	59.05	22.85	6.30	29.90	140	59.03	22.86	6.28	29.89
15	58.94	22.96	6.33	29.66	78	59.36	23.13	6.25	29.98	141	58.95	23.02	6.30	29.64
16	59.14	22.99	6.36	29.80	79	59.19	22.93	6.31	29.94	142	59.12	22.86	6.26	30.00
17	59.13	23.00	6.30	29.83	80	59.22	23.02	6.30	29.90	143	58.90	22.85	6.30	29.74
18	59.37	23.03	6.32	30.01	81	59.15	22.85	6.37	29.93	144	59.41	22.92	6.34	30.16
19	58.95	22.89	6.26	29.79	82	59.06	22.89	6.34	29.83	145	59.03	23.03	6.29	29.71
20	59.05	22.87	6.26	29.92	83	58.93	22.85	6.35	29.73	146	58.93	22.91	6.24	29.78
21	58.99	22.95	6.36	29.69	84	58.85	22.83	6.33	29.69	147	59.07	22.99	6.29	29.79
22	59.24	22.93	6.36	29.95	85	59.02	22.96	6.30	29.76	148	59.26	22.91	6.33	30.02
23	59.03	22.96	6.38	29.70	86	59.02	22.93	6.30	29.79	149	58.96	22.95	6.17	29.84
24	58.95	22.89	6.32	29.74	87	59.00	22.93	6.32	29.75	150	59.02	22.91	6.34	29.77
25	58.71	22.86	6.25	29.60	88	58.85	22.89	6.31	29.65	151	59.29	23.00	6.33	29.96
26	58.97	22.99	6.33	29.65	89	59.05	22.87	6.43	29.75	152	59.26	23.04	6.31	29.90
27	58.92	23.06	6.28	29.59	90	59.32	23.09	6.36	29.86	153	59.02	22.94	6.28	29.81
28	59.21	23.05	6.30	29.86	91	59.18	22.93	6.27	29.98	154	58.93	22.96	6.25	29.73
29	59.50	23.06	6.37	30.07	92	59.14	22.95	6.27	29.91	155	58.79	22.96	6.24	29.60
30	59.21	23.00	6.33	29.87	93	59.20	22.95	6.39	29.86	156	58.93	22.88	6.23	29.81
31	59.30	22.98	6.34	29.98	94	59.25	22.95	6.39	29.91	157	59.10	23.02	6.32	29.76
32	58.96	22.86	6.35	29.75	95	58.88	22.84	6.33	29.71	158	59.17	22.91	6.34	29.92
33	59.09	22.99	6.40	29.71	96	59.10	23.00	6.25	29.85	159	59.09	23.00	6.27	29.83
34	58.89	22.93	6.28	29.69	97	59.02	22.83	6.32	29.88	160	58.95	22.71	6.29	29.96
35	58.98	22.92	6.32	29.73	98	59.02	22.84	6.36	29.83	161	59.17	23.04	6.22	29.91
36	59.03	22.84	6.37	29.82	99	58.79	22.87	6.34	29.58	162	59.11	23.01	6.34	29.77
37	59.10	22.90	6.34	29.87	100	58.80	22.83	6.31	29.67	163	59.12	23.11	6.26	29.75
38	59.02	22.81	6.36	29.85	101	59.21	22.98	6.35	29.88	164	58.97	22.86	6.25	29.86
39	59.12	22.93	6.38	29.82	102	59.09	23.03	6.30	29.75	165	59.16	22.99	6.36	29.81
40	58.81	22.90	6.32	29.60	103	59.18	23.08	6.30	29.81	166	59.04	22.92	6.35	29.77
41	59.43	23.09	6.26	30.07	104	59.17	22.99	6.25	29.92	167	58.95	22.84	6.28	29.82
42	58.97	22.96	6.30	29.71	105	59.01	23.04	6.29	29.67	168	59.52	23.22	6.31	29.98
43	59.10	22.97	6.33	29.79	106	58.97	23.02	6.25	29.70	169	59.21	23.03	6.30	29.88
44	58.90	22.92	6.25	29.72	107	59.18	22.99	6.34	29.85	170	59.14	22.87	6.29	29.98
45	58.98	22.99	6.30	29.69	108	59.13	22.90	6.35	29.88	171	59.11	22.92	6.39	29.81
46	59.01	22.93	6.31	29.77	109	58.87	22.86	6.32	29.69	172	59.29	22.97	6.36	29.96
47	59.06	22.97	6.34	29.75	110	58.99	22.99	6.36	29.64	173	59.09	23.01	6.31	29.77
48	59.11	23.01	6.22	29.88	111	58.92	22.93	6.30	29.69	174	58.95	23.01	6.30	29.64
49	59.09	22.78	6.36	29.95	112	59.07	22.93	6.25	29.89	175	59.38	22.96	6.35	30.07
50	59.29	22.82	6.33	30.14	113	58.92	23.06	6.31	29.55	176	58.72	22.94	6.33	29.45
51	59.20	22.83	6.29	30.09	114	59.04	22.91	6.39	29.73	177	59.10	23.04	6.26	29.80
52	59.12	22.90	6.23	29.98	115	58.90	22.97	6.29	29.65	178	59.11	22.94	6.31	29.87
53	58.95	23.03	6.28	29.64	116	59.13	22.98	6.37	29.77	179	59.08	22.94	6.37	29.76
54	59.11	22.95	6.35	29.81	117	59.40	22.93	6.32	30.15	180	59.31	23.04	6.34	29.94
55	59.14	22.93	6.29	29.93	118	59.09	23.04	6.28	29.77	181	59.19	22.89	6.36	29.94
56	59.28	22.93	6.32	30.03	119	59.11	22.99	6.31	29.81	182	59.04	23.02	6.29	29.73
57	58.99	22.92	6.28	29.79	120	59.21	23.08	6.34	29.79					
58	58.91	22.88	6.30	29.73	121	59.16	22.96	6.34	29.87					
59	59.25	23.09	6.25	29.92	122	59.01	22.90	6.29	29.82					
60	58.95	22.88	6.30	29.77	123	59.12	22.91	6.26	29.95					
61	58.84	22.90	6.25	29.68	124	58.92	22.92	6.32	29.68					
62	59.01	23.05	6.17	29.79	125	59.00	22.99	6.29	29.72					

