SPC BENCHMARK 1™
FULL DISCLOSURE REPORT

IBM CORPORATION
IBM SYSTEM STORAGE
DS4700 EXPRESS MODEL

SPC-1 V1.10

Submitted for Review: August 21, 2006
Submission Identifier: A00046
Accepted: October 20, 2006
Revised: June 27, 2007

First Edition – August 2006

Trademarks

Table of Contents

AUDIT CERTIFICATION

Bruce McNutt
IBM Corporation
KBV/9062-2
9000 South Rita Road
Tucson, AZ 85744

August 21, 2006

The SPC Benchmark 1™ results listed below for the IBM System Storage DS4700 Express Model were produced in compliance with the SPC Benchmark 1™ V1.10 Remote Audit requirements.

SPC Benchmark 1™ V1.10 Results	
Tested Storage Configuration (TSC) Name: IBM System Storage DS4700 Express Model	
Metric	**Reported Result**
SPC-1 IOPS™	17,195.84
SPC-1 Price-Performance	$13.23/SPC-1 IOPS™
Total ASU Capacity	1,963.270 GB
Data Protection Level	Mirroring
Total TSC Price (including three-year maintenance)	$227,546

The following SPC Benchmark 1™ Remote Audit requirements were reviewed and found compliant with V1.10 of the SPC Benchmark 1™ specification:

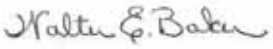
- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository storage items were verified using information supplied by IBM Corporation:
  - ✓ Physical Storage Capacity and requirements.
  - ✓ Configured Storage Capacity and requirements.
  - ✓ Addressable Storage Capacity and 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).

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

AUDIT CERTIFICATION *(CONT.)*

- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters.
- Commands and parameters used to configure the SPC-1 Workload Generator.
- The following Host System requirements were reviewed using documentation supplied by IBM Corporation:
  - ✓ The type of Host System including the number of processors and main memory.
  - ✓ The presence and version number of the Workload Generator on the Host System.
  - ✓ The TSC boundary within the Host System.
- The Test Results Files and resultant Summary Results Files received from IBM Corporation 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 final version of the pricing spreadsheet 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.

Respectfully,



Walter E. Baker
SPC Auditor

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

LETTER OF GOOD FAITH

IBM

Vice President & BLE, Disk Storage

IBM Technology & Systems Group
5600 Cottle Road, San Jose, California 95193

Phone 408-256-7405
Fax: 408-256-7420

August 10, 2005

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

Subject: SPC-1 Letter of Good Faith for the IBM System Storage DS4700 Express Model

IBM Corporation 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 Version 1.10 of the SPC-1 benchmark specification.

Our disclosure of the Benchmark configuration and execution of the benchmark includes all items that, to the best of our knowledge and belief, materially affect the reported results, regardless of whether such items are explicitly required to be disclosed by the SPC-1 benchmark specification.

Sincerely,

Barry Rudolph

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact	IBM Corporation – http://www.ibm.com Peter Leung – leungp@us.ibm.com 65S/9062-2 9000 South Rita Road Tucson, AZ 85744 Phone: (520) 799-2853 FAX: (520) 799-5530
Test Sponsor Alternate Contact	IBM Corporation – http://www.ibm.com Bruce McNutt – bmcnutt@us.ibm.com KBV/9062-2 9000 South Rita Road Tucson, AZ 85744 Phone: (520) 799-2460 FAX: (520) 799-5530
Auditor	Storage Performance Council – http://www.StoragePerformance.org Walter E. Baker – AuditService@StoragePerformance.org 643 Bair Island Road, Suite 103 Redwood City, CA 94063 Phone: (650) 556-9384 FAX: (650) 556-9385

Revision Information and Key Dates

Revision Information and Key Dates	
SPC-1 Specification revision number	V1.10
SPC-1 Workload Generator revision number	V2.00.04a
Date Results were first used publicly	August 21, 2006
Date the FDR was submitted to the SPC	August 21, 2006
Date revised FDR was submitted to the SPC Revised pricing and SPC-1 Price-Performance	June 27, 2007
Date the TSC is available for shipment to customers	currently available
Date the TSC completed audit certification	August 21, 2006

Summary of Results

SPC-1 Results	
Tested Storage Configuration (TSC) Name: IBM System Storage DS4700 Express Model	
Metric	**Reported Result**
SPC-1 IOPS™	17,195.84
SPC-1 Price-Performance	$11.67/SPC-1 IOPS™
Total ASU Capacity	1,963.270 GB
Data Protection Level	Mirroring
Total TSC Price (including three-year maintenance)	$200,666

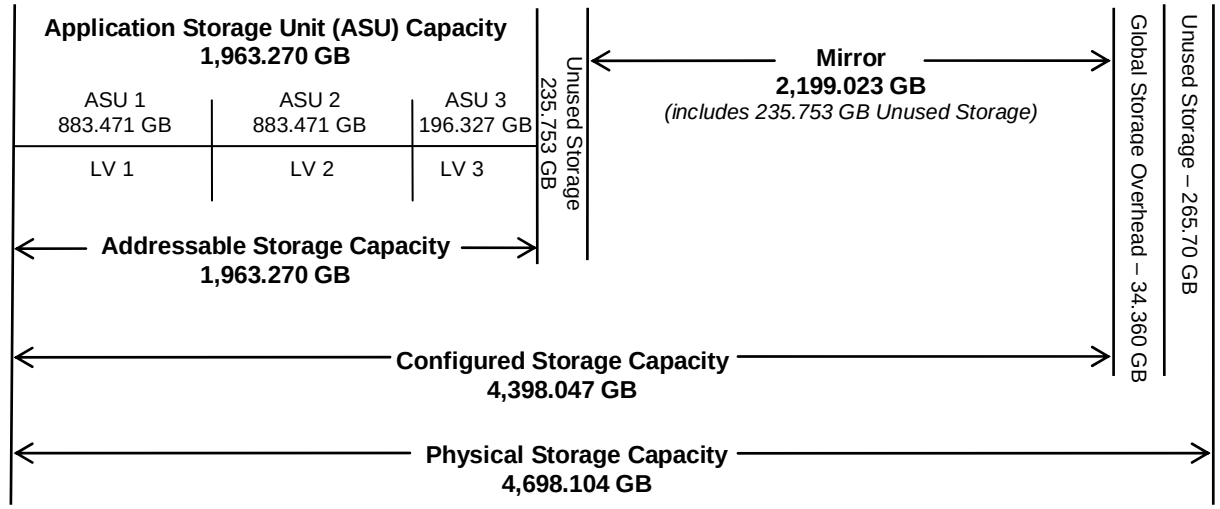
SPC-1 IOPS™ represents the maximum I/O Request Throughput at the 100% load point.

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 Mirroring configures two or more identical copies of user data.

Storage Capacities and Relationships

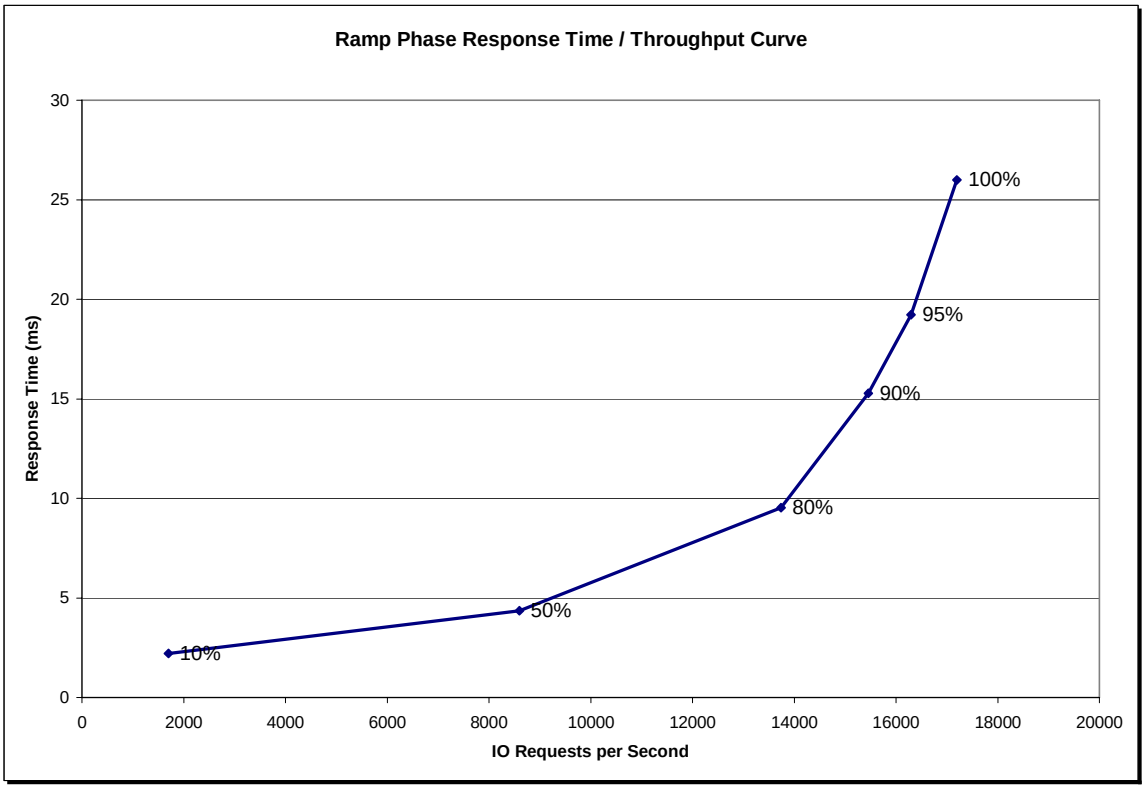
The following diagram documents the various storage capacities, used in this benchmark, and their relationships.



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
I/O Request Throughput	1,699.56	8,598.17	13,742.20	15,457.48	16,293.51	17,195.84
Average Response Time (ms):						
All ASUs	2.20	4.35	9.54	15.27	19.22	26.00
ASU-1	2.71	5.30	10.43	15.59	19.07	25.30
ASU-2	3.31	6.57	14.93	22.72	27.89	36.34
ASU-3	0.62	1.34	5.29	11.34	15.74	22.95
Reads	4.70	9.06	16.34	21.95	25.50	32.26
Writes	0.57	1.27	5.11	10.93	15.13	21.92

Tested Storage Configuration Pricing *(Priced Storage Configuration)*

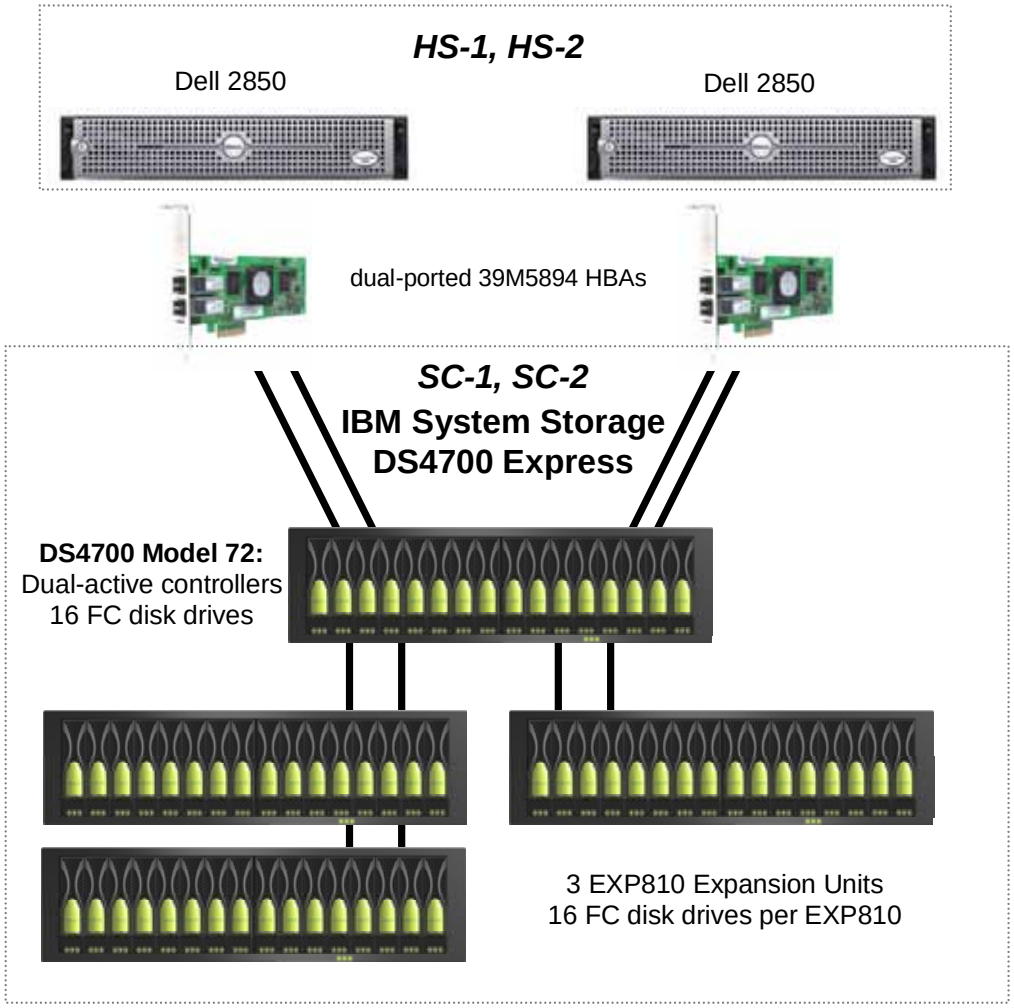
Product	Quantity	List Price each	extended list price
DS4700 Model 72 with: 8 storage partitions Windows Host Kit	1	$44,250	$44,250
DS4000 EXP810 Expansion Unit	3	$6,000	$18,000
Dual ported 39M5894 HBAs	2	$2,485	$4,970
73 GB x15K RPM disk drives	64	$1,679	$107,456
1m Fiber Optic Cable LC-LC	10	$79	$790
annual 24x7x4hr upgrade	3	$8,400	$25,200
TOTAL			**$200,666**

Maintenance/support is provided 24 hours per day, 7 days per week for three years with four hour acknowledgement and four hour subsequent response (support engineer onsite or customer replaceable part available).

