SPC BENCHMARK 1C™
FULL DISCLOSURE REPORT

ORACLE CORPORATION
SUN FLASH ACCELERATOR F20 PCIE CARD

SPC-1C™ V1.3

Submitted for Review: September 17, 2010
Submission Identifier: C00011

First Edition – September 2010

Trademarks

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Sun Flash Accelerator F20 PCIe Card

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Sun Flash Accelerator F20 PCIe Card

AUDIT CERTIFICATION

Steven A. Johnson
Oracle Corporation
500 Eldorado Blvd. UBRM05-194
Broomfield, CO 80021

September 15, 2010

The SPC Benchmark 1C™ results listed below for the Sun Flash Accelerator F20 PCIe Card were produced in compliance with the SPC Benchmark 1C™ V1.3 Audit requirements.

SPC Benchmark 1C™ V1.3 Results	
Tested Storage Product:	
Sun Flash Accelerator F20 PCIe Card	
Metric	**Reported Result**
SPC-1C IOPS™	72,521.11
Total ASU Capacity	147.413 GB
Data Protection Level	Unprotected
Total Price – Priced Storage Configuration	$15,554

The following SPC Benchmark 1C™ Audit requirements were reviewed and found compliant with V1.3 of the SPC Benchmark 1C™ specification:

- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository storage items were verified by physical inspection and information supplied by Oracle Corporation:
  - ✓ Physical Storage Capacity and requirements.
  - ✓ Configured Storage Capacity and requirements.
  - ✓ Addressable Storage Capacity and requirements.
  - ✓ Capacity of each Logical Volume and requirements.
  - ✓ Capacity of each Application Storage Unit (ASU) and requirements.
- An appropriate diagram of the Benchmark Configuration (BC)/Tested Storage Configuration (TSC).
- Physical verification of the components to match the above diagram.
- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters that were changed from default values.

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

AUDIT CERTIFICATION *(CONT.)*

- SPC-1C Workload Generator commands and parameters used for the audited SPC-1C Test Runs.

- The following Host System requirements were verified by physical inspection and information supplied by Oracle Corporation:

  ✓ The type of Host System including the number of processors and main memory.
  ✓ The presence and version number of the SPC-1C Workload Generator on the Host System.
  ✓ The TSC boundary within the Host System.

- The execution of each Test, Test Phase, and Test Run was observed and found compliant with all of the requirements and constraints of Clauses 4 and 5 of the SPC-1 Benchmark Specification.

- The Test Results Files and resultant Summary Results Files for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4, 5 and 6 of the SPC-1C 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 9 of the SPC-1C Benchmark Specification.

- The Full Disclosure Report (FDR) met all of the requirements in Clause 10 of the SPC-1C Benchmark Specification.

- This successfully audited SPC measurement is not subject to an SPC Confidential Review.

Audit Notes:

There were no audit notes or exceptions.

Respectfully,
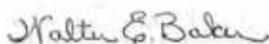
Walter E. Baker

Walter E. Baker
SPC Auditor

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LETTER OF GOOD FAITH

ORACLE

August 20, 2010

From: Graham Lovell

To: Walter Baker

Subject: SPC-1C Letter of Good Faith for Oracle's Sun F20 PCI Flash Accelerators

Oracle Corporation is the SPC-1C Test Sponsor of the above listed product. To the best of our knowledge and belief, the required SPC-1C benchmarks results and materials we have submitted for that product are complete, accurate and in full compliance with V1.3 of the SPC-1C benchmark specification.

In addition, we have reported any items in the Benchmark Configuration and execution of the benchmark necessary to reproduce the reported results even if the items are not explicitly required to be disclosed by the above SPC-1C benchmark specification.

Signed
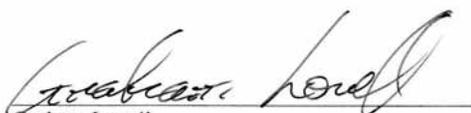
Graham Lovell
Senior Director, Systems Product Management

AUG 20, 2010
Date

Oracle Corporation
4150 Network Circle
Santa Clara, CA 95054

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact	Oracle Corporation – http://www.oracle.com Steven A. Johnson – steven.a.johnson@oracle.com 500 Eldorado Blvd. UBRM05-194 Broomfield, CO 80021 Phone: (303) 272-9476
Test Sponsor Alternate Contact	Oracle Corporation – http://www.oracle.com Jason Schaffer – Jason.schaffer@oracle.com 500 Eldorado Blvd. Broomfield, CO 80021 Phone: (303) 272-4743 FAX: (303) 272-9704
Auditor	Storage Performance Council – http://www.storageperformance.org Walter E. Baker – AuditService@StoragePerformance.org 643 Bair Island Road, Suite 103 Redwood City, CA 94063 Phone: (650) 556-9384 FAX: (650) 556-9385

Revision Information and Key Dates

Revision Information and Key Dates	
SPC-1C Specification revision number	V1.3
SPC-1C Workload Generator revision number	V1.0
Date Results were first used publicly	September 17, 2010
Date the FDR was submitted to the SPC	September 17, 2010
Date the TSC is available for shipment to customers	currently available
Date the TSC completed audit certification	September 15, 2010

Tested Storage Product (TSP) Description

Oracle's Sun Flash Accelerator F20 PCIe Card is a high performance, high density, solid state flash PCIe card with 96 GB of capacity.

The F20 is designed to accelerate IO-intensive database applications.

It is based on enterprise-class SLC flash technology, with advanced wear-leveling, integrated power loss protection for write persistence, solid state robustness and 3M MTBF hour reliability.

Summary of Results

SPC-1C Results	
Tested Storage Product: Sun Flash Accelerator F20 PCIe Card	
Metric	**Reported Result**
SPC-1C IOPS™	72,521.11
Total ASU Capacity	147.413 GB
Data Protection Level	Unprotected
Total Price – Priced Storage Configuration	$15,554

SPC-1C 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-1C benchmark.

A **Data Protection Level** of *Unprotected* provides no data protection in the event of a single point of failure.

Storage Capacities and Relationships

The Tested Storage Configuration (TSC) must be configured so that there is either no Unused Storage or that the sum of Total ASU Capacity and storage required for data protection equals 50% (+-1 GiB) of the Physical Storage Capacity. This configuration meets the 50% requirement as documented below:

> **294.827 GB** *(Physical Storage Capacity)* *** 0.5 = 147.413 GB**

> **147.413 GB** *(Total ASU Capacity)* **+ 0.000 GB** *(data protection)* **= 147.413 GB**

The following diagram documents the various storage capacities, used in this benchmark, and their relationships.
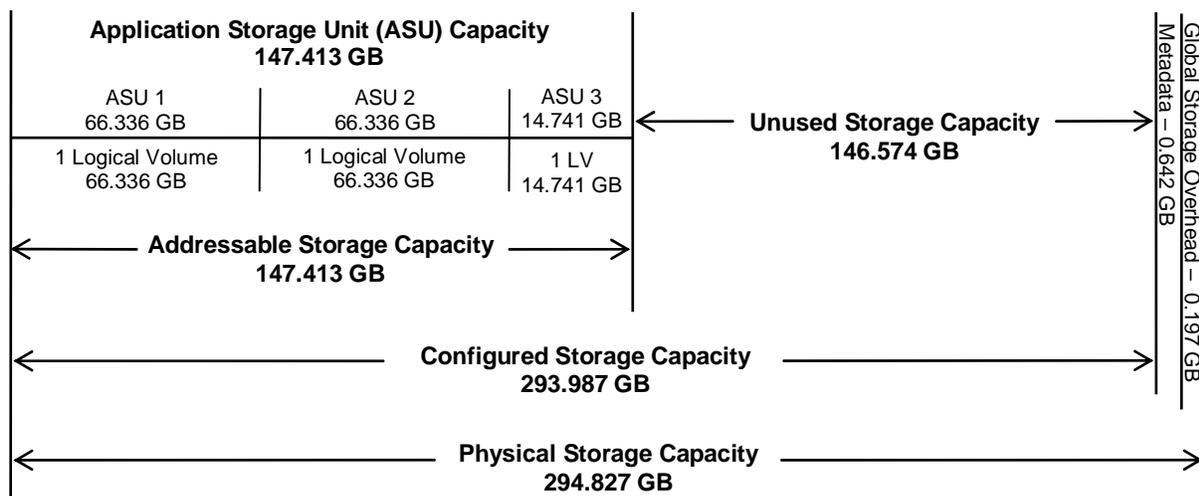
Response Time – Throughput Curve

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-1C IOPS™ metric.

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

Ramp Phase Response Time / Throughput Curve
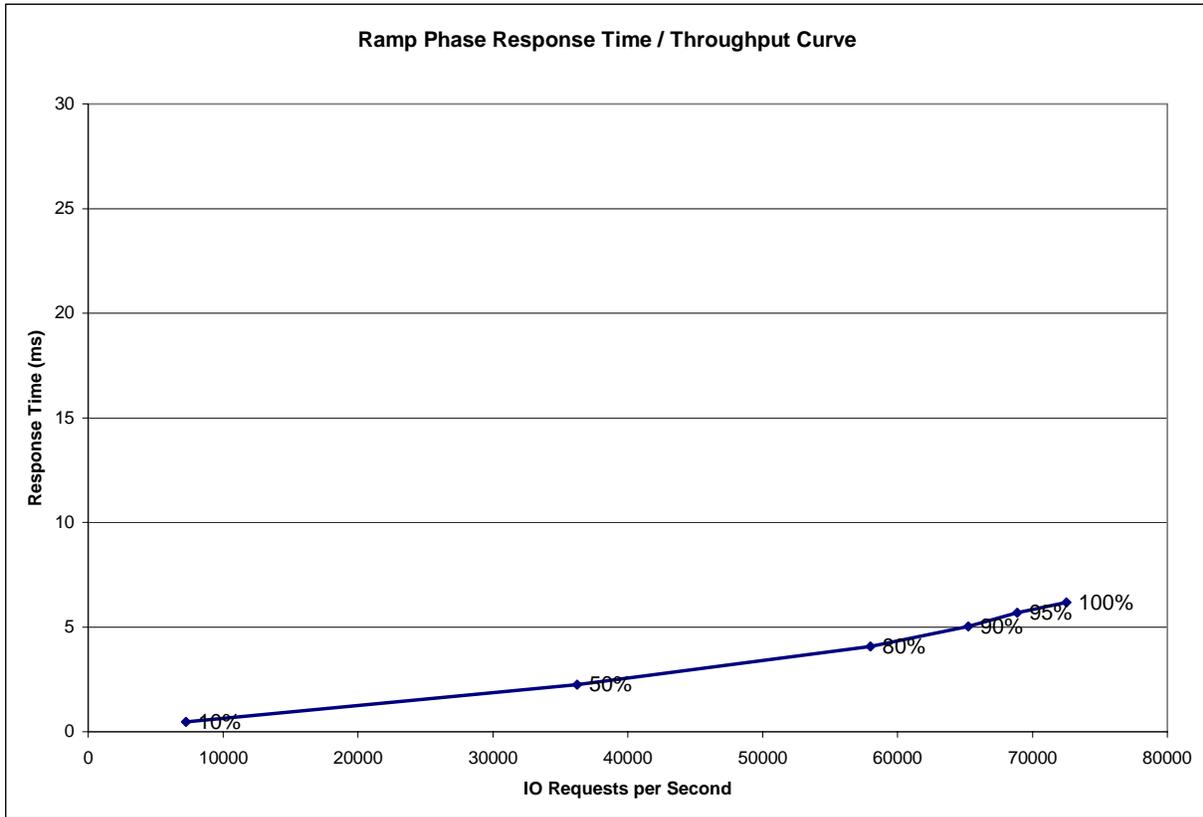
Response Time – Throughput Data

	10% Load	50% Load	80% Load	90% Load	95% Load	100% Load
I/O Request Throughput	7,249.13	36,233.90	57,986.69	65,246.82	68,861.47	72,521.11
Average Response Time (ms):						
All ASUs	0.47	2.26	4.07	5.03	5.70	6.17
ASU-1	0.50	2.32	4.10	5.05	5.72	6.19
ASU-2	0.49	2.32	4.12	5.06	5.69	6.18
ASU-3	0.39	2.11	4.00	4.98	5.66	6.15
Reads	0.63	2.57	4.29	5.23	5.88	6.35
Writes	0.37	2.05	3.92	4.90	5.58	6.06

Priced Storage Configuration Pricing

Part Number	Description	Quantity	US List	Total	discount	Ave. Price
TA-FAS-S3IE96GB-N	96GB solid state Flash Accelerator PCIe card with 2 x 4-wide SAS-1 ports for internal disk drives, 4 x 24GB enterprise-class SLC Flash modules, integrated super cap power backup, low-profile, ROHS-6 compliant	3	$4,695.00	$14,085	35%	$9,155
X4270M2-H1-AA	Sun Fire X4270 M2 server: base chassis with twelve 3.5-inch drive bays (for factory installation)	1	$3,499.00	$3,499	20%	$2,799
333A-25-15-NEMA	Power Cord Kit, North American/Asian, 2.5 Meter, NEMA 5-15P Plug, IEC60320-C13 Connector, 15A, 125VAC	1	$10.00	$10	20%	$8
5933A	Sun Fire servers: 1200 W AC PSU (for factory installation)	1	$349.00	$349	20%	$279
RA-SS1CR-1T7K	1 TB 7200 rpm 3.5-inch SAS HDD with bracket (for factory installation)	1	$659.00	$659	35%	$428
5899A-N	CPU Heatsink for Sun Fire X4270 & X4275 Server. For Factory Integration Only. RoHS-6	1	$0.00	$0	20%	$0
5896A-N	Processor Filler Panels for Sun Fire X4270 & X4275 Server. XATO. RoHS-6	1	$0.00	$0	20%	$0
SG-SAS6-INT-Z	Sun Storage 6 Gb SAS PCIe HBA, Internal: 8 port (for factory installation)	1	$419.00	$419	35%	$272
5897A-N	3.5-inch HDD Filler Panel for Sun Fire X4275 x64 servers. For Factory Integration Only. RoHS-6.	11	$0.00	$0	20%	$0
4910A	4 GB (1 x 4 GB DIMMs) 1333 MHz DDR3 Low Voltage DIMM, for Sun Fire X4270 M2 Server and Sun Fire X4170 M2 Server, Factory Integration	3	$255.00	$765	20%	$612
5879A-N	Sun Fire X4170, Sun Fire X4270, and Sun Netra X4270 servers, and Sun Blade X6275 and Sun Blade X6270 server modules: 1 memory filler panel (for factory installation)	15	$0.00	$0	20%	$0
5921A	Intel Xeon X5670, 6C, 2.93 GHz, 95W, 12MB Cache, 6.4 GT/s QPI, Intel Turbo Boost Technology, Intel HT Technology Processor without Heatsink for Sun Fire X4170 M2 & Sun Fire X4270 M2 Servers. For Factory Integration Only. RoHS-6.	1	$2,499.00	$2,499	20%	$1,999
				$22,285		$15,554

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

3 – Sun Flash Accelerator F20 PCIe Cards
12 – 24 GB SLC Flash modules
(4 modules per card)
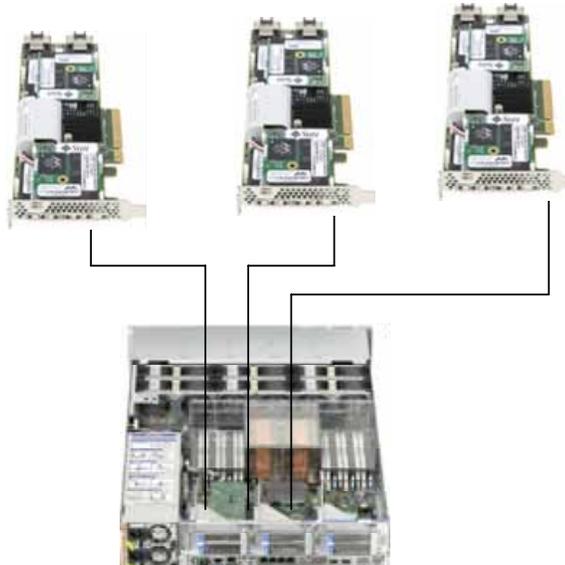
Oracle Sun Fire X4270 M2 Server

Benchmark Configuration/Tested Storage Configuration Components

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

Oracle Sun Fire X4270 M2 Server
1 – Intel Xeon 5670 series processor
    6 cores, 2.93 GHz,
    L1 cache: 32 KB instruction/32 KB data,
    L2 cache: 256 KB unified
    L3 cache: 12 MB shared inclusive
	1 – Sun Storage 6 GB SAS PCIe HBA
	(used for system disk)

	Sun Flash Accelerator F20 PCIe Cards
	3 – 96 GB Sun Flash Accelerator PCIe cards
	    each with:
	        4 – 24 GB SLC Flash modules *(12 total)*
	        2 -4-wide SAS-1 ports for internal disks

12 GB – main memory	
Solaris 10 10/09	Each card directly connected via PCIe Gen 2
PCIe	

In each of the following sections of this document, the appropriate Full Disclosure Report requirement, from the SPC-1C 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 10.4.5.10

The Executive Summary will contain a one page BC/TSC diagram that illustrates all major components of the BC/TSC.