### Sustainability – Data Rate Distribution Graph





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

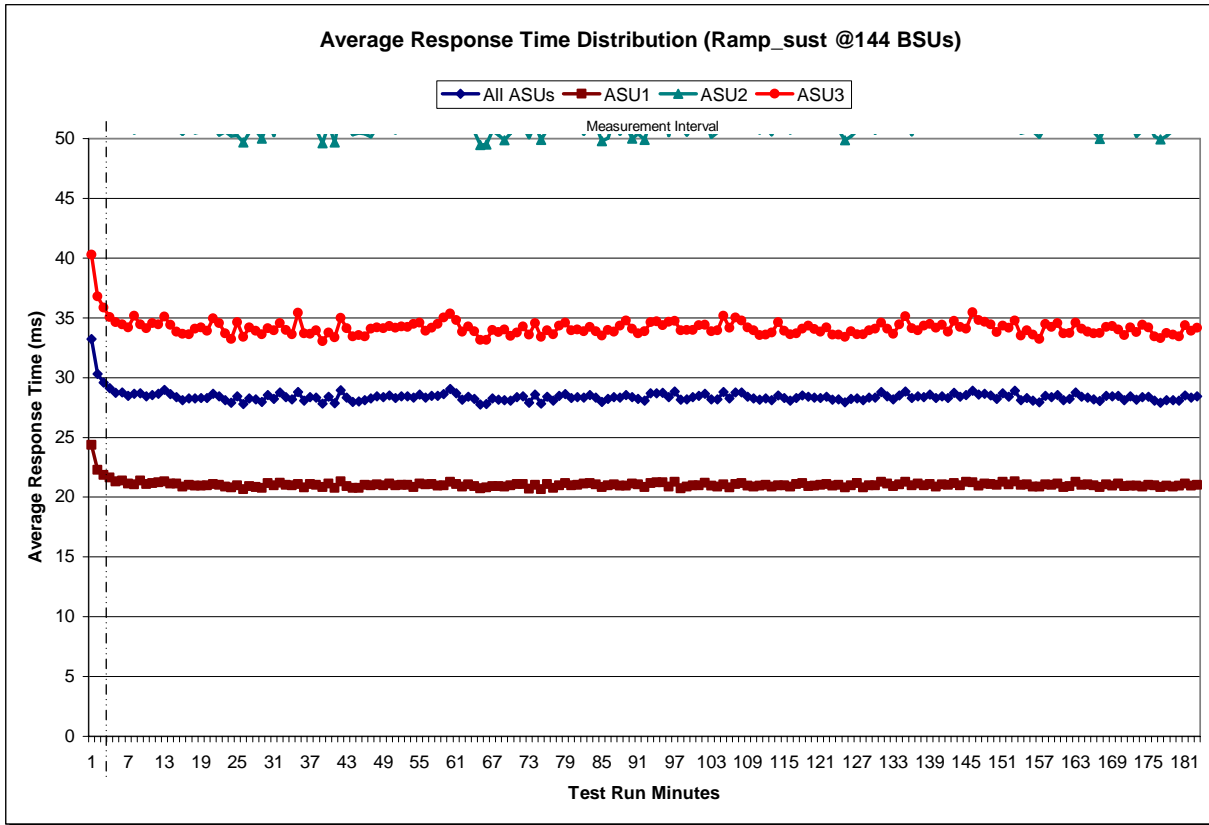


**Sustainability – Average Response Time (ms) Distribution Data**

	Start	Stop	Interval	Duration										
Ramp-Up/Start-Up	21:11:19	21:14:19	0-2	0:03:00										
Measurement Interval	21:14:19	0:14:19	3-182	3:00:00										
Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	33.22	24.38	59.85	40.27	63	28.21	20.90	50.59	33.88	126	28.26	21.15	50.66	33.60
1	30.33	22.29	54.55	36.78	64	27.76	20.75	49.48	33.14	127	28.11	20.80	51.17	33.64
2	29.58	21.86	52.72	35.85	65	27.80	20.81	49.50	33.14	128	28.32	21.00	51.01	33.94
3	29.11	21.63	51.87	35.05	66	28.24	20.92	50.67	33.99	129	28.32	21.00	50.44	34.10
4	28.74	21.31	51.34	34.64	67	28.15	20.92	50.30	33.80	130	28.80	21.27	51.91	34.60
5	28.77	21.38	51.53	34.46	68	28.11	20.86	49.84	34.01	131	28.43	21.14	51.06	34.09
6	28.46	21.12	50.76	34.20	69	28.08	20.99	50.43	33.49	132	28.18	20.91	50.83	33.67
7	28.64	21.05	50.47	35.19	70	28.38	21.10	51.25	33.77	133	28.53	21.07	51.05	34.44
8	28.69	21.38	50.67	34.46	71	28.44	21.08	50.99	34.25	134	28.84	21.26	51.17	35.12
9	28.44	21.09	51.14	34.13	72	27.90	20.68	50.06	33.57	135	28.28	21.00	50.34	34.11
10	28.56	21.17	50.65	34.56	73	28.57	21.03	51.19	34.55	136	28.43	21.13	51.27	33.95
11	28.64	21.24	51.47	34.45	74	27.84	20.66	49.91	33.41	137	28.38	20.98	50.56	34.35
12	28.97	21.30	51.92	35.10	75	28.39	21.11	50.77	33.94	138	28.59	21.11	51.24	34.48
13	28.62	21.14	51.75	34.40	76	28.06	20.77	50.62	33.63	139	28.31	20.89	51.14	34.16
14	28.35	21.13	50.76	33.84	77	28.46	21.00	51.18	34.33	140	28.45	21.05	50.68	34.42
15	28.10	20.88	50.36	33.66	78	28.62	21.17	51.37	34.59	141	28.29	21.01	51.00	33.85
16	28.25	21.03	50.85	33.63	79	28.28	20.98	50.71	33.95	142	28.71	21.18	51.54	34.72
17	28.26	20.96	50.48	34.07	80	28.37	21.03	51.04	34.00	143	28.39	20.99	50.96	34.24
18	28.30	20.94	50.57	34.19	81	28.31	21.12	50.37	33.86	144	28.53	21.26	50.87	34.11
19	28.29	21.00	50.61	33.90	82	28.55	21.16	51.46	34.24	145	28.90	21.24	50.92	35.44
20	28.65	21.11	50.92	34.95	83	28.35	21.04	51.10	33.87	146	28.58	20.96	51.27	34.82
21	28.43	21.01	50.29	34.56	84	27.96	20.86	49.79	33.50	147	28.64	21.13	51.30	34.65
22	28.12	20.87	50.58	33.69	85	28.21	20.99	50.02	33.97	148	28.53	21.08	50.92	34.43
23	27.91	20.80	50.21	33.23	86	28.36	21.04	51.48	33.82	149	28.23	21.03	50.69	33.79
24	28.43	21.00	50.26	34.64	87	28.33	20.96	50.36	34.34	150	28.70	21.28	51.73	34.35
25	27.80	20.67	49.68	33.40	88	28.55	20.95	51.04	34.77	151	28.42	21.05	50.88	34.15
26	28.27	20.91	50.52	34.20	89	28.36	21.14	50.01	34.09	152	28.90	21.31	52.34	34.76
27	28.17	20.83	50.68	33.91	90	28.23	21.04	50.41	33.70	153	28.13	21.01	50.42	33.52
28	27.99	20.78	50.00	33.63	91	28.09	20.85	49.88	33.86	154	28.28	21.05	50.56	33.96
29	28.54	21.18	51.33	34.11	92	28.67	21.16	51.58	34.65	155	28.09	20.89	50.63	33.59
30	28.22	20.98	50.27	33.95	93	28.70	21.26	51.25	34.68	156	27.94	20.89	50.10	33.21
31	28.75	21.21	51.90	34.56	94	28.73	21.25	51.87	34.38	157	28.49	21.04	51.00	34.47
32	28.37	21.02	51.21	33.97	95	28.38	20.86	50.24	34.66	158	28.38	21.04	50.51	34.24
33	28.20	20.97	50.82	33.63	96	28.83	21.27	52.08	34.72	159	28.55	21.14	50.78	34.57
34	28.79	21.10	50.90	35.42	97	28.16	20.73	50.90	33.95	160	28.13	20.84	50.65	33.69
35	28.07	20.81	50.60	33.69	98	28.19	20.87	50.28	33.99	161	28.22	20.91	51.30	33.73
36	28.36	21.09	51.27	33.64	99	28.36	21.00	50.96	33.99	162	28.75	21.28	51.50	34.61
37	28.34	21.04	50.77	33.94	100	28.48	20.97	51.25	34.38	163	28.40	21.02	51.31	34.10
38	27.84	20.86	49.59	33.05	101	28.65	21.20	51.48	34.40	164	28.34	21.04	50.98	33.83
39	28.39	21.13	51.20	33.78	102	28.17	20.95	50.11	33.88	165	28.17	20.97	50.55	33.69
40	27.88	20.78	49.67	33.37	103	28.18	20.87	50.52	33.96	166	28.06	20.83	49.97	33.73
41	28.94	21.30	52.30	34.99	104	28.80	21.06	51.77	35.17	167	28.48	21.06	51.14	34.25
42	28.33	20.93	51.01	34.13	105	28.25	20.81	50.87	34.16	168	28.43	20.95	51.36	34.31
43	27.95	20.77	50.33	33.45	106	28.76	21.09	51.80	35.01	169	28.47	21.14	51.40	34.02
44	28.02	20.78	50.47	33.55	107	28.78	21.17	52.07	34.77	170	28.12	20.91	50.53	33.56
45	28.13	21.03	50.41	33.44	108	28.40	20.96	51.21	34.19	171	28.43	20.96	51.24	34.20
46	28.27	20.99	50.15	34.07	109	28.24	20.88	50.80	33.93	172	28.15	20.95	50.18	33.80
47	28.44	21.05	50.90	34.21	110	28.15	20.97	50.47	33.56	173	28.35	20.89	50.68	34.40
48	28.35	21.00	51.11	34.14	111	28.24	21.03	50.91	33.59	174	28.42	21.01	51.23	34.21
49	28.51	21.13	50.68	34.30	112	28.12	20.90	50.31	33.76	175	28.08	20.97	50.20	33.45
50	28.31	20.97	50.46	34.17	113	28.52	20.97	51.23	34.64	176	27.91	20.83	49.94	33.28
51	28.44	21.04	50.81	34.28	114	28.30	20.97	50.82	33.90	177	28.12	20.93	50.23	33.74
52	28.45	21.01	51.34	34.24	115	28.08	20.88	50.46	33.62	178	28.13	20.89	50.69	33.57
53	28.33	20.83	50.56	34.49	116	28.29	21.09	50.80	33.70	179	28.09	20.94	50.53	33.44
54	28.57	21.12	50.83	34.59	117	28.52	21.16	51.45	34.08	180	28.52	21.15	50.88	34.36
55	28.32	21.04	50.84	33.90	118	28.39	20.93	51.09	34.35	181	28.31	20.96	51.05	33.89
56	28.49	21.09	51.18	34.16	119	28.32	20.95	50.69	34.06	182	28.42	21.03	51.15	34.17
57	28.49	20.96	51.34	34.50	120	28.30	21.04	50.95	33.84	Average	28.36	21.02	50.84	34.11
58	28.62	21.00	51.04	35.04	121	28.42	21.10	50.60	34.20					
59	29.07	21.29	52.46	35.35	122	28.14	20.94	50.57	33.58					
60	28.67	21.09	51.34	34.79	123	28.20	21.02	50.72	33.59					
61	28.17	20.89	50.62	33.84	124	27.93	20.81	49.84	33.41					
62	28.41	21.06	50.91	34.26	125	28.22	20.98	50.19	33.89					



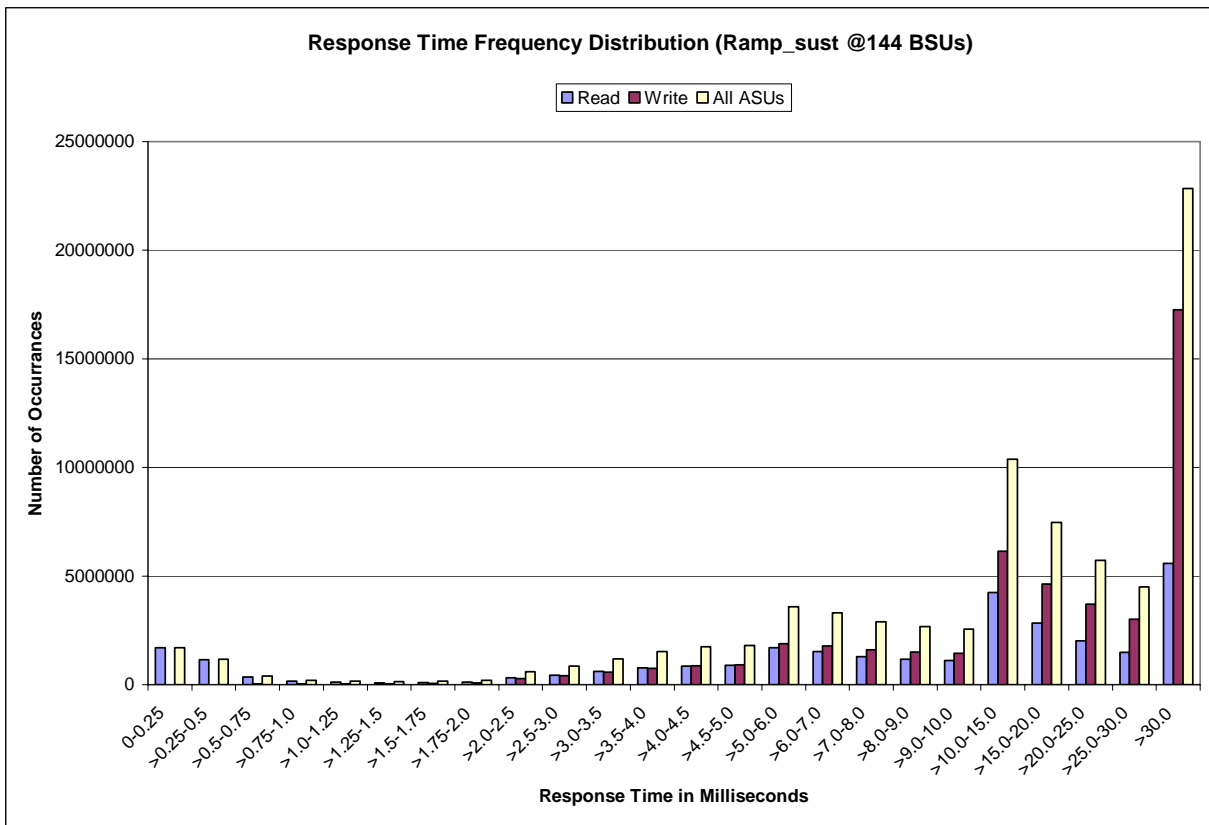
### Sustainability – Average Response Time (ms) Distribution Graph



**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	1,703,172	1,158,778	354,069	158,091	113,125	87,896	107,976	125,591
Write	166	8,215	33,295	40,204	40,295	45,337	54,360	74,166
All ASUs	1,703,338	1,166,993	387,364	198,295	153,420	133,233	162,336	199,757
ASU1	1,263,735	857,833	262,745	118,360	87,798	78,993	109,267	143,712
ASU2	439,437	300,952	91,417	39,847	25,773	11,127	9,385	10,295
ASU3	166	8,208	33,202	40,088	39,849	43,113	43,684	45,750
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	323,405	441,739	616,663	771,037	856,803	892,003	1,695,573	1,532,947
Write	273,754	417,361	570,149	762,121	880,440	913,363	1,882,005	1,784,764
All ASUs	597,159	859,100	1,186,812	1,533,158	1,737,243	1,805,366	3,577,578	3,317,711
ASU1	437,136	613,532	859,327	1,099,737	1,248,734	1,313,428	2,557,362	2,321,666
ASU2	31,179	42,625	53,613	69,618	88,909	106,205	228,572	218,515
ASU3	128,844	202,943	273,872	363,803	399,600	385,733	791,644	777,530
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	1,295,469	1,165,932	1,104,153	4,248,228	2,839,730	2,017,300	1,481,516	5,581,742
Write	1,603,741	1,513,258	1,443,657	6,133,358	4,637,008	3,703,966	3,008,949	17,260,484
All ASUs	2,899,210	2,679,190	2,547,810	10,381,586	7,476,738	5,721,266	4,490,465	22,842,226
ASU1	2,010,670	1,839,366	1,745,674	6,883,697	4,713,596	3,423,704	2,556,051	9,801,485
ASU2	203,162	190,905	177,325	782,062	639,862	555,017	490,458	4,758,827
ASU3	685,378	648,919	624,811	2,715,827	2,123,280	1,742,545	1,443,956	8,281,914

**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 5.1.0 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>	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
MIM	0.0350	0.1404	0.007	0.2101	0.0180	0.0700	0.0350	0.2809
COV	0.008	0.002	0.005	0.003	0.012	0.006	0.008	0.002

## Primary Metrics Test – IOPS Test Phase

### Clause 5.4.2.2

*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 9.2.4.7.2

*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 61.

## IOPS Test Results File

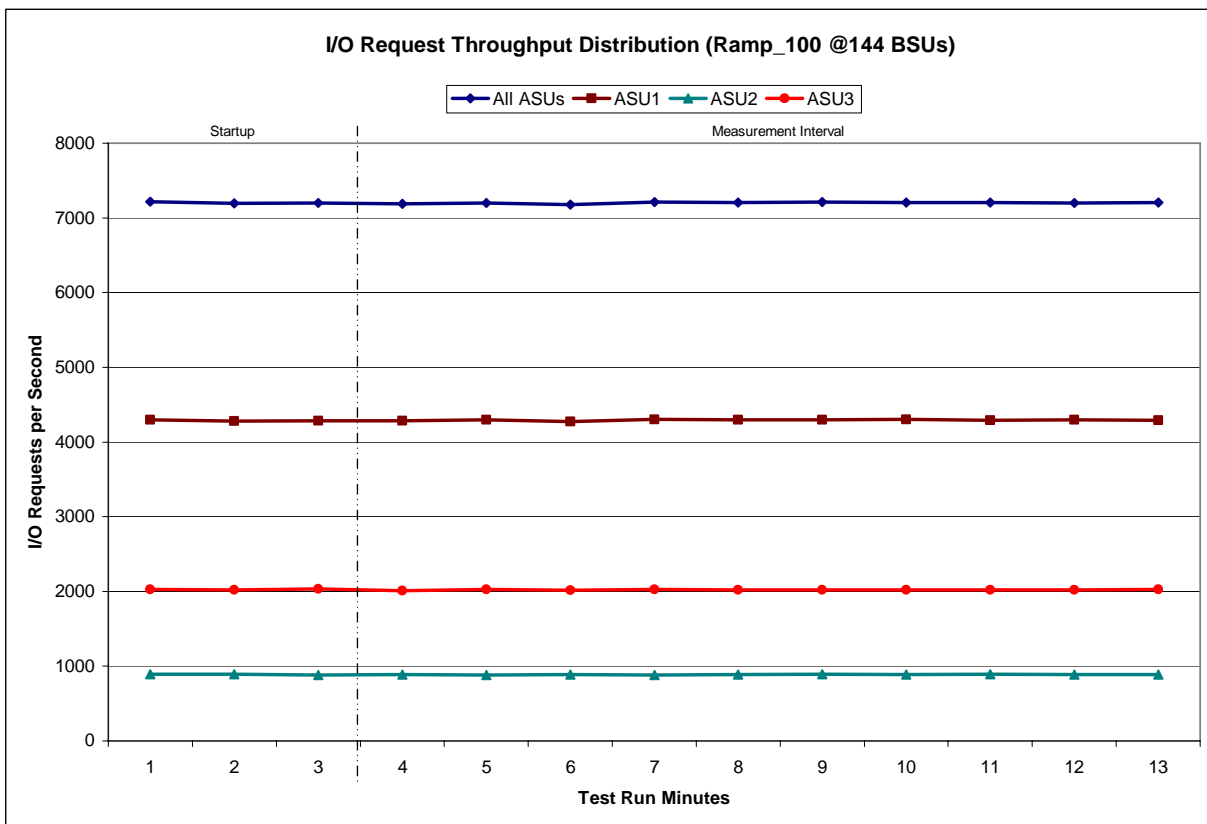
A link to the test results file generated from the IOPS Test Run is listed below.