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

Each disk drive in the Priced Storage Configuration is mounted in an IBM drive carrier and configured to self-identify as a DS4000 brand.

Benchmark Configuration/Tested Storage Configuration Diagram



Host System:	Tested Storage Configuration (TSC):
UID=HS-1, HS-2	2 – 39M5894 HBAs *(1 per Host System)*
2 – Dell 2850 Servers each server configured with:	***UID=SC-1, SC-2:*** **IBM System Storage DS4700 Express Model**
2 – 3.6 GHz Pentium 4 Xeon CPUs 2 MB L2 cache per CPU	Dual active RAID Controller 2 GB RAM per controller
3 GB main memory	8 – 4Gb Fibre Channel host connections *(4 used)*
Windows 2003 Enterprise Edition SP1	4 – 4Gb Fibre Channel drive connections
PCI-X	3 – DS4000 EXP810 Expansion Units
WG	64 – 73 GB 15K RPM disk drives

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 14 *(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) was configured with local storage and, as such, did not employ a storage network.

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 14 *(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 59 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 61 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 66.

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 55 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)	1,963.270
Addressable Storage Capacity	Gigabytes (GB)	1,963.270
Configured Storage Capacity	Gigabytes (GB)	4,398.047
Physical Storage Capacity	Gigabytes (GB)	4,698.104
Data Protection (Mirroring)	Gigabytes (GB)	2,199.023
Required Storage	Gigabytes (GB)	0.000
Global Storage Overhead	Gigabytes (GB)	34.360
Total Unused Storage	Gigabytes (GB)	737.204

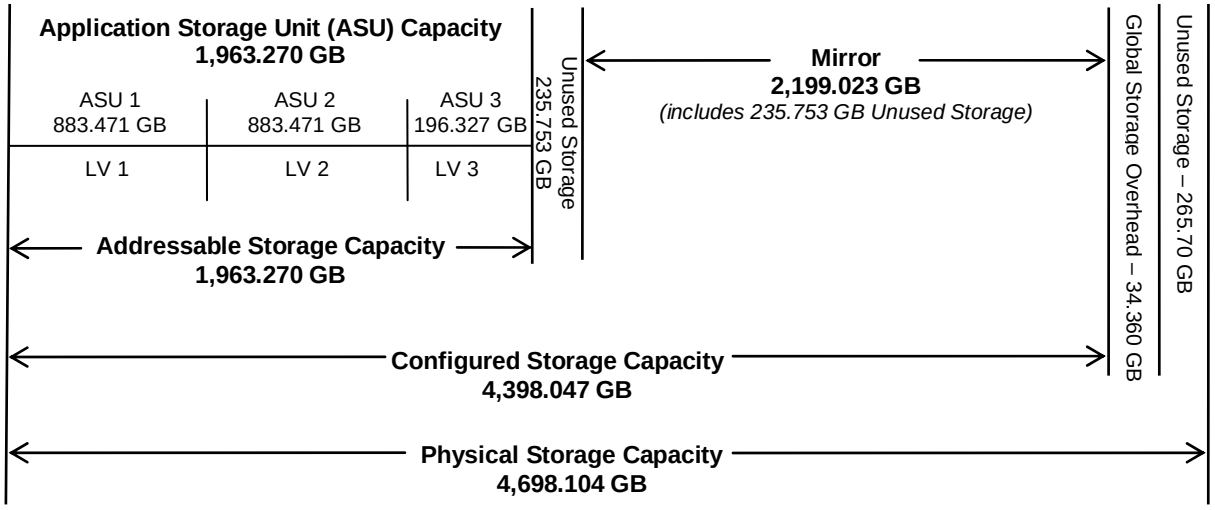
SPC-1 Storage Hierarchy Ratios

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	44.64%	41.71%
Required for Data Protection (Mirroring)		50.00%	46.81%
Addressable Storage Capacity		44.64%	41.79%
Required Storage		0.00%	0.00%
Configured Storage Capacity			93.61%
Global Storage Overhead			0.73%
Unused Storage:			
Addressable	0.00%		
Configured		10.72%	
Physical			5.66%

The Physical Storage Capacity consisted of 4,698.104 GB distributed over 64 disk drives each with a formatted capacity of 73.408 GB. There was 265.697 GB (5.66%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 34.360 GB (0.73%) of Physical Storage Capacity. There was 471.507 GB (10.72%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 100 % of the Addressable Storage Capacity resulting in 0.000 GB (0.00%) of Unused Storage within the Addressable Storage Capacity.

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 (883.471 GB)	**ASU-2 (883.471 GB)**	**ASU-3 (196.327 GB)**
1 Logical Volume 883.471 GB per Logical Volume (883.471 GB used per Logical Volume)	1 Logical Volume 883.471 GB per Logical Volume (883.471 GB used per Logical Volume)	1 Logical Volume 196.327 GB per Logical Volume (196.327 GB used per Logical Volume)

The Data Protection Level used for all Logical Volumes was Mirroring as described on page 11. 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 56 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 Primary Metrics Test, which consists of the Sustainability, IOPS, and Response Time Ramp Test Runs, are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 69.

Sustainability Test Results File

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

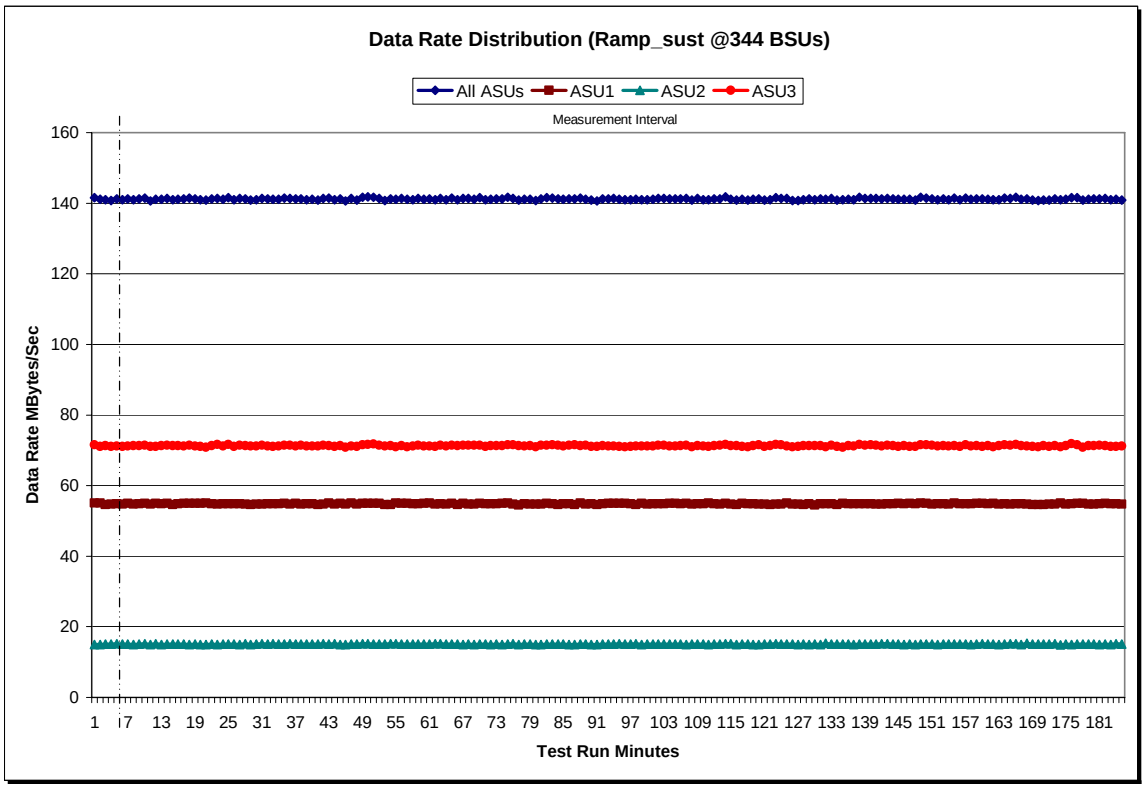
Sustainability Test Results File

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

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	13:06:43	13:11:43	0-4	0:05:00
Measurement Interval	13:11:43	16:11:43	5-184	3:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	141.56	55.01	14.96	71.59	63	141.02	54.75	15.07	71.20	126	140.73	54.67	15.01	71.06
1	141.13	55.04	14.99	71.10	64	141.46	54.96	15.05	71.45	127	141.01	54.62	15.05	71.33
2	141.03	54.64	15.13	71.26	65	141.02	54.64	15.05	71.32	128	141.17	54.89	15.01	71.27
3	140.76	54.67	15.06	71.03	66	141.32	54.91	14.94	71.47	129	140.98	54.54	15.12	71.31
4	141.23	54.82	15.19	71.22	67	141.29	54.75	15.09	71.45	130	141.21	54.82	15.02	71.36
5	140.96	54.73	15.13	71.11	68	141.16	54.73	14.98	71.45	131	141.09	54.79	15.32	70.99
6	141.25	54.95	15.14	71.17	69	141.54	54.97	15.12	71.46	132	141.30	54.78	15.13	71.39
7	141.05	54.73	15.01	71.31	70	141.03	54.78	15.13	71.12	133	140.88	54.64	15.14	71.10
8	141.23	54.79	15.12	71.32	71	141.13	54.84	15.00	71.29	134	140.96	55.00	15.06	70.90
9	141.45	54.90	15.16	71.40	72	141.27	54.84	15.14	71.29	135	141.13	54.78	15.09	71.26
10	140.64	54.66	14.95	71.04	73	141.25	54.99	14.99	71.26	136	141.02	54.81	15.01	71.20
11	141.14	54.91	15.19	71.04	74	141.64	55.01	15.08	71.56	137	141.65	54.83	15.14	71.68
12	141.10	54.82	15.03	71.26	75	141.39	54.72	15.19	71.48	138	141.39	54.87	15.12	71.39
13	141.34	54.91	15.05	71.38	76	140.86	54.51	15.01	71.34	139	141.36	54.78	15.10	71.48
14	141.02	54.62	15.08	71.33	77	141.08	54.81	15.06	71.21	140	141.31	54.74	15.14	71.42
15	141.16	54.86	15.05	71.25	78	141.11	54.70	15.06	71.35	141	141.20	54.77	15.20	71.24
16	141.22	54.91	15.14	71.17	79	140.74	54.74	14.99	71.01	142	141.35	54.78	15.16	71.41
17	141.40	54.98	14.96	71.46	80	141.21	54.75	15.01	71.45	143	141.25	54.82	15.11	71.31
18	141.22	54.94	15.08	71.21	81	141.52	54.99	15.07	71.46	144	141.13	54.90	15.12	71.11
19	140.99	54.99	14.93	71.07	82	141.43	54.85	15.04	71.54	145	141.13	54.80	15.00	71.32
20	140.88	55.06	15.03	70.79	83	141.22	54.65	15.10	71.46	146	141.14	54.93	15.12	71.08
21	141.24	54.81	15.14	71.28	84	141.12	54.79	15.14	71.18	147	140.87	54.81	14.97	71.08
22	141.34	54.68	14.99	71.67	85	141.28	54.84	15.03	71.40	148	141.69	55.09	15.08	71.52
23	141.13	54.80	15.11	71.22	86	141.17	54.64	14.96	71.57	149	141.48	54.89	15.06	71.53
24	141.57	54.77	15.13	71.67	87	141.42	55.01	15.10	71.31	150	141.25	54.71	15.09	71.44
25	140.98	54.86	15.04	71.08	88	141.16	54.72	15.06	71.39	151	141.05	54.87	14.98	71.20
26	141.31	54.85	15.03	71.43	89	140.87	54.82	15.00	71.05	152	141.27	54.86	15.07	71.33
27	141.27	54.77	15.22	71.28	90	140.65	54.56	15.03	71.05	153	140.96	54.69	15.07	71.20
28	140.82	54.55	15.03	71.24	91	141.25	54.84	15.10	71.31	154	141.42	55.00	15.10	71.31
29	140.98	54.77	15.03	71.18	92	141.22	54.93	15.10	71.19	155	140.95	54.78	15.10	71.06
30	141.40	54.75	15.18	71.47	93	141.34	55.00	15.12	71.21	156	141.45	54.82	15.14	71.49
31	141.21	54.89	15.15	71.18	94	141.11	54.90	15.17	71.04	157	141.07	54.82	15.01	71.23
32	141.08	54.82	15.19	71.07	95	140.98	54.89	15.10	70.99	158	141.27	54.92	15.04	71.32
33	141.08	54.82	15.11	71.15	96	140.99	54.86	15.07	71.07	159	141.19	54.89	15.19	71.11
34	141.40	54.93	15.04	71.43	97	141.07	54.64	15.19	71.24	160	141.08	54.79	15.04	71.25
35	141.29	54.71	15.22	71.36	98	141.04	54.89	14.94	71.21	161	140.97	54.95	15.05	70.97
36	141.22	54.97	15.08	71.17	99	140.96	54.67	15.08	71.21	162	141.01	54.70	15.01	71.30
37	141.26	54.76	15.13	71.38	100	141.06	54.82	15.07	71.16	163	141.47	54.88	15.06	71.53
38	141.04	54.78	15.12	71.14	101	141.37	54.84	15.12	71.42	164	141.28	54.75	15.15	71.38
39	141.11	54.86	15.06	71.19	102	141.35	54.86	15.11	71.38	165	141.69	54.84	15.17	71.68
40	140.83	54.58	15.09	71.16	103	141.19	54.93	15.07	71.19	166	141.09	54.85	14.99	71.25
41	141.37	54.74	15.21	71.41	104	141.22	54.92	15.06	71.24	167	141.26	54.75	15.33	71.18
42	141.47	55.04	15.08	71.35	105	141.23	54.81	15.09	71.33	168	140.82	54.65	15.11	71.06
43	140.96	54.71	15.16	71.09	106	141.37	54.99	15.02	71.37	169	140.71	54.61	15.09	71.01
44	141.24	54.96	14.93	71.35	107	140.86	54.73	15.12	71.01	170	140.93	54.57	15.07	71.29
45	140.63	54.74	15.03	70.86	108	141.31	54.85	15.14	71.32	171	140.88	54.74	15.10	71.04
46	141.36	55.02	15.10	71.24	109	141.04	54.79	15.08	71.17	172	141.18	54.73	15.17	71.27
47	140.86	54.71	15.12	71.03	110	141.05	55.02	14.96	71.06	173	140.95	55.04	14.92	70.99
48	141.68	54.96	15.16	71.56	111	141.22	54.82	15.14	71.26	174	141.11	54.72	15.14	71.25
49	141.77	54.95	15.16	71.66	112	141.23	54.68	15.12	71.42	175	141.60	54.80	14.97	71.83
50	141.72	54.93	15.03	71.76	113	141.75	54.95	15.18	71.62	176	141.55	54.97	15.07	71.51
51	141.30	54.89	15.04	71.37	114	141.16	54.68	15.17	71.31	177	140.92	54.90	15.13	70.90
52	140.82	54.58	15.08	71.16	115	140.90	54.60	14.97	71.32	178	141.15	54.76	15.13	71.27
53	141.20	54.65	15.22	71.33	116	141.10	54.95	15.05	71.10	179	141.19	54.77	15.06	71.36
54	141.14	55.01	15.18	70.94	117	140.90	54.86	15.03	71.01	180	141.18	54.82	15.01	71.36
55	141.39	54.91	15.13	71.36	118	141.14	54.79	15.02	71.34	181	141.38	54.91	15.11	71.36
56	141.11	54.97	15.12	71.01	119	141.22	54.76	14.97	71.48	182	140.98	54.87	15.03	71.09
57	140.99	54.80	15.04	71.15	120	140.83	54.68	15.10	71.05	183	141.09	54.88	15.15	71.06
58	141.30	54.85	15.08	71.37	121	140.98	54.59	15.10	71.29	184	140.93	54.70	15.04	71.19
59	141.17	54.97	15.04	71.16	122	141.55	54.76	15.18	71.62					
60	141.23	55.04	15.05	71.15	123	141.31	54.69	15.13	71.50					
61	140.97	54.71	15.16	71.11	124	141.29	55.05	15.04	71.20					
62	141.39	54.80	15.18	71.41	125	140.75	54.71	15.05	70.99					