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

Host System and Tested Storage Configuration

Clause 10.4.5.11

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

The table listing the major components of each Host System and the Tested Storage Configuration may be found on **page 13** *(Benchmark Configuration/Tested Storage Configuration Components).*

Customer Tunable Parameters and Options

Clause 10.4.6.1

All Benchmark Configuration (BC) components with customer tunable parameters and options that have been altered from their default values must be listed in the Full Disclosure Report (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 10.4.6.2

The Full Disclosure Report must include sufficient information to recreate the logical representation of the Tested Storage Configuration (TS)C. In addition to customer tunable parameters and options (Clause 10.4.6.1), 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 10.4.5.10.*

> ➢ *The logical representation of the TSC, configured from the above components that will be presented to the SPC-1C 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-1C Workload Generator Storage Configuration

Clause 10.4.6.3

The Full Disclosure Report will include all SPC-1C Workload Generator storage configuration commands and parameters used in the SPC-1C benchmark measurements.

The SPC-1C Workload Generator storage configuration commands and parameters for this measurement appear in "Appendix D: SPC-1C Workload Generator Storage Commands and Parameters" on page 62.

SPC-1C DATA REPOSITORY

This portion of the Full Disclosure Report presents the detailed information that fully documents the various SPC-1C storage capacities and mappings used in the Tested Storage Configuration. "SPC-1C Data Repository Definitions" on page 53 contains definitions of terms specific to the SPC-1C Data Repository.

Storage Capacities and Relationships

Clause 10.4.7.1

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

SPC-1C Storage Capacities

SPC-1C Storage Capacities		
Storage Hierarchy Component	**Units**	**Capacity**
Total ASU Capacity	Gigabytes (GB)	147.413
Addressable Storage Capacity	Gigabytes (GB)	147.413
Configured Storage Capacity	Gigabytes (GB)	293.987
Physical Storage Capacity	Gigabytes (GB)	294.827
Data Protection *(Unprotected)*	Gigabytes (GB)	0.000
Required Storage *(metadata)*	Gigabytes (GB)	0.642
Global Storage Overhead	Gigabytes (GB)	0.197
Total Unused Storage	Gigabytes (GB)	146.574

SPC-1C Storage Hierarchy Ratios

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	50.14%	50.00%
Required for Data Protection *(RAID-5 parity)*		0.00%	0.00%
Addressable Storage Capacity		54.14%	50.00%
Required Storage		0.22%	0.22%
Configured Storage Capacity			99.72%
Global Storage Overhead			0.07%
Unused Storage:			
Addressable	0.00%		
Configured		49.86%	
Physical			0.00%

The Physical Storage Capacity consisted of 294.827 GB distributed over 12 Flash modules each with a "raw" capacity of 24.569 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 0.197 GB (0.07%) of Physical Storage Capacity. There was 146.574 GB (49.86%%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 100.00% of the Addressable Storage Capacity resulting in 0.000 GB (0.00%) of Unused Storage within the Addressable Storage Capacity.

SPC-1C Storage Capacities and Relationships Illustration

The various storage capacities configured in the benchmark result are illustrated below (not to scale).
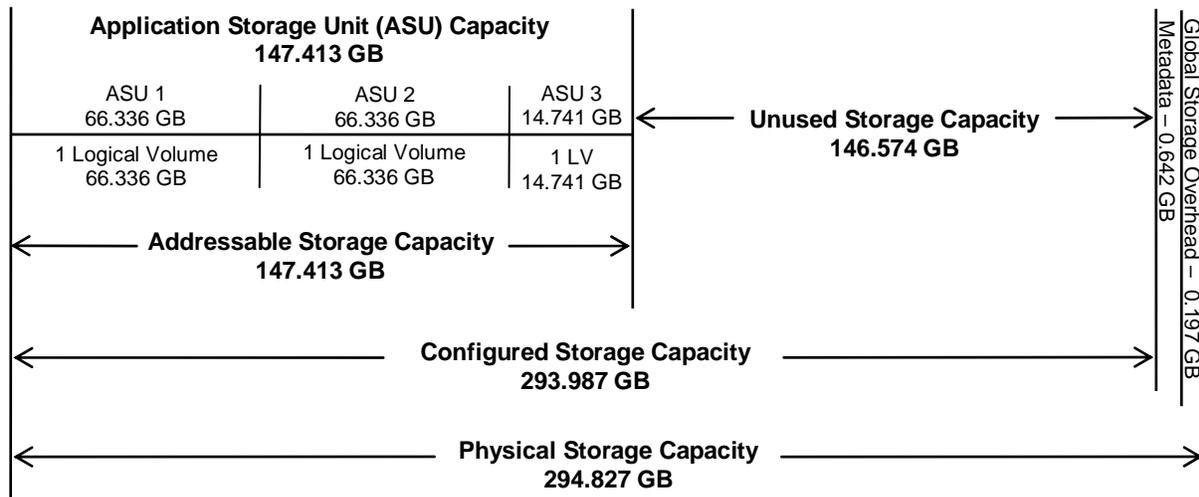
Logical Volume Capacity and ASU Mapping

Clause 10.4.7.2

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 2.7) used on each Logical Volume.

Logical Volume Capacity and Mapping		
ASU-1 (66.336 GB)	**ASU-2 (66.336 GB)**	**ASU-3 (14.741 GB)**
1 Logical Volume 66.336 GB per Logical Volume (66.336 GB used per Logical Volume)	1 Logical Volume 66.336 GB per Logical Volume (66.336 GB used per Logical Volume)	1 Logical Volume 14.741 GB per Logical Volume (14.741 GB used per Logical Volume)

There was no data protection used for the Logical Volumes as described on page 10. See "ASU Configuration" in the **IOPS Test Results File** for more detailed configuration information.

SPC-1C BENCHMARK EXECUTION RESULTS

This portion of the Full Disclosure Report documents the results of the various SPC-1C Tests, Test Phases, and Test Runs. "SPC-1C Test Execution Definitions" on page 54 contains definitions of terms specific to the SPC-1C Tests, Test Phases, and Test Runs.

Clause 6.4.2

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 selected Test sequence. If the selected Test sequence is interrupted, the SPC-1C measurement is invalid. This does not apply to the interruption caused by the Host System/TSC power cycle between Persistence Test Run 1 and Persistence Test Run 2.

SPC-1C Tests, Test Phases, and Test Runs

The SPC-1C 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**
    - o **95% of IOPS Test Run**
    - o **90% of IOPS Test Run**
    - o **80% of IOPS Test Run**
    - o **50% of IOPS Test Run**
    - o **10% of IOPS Test Run (LRT)**

- **Repeatability Test**
  - ➢ **Repeatability Test Phase 1**
    - o **10% of IOPS Test Run (LRT)**
    - o **IOPS Test Run**
  - ➢ **Repeatability Test Phase 2**
    - o **10% of IOPS Test Run (LRT)**
    - o **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 6.4.3.2

The Sustainability Test Phase has exactly one Test Run and shall demonstrate the maximum sustainable I/O Request Throughput within a continuous one (1) hour Measurement Interval.

Clause 6.4.3.2.6

The computed I/O Request Throughput of the Sustainability Test Run must be no less than 95% of the reported SPC-1C IOPS™ result or the Test Run is invalid.

Clause 6.4.3.2.7

The Average Response Time, as defined in Clause 0, will be computed and reported for the Sustainability Test Run and cannot exceed 30 milliseconds. If the Average Response Time exceeds that 30-millisecond constraint, the Test Run is invalid.

Clause 10.4.8.1

The FDR shall contain the following for the single Test Run in the Sustainability/IOPS Test Phase:

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-1C Workload Generator Input Parameters

The SPC-1C Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1C Workload Generator Input Parameters" on Page 63.

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)*

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	10:56:56	11:04:56	0-7	0:08:00
Measurement Interval	11:04:56	12:04:56	8-67	1:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	595.70	231.36	63.57	300.77	34	595.35	231.06	63.73	300.56
1	595.04	230.93	63.49	300.62	35	595.43	230.60	63.56	301.26
2	594.74	230.57	63.79	300.37	36	594.72	231.05	63.57	300.10
3	595.29	230.89	63.66	300.74	37	594.91	231.13	63.64	300.14
4	595.30	231.19	63.63	300.48	38	595.97	231.43	63.43	301.12
5	594.69	231.01	63.59	300.08	39	595.31	231.02	63.70	300.60
6	595.72	231.48	63.37	300.88	40	594.52	230.84	63.56	300.12
7	594.14	231.09	63.55	299.50	41	595.29	231.08	63.54	300.68
8	595.64	230.99	63.70	300.95	42	595.47	231.05	63.42	300.99
9	595.63	230.70	63.78	301.15	43	593.15	230.62	63.43	299.10
10	594.66	230.83	63.59	300.24	44	595.21	230.93	63.65	300.63
11	594.45	231.42	63.36	299.68	45	595.31	231.02	63.58	300.71
12	595.06	230.73	63.61	300.73	46	595.70	231.38	63.54	300.79
13	594.62	231.06	63.56	300.01	47	595.36	231.15	63.75	300.46
14	595.23	231.11	63.39	300.74	48	594.53	230.73	63.64	300.16
15	594.02	230.72	63.72	299.58	49	594.89	231.05	63.91	299.93
16	594.98	231.60	63.55	299.83	50	594.76	231.18	63.43	300.15
17	594.92	230.86	63.53	300.53	51	595.31	231.02	63.64	300.66
18	595.08	230.96	63.67	300.46	52	594.83	230.90	63.64	300.28
19	595.77	231.40	63.45	300.92	53	594.55	230.93	63.35	300.28
20	595.43	231.45	63.20	300.78	54	594.62	230.87	63.57	300.17
21	594.23	230.88	63.54	299.81	55	595.05	230.95	63.59	300.51
22	595.37	231.30	63.71	300.35	56	595.26	231.06	63.39	300.80
23	594.63	230.68	63.56	300.38	57	595.43	230.95	63.58	300.90
24	595.43	230.88	63.56	301.00	58	594.49	230.80	63.70	299.99
25	594.59	231.17	63.26	300.16	59	594.39	230.90	63.59	299.89
26	594.18	230.85	63.35	299.98	60	595.76	230.81	63.43	301.53
27	594.93	231.02	63.68	300.23	61	594.61	230.86	63.49	300.26
28	594.57	230.82	63.76	299.99	62	595.09	231.11	63.41	300.56
29	593.65	231.00	63.31	299.34	63	596.21	231.62	63.56	301.03
30	595.42	231.01	63.50	300.90	64	595.68	231.49	63.73	300.46
31	593.90	230.88	63.43	299.59	65	593.70	230.71	63.47	299.52
32	594.63	231.22	63.30	300.10	66	595.81	231.58	63.75	300.48
33	594.49	230.93	63.38	300.18	67	594.80	230.51	63.53	300.76

Sustainability – Data Rate Distribution Graph
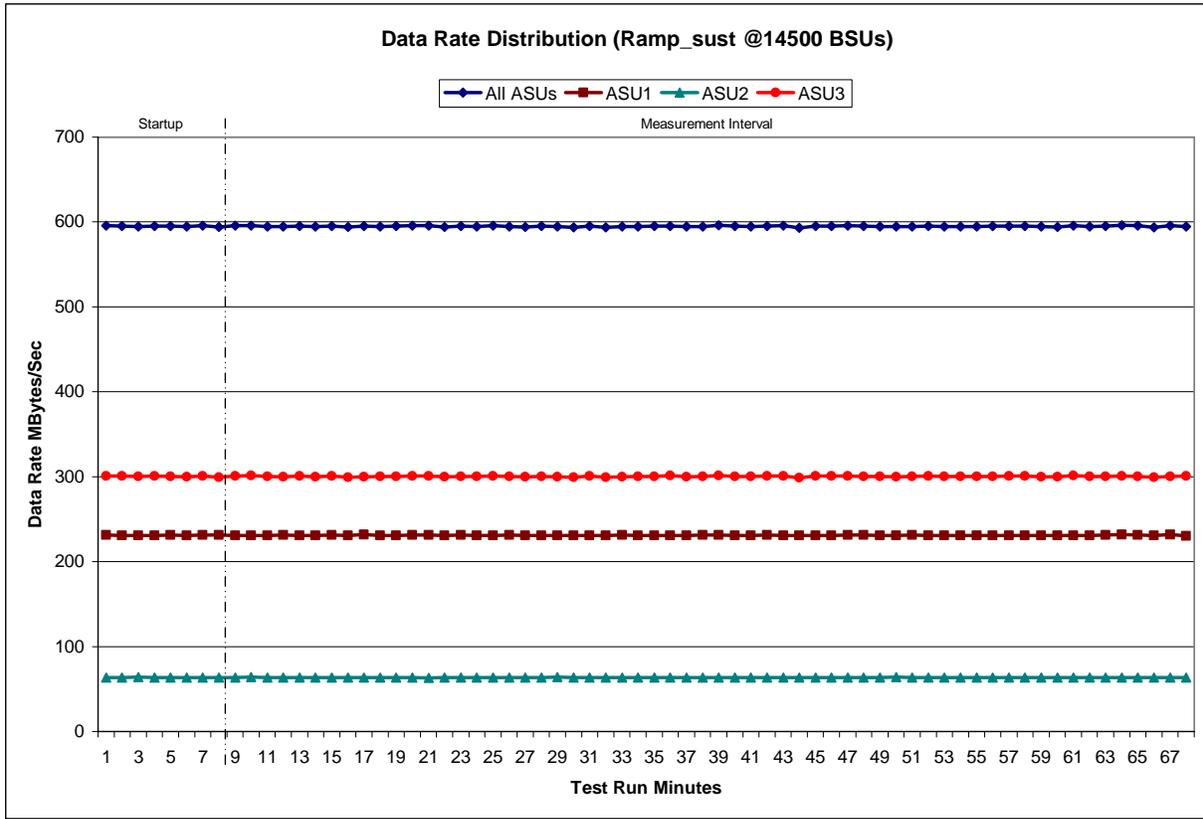
Sustainability – I/O Request Throughput Distribution Data

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	10:56:56	11:04:56	0-7	0:08:00
Measurement Interval	11:04:56	12:04:56	8-67	1:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	72,593.00	43,246.68	8,936.13	20,410.18	34	72,575.72	43,246.93	8,935.77	20,393.02
1	72,507.58	43,197.18	8,935.47	20,374.93	35	72,478.37	43,157.45	8,946.00	20,374.92
2	72,479.78	43,181.47	8,927.05	20,371.27	36	72,482.18	43,206.00	8,907.20	20,368.98
3	72,500.33	43,173.78	8,924.58	20,401.97	37	72,497.00	43,215.18	8,913.83	20,367.98
4	72,544.63	43,245.78	8,917.10	20,381.75	38	72,572.15	43,281.90	8,913.43	20,376.82
5	72,518.80	43,234.48	8,921.32	20,363.00	39	72,451.53	43,185.83	8,915.48	20,350.22
6	72,542.15	43,229.67	8,920.67	20,391.82	40	72,486.37	43,193.22	8,921.08	20,372.07
7	72,511.67	43,237.53	8,913.42	20,360.72	41	72,538.70	43,215.25	8,920.35	20,403.10
8	72,510.15	43,201.57	8,917.68	20,390.90	42	72,567.98	43,239.67	8,911.52	20,416.80
9	72,495.77	43,171.38	8,945.03	20,379.35	43	72,430.80	43,196.63	8,917.92	20,316.25
10	72,425.12	43,143.72	8,915.68	20,365.72	44	72,539.35	43,201.67	8,941.98	20,395.70
11	72,496.23	43,245.50	8,912.67	20,338.07	45	72,489.17	43,209.07	8,910.20	20,369.90
12	72,505.77	43,188.27	8,923.05	20,394.45	46	72,518.78	43,234.52	8,916.47	20,367.80
13	72,479.08	43,190.23	8,919.75	20,369.10	47	72,505.88	43,207.75	8,914.57	20,383.57
14	72,510.35	43,231.15	8,904.53	20,374.67	48	72,494.40	43,211.05	8,900.25	20,383.10
15	72,484.75	43,190.97	8,926.42	20,367.37	49	72,463.75	43,206.58	8,932.23	20,324.93
16	72,552.52	43,253.60	8,934.82	20,364.10	50	72,429.17	43,151.32	8,922.22	20,355.63
17	72,524.80	43,207.63	8,902.03	20,415.13	51	72,548.65	43,242.22	8,921.47	20,384.97
18	72,566.37	43,250.78	8,930.85	20,384.73	52	72,513.92	43,191.15	8,929.00	20,393.77
19	72,529.00	43,226.80	8,900.43	20,401.77	53	72,468.30	43,201.28	8,896.83	20,370.18
20	72,510.08	43,222.18	8,903.15	20,384.75	54	72,489.85	43,202.40	8,910.65	20,376.80
21	72,446.18	43,188.87	8,915.40	20,341.92	55	72,563.93	43,229.87	8,932.42	20,401.65
22	72,523.63	43,231.67	8,916.33	20,375.63	56	72,470.62	43,178.00	8,909.80	20,382.82
23	72,512.13	43,207.98	8,921.90	20,382.25	57	72,530.60	43,203.78	8,936.42	20,390.40
24	72,500.77	43,211.85	8,898.63	20,390.28	58	72,471.47	43,201.65	8,916.65	20,353.17
25	72,487.57	43,202.50	8,895.98	20,389.08	59	72,523.28	43,223.58	8,938.20	20,361.50
26	72,488.82	43,182.53	8,916.10	20,390.18	60	72,505.85	43,194.08	8,913.92	20,397.85
27	72,507.75	43,204.62	8,945.02	20,358.12	61	72,448.57	43,172.87	8,906.40	20,369.30
28	72,494.37	43,196.78	8,929.45	20,368.13	62	72,537.40	43,251.63	8,897.23	20,388.53
29	72,507.15	43,238.23	8,922.13	20,346.78	63	72,539.67	43,245.77	8,907.97	20,385.93
30	72,536.32	43,233.85	8,915.80	20,386.67	64	72,569.65	43,253.68	8,926.58	20,389.38
31	72,427.88	43,193.03	8,906.68	20,328.17	65	72,465.53	43,178.93	8,916.38	20,370.22
32	72,530.67	43,232.82	8,909.68	20,388.17	66	72,523.45	43,249.62	8,915.52	20,358.32
33	72,454.60	43,174.78	8,902.58	20,377.23	67	72,470.83	43,162.32	8,906.27	20,402.25
					Average	*72,502.84*	*43,209.44*	*8,917.57*	*20,375.84*