[IOPS Test Results File](#)

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

144 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	0:14:24	0:17:25	0-2	0:03:01
<i>Measurement Interval</i>	0:17:25	0:27:25	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	7,215.15	4,295.55	893.45	2,026.15
1	7,190.95	4,278.62	889.98	2,022.35
2	7,198.85	4,286.43	881.90	2,030.52
3	7,187.73	4,285.93	889.38	2,012.42
4	7,202.10	4,295.68	881.03	2,025.38
5	7,178.37	4,275.87	884.37	2,018.13
6	7,213.03	4,302.85	883.63	2,026.55
7	7,204.65	4,297.88	884.57	2,022.20
8	7,208.25	4,294.28	890.77	2,023.20
9	7,207.03	4,300.83	885.70	2,020.50
10	7,204.78	4,292.92	890.67	2,021.20
11	7,202.28	4,295.40	887.30	2,019.58
12	7,204.97	4,292.62	884.53	2,027.82
<b>Average</b>	<b>7,201.32</b>	<b>4,293.43</b>	<b>886.20</b>	<b>2,021.70</b>

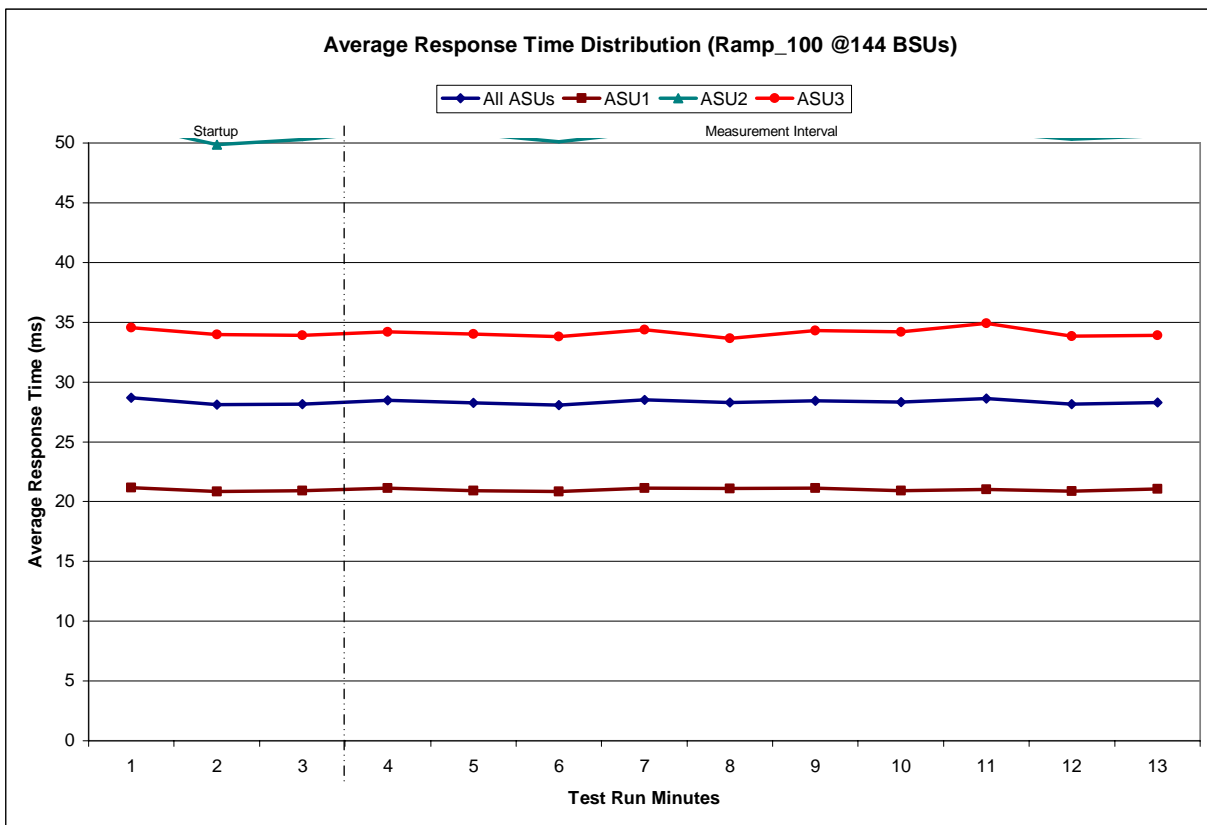
**IOPS Test Run – I/O Request Throughput Distribution Graph**



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

144 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	0:14:24	0:17:25	0-2	0:03:01
<i>Measurement Interval</i>	0:17:25	0:27:25	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	28.68	21.18	51.45	34.55
1	28.13	20.84	49.86	33.97
2	28.16	20.90	50.28	33.90
3	28.49	21.14	50.96	34.21
4	28.25	20.92	50.77	34.01
5	28.08	20.83	50.10	33.81
6	28.49	21.12	50.91	34.37
7	28.28	21.09	50.90	33.66
8	28.45	21.13	50.49	34.29
9	28.32	20.92	50.82	34.21
10	28.60	21.01	50.87	34.91
11	28.14	20.87	50.34	33.84
12	28.30	21.06	50.63	33.90
<b>Average</b>	28.34	21.01	50.68	34.12

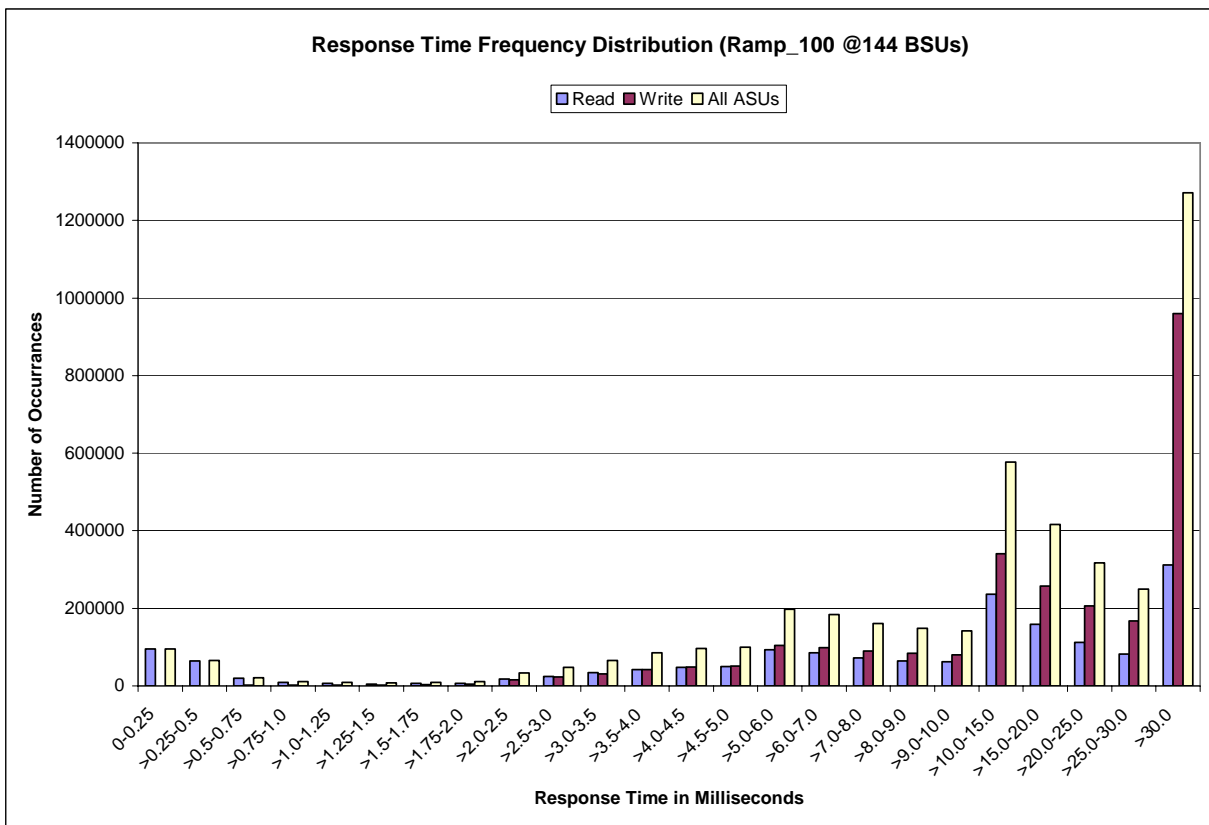
**IOPS Test Run – Average Response Time (ms) Distribution Graph**



**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	94,926	64,586	19,574	8,673	6,362	4,972	6,155	7,016
Write	7	447	1,868	2,217	2,206	2,478	2,923	4,054
All ASUs	94,933	65,033	21,442	10,890	8,568	7,450	9,078	11,070
ASU1	70,213	47,941	14,436	6,481	4,945	4,430	6,208	8,006
ASU2	24,713	16,645	5,140	2,203	1,446	659	538	615
ASU3	7	447	1,866	2,206	2,177	2,361	2,332	2,449
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	17,980	24,409	34,393	42,668	47,528	49,524	93,574	85,258
Write	15,156	22,790	31,293	42,212	48,599	50,710	104,097	98,850
All ASUs	33,136	47,199	65,686	84,880	96,127	100,234	197,671	184,108
ASU1	24,343	33,796	47,659	61,110	69,104	72,806	141,520	129,116
ASU2	1,856	2,443	3,044	3,942	4,920	5,913	12,884	12,017
ASU3	6,937	10,960	14,983	19,828	22,103	21,515	43,267	42,975
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	71,704	64,362	61,933	236,040	158,276	111,858	82,286	311,516
Write	89,351	84,407	80,108	340,585	257,686	205,897	167,377	959,710
All ASUs	161,055	148,769	142,041	576,625	415,962	317,755	249,663	1,271,226
ASU1	111,571	102,020	97,366	383,212	262,616	190,249	142,544	544,271
ASU2	11,276	10,467	9,851	43,306	35,505	30,677	27,054	264,563
ASU3	38,208	36,282	34,824	150,107	117,841	96,829	80,065	462,392

**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
4,320,601	3,049,375	1,271,226

### 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 5.1.0 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	0.2814	0.0701	0.2098	0.0180	0.0700	0.0351	0.2807
COV	0.009	0.003	0.006	0.004	0.010	0.006	0.007	0.002



## Primary Metrics Test – Response Time Ramp Test Phase

### Clause 5.4.2.3

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 11.

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 9.2.4.7.3

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 61.