Sustainability – Data Rate Distribution Graph

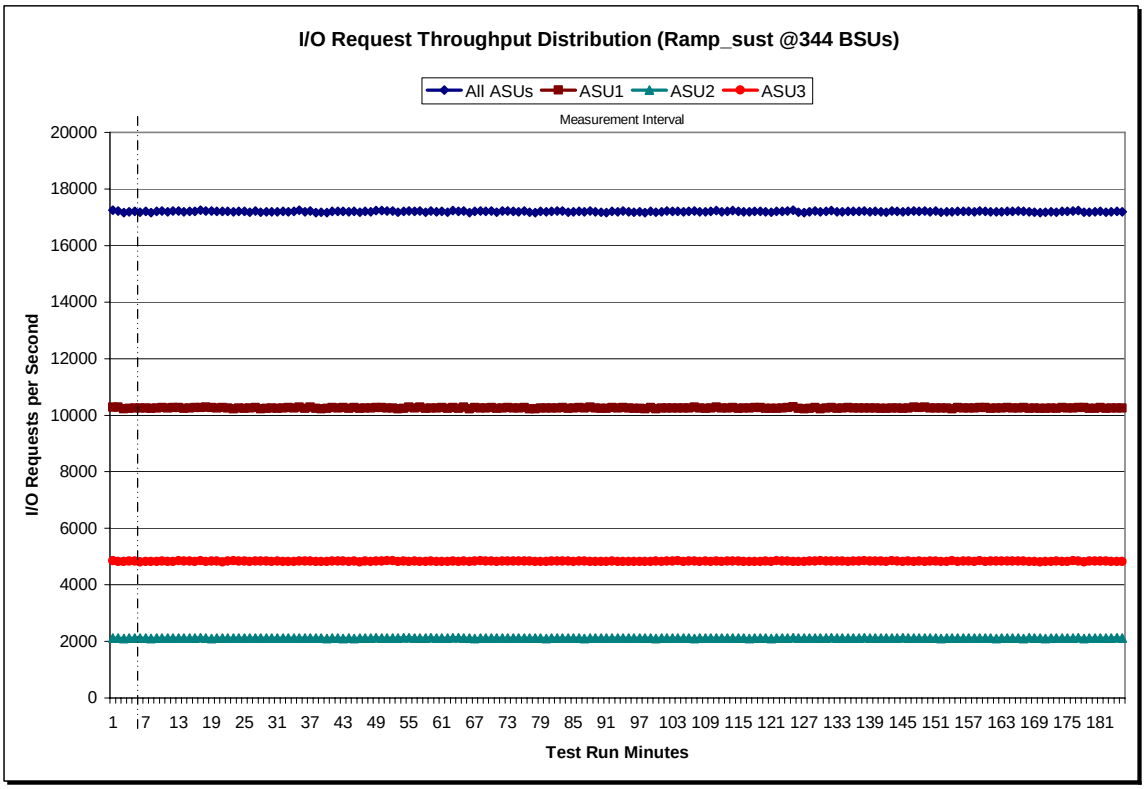


Sustainability – I/O Request Throughput Distribution Data

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	13:06:43	13:11:43	0-4	0:05:00
Measurement Interval	13:11:43	16:11:43	5-184	3:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	17,252.98	10,284.42	2,115.78	4,852.78	63	17,199.60	10,244.48	2,126.47	4,828.65	126	17,167.43	10,221.78	2,118.78	4,826.87
1	17,214.43	10,274.50	2,110.38	4,829.55	64	17,223.17	10,273.85	2,113.05	4,836.27	127	17,193.75	10,242.90	2,117.18	4,833.67
2	17,164.87	10,227.60	2,108.32	4,828.95	65	17,160.68	10,228.82	2,109.63	4,822.23	128	17,216.05	10,260.22	2,116.22	4,839.62
3	17,194.97	10,242.02	2,117.18	4,835.77	66	17,211.25	10,259.82	2,108.28	4,843.15	129	17,197.15	10,229.95	2,118.30	4,848.90
4	17,201.58	10,246.77	2,123.02	4,831.80	67	17,217.35	10,251.78	2,117.27	4,848.30	130	17,199.63	10,246.92	2,113.95	4,838.77
5	17,179.68	10,249.98	2,114.82	4,814.88	68	17,204.72	10,252.28	2,109.53	4,842.90	131	17,229.18	10,262.70	2,124.32	4,842.17
6	17,206.20	10,258.68	2,122.40	4,825.12	69	17,216.02	10,262.55	2,109.43	4,844.03	132	17,189.40	10,241.78	2,111.02	4,836.60
7	17,170.17	10,240.80	2,108.80	4,820.57	70	17,182.50	10,235.10	2,119.80	4,827.60	133	17,196.80	10,247.13	2,114.13	4,835.53
8	17,200.20	10,253.88	2,119.78	4,826.53	71	17,216.23	10,256.35	2,114.80	4,845.08	134	17,209.18	10,270.72	2,114.57	4,823.90
9	17,219.55	10,261.85	2,122.52	4,835.18	72	17,218.27	10,268.62	2,114.28	4,835.37	135	17,209.75	10,258.80	2,117.73	4,833.22
10	17,194.97	10,252.40	2,114.97	4,827.60	73	17,202.95	10,258.52	2,111.18	4,833.25	136	17,200.60	10,251.47	2,114.73	4,834.40
11	17,221.05	10,272.22	2,123.22	4,825.62	74	17,198.53	10,248.12	2,115.32	4,835.10	137	17,224.27	10,246.73	2,128.88	4,848.65
12	17,221.53	10,259.48	2,116.00	4,846.05	75	17,224.13	10,262.87	2,122.65	4,838.62	138	17,198.85	10,246.58	2,112.88	4,839.38
13	17,191.70	10,242.90	2,115.53	4,833.27	76	17,172.62	10,220.93	2,119.45	4,832.23	139	17,200.63	10,246.07	2,115.15	4,839.42
14	17,203.23	10,252.98	2,115.43	4,834.82	77	17,168.02	10,226.23	2,113.58	4,828.20	140	17,198.10	10,241.18	2,115.90	4,841.02
15	17,207.00	10,263.47	2,113.78	4,829.75	78	17,204.38	10,256.78	2,122.88	4,824.72	141	17,183.98	10,237.38	2,119.28	4,827.32
16	17,245.45	10,269.25	2,127.42	4,848.78	79	17,193.05	10,257.63	2,108.28	4,827.13	142	17,219.23	10,254.23	2,119.20	4,845.80
17	17,223.52	10,276.80	2,120.80	4,825.92	80	17,200.65	10,248.00	2,112.63	4,840.02	143	17,206.80	10,253.63	2,117.20	4,835.97
18	17,214.58	10,265.27	2,107.18	4,842.13	81	17,216.73	10,253.62	2,121.98	4,841.13	144	17,189.05	10,237.12	2,125.80	4,826.13
19	17,202.53	10,258.98	2,110.27	4,833.28	82	17,228.13	10,270.45	2,113.60	4,844.08	145	17,211.37	10,252.13	2,122.53	4,836.70
20	17,200.95	10,271.38	2,114.68	4,814.88	83	17,184.48	10,235.95	2,112.57	4,835.97	146	17,226.30	10,279.40	2,122.75	4,824.15
21	17,208.22	10,251.98	2,119.08	4,837.15	84	17,195.90	10,250.15	2,115.75	4,830.00	147	17,209.13	10,266.30	2,111.08	4,831.75
22	17,187.87	10,229.98	2,109.73	4,848.15	85	17,213.15	10,259.85	2,110.92	4,842.38	148	17,222.82	10,282.53	2,114.20	4,826.08
23	17,201.72	10,245.22	2,117.85	4,838.65	86	17,197.53	10,253.10	2,104.72	4,839.72	149	17,198.10	10,252.98	2,113.42	4,831.70
24	17,204.43	10,244.43	2,119.43	4,840.57	87	17,217.78	10,273.65	2,118.28	4,825.85	150	17,222.68	10,258.50	2,121.60	4,842.58
25	17,183.20	10,247.20	2,110.43	4,825.57	88	17,193.20	10,251.92	2,112.07	4,829.22	151	17,175.87	10,247.20	2,109.02	4,819.65
26	17,214.67	10,259.47	2,111.83	4,843.37	89	17,183.05	10,244.03	2,110.80	4,828.22	152	17,187.90	10,253.18	2,112.07	4,822.65
27	17,181.88	10,225.57	2,116.85	4,839.47	90	17,169.98	10,231.13	2,115.67	4,823.18	153	17,198.35	10,230.10	2,115.88	4,852.37
28	17,196.43	10,243.25	2,110.03	4,843.15	91	17,212.10	10,259.43	2,116.82	4,835.85	154	17,210.37	10,267.77	2,119.65	4,822.95
29	17,194.35	10,249.92	2,119.00	4,825.43	92	17,194.98	10,254.45	2,115.70	4,824.83	155	17,201.45	10,249.97	2,115.00	4,836.48
30	17,194.50	10,240.63	2,114.97	4,838.90	93	17,218.88	10,272.07	2,117.10	4,829.72	156	17,200.80	10,245.27	2,113.63	4,841.90
31	17,200.32	10,258.00	2,114.30	4,828.02	94	17,197.68	10,257.12	2,120.05	4,820.52	157	17,193.27	10,244.90	2,120.80	4,827.57
32	17,198.45	10,260.00	2,120.97	4,817.48	95	17,182.62	10,238.30	2,114.57	4,829.75	158	17,224.17	10,261.07	2,116.75	4,846.35
33	17,201.67	10,258.07	2,122.85	4,820.75	96	17,186.03	10,243.22	2,114.38	4,828.43	159	17,212.95	10,270.92	2,123.62	4,818.42
34	17,244.03	10,282.53	2,120.57	4,840.93	97	17,160.82	10,219.87	2,113.18	4,827.77	160	17,188.77	10,238.92	2,118.60	4,831.25
35	17,192.40	10,240.70	2,113.92	4,837.78	98	17,204.87	10,265.20	2,109.90	4,829.77	161	17,198.42	10,257.17	2,101.27	4,839.98
36	17,228.02	10,281.77	2,113.87	4,832.38	99	17,171.12	10,227.42	2,107.95	4,835.75	162	17,199.08	10,249.50	2,113.92	4,835.67
37	17,168.85	10,237.25	2,111.52	4,820.08	100	17,193.08	10,249.40	2,122.52	4,821.17	163	17,213.17	10,264.25	2,110.58	4,838.33
38	17,181.17	10,230.03	2,123.50	4,827.63	101	17,214.85	10,257.20	2,119.30	4,838.35	164	17,208.50	10,258.72	2,113.68	4,836.10
39	17,164.97	10,239.02	2,101.95	4,824.00	102	17,199.98	10,249.95	2,110.37	4,839.67	165	17,214.77	10,256.07	2,115.87	4,842.83
40	17,210.10	10,260.50	2,117.87	4,831.73	103	17,212.20	10,252.20	2,113.87	4,846.13	166	17,209.88	10,264.17	2,104.02	4,841.70
41	17,202.68	10,247.05	2,121.90	4,833.73	104	17,197.08	10,257.65	2,112.43	4,827.00	167	17,195.90	10,241.63	2,129.83	4,824.43
42	17,212.85	10,269.75	2,108.10	4,835.00	105	17,211.50	10,253.07	2,122.52	4,835.92	168	17,174.58	10,245.08	2,109.67	4,819.83
43	17,190.23	10,244.45	2,115.70	4,830.08	106	17,224.23	10,277.23	2,108.45	4,838.55	169	17,156.98	10,233.22	2,117.02	4,806.75
44	17,212.17	10,273.47	2,103.87	4,834.83	107	17,193.52	10,254.28	2,118.13	4,821.10	170	17,172.08	10,240.67	2,104.38	4,827.03
45	17,173.97	10,236.58	2,121.88	4,815.50	108	17,185.23	10,242.87	2,109.88	4,832.48	171	17,195.80	10,250.50	2,119.08	4,826.22
46	17,203.40	10,252.97	2,113.48	4,836.95	109	17,199.53	10,248.97	2,120.47	4,830.10	172	17,181.40	10,237.43	2,110.48	4,833.48
47	17,193.50	10,254.82	2,111.23	4,827.45	110	17,234.88	10,287.68	2,112.73	4,834.47	173	17,204.25	10,270.92	2,110.75	4,822.58
48	17,233.98	10,265.73	2,126.85	4,841.40	111	17,196.75	10,252.62	2,118.72	4,825.42	174	17,200.07	10,249.25	2,121.03	4,829.78
49	17,228.53	10,265.65	2,122.22	4,840.67	112	17,209.48	10,254.30	2,116.00	4,839.18	175	17,217.57	10,251.23	2,115.18	4,851.15
50	17,219.77	10,257.62	2,111.20	4,850.95	113	17,228.78	10,270.32	2,116.93	4,841.53	176	17,230.60	10,273.48	2,124.40	4,832.72
51	17,216.70	10,245.47	2,118.87	4,852.37	114	17,204.98	10,242.93	2,120.93	4,841.12	177	17,182.87	10,259.63	2,107.18	4,816.05
52	17,173.97	10,227.20	2,119.00	4,827.77	115	17,191.40	10,250.38	2,111.27	4,829.75	178	17,184.97	10,241.67	2,111.02	4,832.28
53	17,212.78	10,242.73	2,127.18	4,842.87	116	17,186.72	10,255.02	2,107.55	4,824.15	179	17,192.43	10,236.13	2,114.97	4,841.33
54	17,225.77	10,278.67	2,124.38	4,822.72	117	17,205.80	10,263.35	2,116.53	4,825.92	180	17,210.93	10,265.20	2,111.52	4,834.22
55	17,201.95	10,246.32	2,117.72	4,837.92	118	17,204.75	10,260.03	2,117.90	4,826.82	181	17,181.55	10,237.43	2,110.23	4,833.88
56	17,221.42	10,278.67	2,122.05	4,820.70	119	17,191.22	10,243.32	2,112.27	4,835.63	182	17,189.98	10,249.90	2,115.98	4,824.10
57	17,183.20	10,243.67	2,115.08	4,824.45	120	17,171.38	10,244.02	2,107.35	4,820.02	183	17,210.15	10,255.47	2,130.80	4,823.88
58	17,219.40	10,255.93	2,124.65	4,838.82	121	17,206.25	10,244.75	2,113.12	4,848.38	184	17,196.03	10,255.35	2,118.67	4,822.02
59	17,193.55	10,253.82	2,116.42	4,823.32	122	17,202.73	10,249.67	2,116.32	4,836.75	Average	17,201.57	10,252.88	2,115.88	4,832.80
60	17,203.33	10,272.35	2,109.63	4,821.35	123	17,215.10	10,270.10	2,110.67	4,834.33					
61	17,177.13	10,231.18	2,123.67	4,822.28	124	17,245.40	10,289.80	2,124.90	4,830.70					
62	17,232.45	10,262.17	2,129.52	4,840.77	125	17,183.75	10,239.55	2,113.45	4,830.75					