Sustainability – I/O Request Throughput Distribution Graph

Sustainability – Average Response Time (ms) Distribution Data

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	10:56:56	11:04:56	0-7	0:08:00
Measurement Interval	11:04:56	12:04:56	8-67	1:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	6.38	6.62	6.33	5.89	34	4.35	4.38	4.34	4.29
1	2.33	2.39	2.44	2.18	35	4.06	4.08	4.09	4.02
2	2.36	2.39	2.44	2.25	36	4.15	4.18	4.17	4.09
3	2.29	2.32	2.35	2.19	37	4.14	4.17	4.18	4.06
4	2.39	2.41	2.45	2.31	38	3.97	3.99	4.00	3.89
5	2.38	2.40	2.43	2.29	39	3.94	3.96	3.97	3.88
6	2.41	2.44	2.47	2.34	40	4.16	4.18	4.18	4.11
7	2.41	2.43	2.46	2.33	41	3.87	3.90	3.90	3.81
8	2.28	2.31	2.33	2.19	42	4.10	4.12	4.11	4.03
9	2.40	2.43	2.45	2.33	43	3.89	3.91	3.90	3.84
10	2.39	2.41	2.44	2.31	44	3.98	4.01	3.99	3.91
11	2.38	2.41	2.42	2.30	45	3.99	4.02	4.03	3.92
12	2.37	2.39	2.41	2.29	46	4.07	4.09	4.09	4.00
13	2.32	2.36	2.38	2.24	47	4.09	4.11	4.10	4.03
14	2.24	2.27	2.28	2.14	48	4.49	4.52	4.49	4.43
15	2.30	2.33	2.34	2.22	49	5.50	5.52	5.49	5.45
16	2.70	2.73	2.74	2.62	50	5.31	5.34	5.30	5.24
17	3.03	3.05	3.06	2.97	51	5.06	5.08	5.05	5.02
18	2.88	2.90	2.91	2.81	52	4.93	4.96	4.94	4.88
19	2.86	2.89	2.90	2.79	53	4.98	5.00	4.98	4.93
20	2.82	2.84	2.86	2.75	54	5.05	5.08	5.03	5.00
21	2.86	2.89	2.90	2.80	55	4.94	4.96	4.93	4.89
22	2.85	2.87	2.89	2.79	56	5.11	5.13	5.09	5.07
23	2.78	2.80	2.80	2.71	57	5.05	5.08	5.02	5.01
24	2.79	2.82	2.82	2.73	58	4.92	4.94	4.91	4.88
25	2.91	2.93	2.94	2.85	59	4.87	4.89	4.87	4.83
26	2.72	2.74	2.75	2.64	60	5.26	5.29	5.22	5.21
27	2.69	2.72	2.72	2.61	61	5.10	5.13	5.11	5.04
28	2.82	2.85	2.85	2.75	62	5.06	5.09	5.04	4.99
29	2.72	2.75	2.75	2.65	63	5.06	5.08	5.05	5.01
30	2.81	2.83	2.84	2.74	64	5.24	5.25	5.24	5.20
31	2.78	2.80	2.81	2.71	65	5.88	5.90	5.88	5.84
32	3.36	3.38	3.39	3.30	66	5.72	5.75	5.67	5.67
33	4.42	4.44	4.43	4.37	67	5.64	5.67	5.64	5.58
					Average	*3.86*	*3.88*	*3.87*	*3.79*

Sustainability – Average Response Time (ms) Distribution Graph
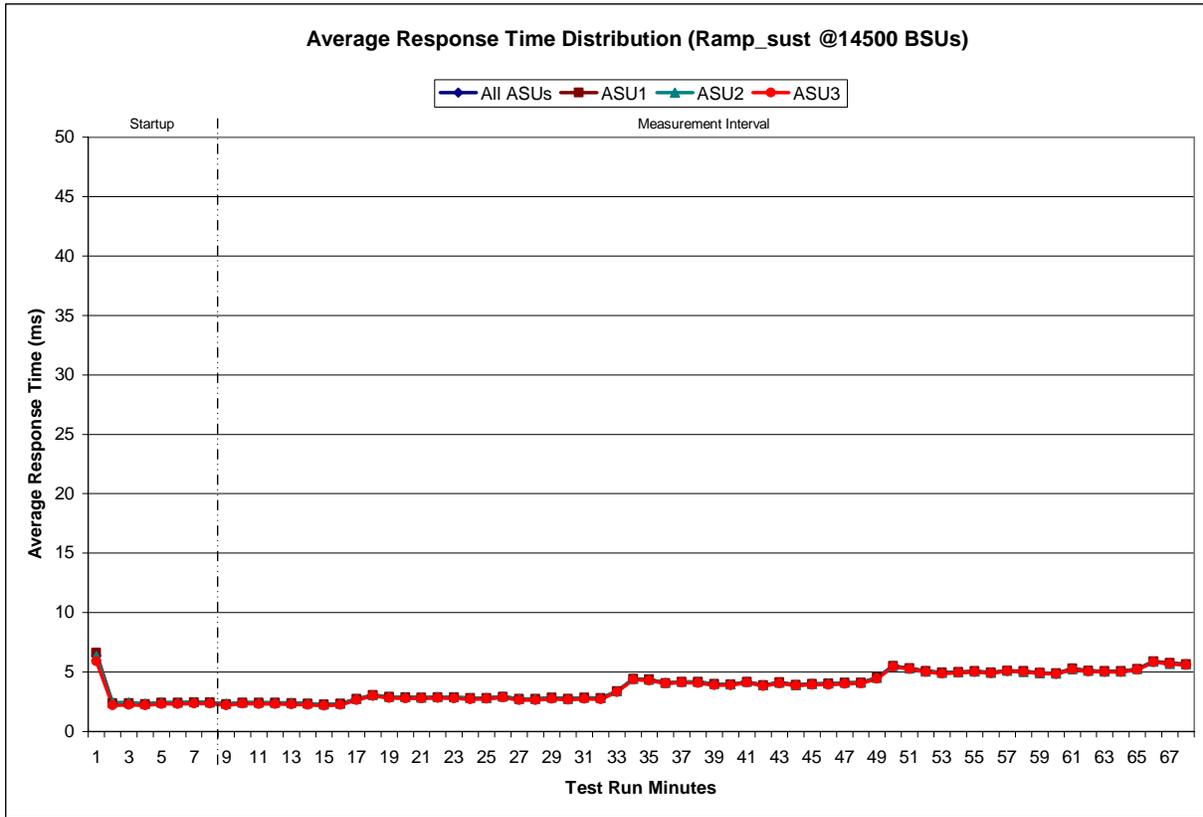
Sustainability – Response Time Frequency Distribution Data

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	2,136	3,607,563	5,201,635	10,154,695	9,567,108	8,727,058	7,454,084	6,608,136
Write	6,297,260	14,947,779	16,111,674	14,696,443	13,739,777	11,740,145	9,797,525	8,081,174
All ASUs	6,299,396	18,555,342	21,313,309	24,851,138	23,306,885	20,467,203	17,251,609	14,689,310
ASU1	3,078,463	9,944,210	11,600,191	15,101,342	14,136,082	12,499,501	10,503,274	9,002,584
ASU2	720,296	2,129,699	2,460,416	3,044,991	2,884,518	2,535,285	2,125,910	1,813,557
ASU3	2,500,637	6,481,433	7,252,702	6,704,805	6,286,285	5,432,417	4,622,425	3,873,169

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	11,222,387	8,768,859	6,192,689	4,476,774	3,416,393	2,654,104	3,625,138	2,197,765
Write	12,524,438	9,512,281	7,217,120	5,446,196	4,165,945	3,207,432	4,380,895	2,652,670
All ASUs	23,746,825	18,281,140	13,409,809	9,922,970	7,582,338	5,861,536	8,006,033	4,850,435
ASU1	14,718,148	11,354,512	8,208,395	6,019,078	4,597,288	3,558,348	4,863,361	2,951,360
ASU2	2,970,851	2,313,355	1,695,201	1,258,822	964,522	747,011	1,021,645	619,601
ASU3	6,057,826	4,613,273	3,506,213	2,645,070	2,020,528	1,556,177	2,121,027	1,279,474

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	1,378,559	907,260	643,962	1,646,975	929,403	707,938	573,593	2,273,041
Write	1,688,420	1,177,204	899,406	2,703,419	1,491,728	1,100,214	890,653	3,603,033
All ASUs	3,066,979	2,084,464	1,543,368	4,350,394	2,421,131	1,808,152	1,464,246	5,876,074
ASU1	1,865,476	1,259,883	922,745	2,539,006	1,424,941	1,069,373	865,799	3,470,512
ASU2	391,580	263,014	193,195	532,724	296,543	222,670	180,837	716,981
ASU3	809,923	561,567	427,428	1,278,664	699,647	516,109	417,610	1,688,581

Sustainability – Response Time Frequency Distribution Graph
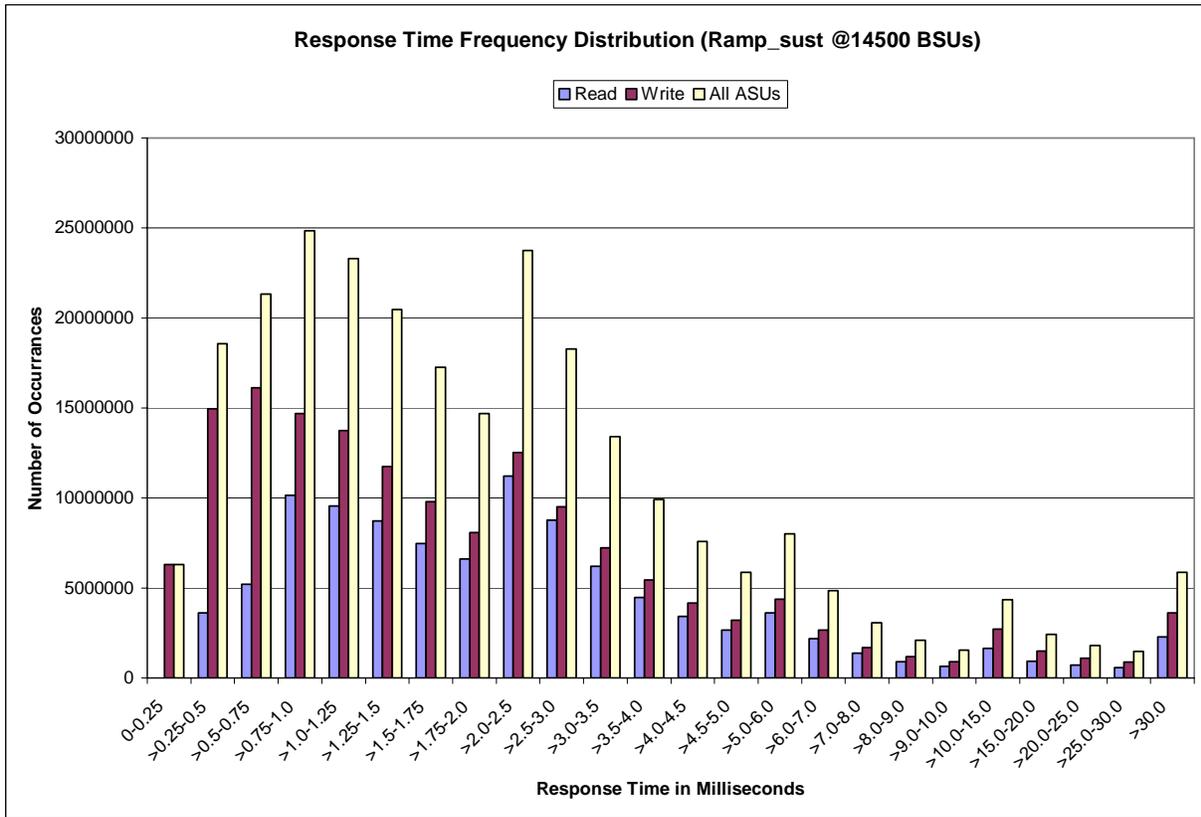
Sustainability – Measured Intensity Multiplier and Coefficient of Variation

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 6.1.0

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).*

Clause 6.3.13.3

COV – Coefficient of Variation: *This measure of variation for the Measured Intensity Multiplier cannot exceed 0.5.*

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

Primary Metrics Test – IOPS Test Phase

Clause 6.4.3.3

The IOPS Test Phase consists of one Test Run at the 100% load point with a Measurement Interval of five (5) minutes. The IOPS Test Phase immediately follows the Sustainability Test Phase without any interruption or manual intervention.

The IOPS Test Run generates the SPC-1C 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 10.4.8.2

For the IOPS Test Phase the FDR shall contain:

1. *I/O Request Throughput Distribution (data and graph).*
2. *Response Time Frequency Distribution (data and graph).*
3. *Average Response Time Distribution (data and graph).*
4. *The human readable SPC-1C Test Run Results File produced by the SPC-1C Workload Generator.*
5. *A listing of all input parameters supplied to the SPC-1C Workload Generator.*
6. *The Measured Intensity Multiplier for each I/O Stream.*
7. *The variability of the Measured Intensity Multiplier, as defined in Clause 6.3.13.3.*
8. *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-1C Workload Generator Input Parameters

The SPC-1C Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1C Workload Generator Input Parameters" on Page 63.