## 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](#)

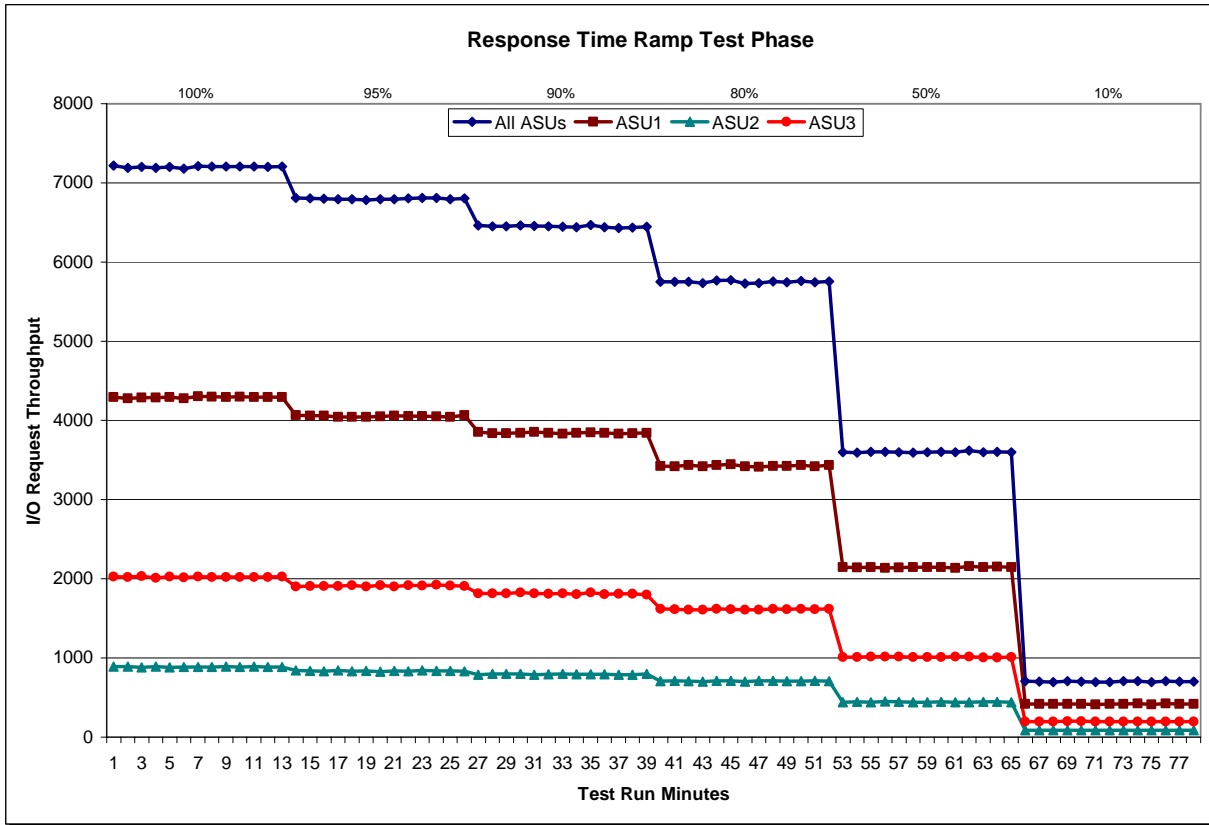
[10% Load Level](#)

**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 - 114 BSUs					95% Load Level - 136 BSUs				
Start	Stop	Interval	Duration		Start	Stop	Interval	Duration	
0:14:24	0:17:25	0-2	0:03:01		0:27:28	0:30:29	0-2	0:03:01	
0:17:25	0:27:25	3-12	0:10:00		0:30:29	0:40:29	3-12	0:10:00	
<i>(60 second intervals)</i>					<i>(60 second intervals)</i>				
All ASUs	ASU-1	ASU-2	ASU-3		All ASUs	ASU-1	ASU-2	ASU-3	
0	7,215.15	4,295.55	893.45	2,026.15	0	6,810.52	4,064.08	841.70	1,904.73
1	7,190.95	4,278.62	889.98	2,022.35	1	6,802.82	4,060.55	836.68	1,905.58
2	7,198.85	4,286.43	881.90	2,030.52	2	6,800.90	4,062.10	830.63	1,908.17
3	7,187.73	4,285.93	889.38	2,012.42	3	6,793.97	4,044.98	841.13	1,907.85
4	7,202.10	4,295.68	881.03	2,025.38	4	6,792.27	4,042.20	832.92	1,917.15
5	7,178.37	4,275.87	884.37	2,018.13	5	6,783.75	4,042.47	836.85	1,904.43
6	7,213.03	4,302.85	883.63	2,026.55	6	6,793.65	4,049.17	827.18	1,917.30
7	7,204.65	4,297.88	884.57	2,022.20	7	6,796.08	4,058.72	836.90	1,900.47
8	7,208.25	4,294.28	890.77	2,023.20	8	6,802.43	4,053.43	832.88	1,916.12
9	7,207.03	4,300.83	885.70	2,020.50	9	6,812.27	4,054.97	843.30	1,914.00
10	7,204.78	4,292.92	890.67	2,021.20	10	6,811.67	4,051.47	837.28	1,922.92
11	7,202.28	4,295.40	887.30	2,019.58	11	6,791.58	4,040.97	836.87	1,913.75
12	7,204.97	4,292.62	884.53	2,027.82	12	6,804.20	4,063.13	832.78	1,908.28
Average	7,201.32	4,293.43	886.20	2,021.70	Average	6,798.19	4,050.15	835.81	1,912.23
90% Load Level - 129 BSUs					80% Load Level - 115 BSUs				
Start	Stop	Interval	Duration		Start	Stop	Interval	Duration	
0:40:32	0:43:33	0-2	0:03:01		0:53:36	0:56:37	0-2	0:03:01	
0:43:33	0:53:33	3-12	0:10:00		0:56:37	1:06:37	3-12	0:10:00	
<i>(60 second intervals)</i>					<i>(60 second intervals)</i>				
All ASUs	ASU-1	ASU-2	ASU-3		All ASUs	ASU-1	ASU-2	ASU-3	
0	6,459.52	3,851.53	790.20	1,817.78	0	5,750.85	3,424.27	708.78	1,617.80
1	6,451.15	3,837.02	798.42	1,815.72	1	5,748.58	3,420.27	711.60	1,616.72
2	6,452.52	3,838.50	796.97	1,817.05	2	5,749.28	3,433.62	705.42	1,610.25
3	6,464.42	3,841.30	798.28	1,824.83	3	5,734.17	3,419.77	703.57	1,610.83
4	6,457.35	3,851.30	790.72	1,815.33	4	5,763.77	3,434.88	710.05	1,618.83
5	6,448.53	3,844.38	792.23	1,811.92	5	5,773.37	3,446.73	711.75	1,614.88
6	6,444.20	3,830.68	799.03	1,814.48	6	5,728.23	3,419.37	702.70	1,606.17
7	6,441.08	3,842.48	792.68	1,805.92	7	5,731.22	3,412.05	709.42	1,609.75
8	6,467.32	3,846.07	794.53	1,826.72	8	5,754.00	3,425.35	709.33	1,619.32
9	6,442.75	3,844.92	791.92	1,805.92	9	5,743.60	3,421.55	707.95	1,614.10
10	6,430.27	3,831.82	789.43	1,809.02	10	5,758.73	3,432.42	708.43	1,617.88
11	6,434.30	3,835.12	789.58	1,809.60	11	5,745.43	3,419.40	709.27	1,616.77
12	6,443.38	3,841.28	801.00	1,801.10	12	5,757.68	3,432.15	706.50	1,619.03
Average	6,447.36	3,840.94	793.94	1,812.48	Average	5,749.02	3,426.37	707.90	1,614.76
50% Load Level - 72 BSUs					10% Load Level - 14 BSUs				
Start	Stop	Interval	Duration		Start	Stop	Interval	Duration	
1:06:40	1:09:41	0-2	0:03:01		1:19:44	1:22:45	0-2	0:03:01	
1:09:41	1:19:41	3-12	0:10:00		1:22:45	1:32:45	3-12	0:10:00	
<i>(60 second intervals)</i>					<i>(60 second intervals)</i>				
All ASUs	ASU-1	ASU-2	ASU-3		All ASUs	ASU-1	ASU-2	ASU-3	
0	3,595.37	2,147.05	437.62	1,010.70	0	703.98	419.07	88.55	196.37
1	3,594.87	2,143.47	443.18	1,008.22	1	703.58	419.65	87.20	196.73
2	3,604.70	2,149.35	437.73	1,017.62	2	697.70	416.45	86.07	195.18
3	3,600.55	2,133.68	449.03	1,017.83	3	706.83	420.65	87.77	198.42
4	3,599.48	2,139.00	443.12	1,017.37	4	702.32	416.02	86.55	199.75
5	3,593.43	2,144.70	440.52	1,008.22	5	693.75	413.93	84.83	194.98
6	3,596.92	2,147.43	440.78	1,008.70	6	696.67	417.40	85.63	193.63
7	3,602.50	2,146.82	443.40	1,012.28	7	703.82	420.73	85.25	197.83
8	3,596.67	2,136.48	441.92	1,018.27	8	705.47	422.25	86.55	196.67
9	3,617.45	2,159.98	441.03	1,016.43	9	697.42	415.68	85.93	195.80
10	3,596.28	2,145.33	444.75	1,006.20	10	706.17	422.08	86.40	197.68
11	3,601.93	2,152.53	444.03	1,005.37	11	703.73	418.35	88.02	197.37
12	3,599.88	2,146.07	442.73	1,011.08	12	700.50	419.07	85.05	196.38
Average	3,600.51	2,145.20	443.13	1,012.18	Average	701.67	418.62	86.20	196.85

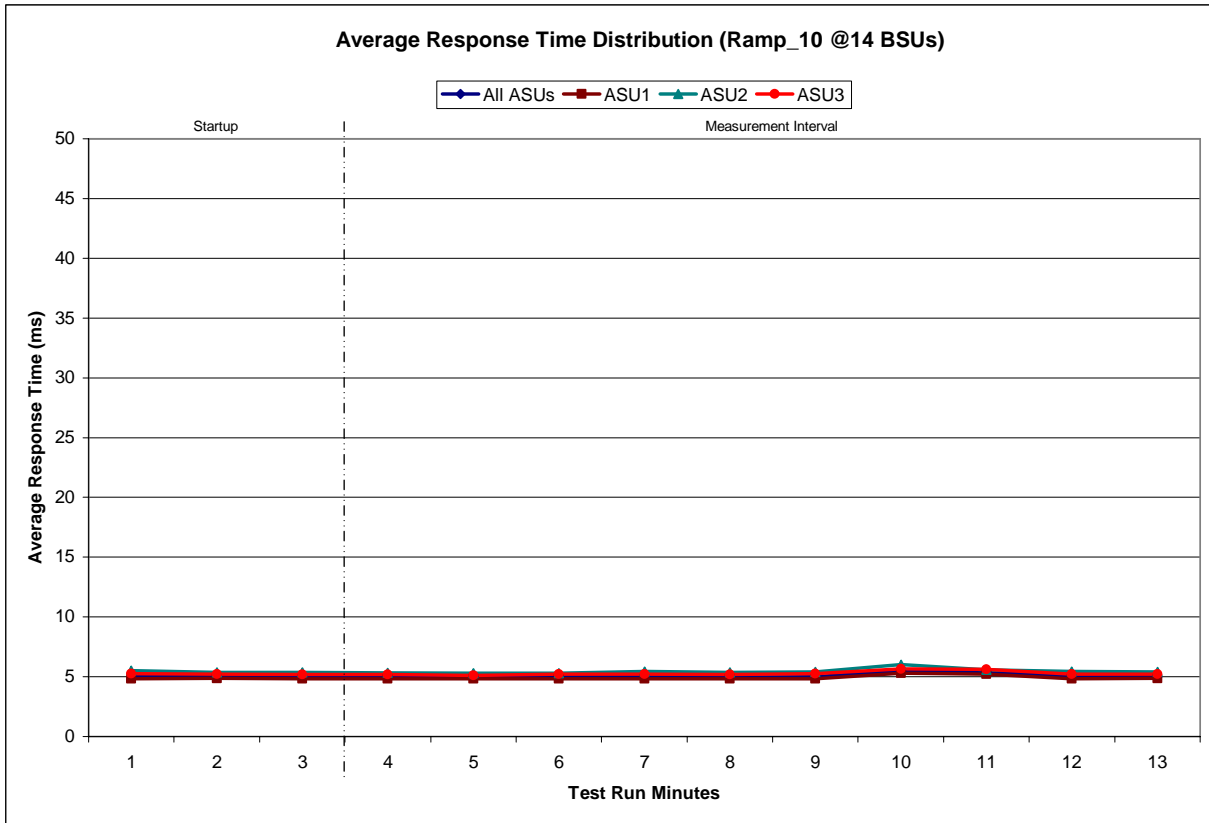
**Response Time Ramp Distribution (IOPS) Graph**



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

14 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	1:19:44	1:22:45	0-2	0:03:01
<i>Measurement Interval</i>	1:22:45	1:32:45	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	5.03	4.84	5.51	5.24
1	5.01	4.85	5.35	5.21
2	4.99	4.81	5.37	5.19
3	5.00	4.83	5.34	5.20
4	4.96	4.81	5.30	5.13
5	5.00	4.83	5.31	5.23
6	5.02	4.84	5.43	5.22
7	4.98	4.81	5.35	5.18
8	5.02	4.83	5.41	5.24
9	5.49	5.30	6.02	5.66
10	5.38	5.23	5.57	5.63
11	5.00	4.81	5.42	5.22
12	5.02	4.85	5.40	5.21
<b>Average</b>	5.09	4.91	5.45	5.29

**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 5.1.0 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	0.0351	0.2811	0.0703	0.2101	0.0182	0.0700	0.0347	0.2805
COV	0.025	0.009	0.017	0.013	0.036	0.019	0.027	0.006

## 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%.*

*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 9.2.4.7.4

*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 61.