Sustainability – I/O Request Throughput Distribution Graph

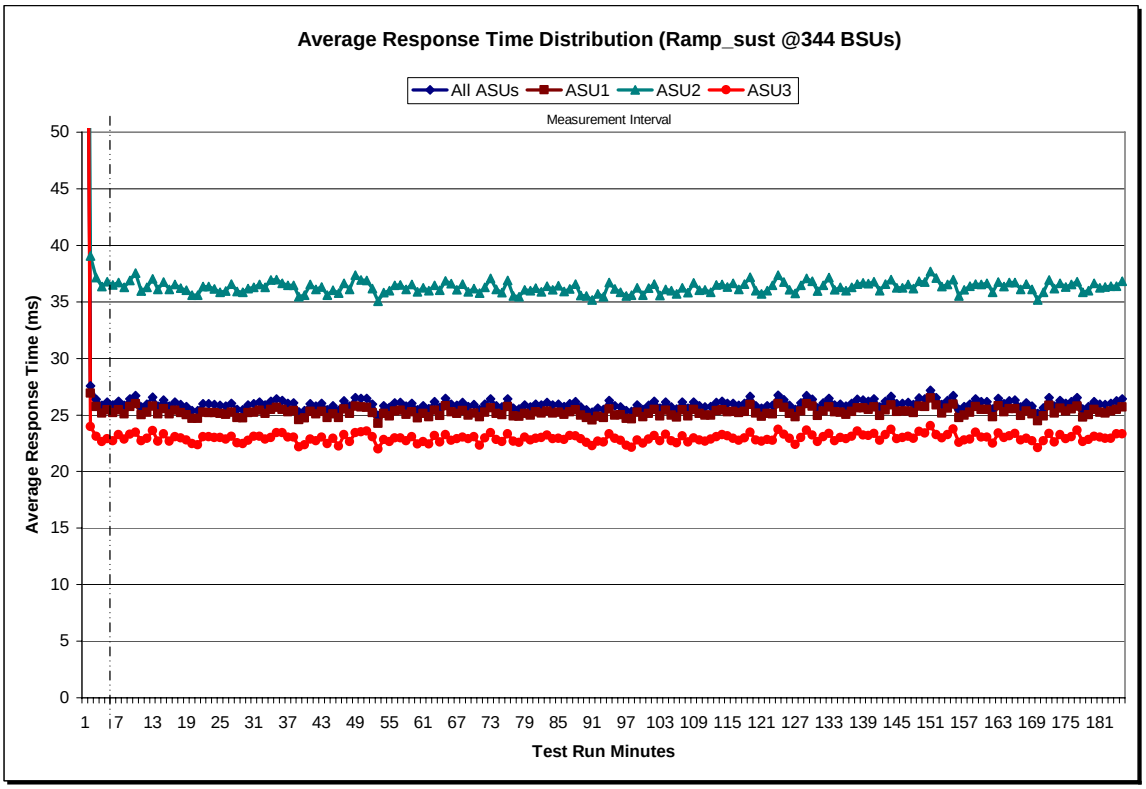


Sustainability – Average Response Time (ms) Distribution Data

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	13:06:43	13:11:43	0-4	0:05:00
Measurement Interval	13:11:43	16:11:43	5-184	3:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	114.39	114.03	124.36	110.83	63	25.67	24.95	36.04	22.61	126	25.50	24.84	35.75	22.40
1	27.58	26.91	39.06	23.98	64	26.45	25.81	36.87	23.26	127	26.05	25.33	36.48	23.02
2	26.40	25.74	37.17	23.10	65	25.96	25.28	36.61	22.75	128	26.69	26.00	37.07	23.63
3	25.84	25.18	36.35	22.65	66	25.84	25.14	36.09	22.88	129	26.40	25.76	36.83	23.20
4	26.12	25.44	36.80	22.88	67	26.11	25.39	36.58	23.04	130	25.65	24.94	35.95	22.65
5	25.88	25.18	36.51	22.71	68	25.73	24.97	35.90	22.91	131	26.07	25.34	36.45	23.07
6	26.22	25.45	36.72	23.24	69	25.93	25.17	36.17	23.08	132	26.45	25.70	37.16	23.37
7	25.85	25.11	36.29	22.87	70	25.49	24.84	35.80	22.32	133	25.88	25.26	36.08	22.73
8	26.44	25.75	36.91	23.31	71	25.94	25.22	36.28	22.95	134	25.96	25.23	36.30	22.99
9	26.71	25.99	37.55	23.46	72	26.43	25.65	37.09	23.43	135	25.79	25.05	35.99	22.90
10	25.72	25.01	35.98	22.72	73	25.83	25.13	36.10	22.82	136	26.04	25.31	36.28	23.12
11	25.94	25.22	36.30	22.92	74	25.69	25.02	35.83	22.66	137	26.40	25.62	36.57	23.57
12	26.55	25.78	37.04	23.61	75	26.44	25.75	36.90	23.31	138	26.32	25.64	36.67	23.22
13	25.76	25.08	36.11	22.69	76	25.58	24.90	35.52	22.66	139	26.21	25.49	36.61	23.20
14	26.31	25.56	36.77	23.33	77	25.52	24.86	35.46	22.56	140	26.41	25.72	36.78	23.35
15	25.77	25.10	36.10	22.69	78	25.89	25.13	36.08	23.03	141	25.69	24.94	36.01	22.74
16	26.13	25.43	36.53	23.06	79	25.71	24.98	35.98	22.78	142	26.20	25.45	36.59	23.25
17	25.93	25.20	36.20	22.98	80	25.94	25.26	36.20	22.92	143	26.64	25.88	36.97	23.71
18	25.74	25.02	36.04	22.77	81	25.87	25.15	35.90	22.99	144	25.98	25.30	36.25	22.90
19	25.39	24.68	35.59	22.45	82	26.11	25.36	36.39	23.23	145	26.03	25.34	36.23	23.02
20	25.37	24.68	35.60	22.36	83	25.87	25.18	36.07	22.89	146	26.10	25.33	36.55	23.13
21	26.00	25.23	36.36	23.09	84	25.96	25.24	36.42	22.92	147	25.92	25.21	36.17	22.95
22	25.98	25.21	36.37	23.09	85	25.75	25.04	35.93	22.82	148	26.51	25.79	36.82	23.53
23	25.93	25.20	36.14	23.00	86	26.00	25.26	36.13	23.17	149	26.43	25.74	36.74	23.40
24	25.83	25.11	35.84	22.99	87	26.17	25.44	36.57	23.14	150	27.18	26.49	37.68	24.04
25	25.79	25.06	35.97	22.87	88	25.69	24.96	35.56	22.90	151	26.52	25.89	37.13	23.24
26	26.02	25.23	36.56	23.11	89	25.46	24.77	35.51	22.55	152	25.91	25.15	36.35	22.97
27	25.50	24.76	35.91	22.52	90	25.22	24.55	35.17	22.27	153	26.28	25.60	36.53	23.26
28	25.45	24.73	35.86	22.45	91	25.60	24.88	35.72	22.68	154	26.69	25.95	36.97	23.75
29	25.87	25.20	36.19	22.76	92	25.47	24.76	35.45	22.60	155	25.47	24.76	35.55	22.57
30	25.99	25.23	36.28	23.11	93	26.27	25.51	36.70	23.32	156	25.73	24.99	36.08	22.79
31	26.13	25.41	36.55	23.11	94	25.79	24.99	36.15	22.94	157	25.94	25.23	36.41	22.84
32	25.87	25.14	36.27	22.86	95	25.71	25.01	35.87	22.74	158	26.43	25.75	36.56	23.45
33	26.19	25.48	36.93	22.99	96	25.37	24.70	35.54	22.33	159	26.16	25.47	36.52	23.05
34	26.43	25.67	36.98	23.43	97	25.30	24.65	35.60	22.16	160	26.17	25.50	36.63	23.02
35	26.29	25.50	36.65	23.45	98	25.89	25.22	36.23	22.79	161	25.54	24.85	35.87	22.50
36	26.03	25.29	36.48	23.05	99	25.50	24.84	35.59	22.50	162	26.47	25.80	36.76	23.39
37	26.07	25.36	36.48	23.03	100	25.86	25.12	36.22	22.86	163	25.99	25.27	36.35	23.01
38	25.25	24.58	35.46	22.19	101	26.19	25.47	36.56	23.19	164	26.24	25.55	36.70	23.14
39	25.39	24.73	35.62	22.35	102	25.60	24.90	35.58	22.71	165	26.32	25.57	36.71	23.37
40	26.01	25.32	36.53	22.86	103	26.13	25.41	36.10	23.31	166	25.71	24.96	36.09	22.79
41	25.78	25.07	36.10	22.73	104	25.70	24.98	35.99	22.72	167	26.06	25.35	36.56	22.94
42	26.01	25.29	36.31	23.05	105	25.52	24.82	35.72	22.55	168	25.78	25.09	36.12	22.72
43	25.45	24.78	35.59	22.45	106	26.12	25.44	36.26	23.14	169	25.13	24.48	35.17	22.11
44	25.82	25.10	36.02	22.92	107	25.60	24.90	35.82	22.59	170	25.63	24.91	35.84	22.72
45	25.42	24.78	35.78	22.23	108	26.15	25.49	36.67	22.96	171	26.52	25.85	36.93	23.38
46	26.26	25.53	36.63	23.27	109	25.82	25.14	36.04	22.79	172	25.79	25.16	36.18	22.59
47	25.78	25.13	36.11	22.64	110	25.71	25.00	36.06	22.69	173	26.29	25.58	36.64	23.26
48	26.55	25.78	37.37	23.42	111	25.72	24.99	35.84	22.85	174	26.01	25.35	36.34	22.88
49	26.46	25.69	36.94	23.50	112	26.10	25.38	36.50	23.07	175	26.19	25.52	36.53	23.08
50	26.45	25.66	36.91	23.58	113	26.20	25.46	36.55	23.24	176	26.53	25.77	36.78	23.64
51	25.95	25.20	36.19	23.06	114	26.04	25.28	36.33	23.13	177	25.54	24.79	35.85	22.63
52	24.96	24.27	35.06	21.99	115	26.03	25.32	36.63	22.92	178	25.74	25.01	35.98	22.82
53	25.80	25.14	35.83	22.81	116	25.84	25.19	36.10	22.74	179	26.18	25.48	36.63	23.10
54	25.65	24.93	36.01	22.64	117	26.02	25.29	36.56	22.96	180	25.96	25.23	36.24	23.04
55	26.06	25.36	36.48	22.98	118	26.63	25.93	37.19	23.46	181	25.91	25.18	36.31	22.92
56	26.10	25.42	36.51	22.97	119	25.82	25.15	36.00	22.80	182	26.02	25.34	36.38	22.94
57	25.76	25.06	36.12	22.71	120	25.58	24.87	35.72	22.66	183	26.23	25.48	36.40	23.32
58	26.04	25.27	36.53	23.06	121	25.82	25.13	36.01	22.84	184	26.41	25.70	36.84	23.34
59	25.47	24.74	35.88	22.44	122	25.84	25.11	36.48	22.74	Average	25.96	25.25	36.29	22.95
60	25.80	25.13	36.26	22.66	123	26.75	26.00	37.37	23.71					
61	25.54	24.84	35.98	22.43	124	26.36	25.65	36.75	23.30					
62	26.15	25.42	36.47	23.17	125	25.86	25.14	36.06	22.93					