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

14,500 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:05:23	12:13:24	0-7	0:08:01
Measurement Interval	12:13:24	12:18:24	8-12	0:05:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	72,498.50	43,193.98	8,914.42	20,390.10
1	72,487.08	43,198.40	8,924.85	20,363.83
2	72,518.72	43,249.22	8,911.12	20,358.38
3	72,529.23	43,237.48	8,892.95	20,398.80
4	72,533.03	43,251.25	8,900.98	20,380.80
5	72,514.48	43,188.92	8,926.15	20,399.42
6	72,518.27	43,191.70	8,919.00	20,407.57
7	72,527.90	43,227.43	8,921.60	20,378.87
8	72,466.52	43,234.35	8,890.93	20,341.23
9	72,573.33	43,236.60	8,921.22	20,415.52
10	72,515.67	43,218.22	8,921.07	20,376.38
11	72,506.93	43,218.87	8,929.72	20,358.35
12	72,543.08	43,251.87	8,915.20	20,376.02
Average	72,521.11	43,231.98	8,915.63	20,373.50

IOPS Test Run – I/O Request Throughput Distribution Graph
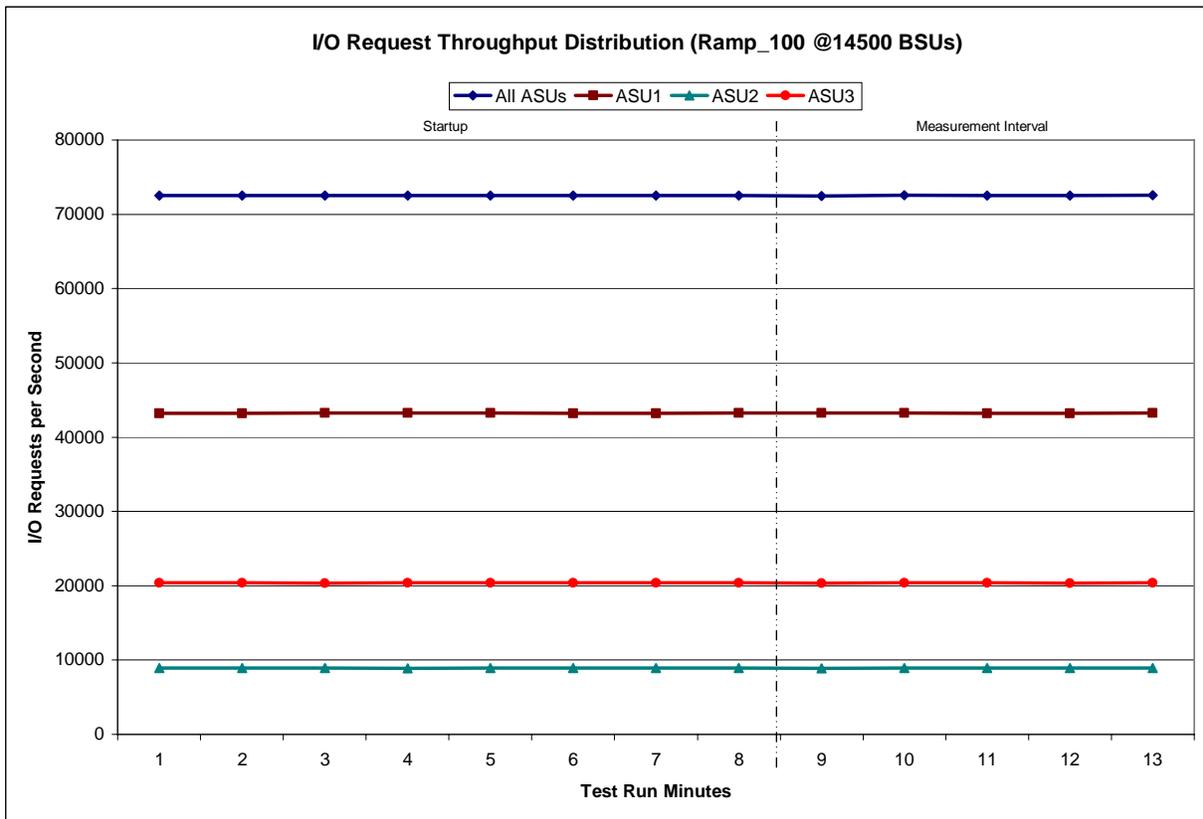
IOPS Test Run – Average Response Time (ms) Distribution Data

14,500 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:05:23	12:13:24	0-7	0:08:01
Measurement Interval	12:13:24	12:18:24	8-12	0:05:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	25.65	25.98	25.20	25.15
1	8.42	8.48	8.43	8.28
2	6.60	6.63	6.65	6.53
3	5.80	5.81	5.84	5.78
4	6.63	6.64	6.67	6.60
5	5.73	5.75	5.74	5.67
6	5.93	5.94	5.97	5.90
7	5.44	5.46	5.48	5.39
8	5.68	5.69	5.70	5.67
9	6.48	6.49	6.55	6.44
10	5.80	5.82	5.82	5.77
11	6.27	6.30	6.23	6.23
12	6.62	6.63	6.63	6.62
Average	6.17	6.19	6.18	6.15

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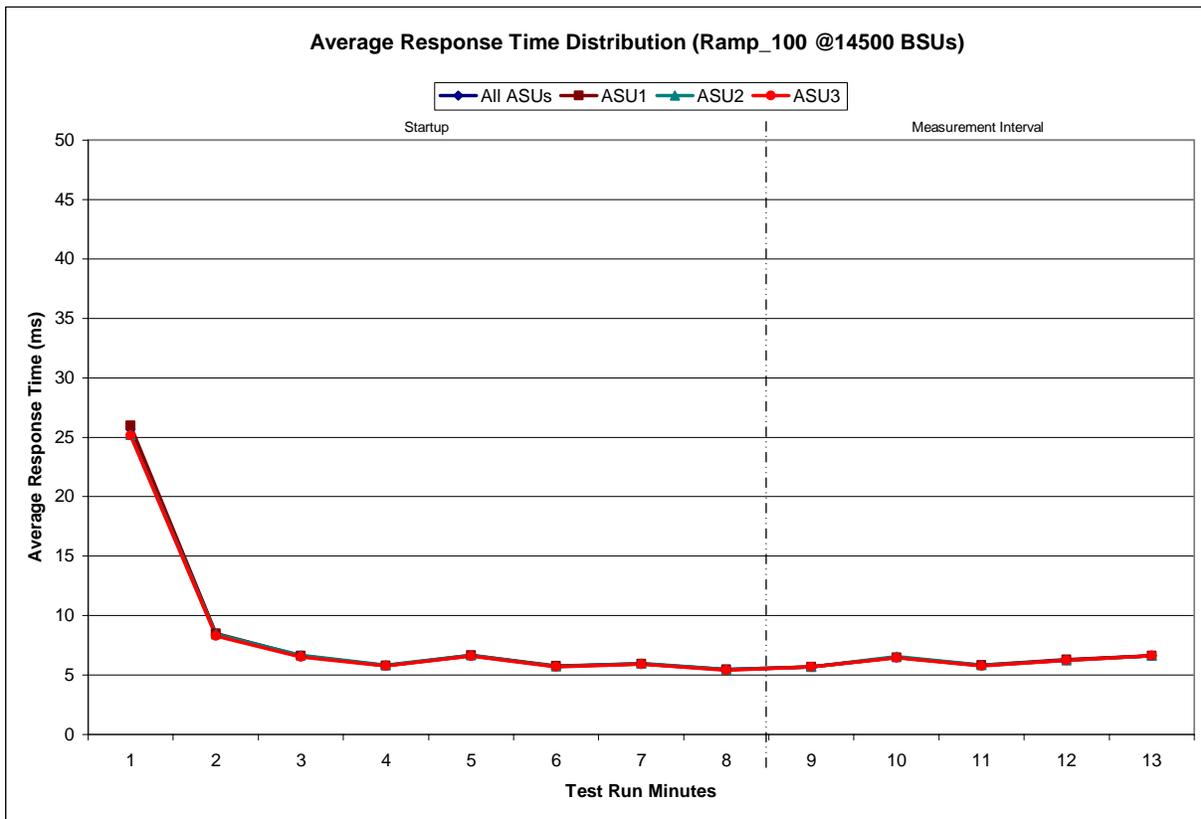
IOPS Test Run – Response Time Frequency Distribution Data

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	210	287,931	446,103	822,487	768,814	698,328	588,774	514,623
Write	544694	1,229,709	1,330,367	1,205,341	1,100,669	916,765	750,699	608,545
All ASUs	544904	1,517,640	1,776,470	2,027,828	1,869,483	1,615,093	1,339,473	1,123,168
ASU1	265975	810,107	971,850	1,229,339	1,133,548	989,712	819,357	691,232
ASU2	61869	172,960	204,362	247,461	230,006	199,470	164,919	139,339
ASU3	217060	534,573	600,258	551,028	505,929	425,911	355,197	292,597
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	849,824	647,599	452,869	325,108	247,195	191,522	266,442	168,755
Write	919,082	675,930	502,070	376,184	286,264	221,610	312,936	205,229
All ASUs	1,768,906	1,323,529	954,939	701,292	533,459	413,132	579,378	373,984
ASU1	1,101,532	827,089	589,180	429,399	325,794	252,366	354,440	227,258
ASU2	221,327	168,539	121,960	89,696	68,697	53,507	74,952	48,205
ASU3	446,047	327,901	243,799	182,197	138,968	107,259	149,986	98,521
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	113,676	83,298	64,704	202,998	140,664	119,366	103,851	475,532
Write	146,170	113,403	93,627	322,214	219,294	182,962	160,062	751,536
All ASUs	259,846	196,701	158,331	525,212	359,958	302,328	263,913	1,227,068
ASU1	157,572	117,578	94,192	309,218	213,329	179,070	156,175	724,099
ASU2	33,234	25,046	19,900	64,617	44,020	37,574	32,501	150,491
ASU3	69,040	54,077	44,239	151,377	102,609	85,684	75,237	352,478

IOPS Test Run –Response Time Frequency Distribution Graph
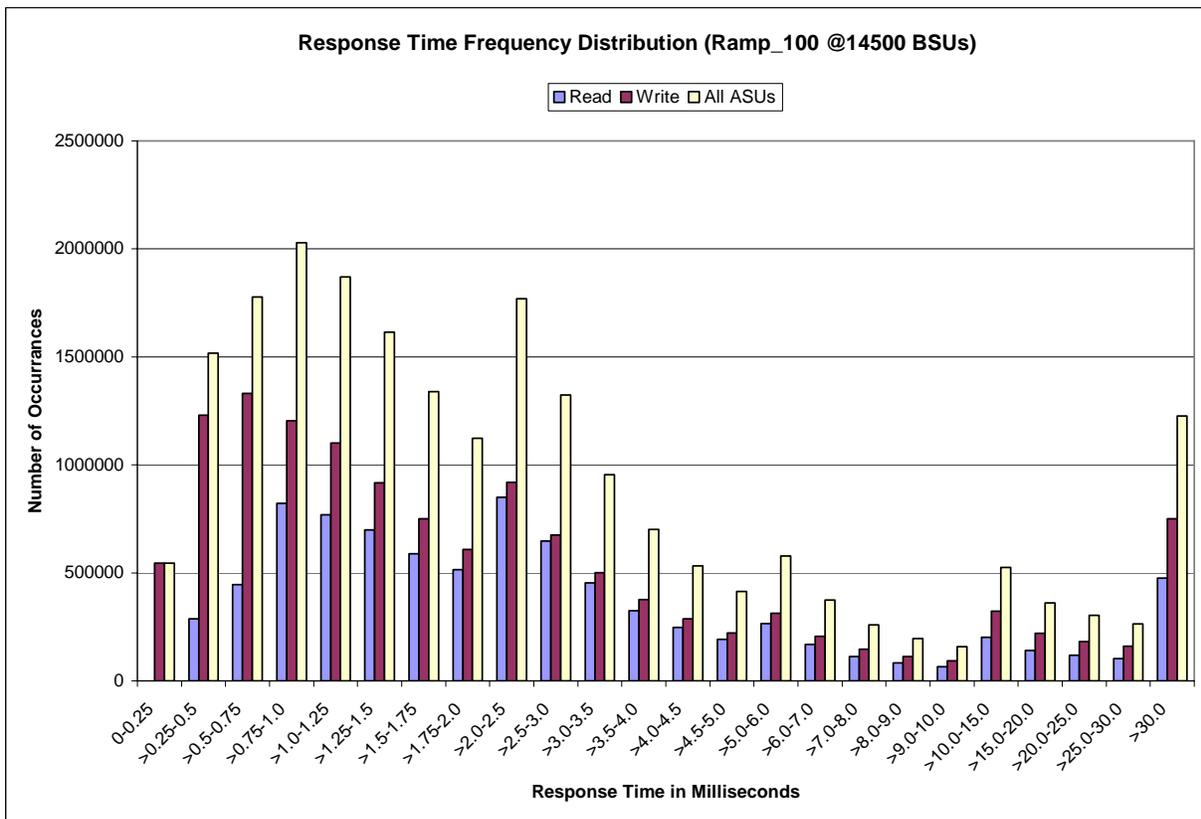
IOPS Test Run – I/O Request Information

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
21,756,035	20,528,967	1,227,068

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 6.1.0

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).*

Clause 6.3.13.3

COV – Coefficient of Variation: *This measure of variation for the Measured Intensity Multiplier cannot exceed 0.5.*

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0350	0.2811	0.0700	0.2101	0.0180	0.0700	0.0350	0.2809
COV	0.001	0.001	0.002	0.001	0.002	0.002	0.003	0.001

Primary Metrics Test – Response Time Ramp Test Phase

Clause 6.4.3.4

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-1C IOPS™ primary metric. Each of the five Test Runs has a Measurement Interval of five (5) 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-1C LRT™ metric. That value represents the Average Response Time of a lightly loaded TSC.

Clause 10.4.8.3

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

1. *A Response Time Ramp Distribution graph.*
2. *The human readable Test Run Results File produced by the SPC-1C C Workload Generator for each Test Run within the Response Time Ramp Test Phase.*
3. *An Average Response Time Distribution graph and table for the 10% BSU Level Test Run (the SPC-1C LRT™ metric).*
4. *A listing of all input parameters supplied to the SPC-1C Workload Generator.*

SPC-1C Workload Generator Input Parameters

The SPC-1C Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1C Workload Generator Input Parameters" on Page 63.

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-1C 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 - 14,500 BSUs	Start	Stop	Interval	Duration	95% Load Level - 13,775 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:05:23	12:13:24	0-7	0:08:01	Start-Up/Ramp-Up	12:18:48	12:26:49	0-7	0:08:01
Measurement Interval	12:13:24	12:18:24	8-12	0:05:00	Measurement Interval	12:26:49	12:31:49	8-12	0:05:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	72,498.50	43,193.98	8,914.42	20,390.10	0	68,850.05	41,026.47	8,476.67	19,346.92
1	72,487.08	43,198.40	8,924.85	20,363.83	1	68,850.18	41,055.40	8,456.53	19,338.25
2	72,518.72	43,249.22	8,911.12	20,358.38	2	68,887.52	41,053.83	8,478.17	19,355.52
3	72,529.23	43,237.48	8,892.95	20,398.80	3	68,938.97	41,077.53	8,464.13	19,397.30
4	72,533.03	43,251.25	8,900.98	20,380.80	4	68,863.63	41,030.47	8,483.73	19,349.43
5	72,514.48	43,188.92	8,926.15	20,399.42	5	68,879.25	41,068.22	8,456.02	19,355.02
6	72,518.27	43,191.70	8,919.00	20,407.57	6	68,872.73	41,054.13	8,494.97	19,323.63
7	72,527.90	43,227.43	8,921.60	20,378.87	7	68,909.22	41,065.97	8,460.42	19,382.83
8	72,466.52	43,234.35	8,890.93	20,341.23	8	68,875.77	41,032.15	8,480.63	19,362.98
9	72,573.33	43,236.60	8,921.22	20,415.52	9	68,855.48	41,041.67	8,461.03	19,352.78
10	72,515.67	43,218.22	8,921.07	20,376.38	10	68,875.88	41,046.13	8,487.95	19,341.80
11	72,506.93	43,218.87	8,929.72	20,358.35	11	68,856.35	41,033.30	8,470.50	19,352.55
12	72,543.08	43,251.87	8,915.20	20,376.02	12	68,843.85	41,006.90	8,479.55	19,357.40
Average	72,521.11	43,231.98	8,915.63	20,373.50	Average	68,861.47	41,032.03	8,475.93	19,353.50

90% Load Level - 13,050 BSUs	Start	Stop	Interval	Duration	80% Load Level - 11,600 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:32:12	12:40:13	0-7	0:08:01	Start-Up/Ramp-Up	12:45:35	12:53:36	0-7	0:08:01
Measurement Interval	12:40:13	12:45:13	8-12	0:05:00	Measurement Interval	12:53:36	12:58:36	8-12	0:05:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	65,233.00	38,868.22	8,021.42	18,343.37	0	57,998.30	34,575.40	7,122.63	16,300.27
1	65,323.72	38,953.10	8,037.03	18,333.58	1	57,995.82	34,569.03	7,140.33	16,286.45
2	65,287.22	38,898.08	8,043.43	18,345.70	2	57,989.37	34,552.10	7,136.28	16,300.98
3	65,257.42	38,885.35	8,032.60	18,339.47	3	58,010.38	34,562.47	7,147.12	16,300.80
4	65,260.00	38,906.53	8,016.55	18,336.92	4	57,930.55	34,524.53	7,121.43	16,284.58
5	65,217.27	38,861.73	8,019.55	18,335.98	5	57,974.25	34,556.15	7,115.02	16,303.08
6	65,247.88	38,865.35	8,031.43	18,351.10	6	57,981.18	34,544.63	7,140.00	16,296.55
7	65,269.12	38,915.82	8,021.67	18,331.63	7	58,008.32	34,573.23	7,139.33	16,295.75
8	65,275.77	38,882.63	8,028.60	18,364.53	8	57,976.95	34,565.58	7,125.90	16,285.47
9	65,235.43	38,888.95	8,016.65	18,329.83	9	58,033.13	34,573.80	7,142.60	16,316.73
10	65,245.25	38,873.28	8,025.73	18,346.23	10	57,959.87	34,527.67	7,146.82	16,285.38
11	65,254.95	38,894.90	8,025.87	18,334.18	11	58,004.57	34,578.98	7,138.93	16,286.65
12	65,222.70	38,886.45	8,006.18	18,330.07	12	57,958.95	34,546.32	7,132.80	16,279.83
Average	65,246.82	38,885.24	8,020.61	18,340.97	Average	57,986.69	34,558.47	7,137.41	16,290.81