### Repeatability Test Results File

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

	SPC-1 IOPS™	SPC-1 LRT™
<i>Primary Metrics</i>	<i>7,201.32</i>	<i>5.09 ms</i>
Repeatability Test Phase 1	7,196.61	5.09 ms
Repeatability Test Phase 2	7,196.57	5.07 ms

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.

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.

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 \(IOPS\)](#)

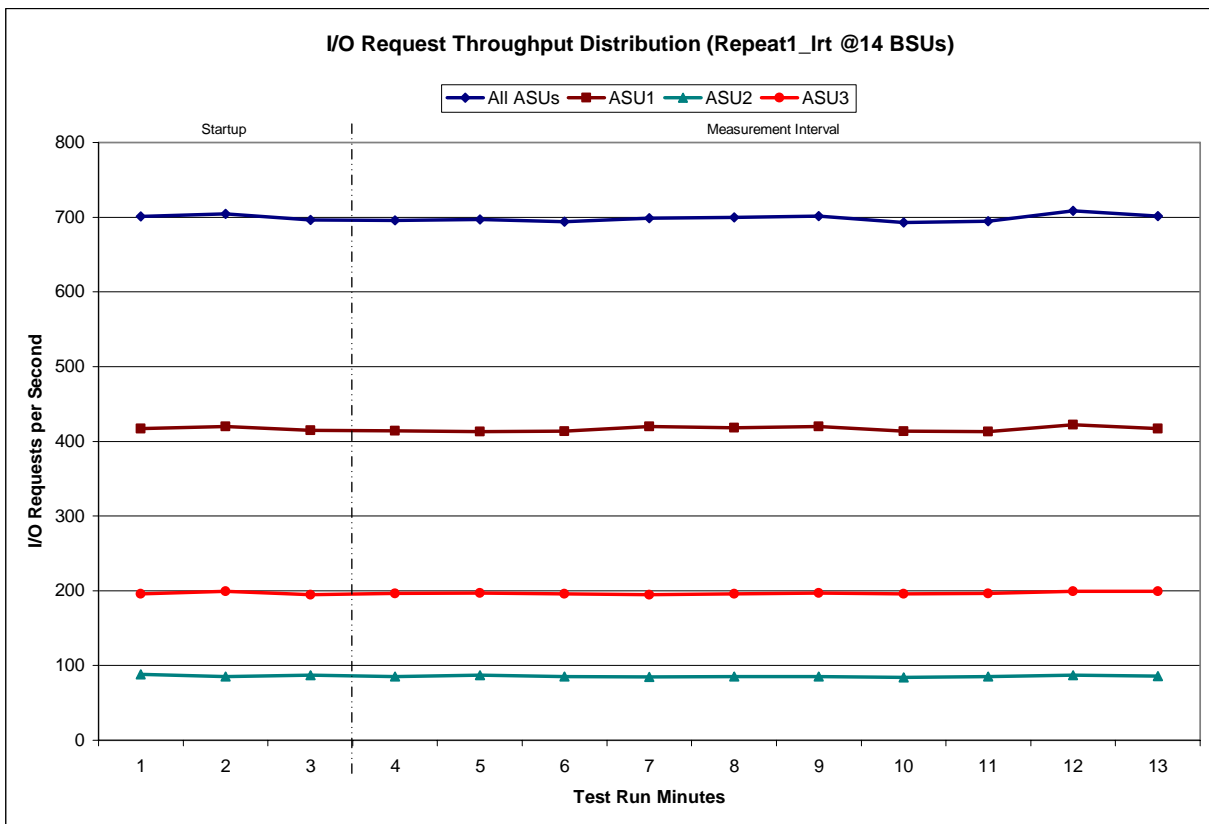
[Repeatability Test Phase 2, Test Run 1 \(LRT\)](#)

[Repeatability Test Phase 2, Test Run 2 \(IOPS\)](#)

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

14 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	1:32:53	1:35:53	0-2	0:03:00
<i>Measurement Interval</i>	1:35:53	1:45:53	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	700.85	416.80	87.98	196.07
1	704.67	420.00	85.52	199.15
2	696.48	414.77	86.83	194.88
3	695.92	413.97	85.27	196.68
4	696.78	412.82	86.80	197.17
5	694.30	413.42	85.18	195.70
6	698.67	419.70	84.45	194.52
7	699.55	418.30	85.22	196.03
8	701.72	419.65	85.35	196.72
9	692.78	413.32	83.92	195.55
10	694.48	412.78	85.15	196.55
11	708.22	422.22	86.77	199.23
12	701.65	416.80	85.62	199.23
<b>Average</b>	698.41	416.30	85.37	196.74

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

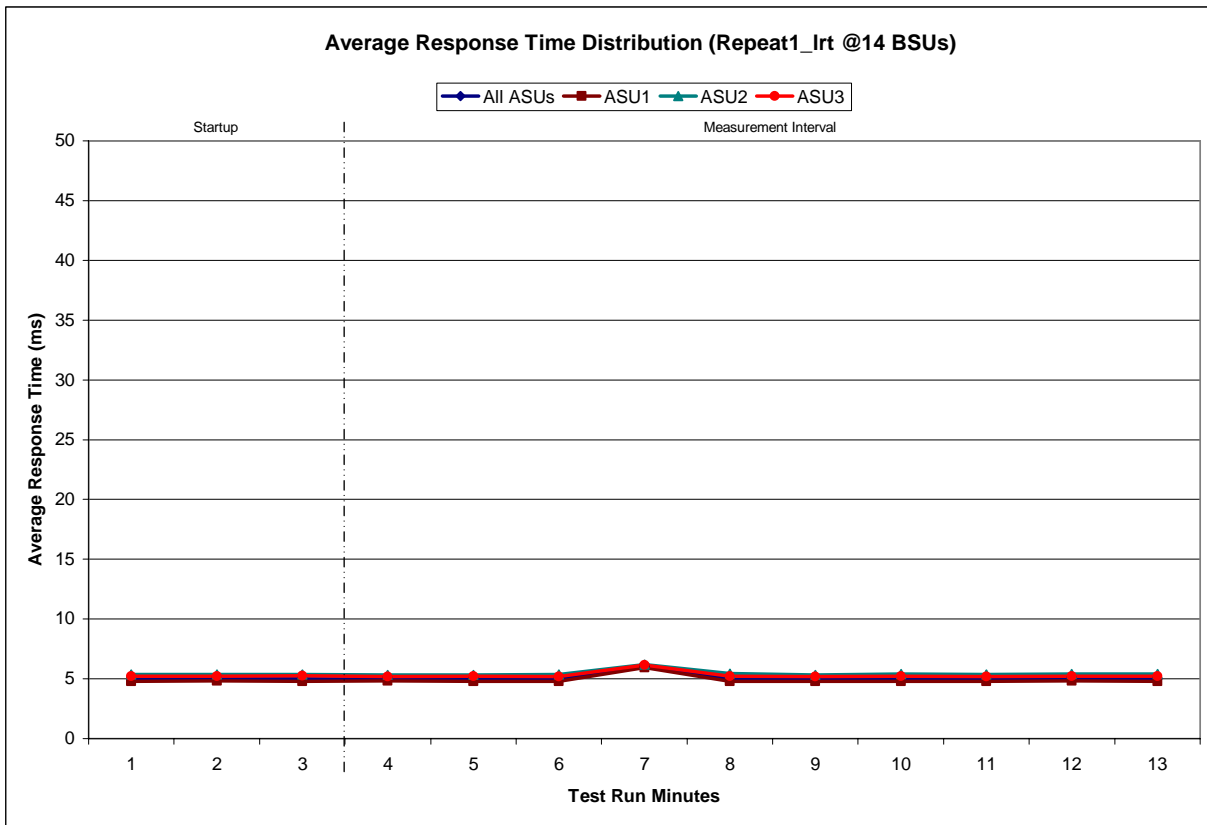




**Repeatability 1 LRT –Average Response Time (ms) Distribution Data**

14 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	1:32:53	1:35:53	0-2	0:03:00
<i>Measurement Interval</i>	1:35:53	1:45:53	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	4.98	4.79	5.36	5.23
1	4.99	4.81	5.35	5.23
2	4.99	4.79	5.37	5.26
3	4.98	4.81	5.31	5.19
4	4.98	4.79	5.34	5.21
5	4.97	4.78	5.36	5.19
6	6.03	5.95	6.18	6.15
7	4.99	4.79	5.42	5.23
8	4.97	4.80	5.32	5.19
9	4.98	4.78	5.38	5.23
10	4.98	4.80	5.36	5.19
11	5.01	4.83	5.39	5.22
12	4.99	4.79	5.40	5.24
<b>Average</b>	5.09	4.91	5.45	5.30

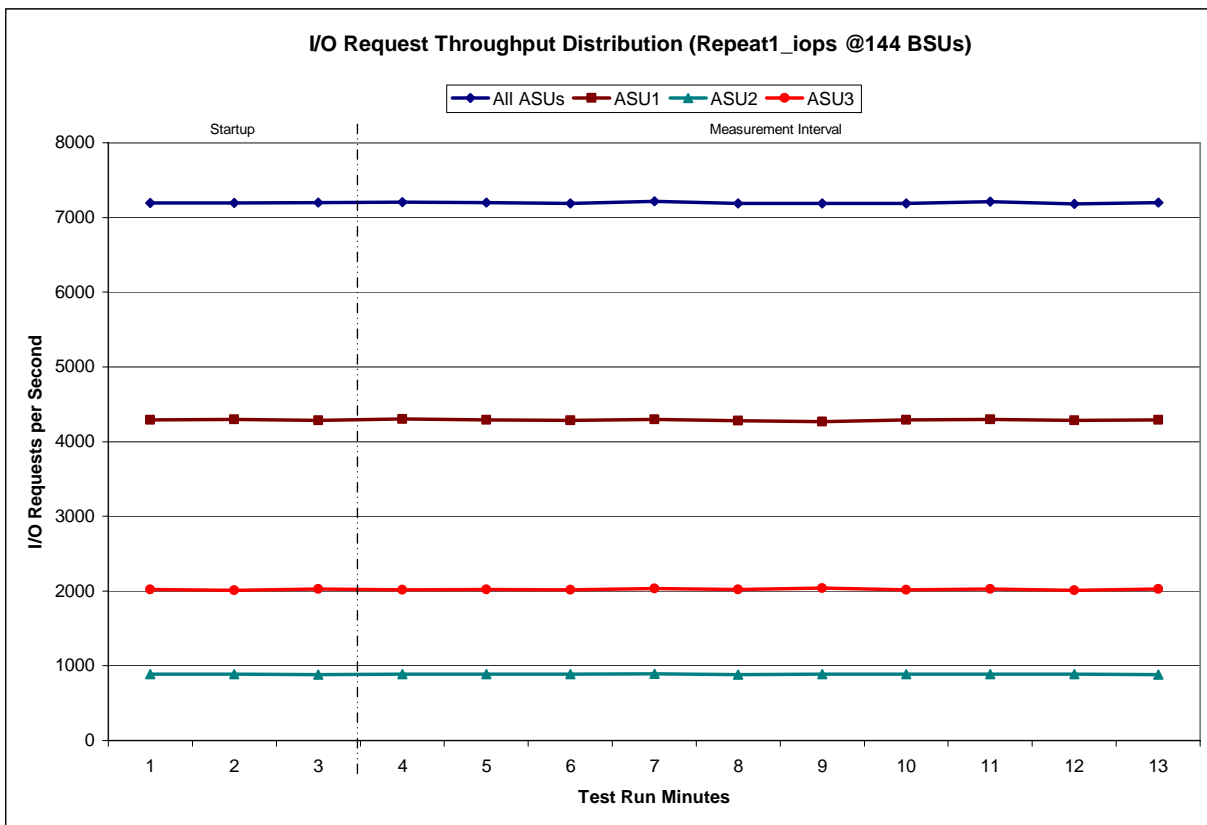
**Repeatability 1 LRT –Average Response Time (ms) Distribution Graph**