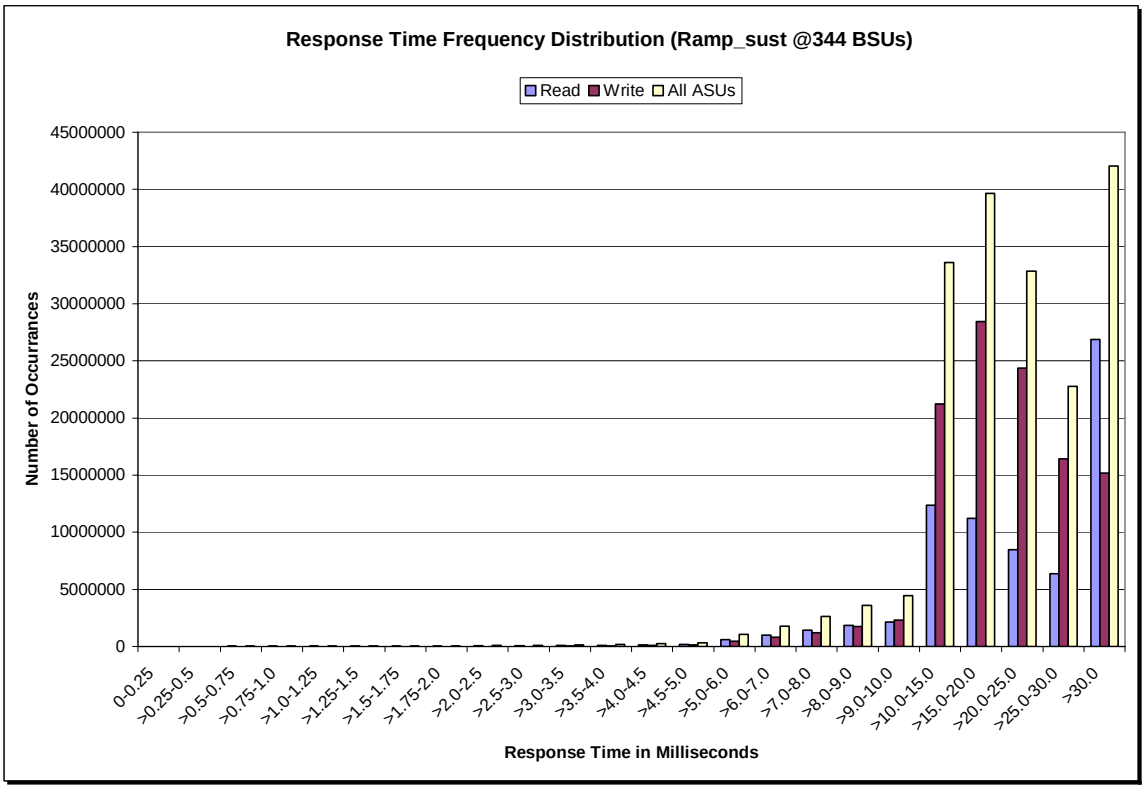
Sustainability – Average Response Time (ms) Distribution Graph



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	943	12,564	30,412	33,834	38,770	38,426	38,801	34,194
Write	-	-	-	11	26	127	393	689
All ASUs	943	12,564	30,412	33,845	38,796	38,553	39,194	34,883
ASU1	878	11,686	28,290	31,548	36,112	35,892	36,315	32,228
ASU2	65	878	2,122	2,295	2,678	2,633	2,755	2,438
ASU3	-	-	-	2	6	28	124	217
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	84,804	82,988	99,309	111,311	154,756	187,867	611,125	989,448
Write	5,616	13,800	32,123	51,456	99,020	133,211	458,140	807,044
All ASUs	90,420	96,788	131,432	162,767	253,776	321,078	1,069,265	1,796,492
ASU1	82,027	84,711	109,574	130,933	195,638	243,641	799,018	1,310,638
ASU2	6,545	7,274	10,313	13,067	21,004	26,638	90,813	162,778
ASU3	1,848	4,803	11,545	18,767	37,134	50,799	179,434	323,076
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	1,441,637	1,840,659	2,150,745	12,367,887	11,209,396	8,491,833	6,369,011	26,864,083
Write	1,206,653	1,759,189	2,310,461	21,241,048	28,436,290	24,355,604	16,414,574	15,166,178
All ASUs	2,648,290	3,599,848	4,461,206	33,608,935	39,645,686	32,847,437	22,783,585	42,030,261
ASU1	1,902,927	2,512,399	3,032,616	20,856,356	22,670,019	18,089,402	12,503,712	25,994,306
ASU2	253,959	358,285	456,718	3,517,872	4,146,425	3,444,041	2,429,708	7,890,179
ASU3	491,404	729,164	971,872	9,234,707	12,829,242	11,313,994	7,850,165	8,145,776

Sustainability – Response Time Frequency Distribution Graph



Sustainability – Measured Intensity Multiplier and Coefficient of Variation

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.005	0.002	0.004	0.002	0.006	0.004	0.005	0.002

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.*

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 Primary Metrics Test, which consists of the Sustainability, IOPS, and Response Time Ramp Test Runs, are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 69.

IOPS Test Results File

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

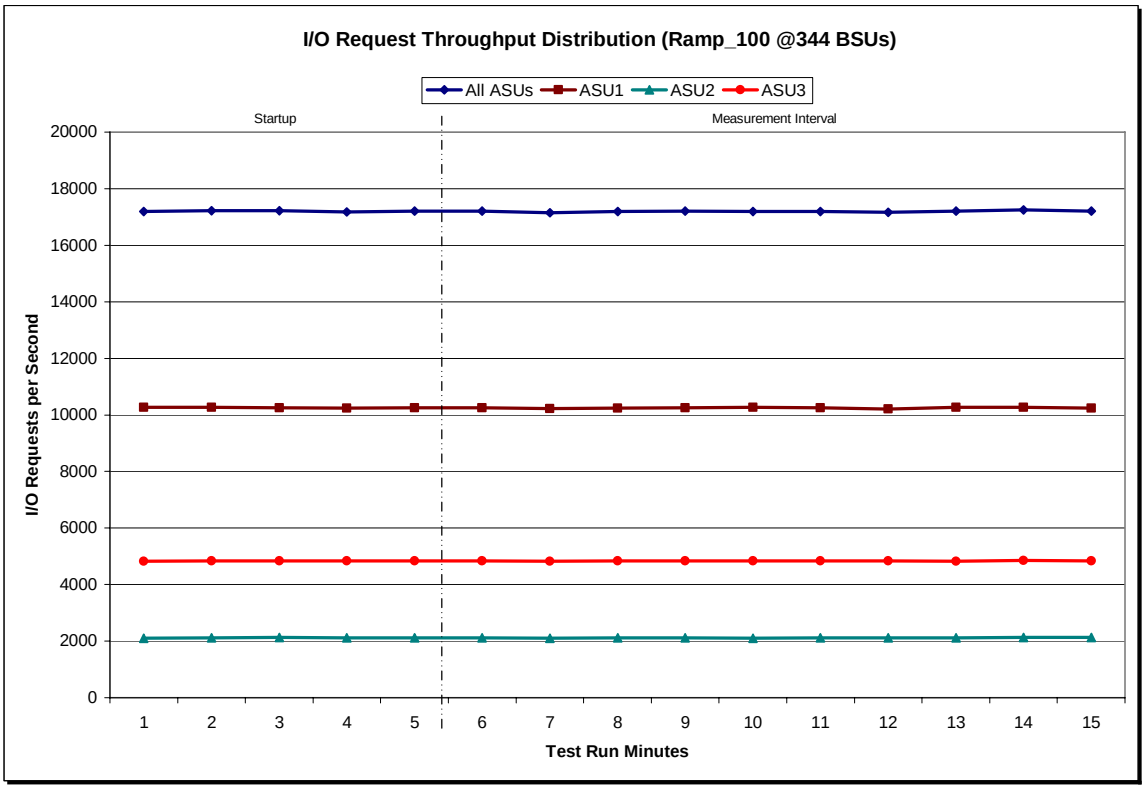
IOPS Test Results File

IOPS Test Run – I/O Request Throughput Distribution Data

344 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	16:11:50	16:16:51	0-4	0:05:01
Measurement Interval	16:16:51	16:26:51	5-14	0:10:00

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	17,193.57	10,261.53	2,107.85	4,824.18
1	17,217.65	10,262.07	2,117.08	4,838.50
2	17,214.15	10,248.12	2,127.30	4,838.73
3	17,180.07	10,235.98	2,111.98	4,832.10
4	17,207.33	10,252.58	2,116.95	4,837.80
5	17,204.23	10,251.98	2,114.02	4,838.23
6	17,146.28	10,228.38	2,098.02	4,819.88
7	17,192.45	10,240.40	2,117.25	4,834.80
8	17,211.43	10,259.10	2,118.35	4,833.98
9	17,193.58	10,259.23	2,103.43	4,830.92
10	17,188.97	10,246.80	2,110.37	4,831.80
11	17,168.48	10,212.53	2,113.58	4,842.37
12	17,199.95	10,260.65	2,121.20	4,818.10
13	17,245.83	10,273.17	2,126.65	4,846.02
14	17,207.15	10,243.32	2,125.02	4,838.82
Average	17,195.84	10,247.56	2,114.79	4,833.49

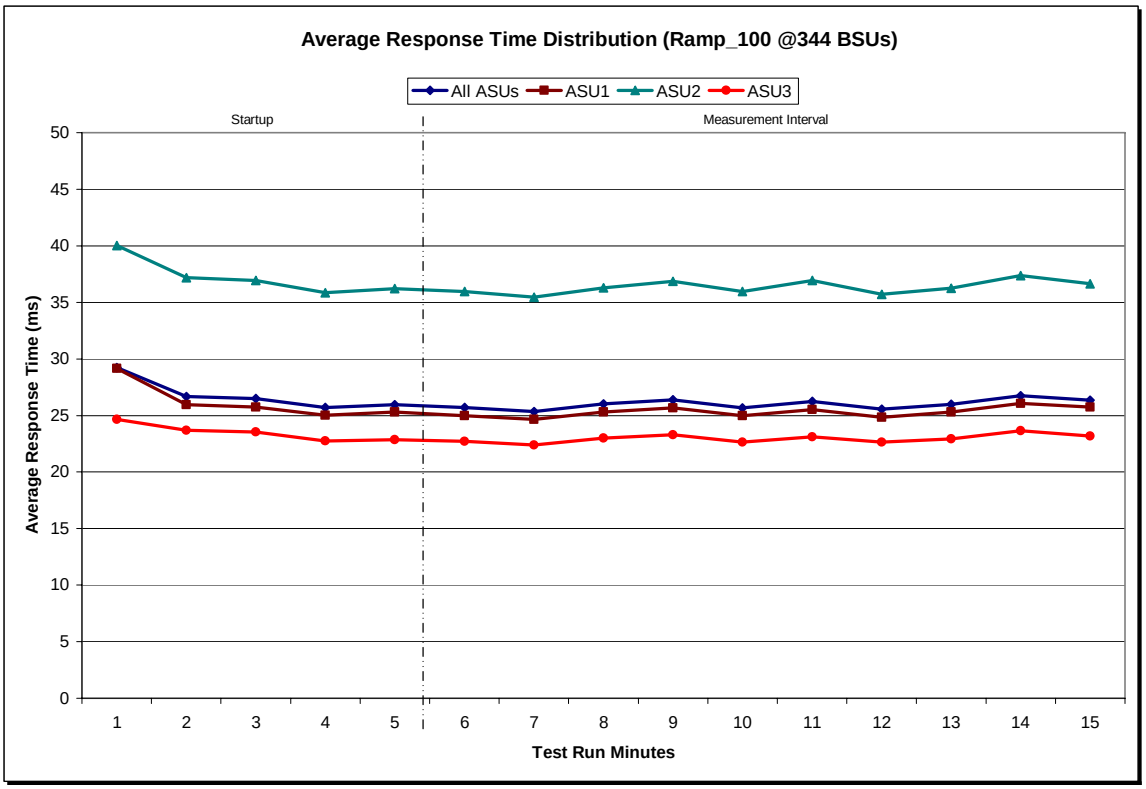
IOPS Test Run – I/O Request Throughput Distribution Graph



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

344 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	16:11:50	16:16:51	0-4	0:05:01
Measurement Interval	16:16:51	16:26:51	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	29.23	29.16	40.03	24.64
1	26.69	25.94	37.17	23.69
2	26.50	25.72	36.95	23.56
3	25.72	25.03	35.85	22.75
4	25.96	25.31	36.21	22.86
5	25.68	24.97	35.96	22.72
6	25.34	24.64	35.48	22.40
7	26.01	25.31	36.27	23.00
8	26.38	25.67	36.86	23.28
9	25.66	24.97	35.95	22.63
10	26.24	25.52	36.95	23.11
11	25.55	24.83	35.70	22.63
12	25.98	25.30	36.25	22.91
13	26.76	26.04	37.37	23.63
14	26.36	25.74	36.66	23.17
Average	26.00	25.30	36.34	22.95