50% Load Level - 7,250 BSUs	Start	Stop	Interval	Duration	10% Load Level - 1,450 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:58:53	13:06:54	0-7	0:08:01	Start-Up/Ramp-Up	13:12:05	13:20:06	0-7	0:08:01
Measurement Interval	13:06:54	13:11:54	8-12	0:05:00	Measurement Interval	13:20:06	13:25:06	8-12	0:05:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	36,223.57	21,597.70	4,451.53	10,174.33	0	7,247.72	4,316.15	889.27	2,042.30
1	36,258.78	21,616.72	4,457.73	10,184.33	1	7,237.97	4,317.60	885.05	2,035.32
2	36,242.03	21,591.58	4,467.63	10,182.82	2	7,236.67	4,309.62	891.05	2,036.00
3	36,223.80	21,607.02	4,457.98	10,158.80	3	7,226.95	4,306.17	888.15	2,032.63
4	36,243.12	21,609.62	4,453.73	10,179.77	4	7,256.45	4,317.18	896.48	2,042.78
5	36,267.57	21,613.32	4,472.78	10,181.47	5	7,253.67	4,328.75	890.20	2,034.72
6	36,285.67	21,622.95	4,474.88	10,187.83	6	7,257.90	4,321.83	894.88	2,041.18
7	36,262.40	21,602.95	4,481.55	10,177.90	7	7,247.20	4,312.08	893.00	2,042.12
8	36,219.18	21,579.30	4,437.88	10,202.00	8	7,231.85	4,311.83	886.60	2,033.42
9	36,241.48	21,584.55	4,466.05	10,190.88	9	7,253.30	4,313.98	894.33	2,044.98
10	36,271.98	21,627.55	4,474.78	10,169.65	10	7,259.32	4,326.08	892.68	2,040.55
11	36,237.03	21,601.48	4,448.72	10,186.83	11	7,250.00	4,328.58	888.75	2,032.67
12	36,199.83	21,583.20	4,449.55	10,167.08	12	7,251.20	4,325.15	887.72	2,038.33
Average	36,233.90	21,595.22	4,455.40	10,183.29	Average	7,249.13	4,321.13	890.02	2,037.99

Response Time Ramp Distribution (IOPS) Graph
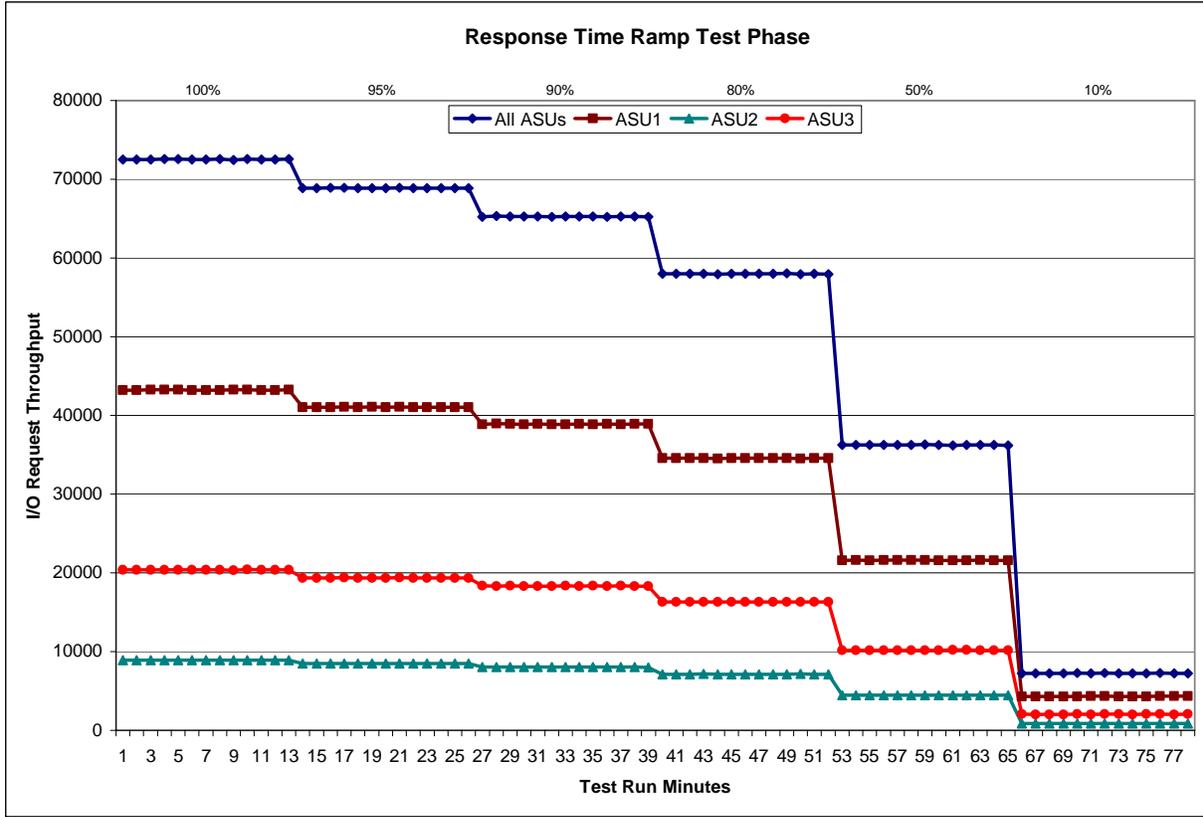
SPC-1C LRT™ Average Response Time (ms) Distribution Data

1,450 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:12:05	13:20:06	0-7	0:08:01
Measurement Interval	13:20:06	13:25:06	7-12	0:05:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.47	0.50	0.50	0.39
1	0.51	0.54	0.52	0.43
2	0.45	0.48	0.46	0.37
3	0.43	0.46	0.44	0.35
4	0.48	0.51	0.51	0.40
5	0.49	0.53	0.52	0.42
6	0.43	0.46	0.46	0.35
7	0.44	0.47	0.46	0.36
8	0.48	0.51	0.49	0.40
9	0.50	0.53	0.53	0.42
10	0.43	0.47	0.46	0.36
11	0.44	0.47	0.46	0.37
12	0.49	0.53	0.51	0.41
Average	*0.47*	*0.50*	*0.49*	*0.39*

SPC-1C LRT™ Average Response Time (ms) Distribution Graph
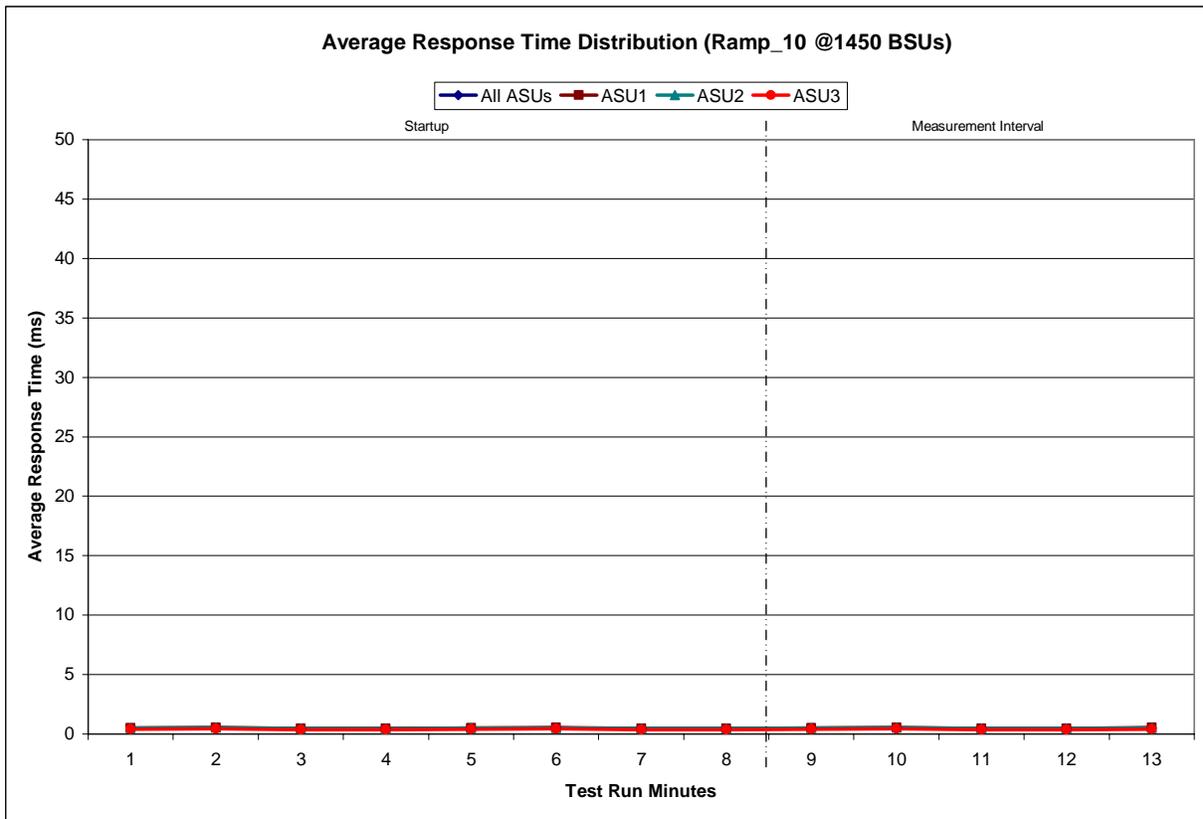
SPC-1C LRT™ (10%) – Measured Intensity Multiplier and Coefficient of Variation

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 6.1.0

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).*

Clause 6.3.13.3

COV – Coefficient of Variation: *This measure of variation for the Measured Intensity Multiplier cannot exceed 0.5.*

	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	0.0354	0.2810	0.0701	0.2097	0.0179	0.0699	0.0350	0.2811
COV	0.013	0.003	0.002	0.004	0.015	0.003	0.006	0.002

Repeatability Test

Clause 6.4.4

The Repeatability Test demonstrates the repeatability and reproducibility of the SPC-1C IOPS™ primary metric and SPC-1C 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 five (5) 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-1C LRT™ metric. Each Average Response Time value must be less than the SPC-1C 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-1C IOPS™ primary metric. Each I/O Request Throughput value must be greater than the SPC-1C 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 10.4.8.4

The FDR shall contain the following for the Repeatability Test:

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

SPC-1C Workload Generator Input Parameters

The SPC-1C Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1C Workload Generator Input Parameters" on Page 63.

Repeatability Test Results File

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

	SPC-1C IOPS™
Primary Metrics	*72,521.11*
Repeatability Test Phase 1	72,494.16
Repeatability Test Phase 2	72,475.66

The SPC-1C 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-1C IOPS™ must greater than 95% of the reported SPC-1C IOPS™ Primary Metric.

	SPC-1C LRT™
Primary Metrics	*0.47 ms*
Repeatability Test Phase 1	0.46 ms
Repeatability Test Phase 2	0.46 ms

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

1,450 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:27:09	13:35:09	0-7	0:08:00
Measurement Interval	13:35:09	13:45:09	8-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	7,259.90	4,324.75	894.57	2,040.58
1	7,266.30	4,321.75	895.90	2,048.65
2	7,260.77	4,326.95	892.28	2,041.53
3	7,233.70	4,307.25	892.30	2,034.15
4	7,241.53	4,320.17	890.08	2,031.28
5	7,256.72	4,318.98	894.22	2,043.52
6	7,252.18	4,330.12	890.02	2,032.05
7	7,254.55	4,312.93	891.02	2,050.60
8	7,241.02	4,317.55	892.47	2,031.00
9	7,244.63	4,310.10	889.70	2,044.83
10	7,251.78	4,330.92	887.03	2,033.83
11	7,240.28	4,313.72	884.82	2,041.75
12	7,240.33	4,320.58	890.30	2,029.45
13	7,237.42	4,314.63	888.72	2,034.07
14	7,259.62	4,333.50	891.05	2,035.07
15	7,256.45	4,323.38	892.52	2,040.55
16	7,252.98	4,318.58	894.92	2,039.48
17	7,248.88	4,311.05	887.43	2,050.40
Average	*7,247.34*	*4,319.40*	*889.90*	*2,038.04*

Repeatability 1 LRT – I/O Request Throughput Distribution Graph
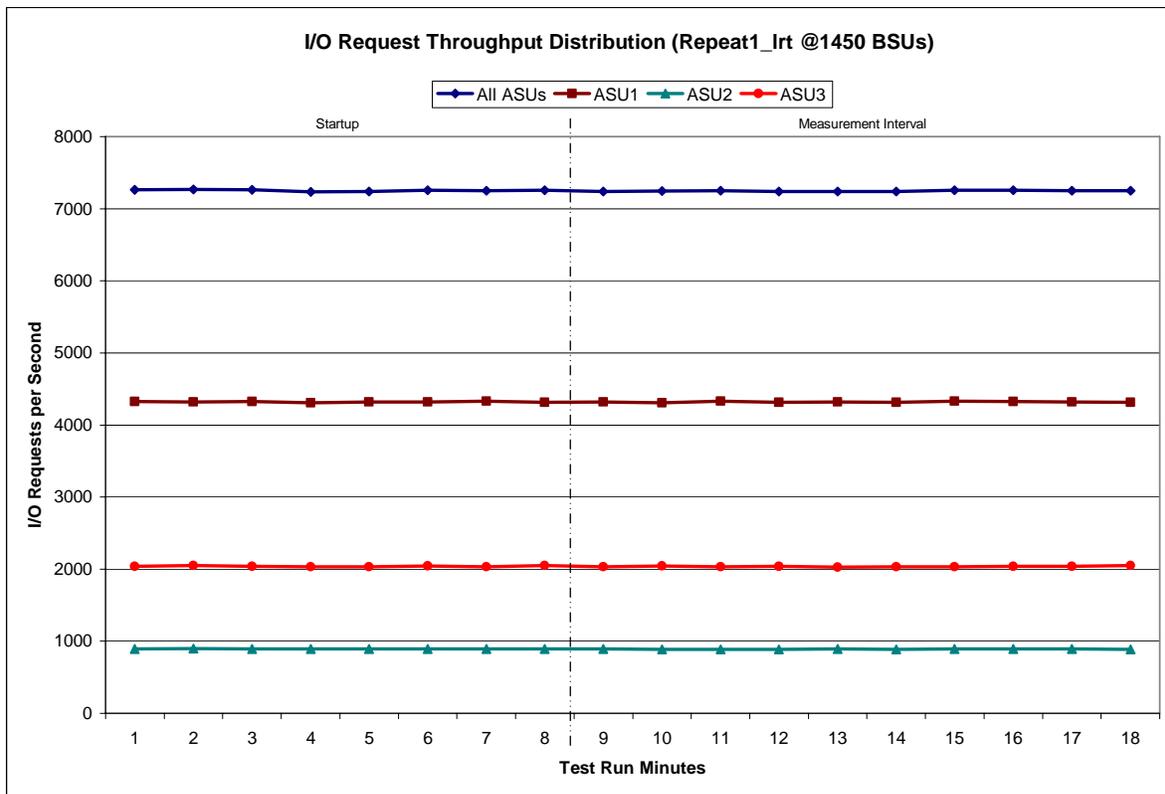
Repeatability 1 LRT –Average Response Time (ms) Distribution Data

1,450 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:27:09	13:35:09	0-7	0:08:00
Measurement Interval	13:35:09	13:45:09	8-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.49	0.52	0.51	0.40
1	0.43	0.46	0.45	0.36
2	0.46	0.50	0.48	0.39
3	0.48	0.51	0.49	0.40
4	0.44	0.47	0.46	0.37
5	0.44	0.47	0.46	0.37
6	0.47	0.50	0.49	0.39
7	0.49	0.52	0.51	0.41
8	0.43	0.46	0.46	0.36
9	0.44	0.47	0.46	0.36
10	0.45	0.49	0.48	0.38
11	0.50	0.53	0.54	0.42
12	0.43	0.46	0.45	0.35
13	0.46	0.49	0.48	0.38
14	0.47	0.50	0.49	0.40
15	0.48	0.51	0.50	0.40
16	0.43	0.47	0.46	0.35
17	0.46	0.49	0.47	0.38
Average	*0.46*	*0.49*	*0.48*	*0.38*