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

144 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	1:45:56	1:48:57	0-2	0:03:01
<i>Measurement Interval</i>	1:48:57	1:58:57	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	7,193.58	4,288.40	886.07	2,019.12
1	7,193.70	4,295.63	887.98	2,010.08
2	7,197.63	4,287.77	880.88	2,028.98
3	7,203.08	4,299.78	886.78	2,016.52
4	7,196.98	4,289.70	888.43	2,018.85
5	7,188.97	4,284.57	889.62	2,014.78
6	7,215.50	4,294.43	889.88	2,031.18
7	7,185.37	4,279.75	882.23	2,023.38
8	7,190.52	4,269.35	884.92	2,036.25
9	7,190.75	4,288.90	886.80	2,015.05
10	7,213.15	4,298.73	884.48	2,029.93
11	7,184.38	4,286.08	889.82	2,008.48
12	7,197.42	4,291.10	880.53	2,025.78
<b>Average</b>	<b>7,196.61</b>	<b>4,288.24</b>	<b>886.35</b>	<b>2,022.02</b>

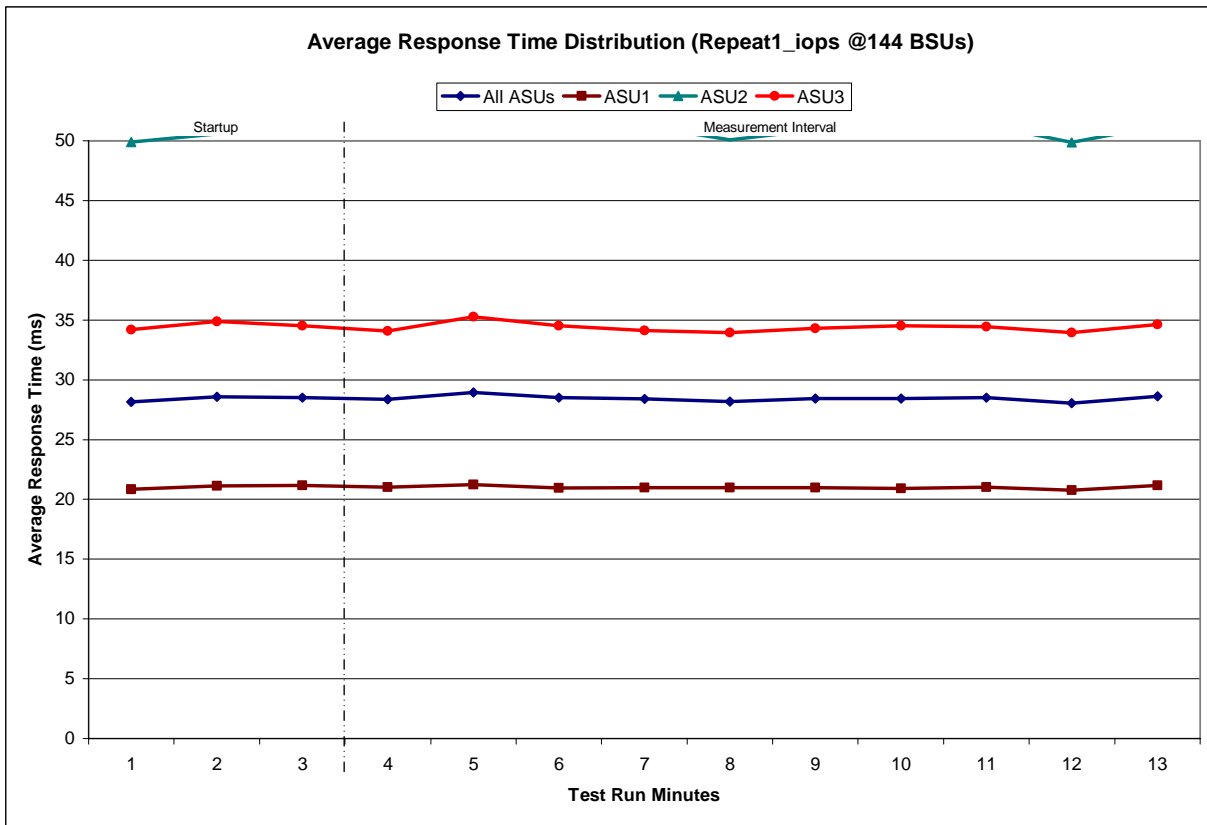
**Repeatability 1 IOPS - I/O Request Throughput Distribution Graph**



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

144 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	1:45:56	1:48:57	0-2	0:03:01
<i>Measurement Interval</i>	1:48:57	1:58:57	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	28.16	20.84	49.88	34.18
1	28.60	21.12	50.56	34.88
2	28.53	21.16	50.60	34.50
3	28.36	21.03	50.87	34.09
4	28.93	21.25	51.55	35.28
5	28.52	20.96	51.33	34.54
6	28.42	21.00	51.22	34.11
7	28.20	20.97	50.08	33.96
8	28.43	20.98	50.89	34.30
9	28.45	20.92	51.06	34.51
10	28.51	21.01	51.34	34.45
11	28.06	20.77	49.86	33.96
12	28.63	21.17	51.22	34.61
<b>Average</b>	28.45	21.01	50.94	34.38

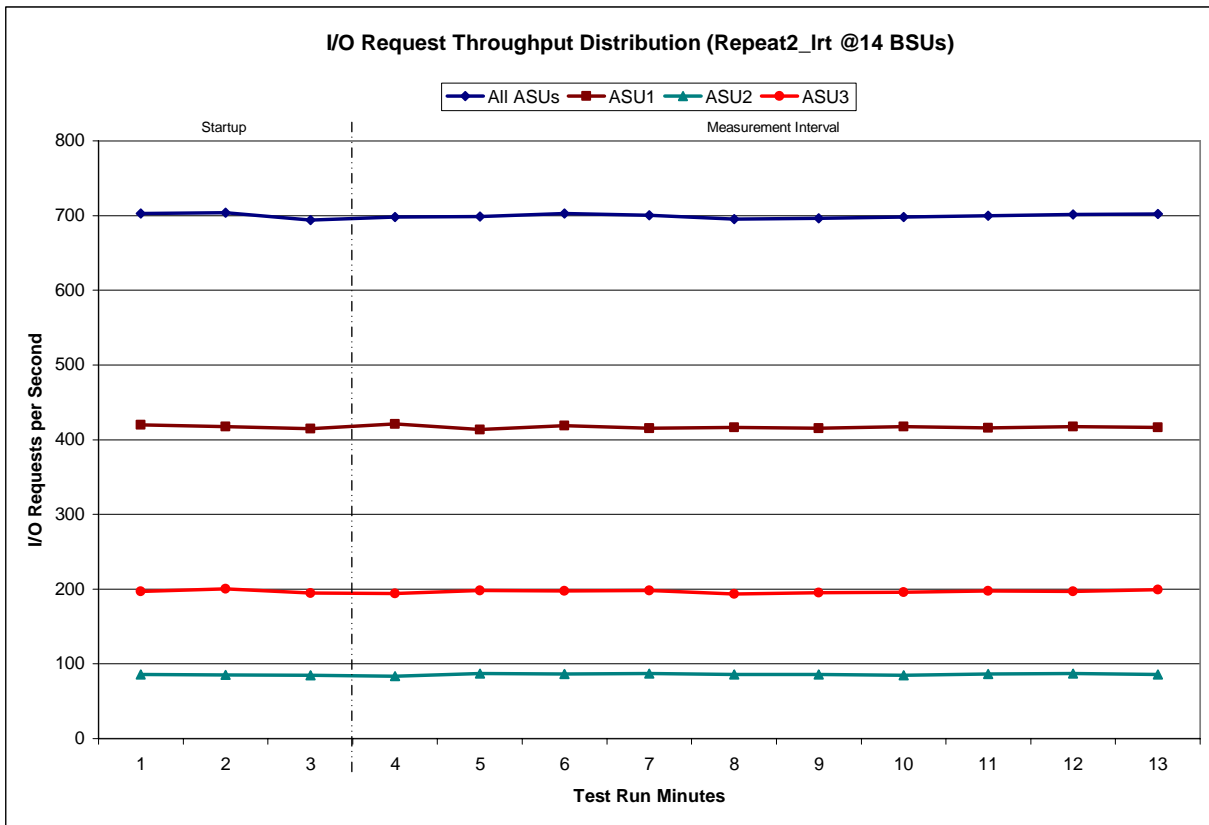
**Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph**



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

14 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	1:59:05	2:02:05	0-2	0:03:00
<i>Measurement Interval</i>	2:02:05	2:12:05	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	702.65	419.85	85.90	196.90
1	703.68	417.70	85.48	200.50
2	694.03	414.67	84.52	194.85
3	698.03	420.77	83.27	194.00
4	698.67	413.43	87.05	198.18
5	702.68	418.83	86.18	197.67
6	700.43	415.50	86.87	198.07
7	695.25	416.47	85.53	193.25
8	696.42	415.18	85.85	195.38
9	698.33	417.47	84.87	196.00
10	699.85	416.07	86.43	197.35
11	701.32	417.43	86.73	197.15
12	701.82	416.52	85.75	199.55
<b>Average</b>	699.28	416.77	85.85	196.66

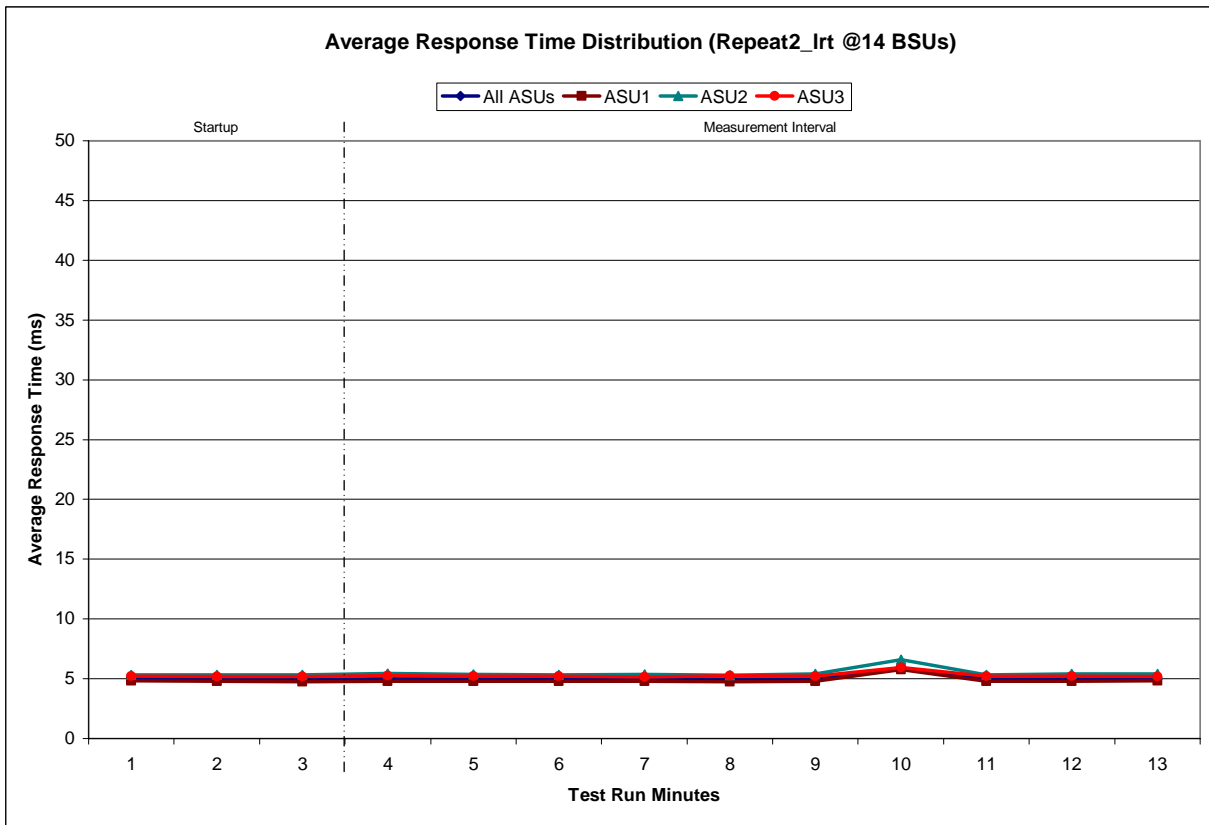
**Repeatability 2 LRT - I/O Request Throughput Distribution Graph**