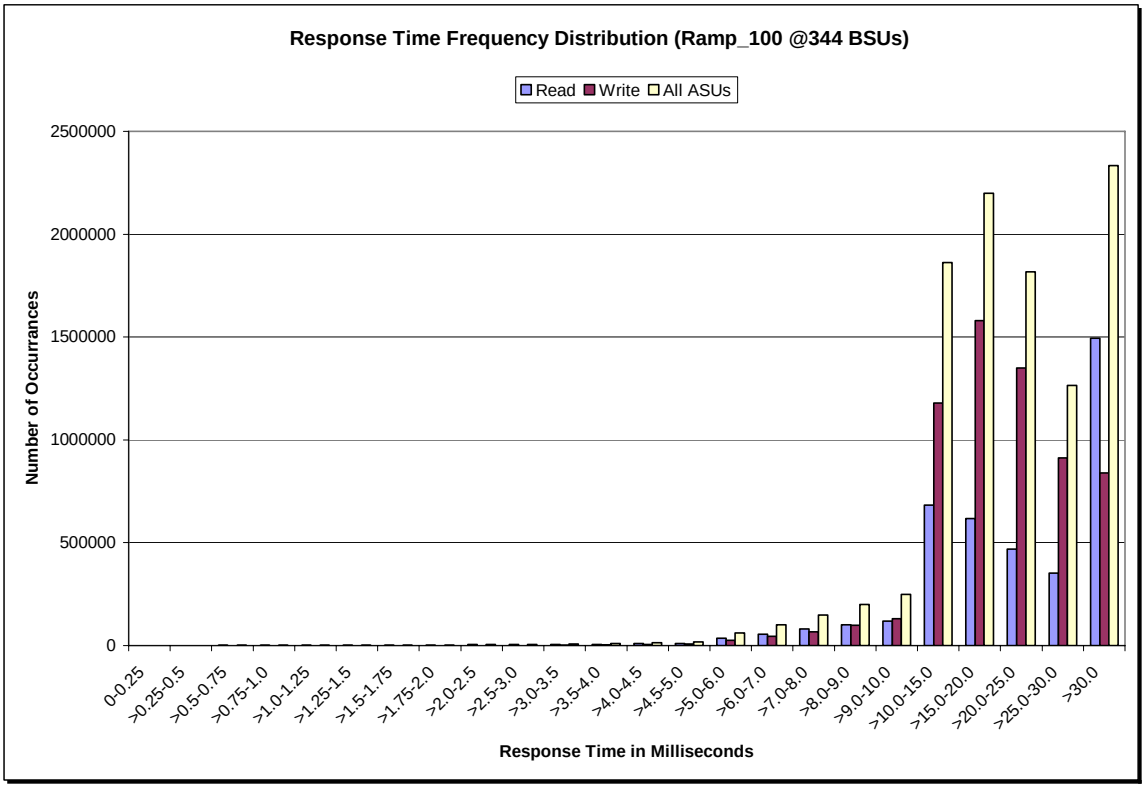
IOPS Test Run – Average Response Time (ms) Distribution Graph



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	62	803	2,007	2,331	2,571	2,507	2,535	2,375
Write	0	0	0	0	1	7	20	47
All ASUs	62	803	2,007	2,331	2,572	2,514	2,555	2,422
ASU1	58	757	1,888	2,194	2,408	2,380	2,406	2,245
ASU2	4	46	119	137	164	133	143	171
ASU3	0	0	0	0	0	1	6	6
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	5,667	5,493	6,317	6,843	9,194	10,689	34,681	55,695
Write	342	858	1,967	3,099	5,606	7,907	26,056	45,753
All ASUs	6,009	6,351	8,284	9,942	14,800	18,596	60,737	101,448
ASU1	5,512	5,620	6,979	8,078	11,562	14,069	45,420	73,818
ASU2	395	441	606	745	1,141	1,467	5,113	9,281
ASU3	102	290	699	1,119	2,097	3,060	10,204	18,349
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	80,635	101,764	119,406	683,326	617,934	468,601	352,092	1,495,375
Write	67,722	99,132	129,672	1,178,899	1,580,480	1,349,014	912,246	839,319
All ASUs	148,357	200,896	249,078	1,862,225	2,198,414	1,817,615	1,264,338	2,334,694
ASU1	106,301	139,947	168,980	1,153,374	1,254,867	1,000,883	692,951	1,445,590
ASU2	14,275	20,053	25,520	195,864	230,190	190,379	134,917	437,479
ASU3	27,781	40,896	54,578	512,987	713,357	626,353	436,470	451,625

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
10,317,050	7,982,356	2,334,694

IOPS Test Run – 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	0.2807	0.0700	0.2101	0.0180	0.0700	0.0350	0.2811
COV	0.006	0.001	0.004	0.003	0.010	0.004	0.007	0.002

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.*

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 12.

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 Primary Metrics Test, which consists of the Sustainability, IOPS, and Response Time Ramp Test Runs, are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 69.

Response Time Ramp Test Results File

A link to each test result file generated from each Response Time Ramp Test Run list listed below.

95% Load Level

90% Load Level

80% Load Level

50% Load Level

10% Load Level

Response Time Ramp Distribution (IOPS) Data

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

100% Load Level - 344 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	16:11:50	16:16:51	0-4	0:05:01
Measurement Interval	16:16:51	16:26:51	5-14	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	17,193.57	10,261.53	2,107.85	4,824.18
1	17,217.65	10,262.07	2,117.08	4,838.50
2	17,214.15	10,248.12	2,127.30	4,838.73
3	17,180.07	10,235.98	2,111.98	4,832.10
4	17,207.33	10,252.58	2,116.95	4,837.80
5	17,204.23	10,251.98	2,114.02	4,838.23
6	17,146.28	10,228.38	2,098.02	4,819.88
7	17,192.45	10,240.40	2,117.25	4,834.80
8	17,211.43	10,259.10	2,118.35	4,833.98
9	17,193.58	10,259.23	2,103.43	4,830.92
10	17,188.97	10,246.80	2,110.37	4,831.80
11	17,168.48	10,212.53	2,113.58	4,842.37
12	17,199.95	10,260.65	2,121.20	4,818.10
13	17,245.83	10,273.17	2,126.65	4,846.02
14	17,207.15	10,243.32	2,125.02	4,838.82
Average	17,195.84	10,247.56	2,114.79	4,833.49

95% Load Level - 326 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	16:26:55	16:31:56	0-4	0:05:01
Measurement Interval	16:31:56	16:41:56	5-14	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	16,305.73	9,717.52	2,001.77	4,586.45
1	16,272.30	9,693.85	1,996.87	4,581.58
2	16,298.30	9,717.77	1,991.87	4,588.67
3	16,341.22	9,728.98	2,011.13	4,601.10
4	16,292.82	9,730.20	2,001.30	4,561.32
5	16,316.25	9,741.73	1,996.82	4,577.70
6	16,299.18	9,708.75	2,012.75	4,577.68
7	16,292.33	9,727.15	1,998.07	4,567.12
8	16,286.30	9,699.55	1,999.77	4,586.98
9	16,303.50	9,712.80	2,005.10	4,585.60
10	16,272.33	9,692.53	1,996.92	4,582.88
11	16,273.63	9,699.48	2,003.63	4,570.52
12	16,289.38	9,699.70	2,009.95	4,579.73
13	16,286.67	9,696.60	1,994.38	4,595.68
14	16,315.48	9,729.75	2,012.10	4,573.63
Average	16,293.51	9,710.81	2,002.95	4,579.75

90% Load Level - 309 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	16:42:00	16:47:01	0-4	0:05:01
Measurement Interval	16:47:01	16:57:01	5-14	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	15,450.28	9,204.72	1,901.68	4,343.88
1	15,436.72	9,194.98	1,908.58	4,333.15
2	15,453.03	9,199.40	1,900.12	4,353.52
3	15,424.03	9,198.65	1,887.88	4,337.50
4	15,439.13	9,203.65	1,901.78	4,333.70
5	15,446.28	9,219.43	1,901.35	4,325.50
6	15,456.15	9,215.45	1,901.08	4,339.62
7	15,479.10	9,224.57	1,903.58	4,350.95
8	15,464.43	9,204.48	1,903.47	4,356.48
9	15,438.10	9,193.53	1,901.23	4,343.33
10	15,432.90	9,193.62	1,901.00	4,338.28
11	15,454.93	9,216.58	1,895.00	4,343.35
12	15,484.03	9,223.02	1,903.67	4,357.35
13	15,469.80	9,228.37	1,896.82	4,344.62
14	15,449.07	9,213.18	1,896.85	4,339.03
Average	15,457.48	9,213.22	1,900.41	4,343.85

80% Load Level - 275 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	16:57:05	17:02:06	0-4	0:05:01
Measurement Interval	17:02:06	17:12:06	5-14	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	13,770.65	8,207.93	1,693.80	3,868.92
1	13,747.65	8,208.47	1,691.05	3,848.13
2	13,742.67	8,188.08	1,691.00	3,863.58
3	13,729.93	8,179.20	1,692.65	3,858.08
4	13,754.22	8,196.65	1,685.30	3,872.27
5	13,751.03	8,203.62	1,692.58	3,854.83
6	13,742.27	8,183.57	1,694.80	3,863.90
7	13,741.90	8,198.32	1,681.93	3,861.65
8	13,736.23	8,191.48	1,678.63	3,866.12
9	13,739.22	8,182.87	1,686.82	3,869.53
10	13,752.98	8,190.98	1,689.88	3,872.12
11	13,723.93	8,177.38	1,686.35	3,860.20
12	13,747.55	8,179.55	1,697.55	3,870.45
13	13,749.23	8,196.37	1,692.25	3,860.62
14	13,737.68	8,191.72	1,688.78	3,857.18
Average	13,742.20	8,189.59	1,688.96	3,863.66

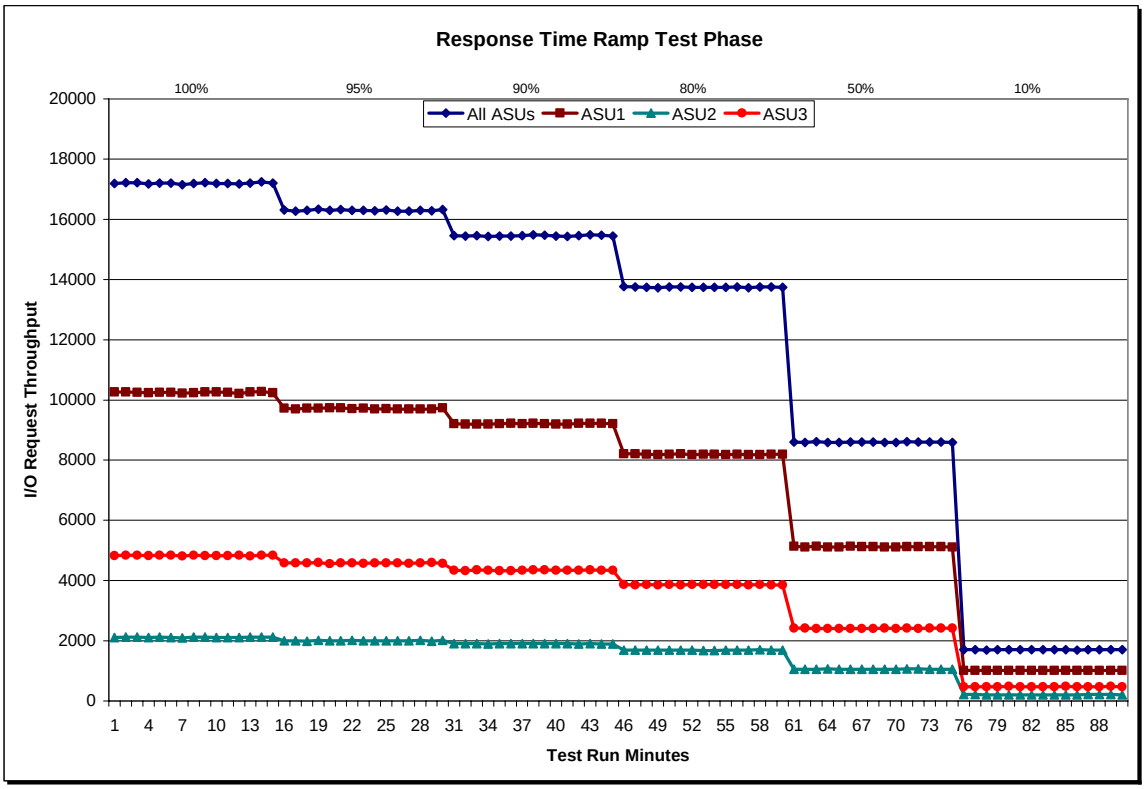
50% Load Level - 172 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:12:10	17:17:11	0-4	0:05:01
Measurement Interval	17:17:11	17:27:11	5-14	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	8,606.20	5,138.48	1,053.65	2,414.07
1	8,586.35	5,109.77	1,060.97	2,415.62
2	8,607.27	5,138.20	1,056.10	2,412.97
3	8,588.47	5,111.53	1,064.08	2,412.85
4	8,584.12	5,118.18	1,055.48	2,410.45
5	8,602.78	5,136.02	1,057.28	2,409.48
6	8,598.00	5,128.17	1,058.38	2,411.45
7	8,595.42	5,125.40	1,058.45	2,411.57
8	8,591.02	5,114.73	1,051.32	2,424.97
9	8,580.52	5,115.22	1,060.97	2,404.33
10	8,611.85	5,127.87	1,063.82	2,420.17
11	8,605.15	5,131.70	1,062.18	2,411.27
12	8,597.48	5,126.83	1,055.02	2,415.63
13	8,606.90	5,129.02	1,059.53	2,418.35
14	8,592.60	5,114.22	1,056.40	2,421.98
Average	8,598.17	5,124.92	1,058.34	2,414.92

10% Load Level - 34 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:27:14	17:32:15	0-4	0:05:01
Measurement Interval	17:32:15	17:42:15	5-14	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	1,709.73	1,020.20	211.20	478.33
1	1,704.98	1,014.02	211.60	479.37
2	1,693.10	1,008.05	208.28	476.77
3	1,698.92	1,014.60	205.77	478.55
4	1,703.08	1,013.80	207.55	481.73
5	1,701.20	1,015.92	208.50	476.78
6	1,703.20	1,016.87	207.85	478.48
7	1,697.73	1,013.32	206.97	477.45
8	1,701.22	1,015.42	208.47	477.33
9	1,702.85	1,012.70	209.20	480.95
10	1,690.67	1,007.83	207.58	475.25
11	1,698.73	1,013.52	210.70	474.52
12	1,699.08	1,010.80	210.67	477.62
13	1,702.20	1,010.52	211.43	480.25
14	1,698.72	1,015.93	204.82	477.97
Average	1,699.56	1,013.28	208.62	477.66