Repeatability 1 LRT –Average Response Time (ms) Distribution Graph
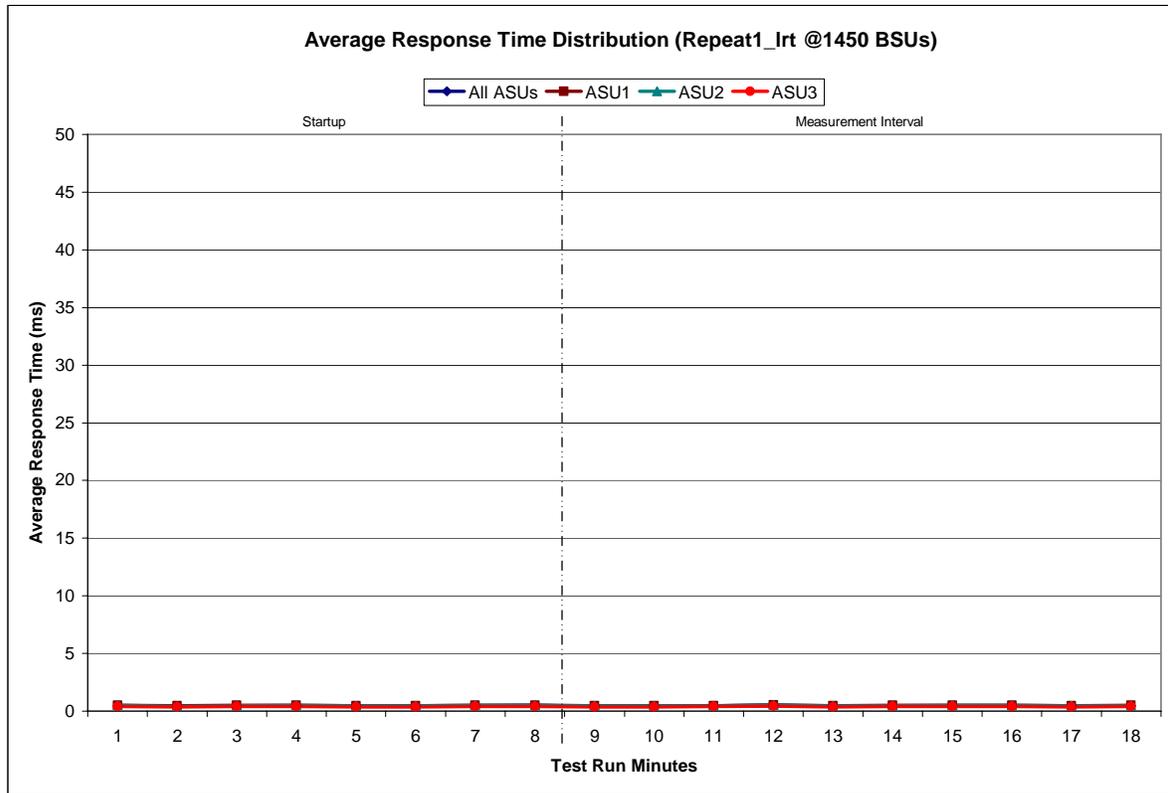
Repeatability 1 IOPS – I/O Request Throughput Distribution Data

| 14,500 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:45:34	13:53:35	0-7	0:08:01
Measurement Interval	13:53:35	14:03:35	8-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	69,671.23	41,542.97	8,570.08	19,558.18
1	75,347.43	44,902.92	9,282.47	21,162.05
2	72,472.93	43,206.23	8,899.42	20,367.28
3	72,466.22	43,192.27	8,935.30	20,338.65
4	72,464.68	43,200.50	8,926.93	20,337.25
5	72,465.78	43,192.15	8,914.13	20,359.50
6	72,539.05	43,212.52	8,924.17	20,402.37
7	72,500.93	43,196.27	8,913.33	20,391.33
8	72,480.58	43,227.90	8,881.67	20,371.02
9	72,505.92	43,226.60	8,900.90	20,378.42
10	72,574.53	43,291.73	8,922.43	20,360.37
11	72,487.12	43,209.20	8,927.12	20,350.80
12	72,513.20	43,214.72	8,915.42	20,383.07
13	72,510.68	43,212.05	8,938.20	20,360.43
14	72,443.42	43,206.98	8,909.32	20,327.12
15	72,439.72	43,183.52	8,921.78	20,334.42
16	72,510.95	43,221.72	8,935.68	20,353.55
17	72,475.52	43,190.75	8,922.78	20,361.98
Average	*72,494.16*	*43,218.52*	*8,917.53*	*20,358.12*

Repeatability 1 IOPS – I/O Request Throughput Distribution Graph
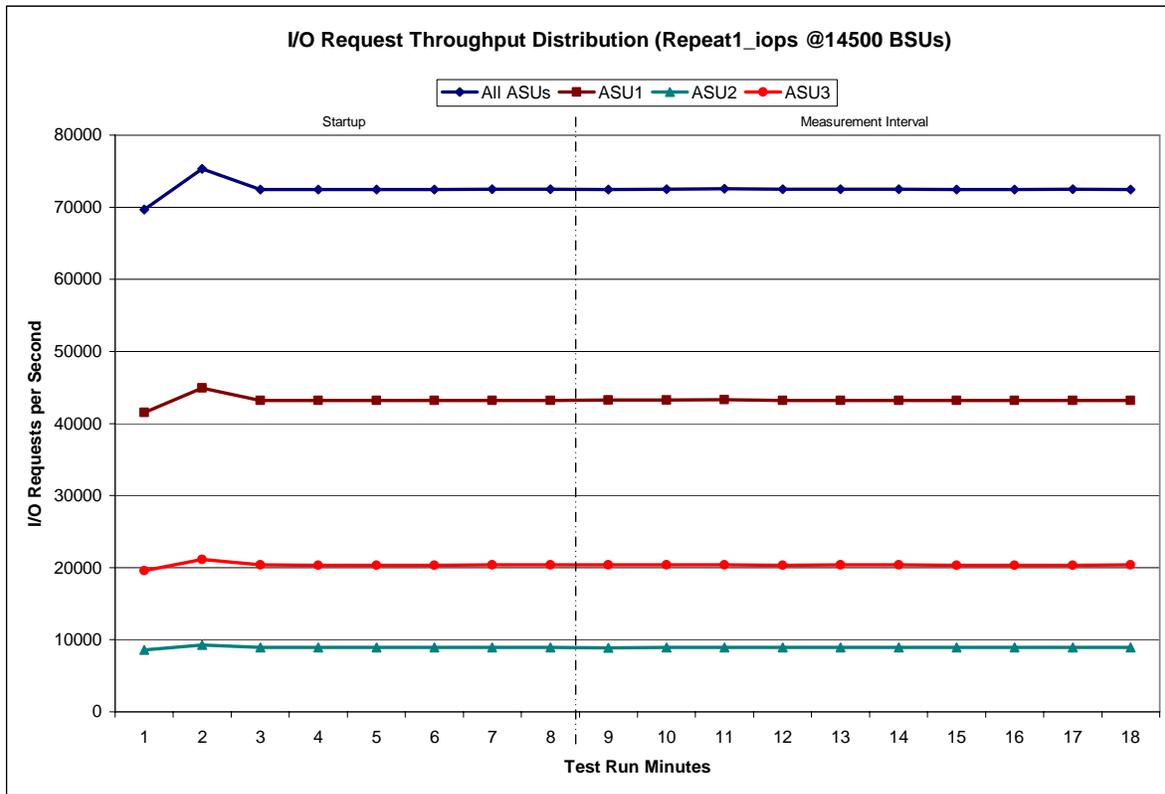
Repeatability 1 IOPS –Average Response Time (ms) Distribution Data

| 14,500 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:45:34	13:53:35	0-7	0:08:01
Measurement Interval	13:53:35	14:03:35	8-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	41.53	41.88	41.08	40.99
1	28.85	28.95	28.51	28.78
2	11.66	11.68	11.60	11.64
3	10.86	10.89	10.77	10.82
4	9.88	9.91	9.86	9.83
5	12.85	12.88	12.76	12.83
6	13.75	13.77	13.59	13.78
7	12.76	12.76	12.64	12.80
8	12.40	12.43	12.30	12.36
9	12.84	12.84	12.78	12.89
10	12.27	12.27	12.18	12.29
11	13.79	13.81	13.59	13.82
12	19.89	19.93	19.45	20.00
13	19.60	19.64	19.32	19.64
14	18.86	18.92	18.47	18.88
15	13.29	13.33	13.09	13.31
16	12.80	12.83	12.68	12.77
17	12.81	12.83	12.67	12.83
Average	*14.85*	*14.88*	*14.65*	*14.88*

Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph
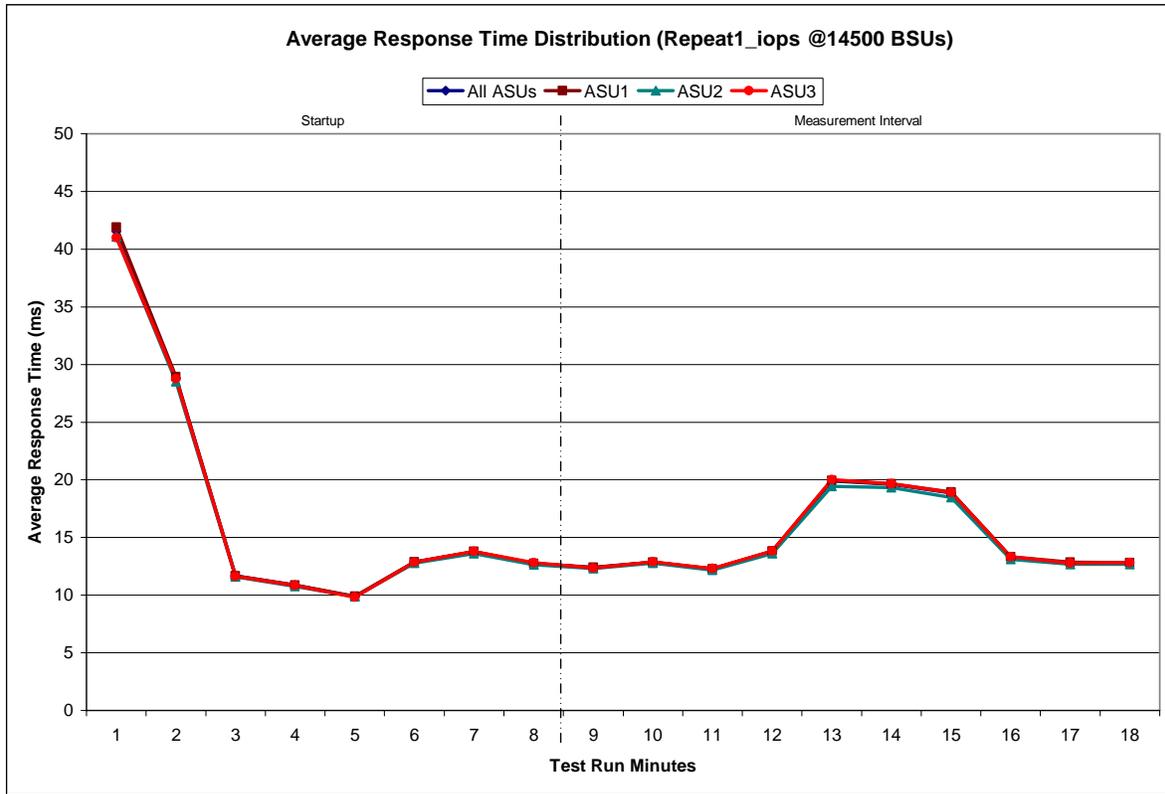
Repeatability 2 LRT – I/O Request Throughput Distribution Data

| 1,450 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:05:06	14:13:06	0-7	0:08:00
Measurement Interval	14:13:06	14:23:06	8-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	7,262.12	4,329.50	895.07	2,037.55
1	7,256.20	4,324.10	895.07	2,037.03
2	7,261.33	4,324.53	894.93	2,041.87
3	7,270.70	4,330.18	888.28	2,052.23
4	7,249.52	4,318.92	890.92	2,039.68
5	7,249.97	4,324.18	889.28	2,036.50
6	7,251.58	4,319.68	896.05	2,035.85
7	7,257.33	4,319.18	899.53	2,038.62
8	7,258.53	4,332.90	894.52	2,031.12
9	7,260.20	4,332.77	888.35	2,039.08
10	7,240.75	4,318.93	893.38	2,028.43
11	7,240.17	4,308.80	890.97	2,040.40
12	7,261.87	4,325.58	895.48	2,040.80
13	7,244.52	4,317.68	890.10	2,036.73
14	7,260.15	4,335.27	893.47	2,031.42
15	7,261.82	4,335.32	887.75	2,038.75
16	7,248.22	4,323.68	893.05	2,031.48
17	7,259.95	4,323.07	896.62	2,040.27
Average	*7,253.62*	*4,325.40*	*892.37*	*2,035.85*

Repeatability 2 LRT – I/O Request Throughput Distribution Graph
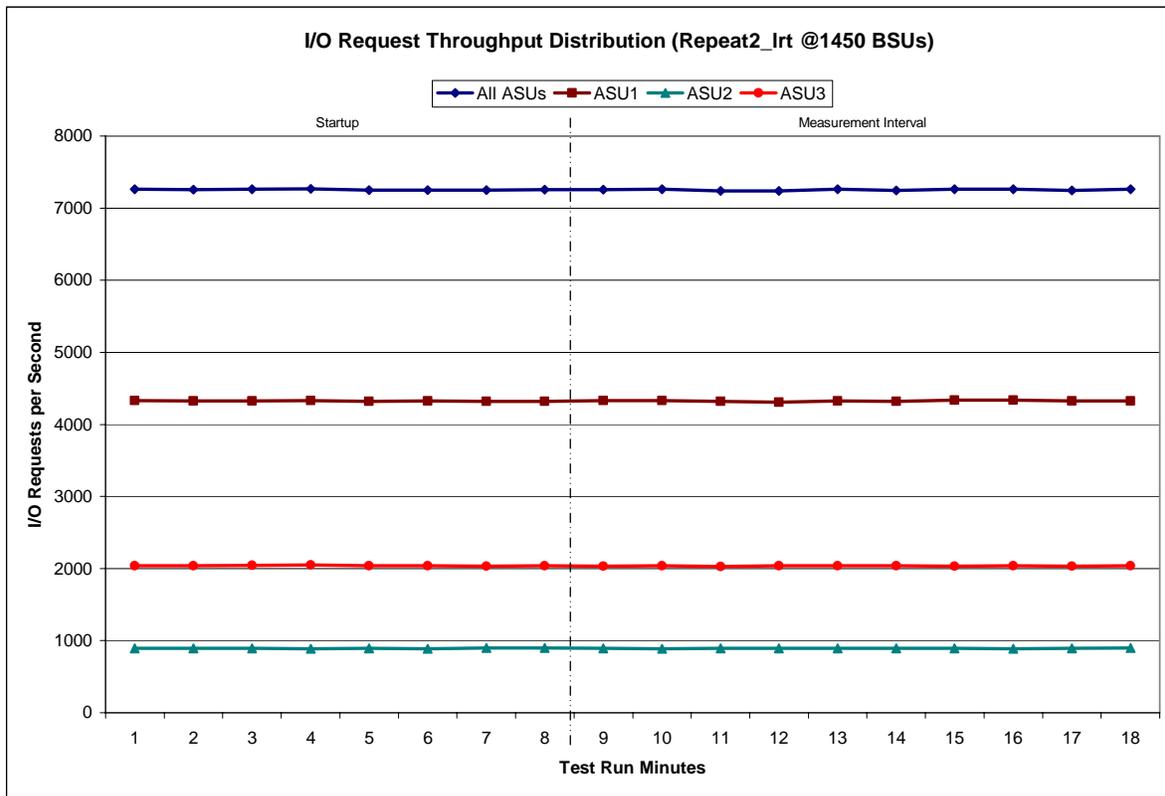
Repeatability 2 LRT –Average Response Time (ms) Distribution Data

| 1,450 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:05:06	14:13:06	0-7	0:08:00
Measurement Interval	14:13:06	14:23:06	8-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.46	0.50	0.48	0.38
1	0.45	0.48	0.47	0.37
2	0.53	0.57	0.56	0.45
3	0.44	0.48	0.46	0.36
4	0.46	0.49	0.50	0.38
5	0.50	0.53	0.53	0.41
6	0.48	0.51	0.51	0.41
7	0.44	0.47	0.45	0.37
8	0.46	0.50	0.48	0.39
9	0.50	0.54	0.53	0.42
10	0.46	0.49	0.48	0.38
11	0.45	0.48	0.48	0.38
12	0.46	0.49	0.49	0.38
13	0.51	0.54	0.52	0.43
14	0.44	0.47	0.47	0.36
15	0.46	0.50	0.49	0.37
16	0.49	0.52	0.51	0.41
17	0.49	0.52	0.51	0.42
Average	*0.47*	*0.50*	*0.50*	*0.39*