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

14 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	1:59:05	2:02:05	0-2	0:03:00
<i>Measurement Interval</i>	2:02:05	2:12:05	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	5.00	4.82	5.32	5.23
1	4.97	4.79	5.33	5.20
2	4.94	4.74	5.35	5.19
3	5.00	4.79	5.44	5.27
4	4.98	4.80	5.38	5.21
5	4.97	4.79	5.31	5.20
6	4.96	4.79	5.37	5.13
7	4.97	4.76	5.29	5.26
8	4.98	4.78	5.40	5.21
9	5.90	5.74	6.59	5.95
10	4.97	4.77	5.32	5.22
11	4.97	4.78	5.40	5.20
12	5.00	4.82	5.40	5.19
<b>Average</b>	5.07	4.88	5.49	5.28

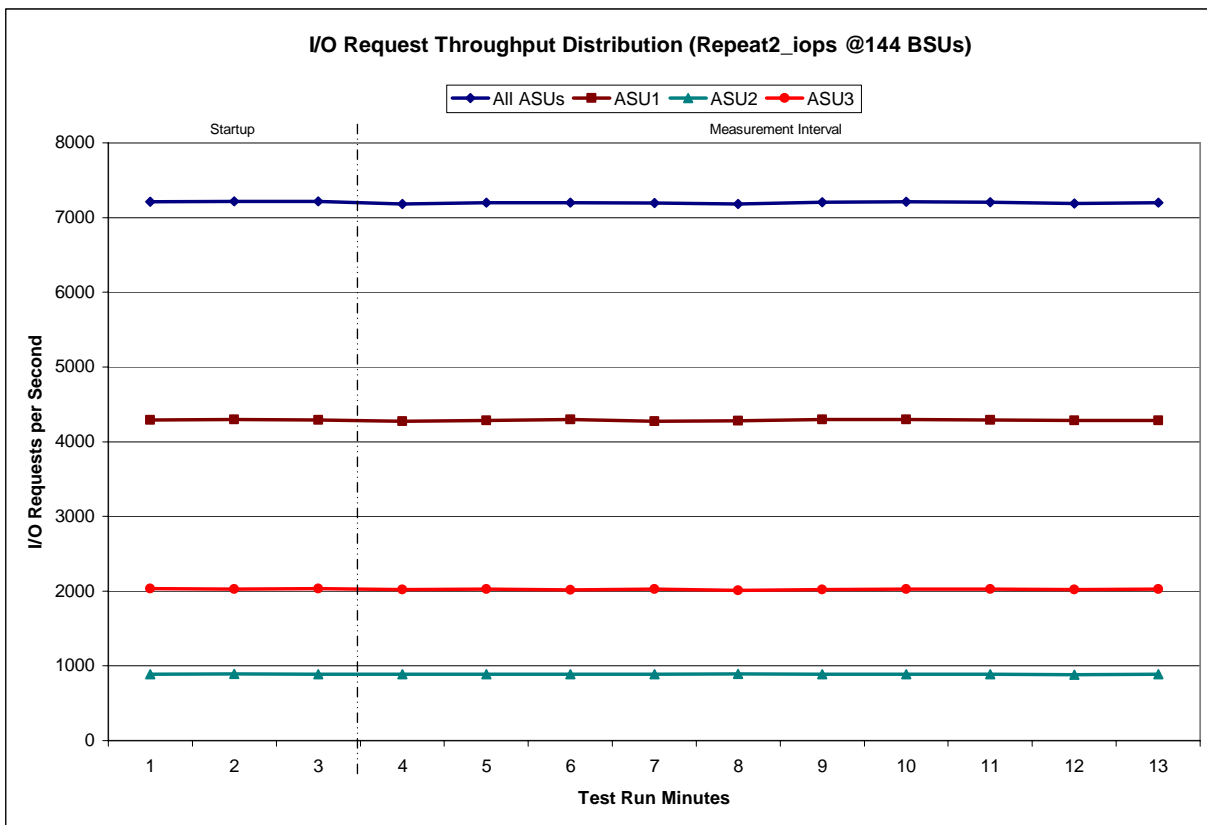
**Repeatability 2 LRT –Average Response Time (ms) Distribution Graph**



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

144 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	2:12:08	2:15:09	0-2	0:03:01
<i>Measurement Interval</i>	2:15:09	2:25:09	2-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	7,212.37	4,291.08	889.63	2,031.65
1	7,219.33	4,296.48	892.75	2,030.10
2	7,214.82	4,292.07	888.03	2,034.72
3	7,184.22	4,275.65	888.63	2,019.93
4	7,197.35	4,287.15	885.60	2,024.60
5	7,200.52	4,297.07	886.27	2,017.18
6	7,194.30	4,276.13	888.30	2,029.87
7	7,182.02	4,278.27	891.30	2,012.45
8	7,205.33	4,295.75	885.53	2,024.05
9	7,209.10	4,297.00	884.28	2,027.82
10	7,202.97	4,288.13	888.02	2,026.82
11	7,190.25	4,286.40	883.30	2,020.55
12	7,199.68	4,287.73	884.13	2,027.82
<b>Average</b>	<b>7,196.57</b>	<b>4,286.93</b>	<b>886.54</b>	<b>2,023.11</b>

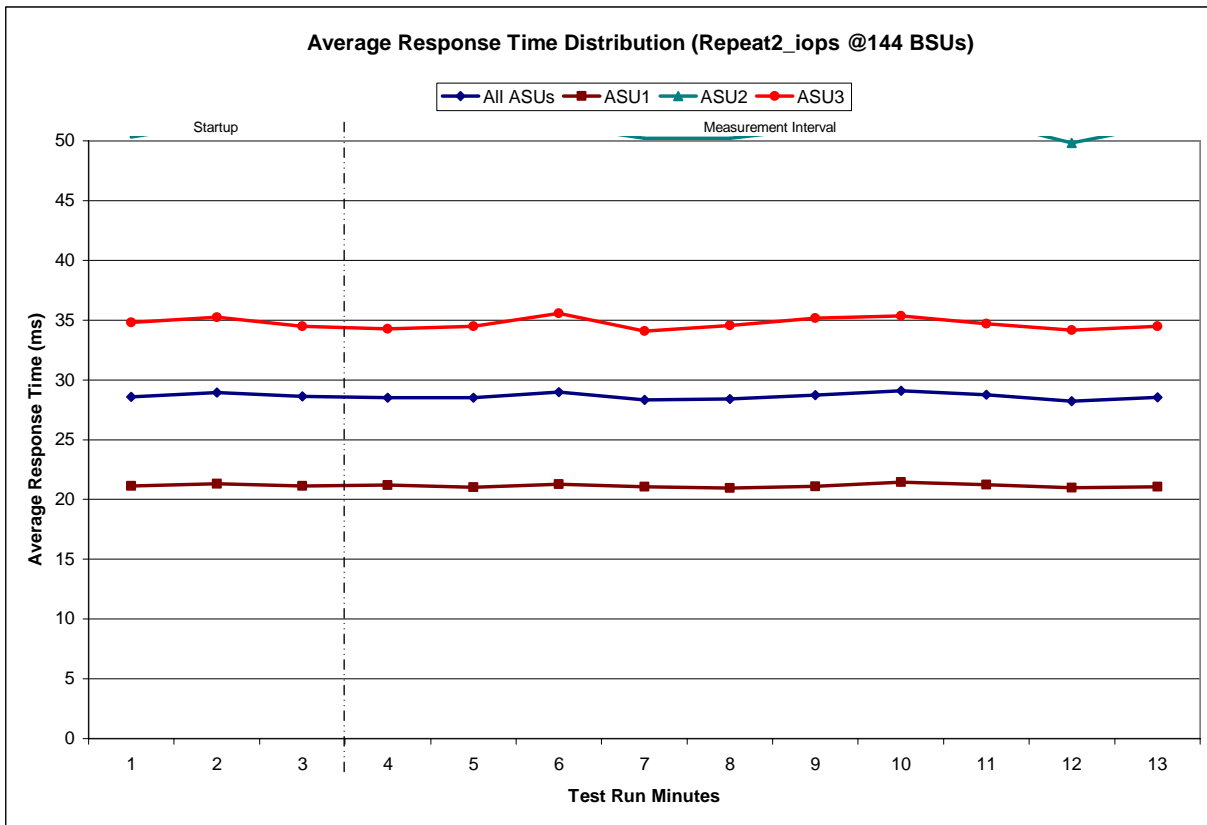
**Repeatability 2 IOPS - I/O Request Throughput Distribution Graph**



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

144 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	2:12:08	2:15:09	0-2	0:03:01
<i>Measurement Interval</i>	2:15:09	2:25:09	2-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	28.58	21.13	50.33	34.80
1	28.95	21.31	51.44	35.24
2	28.60	21.15	51.14	34.49
3	28.51	21.19	50.61	34.28
4	28.50	21.03	50.94	34.49
5	28.97	21.28	51.26	35.58
6	28.34	21.07	50.22	34.08
7	28.39	20.95	50.20	34.56
8	28.74	21.10	51.05	35.18
9	29.08	21.44	51.82	35.34
10	28.78	21.24	51.63	34.71
11	28.23	20.98	49.83	34.16
12	28.55	21.06	51.27	34.48
<b>Average</b>	28.61	21.13	50.88	34.69

**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 5.1.0 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	0.0352	0.2807	0.0700	0.2103	0.0178	0.0695	0.0350	0.2817
COV	0.019	0.006	0.016	0.012	0.037	0.013	0.019	0.006

**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	0.0350	0.2809	0.0702	0.2098	0.0181	0.0700	0.0350	0.2810
COV	0.008	0.002	0.004	0.003	0.017	0.005	0.009	0.004

**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	0.0348	0.2813	0.0693	0.2106	0.0180	0.0701	0.0347	0.2812
COV	0.031	0.008	0.021	0.012	0.035	0.023	0.021	0.008



**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	0.2807	0.0699	0.2101	0.0181	0.0701	0.0350	0.2811
COV	0.008	0.02	0.004	0.002	0.012	0.003	0.009	0.002

## 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 IOP™ 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 Benchmark Configuration 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 9.2.4.8

*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 61.

## 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	17,273,888
Total Number of Logical Blocks Verified	16,733,936
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 must be the date at which all components are committed to be available.*

*The FDR shall state: "The Priced Storage Configuration, as documented in this Full Disclosure Report will be available for shipment to customers on MMMM DD, YYYY." Where Priced Storage Configuration is the TSC Configuration Name as described in Clause 9.2.4.3.3 and MMMM is the alphanumeric month, DD is the numeric day, and YYYY is the numeric year of the date that the Priced Storage Configuration, as documented, is available for shipment to customers as described above.*

**The Sun Storage J4400 Array as documented in this Full Disclosure Report will become available for customer purchase and shipment on July 8, 2008.**

## **PRICING INFORMATION**

### Clause 9.2.4.11

*A statement of the respective calculations for pricing must be included.*

### Clause 9.2.4.11.3

*A list of all differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration must be included.*

**Pricing information may found in the Tested Storage Configuration Pricing section on page 12. 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 12.**

## **ANOMALIES OR IRREGULARITIES**

### Clause 9.2.4.10

*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 J4400 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

**RAID5:** User data is distributed across the disks in the array. Check data corresponding to user data is distributed across multiple disks in the form of bit-by-bit parity.

**Mirroring:** Two or more identical copies of user data are maintained on separate disks.

**Other Protection Level:** Any data protection other than **RAID5** or **Mirroring**.

**Unprotected:** There is no data protection provided.

## 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.

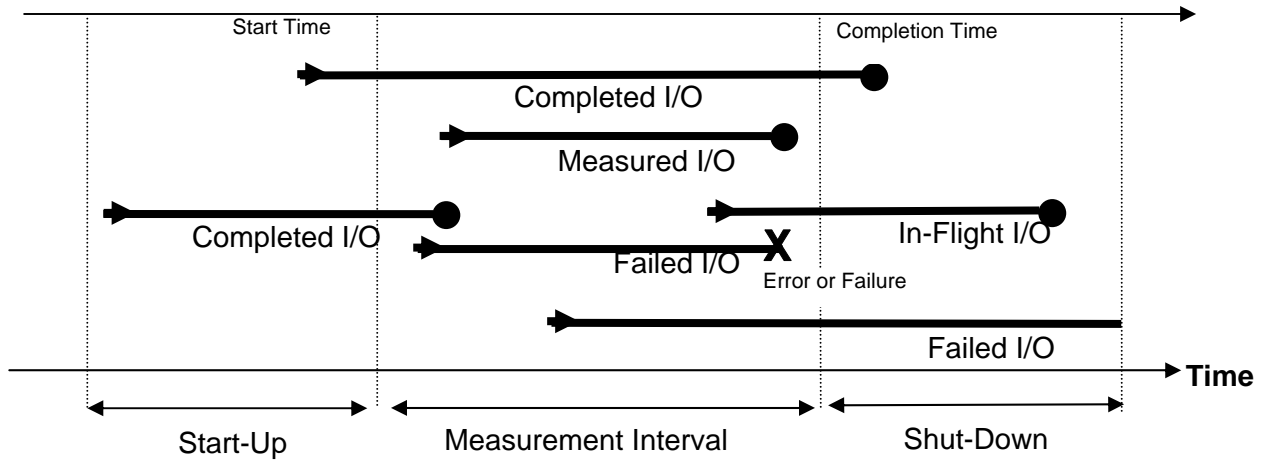
**Test:** A collection of Test Phases and or Test Runs sharing a common objective.