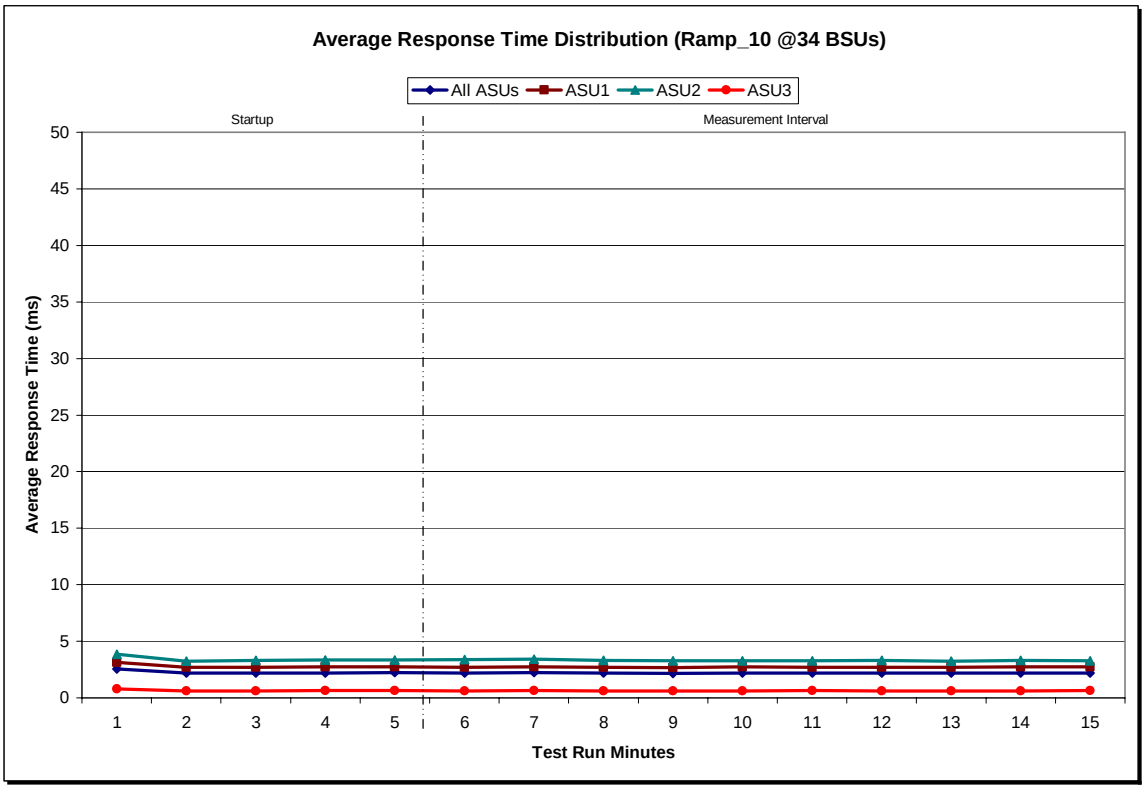
Response Time Ramp Distribution (IOPS) Graph



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

34 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:27:14	17:32:15	0-4	0:05:01
Measurement Interval	17:32:15	17:42:15	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	2.56	3.13	3.85	0.80
1	2.19	2.72	3.24	0.61
2	2.19	2.70	3.33	0.61
3	2.21	2.72	3.34	0.63
4	2.22	2.73	3.35	0.65
5	2.20	2.69	3.40	0.61
6	2.23	2.74	3.41	0.63
7	2.20	2.71	3.31	0.63
8	2.17	2.68	3.28	0.60
9	2.20	2.72	3.28	0.62
10	2.20	2.72	3.29	0.63
11	2.20	2.71	3.30	0.63
12	2.18	2.70	3.25	0.62
13	2.21	2.74	3.31	0.60
14	2.21	2.74	3.29	0.63
Average	2.20	2.71	3.31	0.62

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



SPC-1 LRT™ (10%) – 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	0.0349	0.2809	0.0699	0.2105	0.0179	0.0700	0.0349	0.2810
COV	0.016	0.005	0.013	0.005	0.023	0.012	0.013	0.003

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.*

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 Repeatability Test, which consists of four Repeatability Test Runs, are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 69.

Repeatability Test Results File

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

	SPC-1 IOPS™	SPC-1 LRT™
Primary Metrics	***17,195.84***	***2.20***
Repeatability Test Phase 1	17,200.21	2.21
Repeatability Test Phase 2	17,195.18	2.20

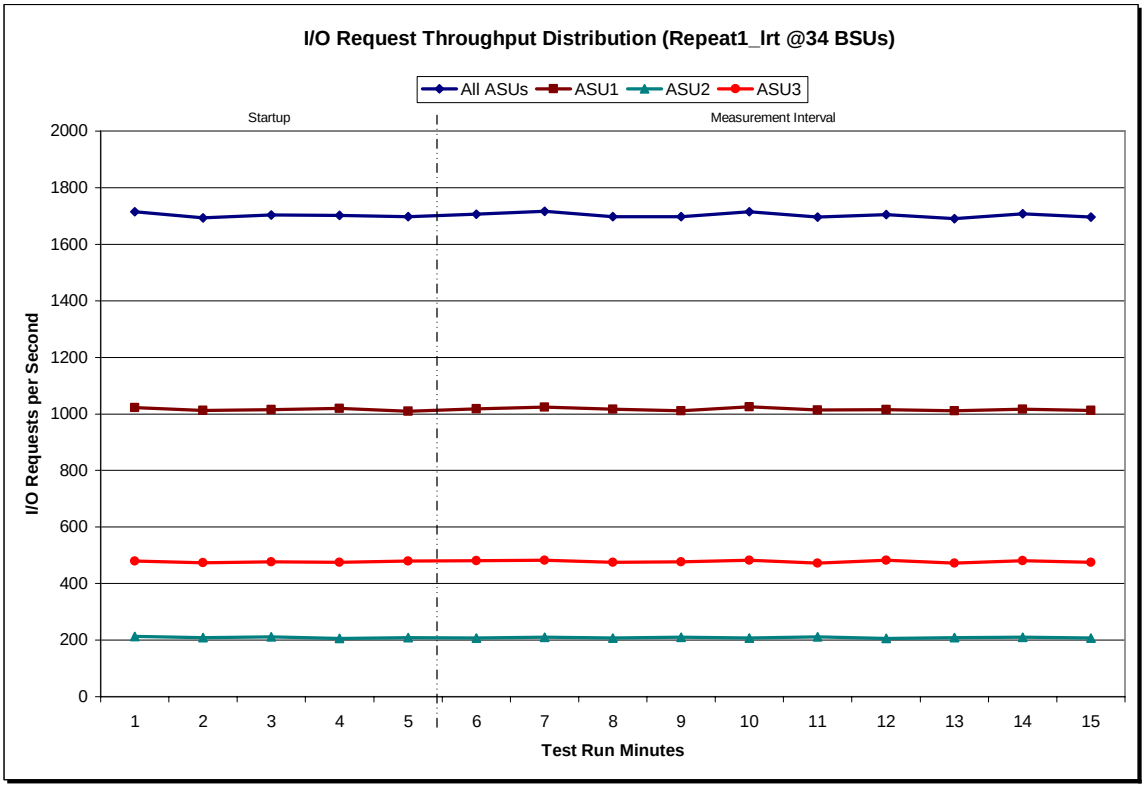
A link to the test result file generated from each Repeatability Test Run list is listed below.

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

34 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:42:22	17:47:22	0-4	0:05:00
Measurement Interval	17:47:22	17:57:22	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	1,714.40	1,021.98	212.60	479.82
1	1,693.68	1,011.57	208.40	473.72
2	1,703.28	1,015.60	211.12	476.57
3	1,701.43	1,019.53	206.17	475.73
4	1,697.70	1,009.57	208.67	479.47
5	1,706.63	1,018.18	207.85	480.60
6	1,716.40	1,023.83	209.93	482.63
7	1,697.88	1,016.20	206.78	474.90
8	1,697.05	1,010.88	210.23	475.93
9	1,715.13	1,024.93	207.88	482.32
10	1,696.87	1,013.45	211.47	471.95
11	1,704.47	1,015.83	206.13	482.50
12	1,691.07	1,010.80	208.18	472.08
13	1,707.28	1,016.20	210.87	480.22
14	1,695.92	1,012.90	207.18	475.83
Average	1,702.87	1,016.32	208.65	477.90

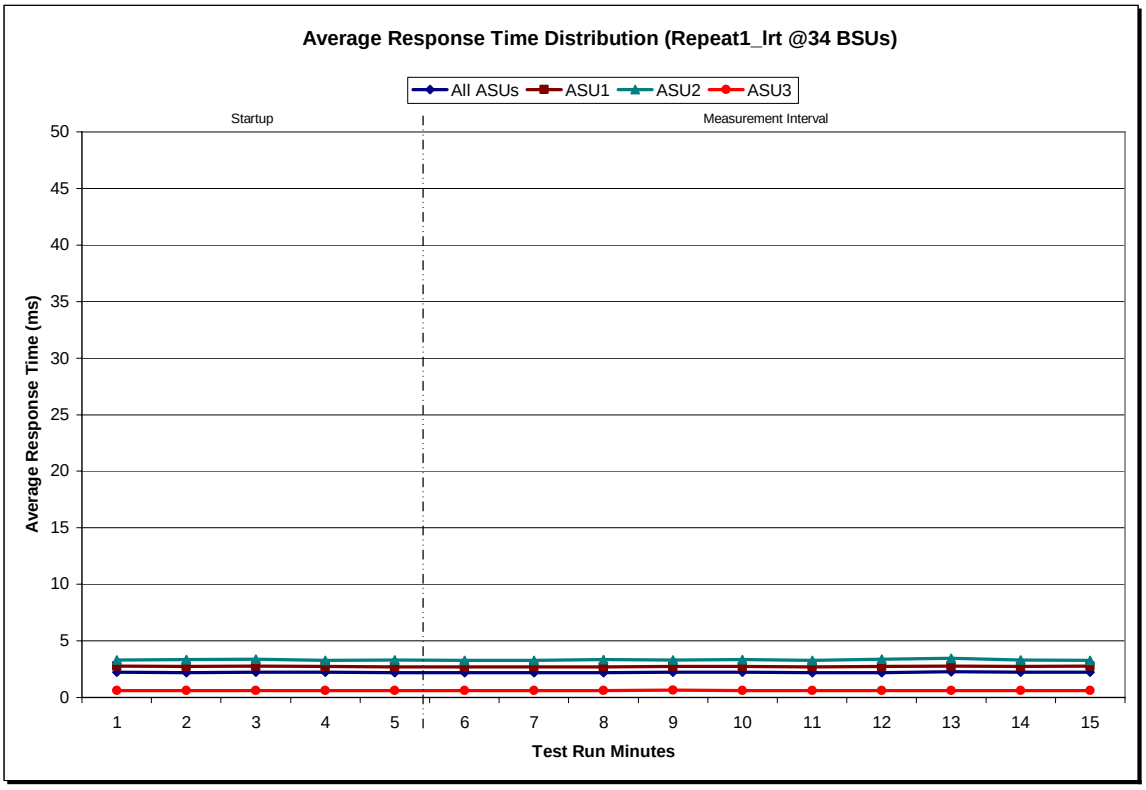
Repeatability 1 LRT – I/O Request Throughput Distribution Graph



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

34 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:42:22	17:47:22	0-4	0:05:00
Measurement Interval	17:47:22	17:57:22	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	2.23	2.76	3.31	0.61
1	2.21	2.72	3.36	0.60
2	2.24	2.76	3.39	0.61
3	2.21	2.74	3.29	0.63
4	2.19	2.70	3.32	0.61
5	2.18	2.69	3.29	0.61
6	2.19	2.72	3.29	0.61
7	2.20	2.70	3.35	0.62
8	2.22	2.73	3.30	0.63
9	2.22	2.74	3.35	0.61
10	2.20	2.71	3.28	0.60
11	2.21	2.72	3.37	0.62
12	2.26	2.77	3.47	0.62
13	2.23	2.75	3.31	0.63
14	2.22	2.76	3.27	0.61
Average	2.21	2.73	3.33	0.61

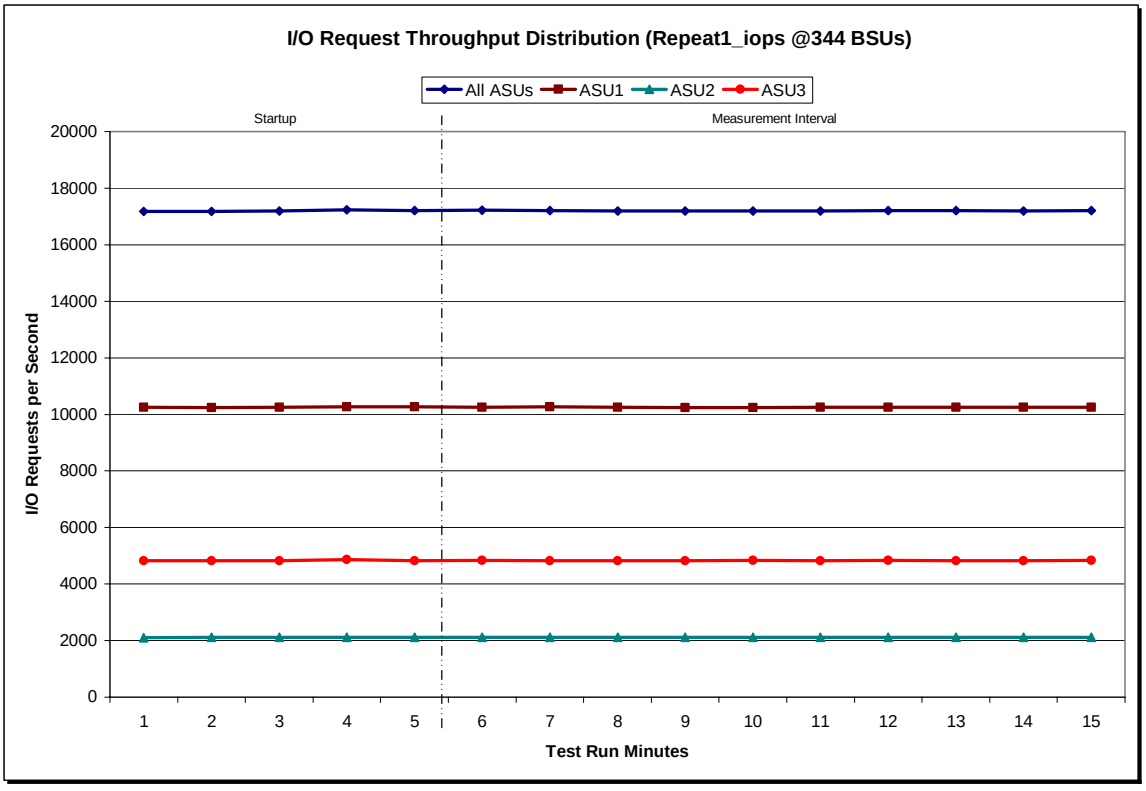
Repeatability 1 LRT –Average Response Time (ms) Distribution Graph