Repeatability 2 LRT –Average Response Time (ms) Distribution Graph
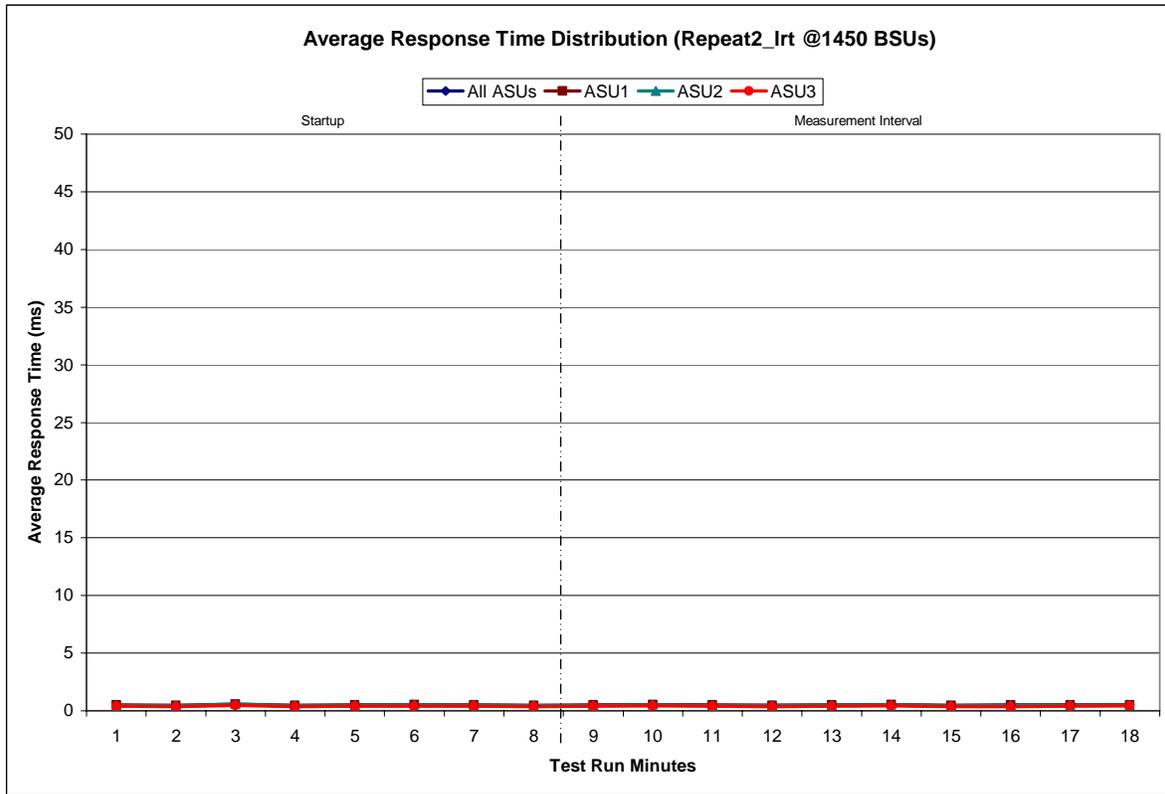
Repeatability 2 IOPS – I/O Request Throughput Distribution Data

| 14,500 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:23:32	14:31:33	0-7	0:08:01
Measurement Interval	14:31:33	14:41:33	8-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	69,526.12	41,438.98	8,567.12	19,520.02
1	75,506.57	45,013.47	9,289.23	21,203.87
2	72,454.18	43,169.23	8,921.53	20,363.42
3	72,502.67	43,231.40	8,914.73	20,356.53
4	72,583.50	43,263.77	8,933.30	20,386.43
5	72,514.47	43,235.37	8,914.80	20,364.30
6	72,531.82	43,214.20	8,922.13	20,395.48
7	72,515.77	43,222.85	8,908.02	20,384.90
8	72,478.47	43,203.33	8,912.40	20,362.73
9	72,466.53	43,184.25	8,901.60	20,380.68
10	72,518.62	43,215.78	8,923.97	20,378.87
11	72,433.93	43,154.53	8,912.37	20,367.03
12	72,501.07	43,224.92	8,896.80	20,379.35
13	72,442.38	43,191.02	8,919.85	20,331.52
14	72,513.32	43,224.82	8,917.48	20,371.02
15	72,493.58	43,225.20	8,910.77	20,357.62
16	72,427.98	43,153.73	8,908.62	20,365.63
17	72,480.68	43,189.33	8,903.83	20,387.52
Average	*72,475.66*	*43,196.69*	*8,910.77*	*20,368.20*

Repeatability 2 IOPS – I/O Request Throughput Distribution Graph
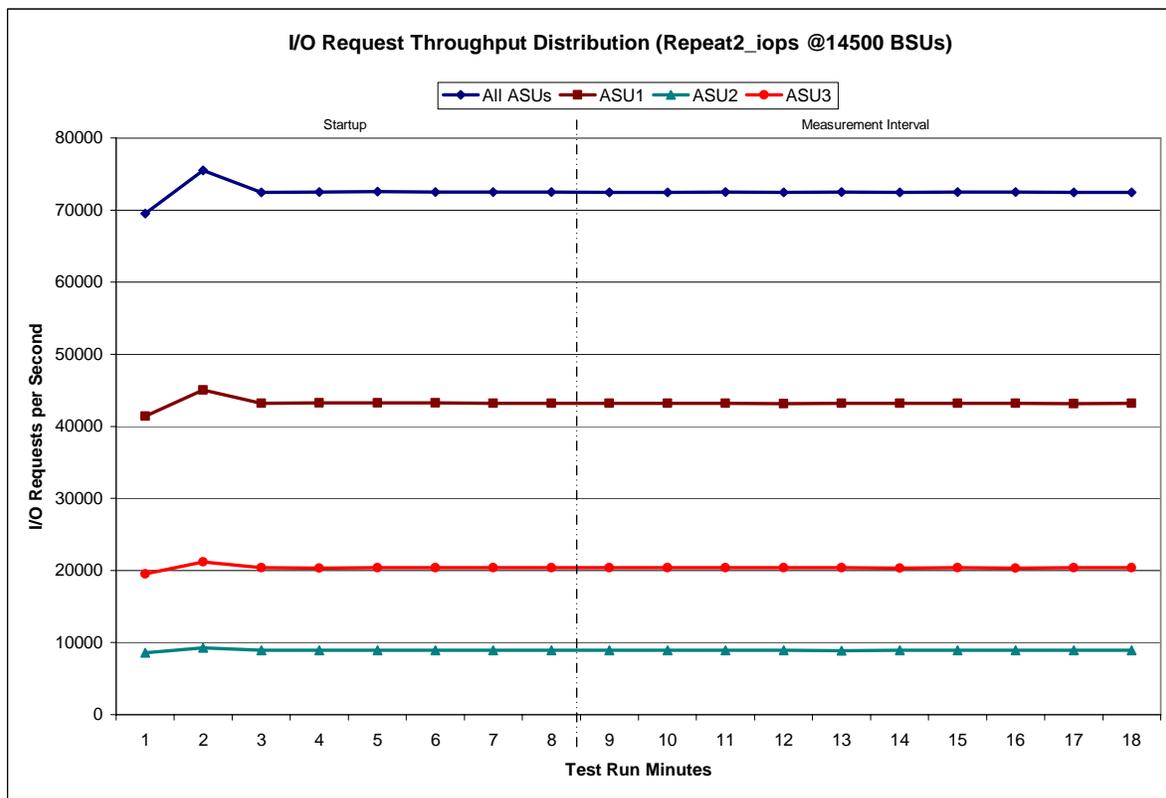
Repeatability 2 IOPS –Average Response Time (ms) Distribution Data

14,500 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:23:32	14:31:33	0-7	0:08:01
Measurement Interval	14:31:33	14:41:33	8-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	41.57	41.83	41.11	41.22
1	29.11	29.20	28.81	29.04
2	12.15	12.19	12.05	12.11
3	10.92	10.94	10.91	10.87
4	9.27	9.27	9.21	9.29
5	9.69	9.72	9.65	9.64
6	9.99	10.01	9.96	9.97
7	10.32	10.34	10.24	10.33
8	10.33	10.36	10.24	10.32
9	9.42	9.42	9.39	9.41
10	9.80	9.80	9.74	9.81
11	10.16	10.17	10.09	10.19
12	13.49	13.53	13.35	13.46
13	25.21	25.31	24.77	25.18
14	19.27	19.33	18.88	19.32
15	16.03	16.10	15.75	16.00
16	11.82	11.86	11.69	11.79
17	10.91	10.94	10.81	10.91
Average	*13.64*	*13.68*	*13.47*	*13.64*

Repeatability 2 IOPS –Average Response Time (ms) Distribution Graph
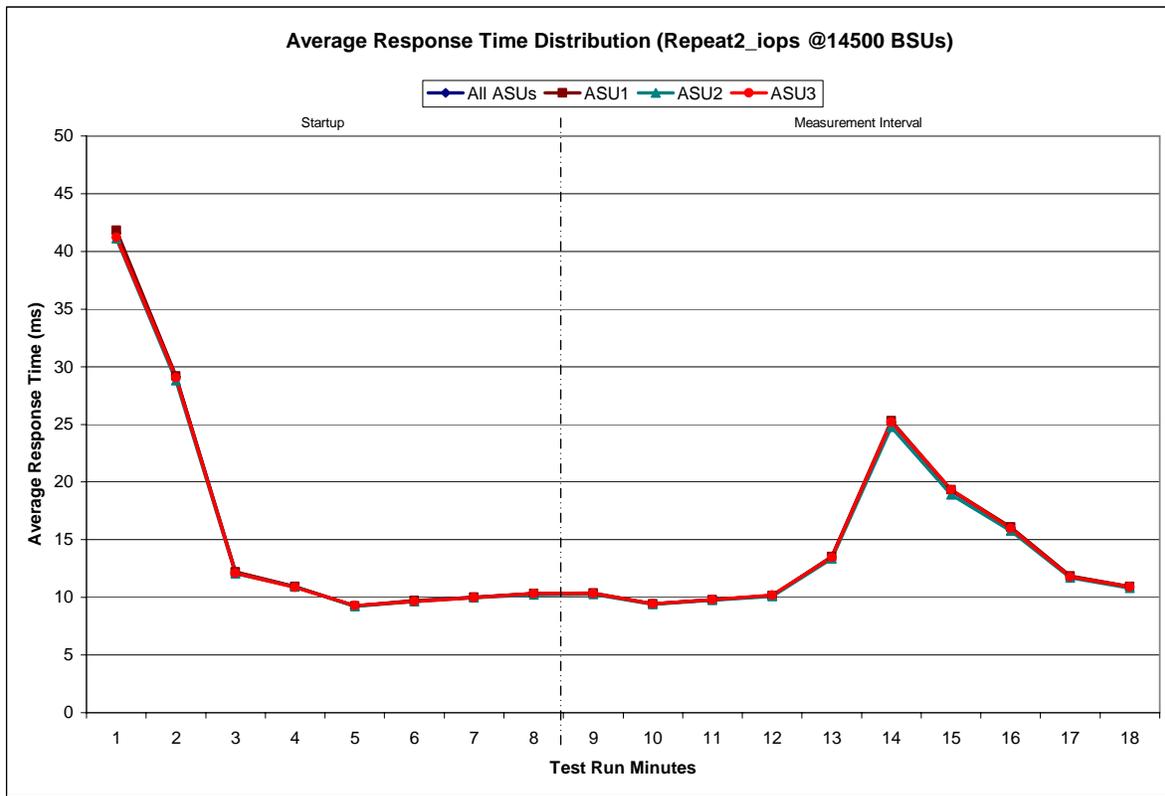
Repeatability 1 (LRT)
Measured Intensity Multiplier and Coefficient of Variation

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 6.1.0

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)._

Clause 6.3.13.3

COV – Coefficient of Variation: _This measure of variation for the Measured Intensity Multiplier cannot exceed 0.5._

	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	0.0349	0.2811	0.0700	0.2100	0.0180	0.0700	0.0349	0.2812
COV	0.010	0.003	0.004	0.003	0.017	0.005	0.008	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
_IM_	_0.0350_	_0.2810_	_0.0700_	_0.2100_	_0.0180_	_0.0700_	_0.0350_	_0.2810_
MIM	0.0350	0.2811	0.0700	0.2101	0.0180	0.0700	0.0350	0.2808
COV	0.002	0.001	0.001	0.001	0.003	0.003	0.002	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
_IM_	_0.0350_	_0.2810_	_0.0700_	_0.2100_	_0.0180_	_0.0700_	_0.0350_	_0.2810_
MIM	0.0351	0.2810	0.0700	0.2103	0.0179	0.0701	0.0350	0.2807
COV	0.009	0.003	0.006	0.002	0.012	0.006	0.006	0.002

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0350	0.2812	0.0700	0.2099	0.0180	0.0700	0.0350	0.2810
COV	0.002	0.001	0.001	0.001	0.004	0.002	0.001	0.001

Data Persistence Test

Clause 7

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

Clause 10.4.8.5

The FDR shall contain the following for the Data Persistence Test:

1. _A listing of the SPC-1C Workload Generator commands and parameters used to execute each of the Test Runs in the Persistence Test._
2. _The human readable SPC-1C Test Results File for each of the Test Runs in the Data Persistence Test._
3. _A table from the successful Persistence Test, which contains the results from the test._

SPC-1C Workload Generator Input Parameters

The SPC-1C Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1C Workload Generator Input Parameters" on Page 63.

Data Persistence Test Results File

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

Persistence 1 Test Results File
Persistence 2 Test Results File

Data Persistence Test Results

Data Persistence Test Results	
Data Persistence Test Run Number: 1	
Total Number of Logical Blocks Written	173, 990,896
Total Number of Logical Blocks Verified	17,993,616
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 10.4.9

The committed delivery date 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. All availability dates, whether for individual components or for the Priced Storage Configuration as a whole, must be disclosed to a precision of one day.

The Availability Date shall be stated in the FDR by either a combination of specific alphanumeric month, numeric day, and numeric year or as "Currently Available" in the case where all components that comprise the Priced Storage Configuration   are currently available for customer order and shipment.

The Sun Flash Accelerator F20 PCIe Card as documented in this Full Disclosure Report is currently available for customer purchase and shipment.

ANOMALIES OR IRREGULARITIES

Clause 10.4.10

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

There were no anomalies or irregularities encountered during the SPC-1C Onsite Audit of the Sun Flash Accelerator F20 PCIe Card.

APPENDIX A: SPC-1C GLOSSARY

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

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

- A kilobyte (KB) is equal to 1,000 (10^3) bytes.
- A megabyte (MB) is equal to 1,000,000 (10^6) bytes.
- A gigabyte (GB) is equal to 1,000,000,000 (10^9) bytes.
- A terabyte (TB) is equal to 1,000,000,000,000 (10^{12}) bytes.
- A petabyte (PB) is equal to 1,000,000,000,000,000 (10^{15}) bytes
- An exabyte (EB) is equal to 1,000,000,000,000,000,000 (10^{18}) bytes

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

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

- A kibibyte (KiB) is equal to 1,024 (2^{10}) bytes.
- A mebibyte (MiB) is equal to 1,048,576 (2^{20}) bytes.
- A gigibyte (GiB) is equal to 1,073,741,824 (2^{30}) bytes.
- A tebibyte (TiB) is equal to 1,099,511,627,776 (2^{40}) bytes.
- A pebibyte (PiB) is equal to 1,125,899,906,842,624 (2^{50}) bytes.
- An exbibyte (EiB) is equal to 1,152,921,504,606,846,967 (2^{60}) bytes.

SPC-1C Data Repository Definitions

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

Application Storage Unit (ASU): The logical interface between the storage and SPC-1C 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-1C 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-1C 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-1C Data Protection Levels

Protected: Data protection in the event of a single point of failure of any of the configured storage devices.

Unprotected: The Test Sponsor asserts no claim of data protection in the event of a single point of failure.

SPC-1C 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-1C 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-1C 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-1C test result or support an SPC-1C 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-1C for the purpose of producing or supporting an SPC-1C test result. SPC-1C 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-1C Test Run Components" below. All SPC-1C Test Runs shall have a Steady State period and a Measurement Interval.