**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

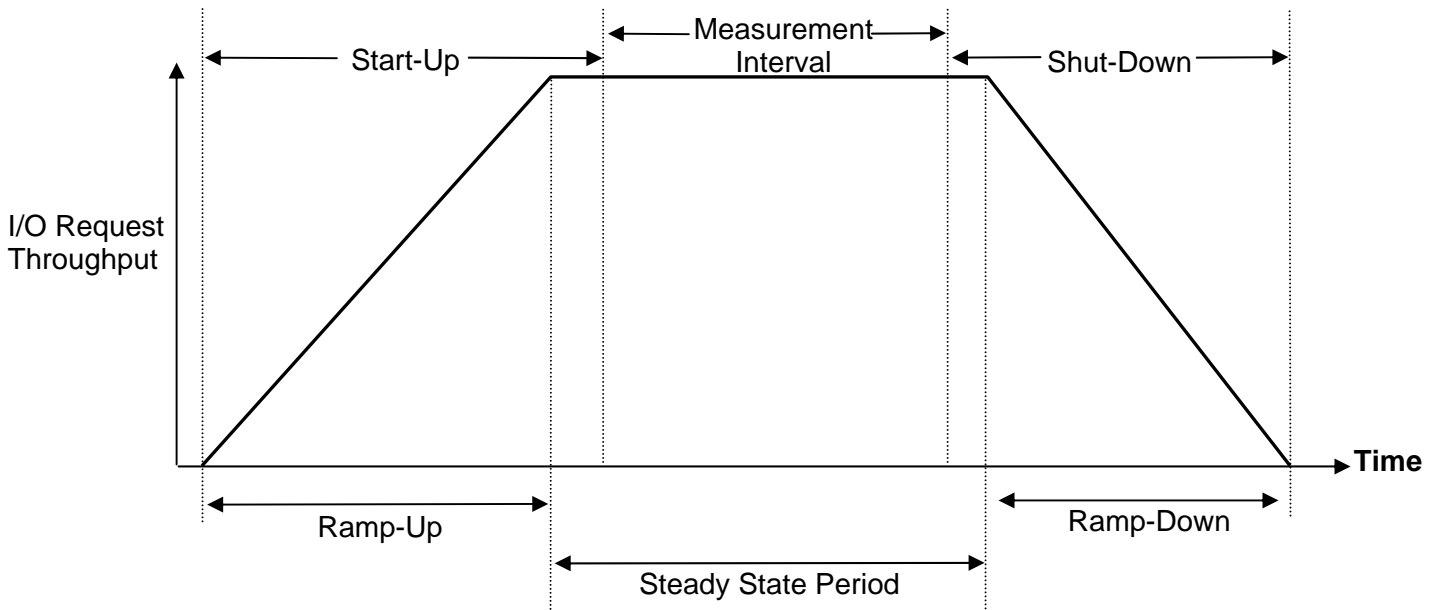
period, Shut-Down period, and Ramp-Down period as illustrated in the “SPC-1 Test Run Components” below. All SPC-1 Test Runs shall have a Steady State period and a Measurement Interval.

**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**



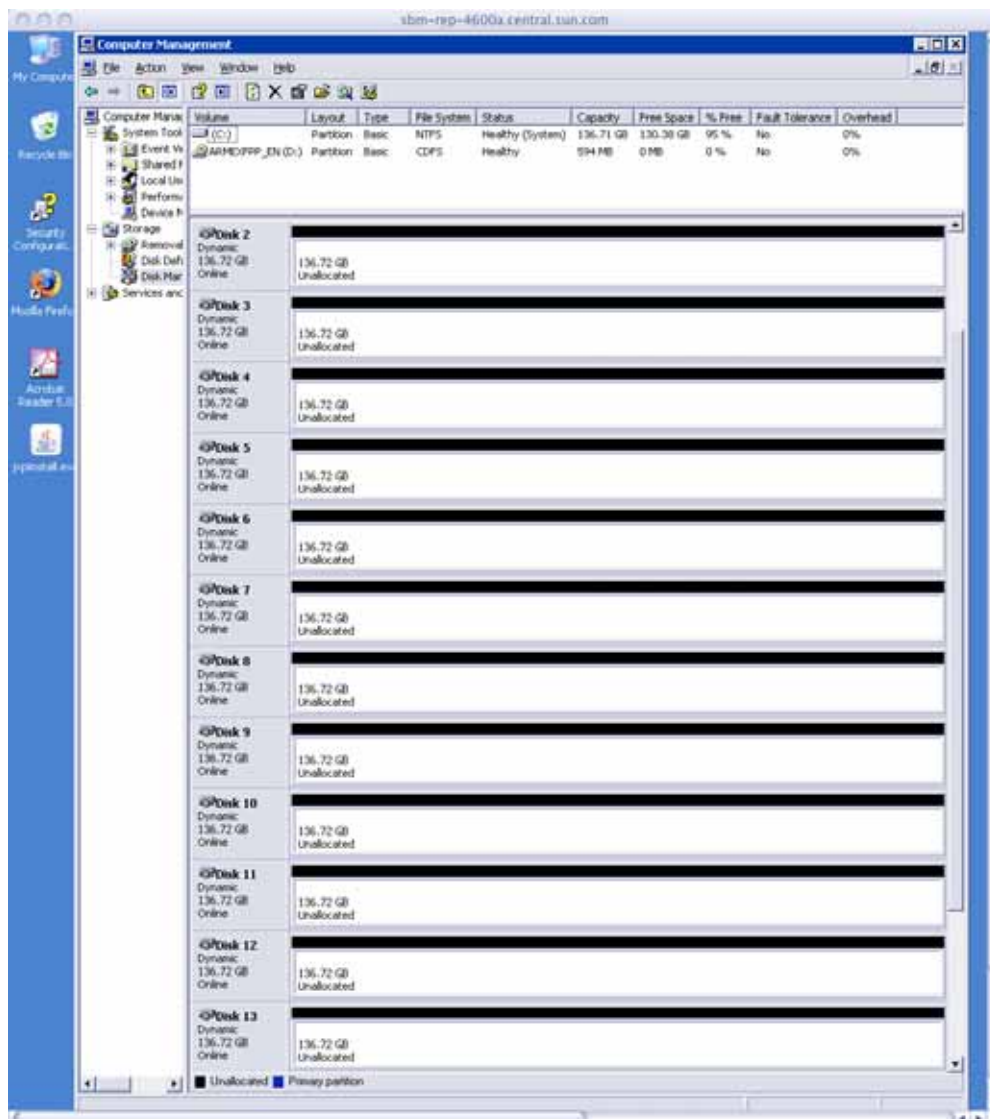


**APPENDIX B: CUSTOMER TUNABLE PARAMETERS AND OPTIONS**

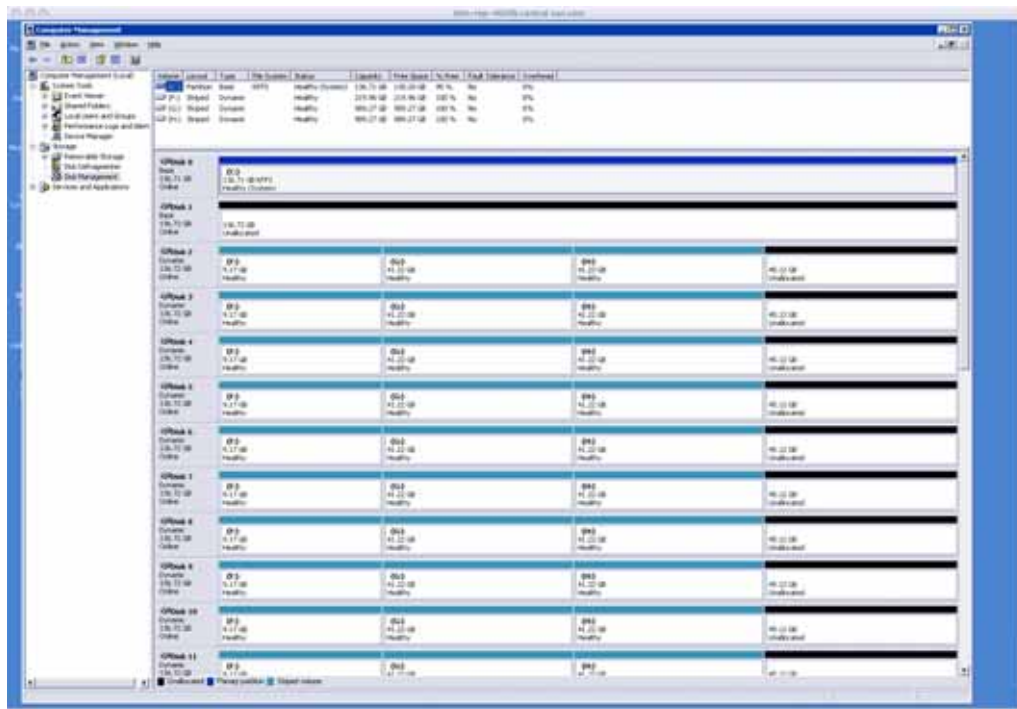
There were no customer tunable parameters or options changed from their default values.

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

1. Install the SAS HBA in the SF4600
2. Boot the SF4600.
3. Launch the Computer Management console from the Administrative Tools found in the Control Panel and select Disk Management. Select Next to the Initialize and Convert Disk Wizard pop-up dialog box. Then select Next to the following Initialize dialog box to initialize the twenty-four new volumes. Verify your twenty-four disks are selected and convert to dynamic disks by selecting Next then Finish.
4. The Computer Management Dialog box should resemble the one below.



5. Select one of the twenty-four Unallocated Dynamic disks then Right mouse click and select the New Volume option. Select Next on the Welcome to the New Volume Wizard dialog window. Select Striped in the Select Volume Type dialog box, then Next. Add all Dynamic disks in the Select Disks dialog window and change the Select the amount of space in Mb: tab to 9380 and select Next. Select Next to the Assign Drive Letter or Path dialog box. Select Do not format this volume in the Format Volume dialog box then select Next. Select Finish in the Completing the New Volume Wizard dialog box to finish creating ASU3.
6. For the next volume "ASU1" follow step 5 and set the size to 42210 .
7. Follow step 5 and set the size to 42210 to create ASU2. The Computer Management dialog box should now look like the one below.



## **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, is listed below.

```
sd=asu1_1,lun=\\.G:,size=988g  
sd=asu2_1,lun=\\.H:,size=988g  
sd=asu3_1,lun=\\.F:,size=218g
```

## **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.

```
@ECHO off
*
*
* Raid 0 stripe then sliced at the host 67% of storage
*
*
:BEGIN

cls

**"C:\Program Files (x86)\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -
Xss64k metrics -b 100

"Y:\export\spc\spc1\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -Xss64k
metrics -b 144
"Y:\export\spc\spc1\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -Xss64k
repeat1 -b 144

"Y:\export\spc\spc1\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -Xss64k
repeat2 -b 144

"Y:\export\spc\spc1\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -Xss64k
persist1 -b 144

*"Y:\export\spc\spc1\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -Xss64k
persist2
:end
```

### **Persistence Test Run 2**

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

```
@ECHO off
*
*
* Raid 0 stripe then sliced at the host 67% of storage
*
*
:BEGIN

cls

**"C:\Program Files (x86)\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -
Xss64k metrics -b 100
```

```
*"Y:\export\spc\spc1\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -Xss64k
metrics -b 144

*"Y:\export\spc\spc1\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -Xss64k
repeat1 -b 144

*"Y:\export\spc\spc1\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -Xss64k
repeat2 -b 144

*"Y:\export\spc\spc1\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -Xss64k
persist1 -b 144

"Y:\export\spc\spc1\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -Xss64k
persist2
:end
```