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

I/O Completion Types
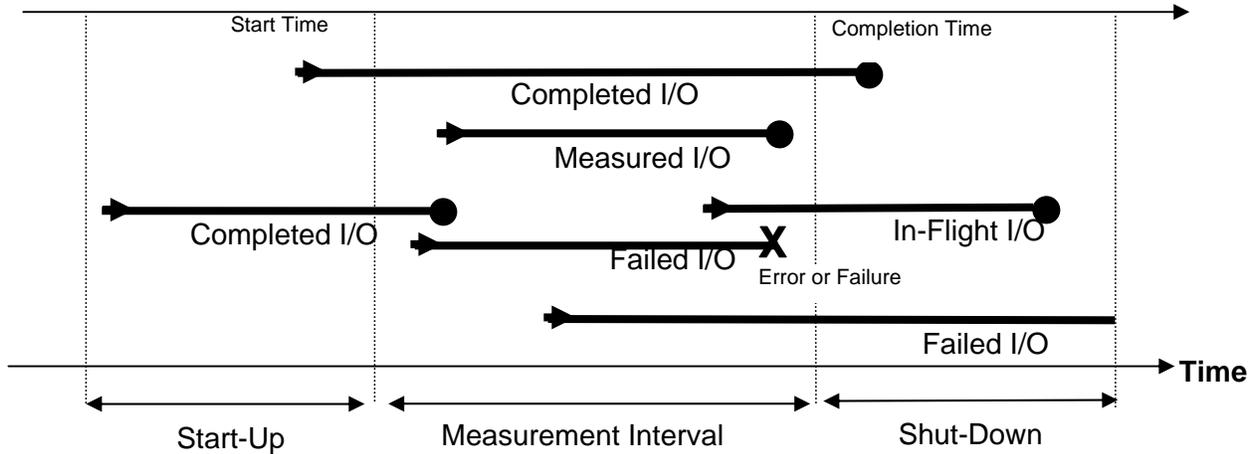
SPC-1C Test Run Components
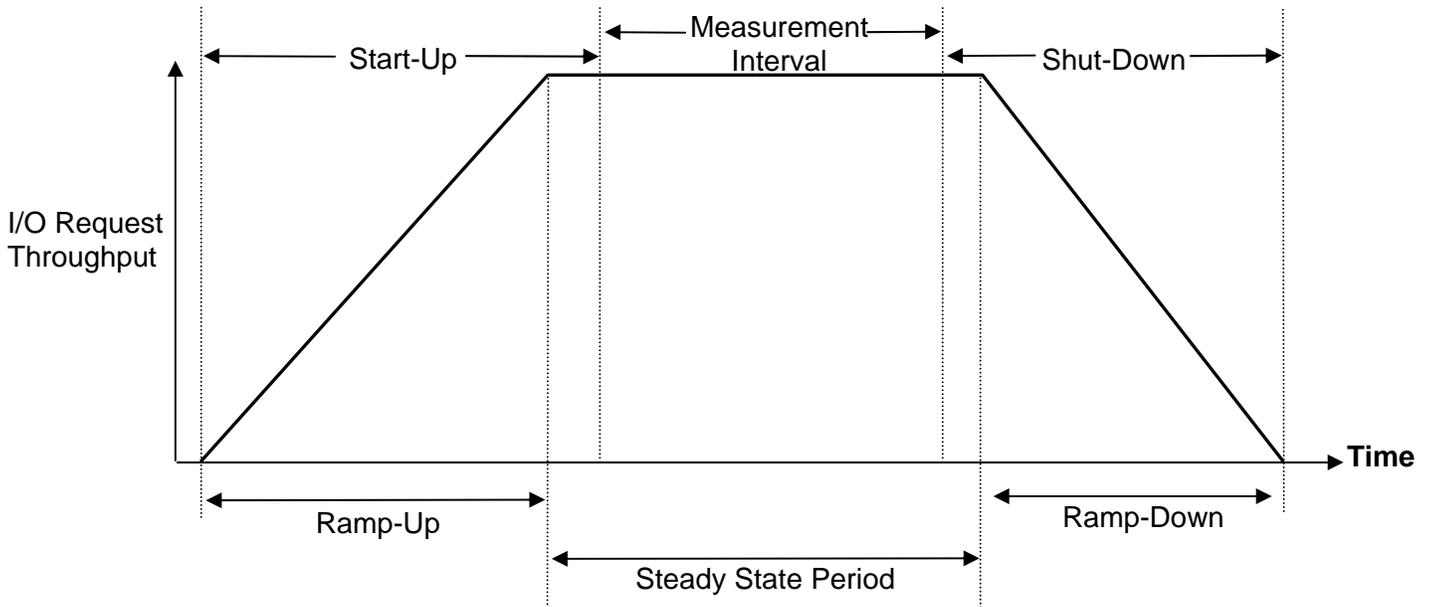
APPENDIX B: CUSTOMER TUNABLE PARAMETERS AND OPTIONS

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

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

The shell script, **config-Aura.sh**, is executed in a command window on the Host System to discover and configure the SPC-1 Logical Volumes. The script performs the following:

- Probes the TSC and adds labels to all of the Flash Modules.

- Creates "Pre-prtvtoc.txt" to document the physical storage capacity.

- Aligns the Flash Modules on a 4K boundry.

- . Creates the "md.tab" file, which is used to create all three ASUs.

- Creates the output file, "prtvtoc txt", which is used to document the logical volume capacity.

- Creates the output file, "disklist.txt", which is a listing of the twelve Flash modules and is used to create the "Pre-prtvtoc.txt", "prtvtoc txt", and "md.tab" files.

- Creates an unused LUN to account for the unused storage capacity.

config-Aura.sh

```
#!/bin/ksh
# work in progress
# script created for spc1 Aura 12-2-2009
# Added support for x86 hosts via EFI 4-23-2010
# mytest file created with fdisk -W mytest
/dev/rdsk/c4t6001blablablayakitismakityA000Cd0p0
# By Javier Chavez
#
set -x
#
clear
rm Pr* pr* di* md.tab
echo " "
echo " "
echo " Removing old Disk links and Meta devices"
echo " "
echo " "
sleep 2
metaclear -fa
#
echo " kill me now or wait 15 minutes ! "
sleep 3
#
## Probe server and remove all old device links
devfsadm -C
## Probe server and add new device links
devfsadm
echo " "
echo " "
##
##
touch disks
ls /dev/rdsk/c1t*d0s2 >> disks
ls /dev/rdsk/c2t*d0s2 >> disks
ls /dev/rdsk/c3t*d0s2 >> disks
echo " "
echo " Starting to Label all new disks"
```

```
sleep 2
cat disks | sed 's/s2\@/s2/g' > disk1
rm disks
#
# Create  prtvtoc.txt file
touch Pre-prtvtoc.txt
for x in `cat disk1`
do
prtvtoc $x >> Pre-prtvtoc.txt
done
## Running new fdisk geometry file first
cat disk1 | sed 's/s2/p0/g' > diskp0
C_disks=diskp0
###
for f in `cat $C_disks`
do
fdisk -F mytest $f
fdisk -F mytest -I $f
sleep 2
done

# Now we move on to create label on all disks
######
######
##
sleep 3
C_disks=disk1
#
for f in `cat $C_disks`
do
format $f << EOFF
y
ty
0
y
label
y
quit
EOFF
done
clear
echo " "
sleep 3
C_disks=disk1
#
for f in `cat $C_disks`
do
format $f << EOFF
y
ty
0
y
label
y
quit
EOFF
done
clear
echo " "
echo " "
echo " All `ls /dev/rdsk/c1t*d0s2 | wc -l ` disks have been configured"
sleep 5
echo " "
```

```
# Create a new disk list
cat disk1 | sed 's/s2/s6/g' > disk4
#
sleep 2
echo " "
echo " "
echo " Configuring asu device files"
sleep 2
# asu config files
# d31
echo " " > asu31
echo " " >> asu31
echo "d31 1 12 \\" >> asu31
cat disk4 >> asu31
echo "-i 1m" >>asu31
echo " " >> asu31
#
# Create md.tab file
cat asu* > m
#
#
rm asu*
# Clean up md.tab file
cat m | sed 's/d0s6/d0s6 \\/g' > md.tab
##
# Copy new md.tab file to /etc/lvm
mv /etc/lvm/md.tab /etc/lvm/save-md.tab-orig
cp md.tab /etc/lvm/md.tab
rm md*
rm m
#cp /etc/lvm/md.tab .

echo " New md.tab file has been created"
sleep 2
echo " Starting to create new metadevices."
# create metadevice
echo " "
metainit d31
#50%
metainit d3 -p d31 14395847k
metainit d1 -p d31 64781309k
metainit d2 -p d31 64781309k
metainit d4 -p d31 all
echo " "
## Display results
sleep 3
clear
metastat
sleep 3
#
# Create  prtvtoc.txt file
touch prtvtoc.txt
for x in `cat disk4`
do
prtvtoc $x >> prtvtoc.txt
done
prtvtoc /dev/md/rdsk/d31 >> prtvtoc.txt
prtvtoc /dev/md/rdsk/d1 >> prtvtoc.txt
prtvtoc /dev/md/rdsk/d2 >> prtvtoc.txt
prtvtoc /dev/md/rdsk/d3 >> prtvtoc.txt
prtvtoc /dev/md/rdsk/d4 >> prtvtoc.txt
#
```

```
clear
##
# Create List of disks for parameter files.
mv disk4 disklist.txt
rm disk?
```

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

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

```
#50%
sd=asu1_1,lun=/dev/md/rdsk/d1,size=66336060416
sd=asu2_1,lun=/dev/md/rdsk/d2,size=66336060416
sd=asu3_1,lun=/dev/md/rdsk/d3,size=14741347328
```

APPENDIX E: SPC-1C 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.**

```
#!/usr/bin/ksh
#
# Created by Javier Chavez
#  4270 M2  8-19-2010
#
script=runSpc1c-aura.sh
#
# Single CPU with 12 G of mem
#
output=Audit-run-1
basedir=/spc/output/spc-1c/aura/4270-M2/AUDIT
outdir=$basedir/$output
mkdir -p $outdir
# Comment this next line if running persist 2
cp $script $outdir
# Uncomment this next line if running persist 2
#cp $script $outdir/$script-P2
#
# Send out email informing myslf benchmark has started
#mailx -s $script-Started -r Javier.Chavez@sun.com Javier.Chavez@sun.com < $script
#
## Create config files and the prtvtoc
clear
#echo " we are going to create the metadevices then run the benchmark "
#cd config-aura ;./config*.sh ; cd
#sleep 30
#
hostdir=$outdir/HostP1
# Uncomment this next line if running persist 2
#hostdir=$outdir/HostP2
mkdir -p $hostdir
#cp /etc/system $hostdir
#cp /kernel/drv/sd.conf $hostdir
#cp /kernel/drv/ssd.conf $hostdir
#cp /kernel/drv/mpt.conf $hostdir
cp spc1c.cfg $hostdir
cp /etc/lvm/md.tab $hostdir
# get a metastat from the hosts
touch $hostdir/metastat-output.txt
metastat >> $hostdir/metastat-output.txt
## Now copy config script and all config files to the output directory
cp -r config-aura $hostdir/
#
touch $outdir/link ; echo " " >> $outdir/link
echo "  Use the link below to Monitor the current run" >> $outdir/link
echo " " >> $outdir/link
echo http://sbm-240a.central.sun.com/export/spc/spc1c/metrics >> $outdir/link
echo " " >> $outdir/link
echo "  Use the link below to Monitor the archive " >> $outdir/link
echo " " >> $outdir/link
echo http://sbm-240a.central.sun.com/export/$outdir >> $outdir/link
```

```
echo " " >> $outdir/link
echo "  The script Below is currently running .. " >> $outdir/link
echo " " >> $outdir/link
head -114  $script >> $outdir/link
mailx -r Javier.Chavez@oracle.com -s $script--Started Javier.Chavez@oracle.com,
steven.a.johnson@oracle.com < $outdir/link
rm $outdir/link
#
bsu=14500
STEP=100
startup=480
while [[ $bsu -le 14500 ]]
do
Outdir=$outdir/${bsu}
mkdir -p $Outdir
cp spc1c.cfg $Outdir
cp /etc/lvm/md.tab $Outdir
#echo "Metrics will start in 10 seconds"
sleep 2
##
java -Xmx1024m -Xss128k -Xms128m metrics -b $bsu -s $startup
sleep 30
mv metrics $Outdir
sleep 30
######### run iostat
###touch $Outdir/iostat-data.txt
###iostat -xnczT d 5 >> $Outdir/iostat-data.txt &
####touch $Outdir/mpstat-data.txt
####mpstat 2 >> $Outdir/mpstat-data.txt &
java -Xmx1024m -Xss512k -Xms256m repeat1 -b $bsu -s $startup
sleep 30
java -Xmx1024m -Xss128k -Xms128m repeat2 -b $bsu -s $startup
sleep 30
java -Xmx1024m -Xss128k -Xms128m persist1 -b $bsu
sleep 30
#java -Xmx1024m -Xss128k -Xms128m persist2
#sleep 30
#mv repeatability1 $Outdir
#mv repeatability2 $Outdir
#mv persistence1 $Outdir
#mv persistence2 $Outdir
#mv asu* $Outdir
#mv SPCOut $Outdir
#pkill iostat
##pkill mpstat
#
#
cd $basedir ;/bin/chmod -R 777 $output ;/usr/bin/zip -r $output.zip $output
#cd $basedir ;/bin/chmod -R 777 $output ;mv $output.zip $output.zip-P1 ;/usr/bin/zip
-r $output.zip $output
touch $basedir/link ; echo " " >> $basedir/link
echo "  Use the link below to download the zipped file" >> $basedir/link
echo " " >> $basedir/link
echo http://sbm-240a.central.sun.com/export/$basedir/$output.zip >> $basedir/link
echo " " >> $basedir/link
echo "  Use the link below to take a look at the output files" >> $basedir/link
echo " " >> $basedir/link
echo http://sbm-240a.central.sun.com/export/$basedir >> $basedir/link
mailx -s $script-is-finished Javier.Chavez@oracle.com, steven.a.johnson@oracle.com <
$basedir/link
rm $basedir/link ; cd

bsu=`expr $bsu + $STEP`
```

```
echo "All done .... sleeping for 5 minutes"
sleep 3
done
halt
```

Persistence Test Run 2

The following script was used to execute Persistence Test Run 2 after the above execution sequence and the required power-off cycle, which followed successful completion of Persistence Test Run 1.

```
#!/usr/bin/ksh
#
# Created by Javier Chavez
#  4270 M2  8-19-2010
#
script=runSpc1c-aura.sh
#
# Single CPU with 12 G of mem
#
output=Audit-run-1
basedir=/spc/output/spc-1c/aura/4270-M2/AUDIT
outdir=$basedir/$output
mkdir -p $outdir
# Comment this next line if running persist 2
#cp $script $outdir
# Uncomment this next line if running persist 2
cp $script $outdir/$script-P2
#
# Send out email informing myslf benchmark has started
#mailx -s $script-Started -r Javier.Chavez@sun.com Javier.Chavez@sun.com < $script
#
## Create config files and the prtvtoc
clear
#echo " we are going to create the metadevices then run the benchmark "
#cd config-aura ;./config*.sh ; cd
#sleep 30
#
#hostdir=$outdir/HostP1
# Uncomment this next line if running persist 2
hostdir=$outdir/HostP2
mkdir -p $hostdir
#cp /etc/system $hostdir
#cp /kernel/drv/sd.conf $hostdir
#cp /kernel/drv/ssd.conf $hostdir
#cp /kernel/drv/mpt.conf $hostdir
cp spc1c.cfg $hostdir
cp /etc/lvm/md.tab $hostdir
# get a metastat from the hosts
touch $hostdir/metastat-output.txt
metastat >> $hostdir/metastat-output.txt
## Now copy config script and all config files to the output directory
cp -r config-aura $hostdir/
#
touch $outdir/link ; echo " " >> $outdir/link
echo "  Use the link below to Monitor the current run" >> $outdir/link
echo " " >> $outdir/link
echo http://sbm-240a.central.sun.com/export/spc/spc1c/metrics >> $outdir/link
echo " " >> $outdir/link
echo "  Use the link below to Monitor the archive " >> $outdir/link
echo " " >> $outdir/link
```

```
echo http://sbm-240a.central.sun.com/export/$outdir >> $outdir/link
echo " " >> $outdir/link
echo "  The script Below is currently running .. " >> $outdir/link
echo " " >> $outdir/link
head -114  $script >> $outdir/link
mailx -r Javier.Chavez@oracle.com -s $script--Started Javier.Chavez@oracle.com,
steven.a.johnson@oracle.com < $outdir/link
rm $outdir/link
#
bsu=14500
STEP=100
startup=480
while [[ $bsu -le 14500 ]]
do
Outdir=$outdir/${bsu}
mkdir -p $Outdir
cp spc1c.cfg $Outdir
cp /etc/lvm/md.tab $Outdir
#echo "Metrics will start in 10 seconds"
sleep 2
##
#java -Xmx1024m -Xss128k -Xms128m metrics -b $bsu -s $startup
#sleep 30
#mv metrics $Outdir
#sleep 30
######### run iostat
###touch $Outdir/iostat-data.txt
###iostat -xnczT d 5 >> $Outdir/iostat-data.txt &
####touch $Outdir/mpstat-data.txt
####mpstat 2 >> $Outdir/mpstat-data.txt &
#java -Xmx1024m -Xss512k -Xms256m repeat1 -b $bsu -s $startup
#sleep 30
#java -Xmx1024m -Xss128k -Xms128m repeat2 -b $bsu -s $startup
#sleep 30
#java -Xmx1024m -Xss128k -Xms128m persist1 -b $bsu
#sleep 30
java -Xmx1024m -Xss128k -Xms128m persist2
sleep 30
mv repeatability1 $Outdir
mv repeatability2 $Outdir
mv persistence1 $Outdir
mv persistence2 $Outdir
mv asu* $Outdir
mv SPCOut $Outdir
#pkill iostat
##pkill mpstat
#
#
#cd $basedir ;/bin/chmod -R 777 $output ;/usr/bin/zip -r $output.zip $output
cd $basedir ;/bin/chmod -R 777 $output ;mv $output.zip $output.zip-P1 ;/usr/bin/zip
-r $output.zip $output
touch $basedir/link ; echo " " >> $basedir/link
echo "  Use the link below to download the zipped file" >> $basedir/link
echo " " >> $basedir/link
echo http://sbm-240a.central.sun.com/export/$basedir/$output.zip >> $basedir/link
echo " " >> $basedir/link
echo "  Use the link below to take a look at the output files" >> $basedir/link
echo " " >> $basedir/link
echo http://sbm-240a.central.sun.com/export/$basedir >> $basedir/link
mailx -s $script-is-finished Javier.Chavez@oracle.com, steven.a.johnson@oracle.com <
$basedir/link
rm $basedir/link ; cd
```

```
bsu=`expr $bsu + $STEP`
echo "All done .... sleeping for 5 minutes"
sleep 3
done
#halt
```