Repeatability 1 IOPS – I/O Request Throughput Distribution Data

344 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:57:27	18:02:28	0-4	0:05:01
Measurement Interval	18:02:28	18:12:28	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	17,181.93	10,246.22	2,107.18	4,828.53
1	17,171.65	10,231.58	2,112.83	4,827.23
2	17,199.35	10,259.08	2,115.87	4,824.40
3	17,241.80	10,262.48	2,114.22	4,865.10
4	17,206.85	10,262.70	2,113.43	4,830.72
5	17,215.93	10,257.82	2,123.28	4,834.83
6	17,209.80	10,269.70	2,117.98	4,822.12
7	17,197.08	10,257.00	2,109.90	4,830.18
8	17,185.68	10,236.45	2,118.60	4,830.63
9	17,194.78	10,236.52	2,117.30	4,840.97
10	17,195.57	10,251.68	2,116.48	4,827.40
11	17,200.22	10,252.13	2,114.97	4,833.12
12	17,201.02	10,255.70	2,118.80	4,826.52
13	17,192.08	10,250.78	2,117.70	4,823.60
14	17,209.97	10,250.73	2,121.15	4,838.08
Average	17,200.21	10,251.85	2,117.62	4,830.75

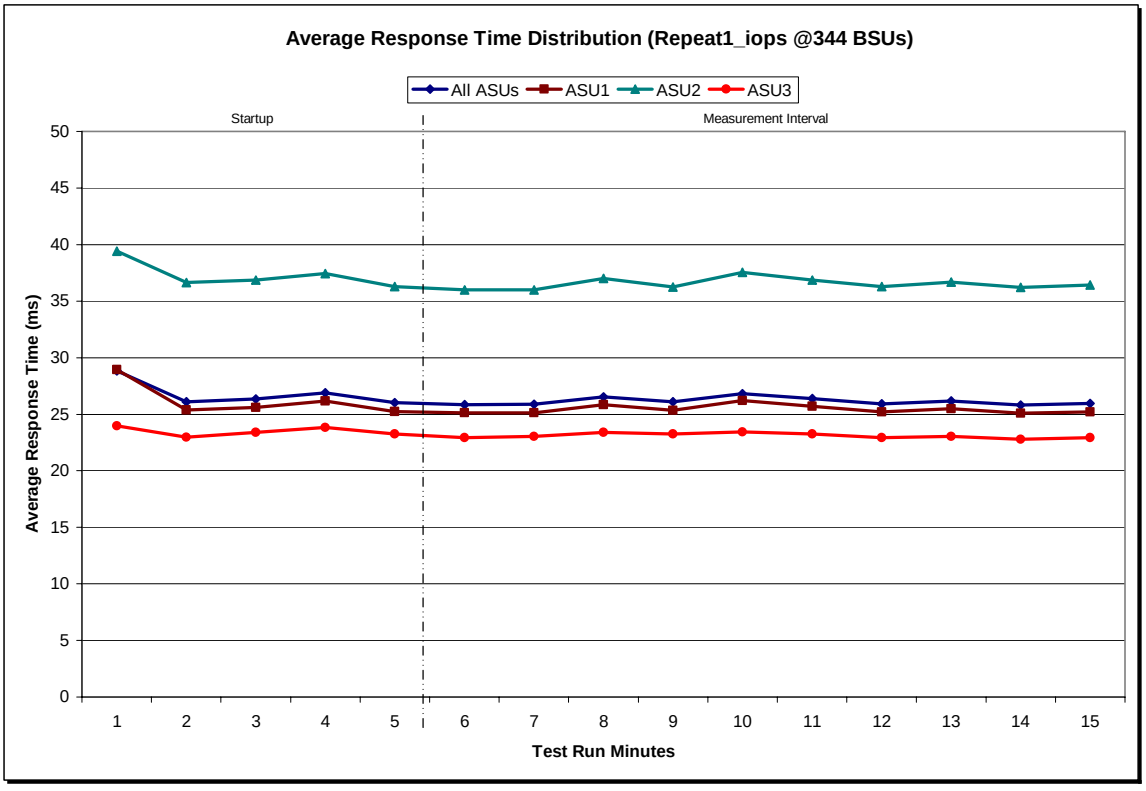
Repeatability 1 IOPS – I/O Request Throughput Distribution Graph



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

344 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:57:27	18:02:28	0-4	0:05:01
Measurement Interval	18:02:28	18:12:28	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	28.84	28.94	39.43	23.99
1	26.09	25.38	36.66	22.97
2	26.36	25.59	36.88	23.39
3	26.89	26.16	37.45	23.84
4	26.04	25.24	36.28	23.25
5	25.85	25.13	35.99	22.91
6	25.89	25.14	36.00	23.05
7	26.53	25.84	37.02	23.41
8	26.09	25.33	36.25	23.25
9	26.81	26.19	37.53	23.43
10	26.38	25.70	36.87	23.24
11	25.91	25.19	36.27	22.92
12	26.18	25.50	36.67	23.02
13	25.82	25.09	36.22	22.78
14	25.94	25.19	36.43	22.94
Average	26.14	25.43	36.52	23.10

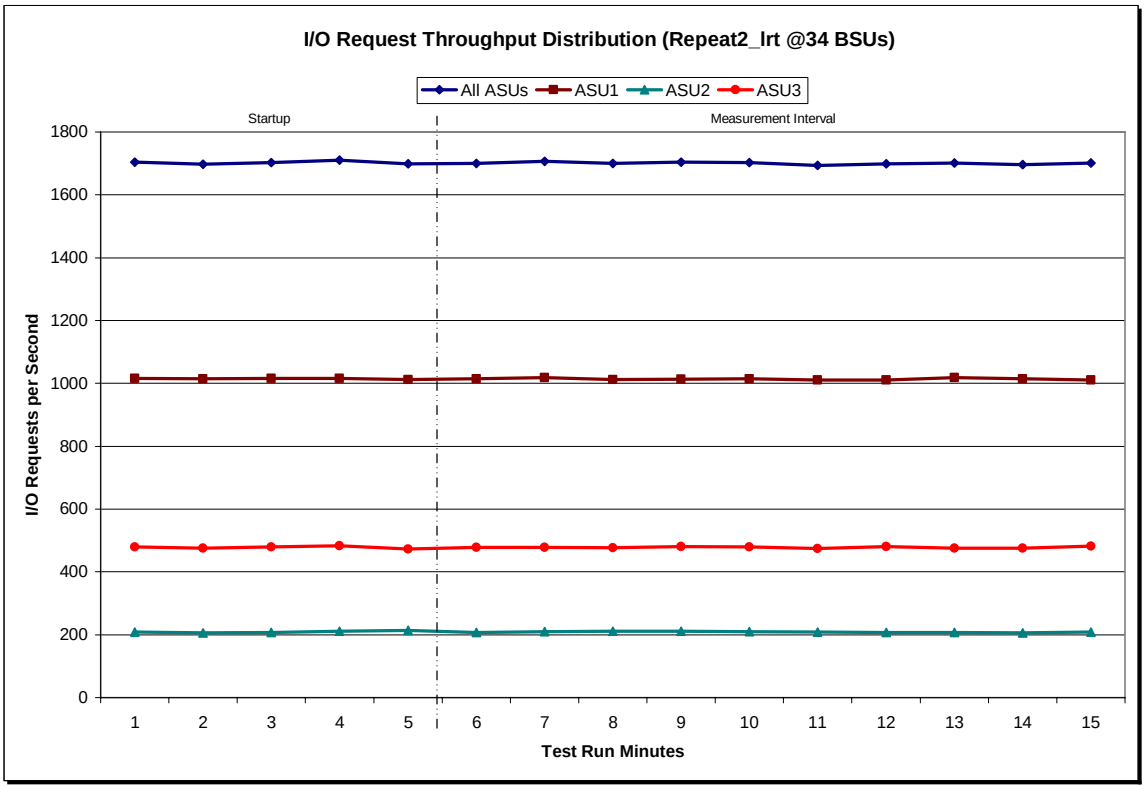
Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph



Repeatability 2 LRT – I/O Request Throughput Distribution Data

34 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:12:36	18:17:36	0-4	0:05:00
Measurement Interval	18:17:36	18:27:36	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	1,704.23	1,015.92	208.33	479.98
1	1,697.03	1,015.12	206.58	475.33
2	1,702.77	1,015.42	207.42	479.93
3	1,710.97	1,016.58	210.90	483.48
4	1,699.00	1,012.17	213.57	473.27
5	1,700.40	1,014.95	206.70	478.75
6	1,706.22	1,018.23	210.25	477.73
7	1,700.35	1,012.13	211.12	477.10
8	1,704.10	1,013.03	210.82	480.25
9	1,703.45	1,014.37	209.88	479.20
10	1,693.58	1,010.47	208.28	474.83
11	1,698.40	1,010.32	207.45	480.63
12	1,701.87	1,019.02	207.30	475.55
13	1,696.57	1,014.50	206.43	475.63
14	1,701.27	1,011.27	208.33	481.67
Average	1,700.62	1,013.83	208.66	478.14

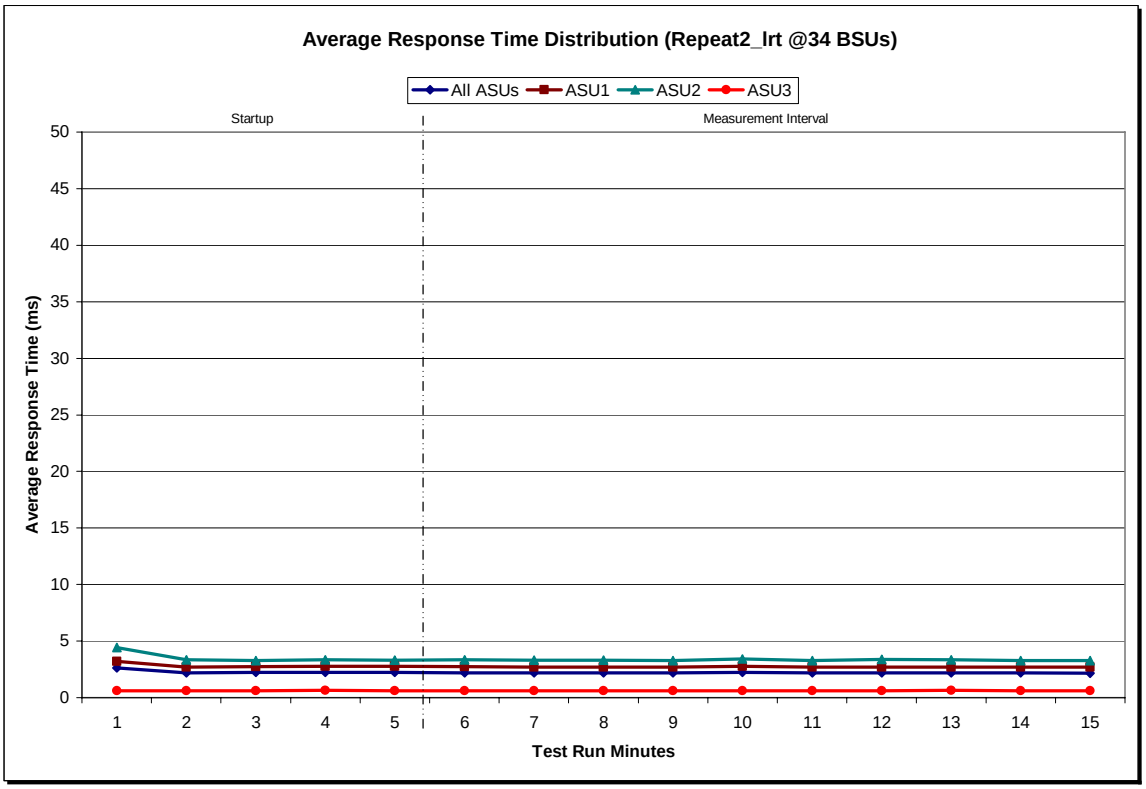
Repeatability 2 LRT – I/O Request Throughput Distribution Graph



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

34 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:12:36	18:17:36	0-4	0:05:00
Measurement Interval	18:17:36	18:27:36	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	2.62	3.19	4.42	0.62
1	2.20	2.71	3.36	0.60
2	2.22	2.75	3.29	0.63
3	2.24	2.77	3.36	0.64
4	2.23	2.76	3.31	0.61
5	2.21	2.73	3.33	0.62
6	2.20	2.71	3.31	0.62
7	2.19	2.69	3.30	0.61
8	2.18	2.70	3.27	0.62
9	2.24	2.77	3.41	0.62
10	2.19	2.69	3.28	0.63
11	2.20	2.71	3.38	0.62
12	2.21	2.71	3.36	0.63
13	2.19	2.71	3.26	0.61
14	2.17	2.69	3.29	0.61
Average	2.20	2.71	3.32	0.62

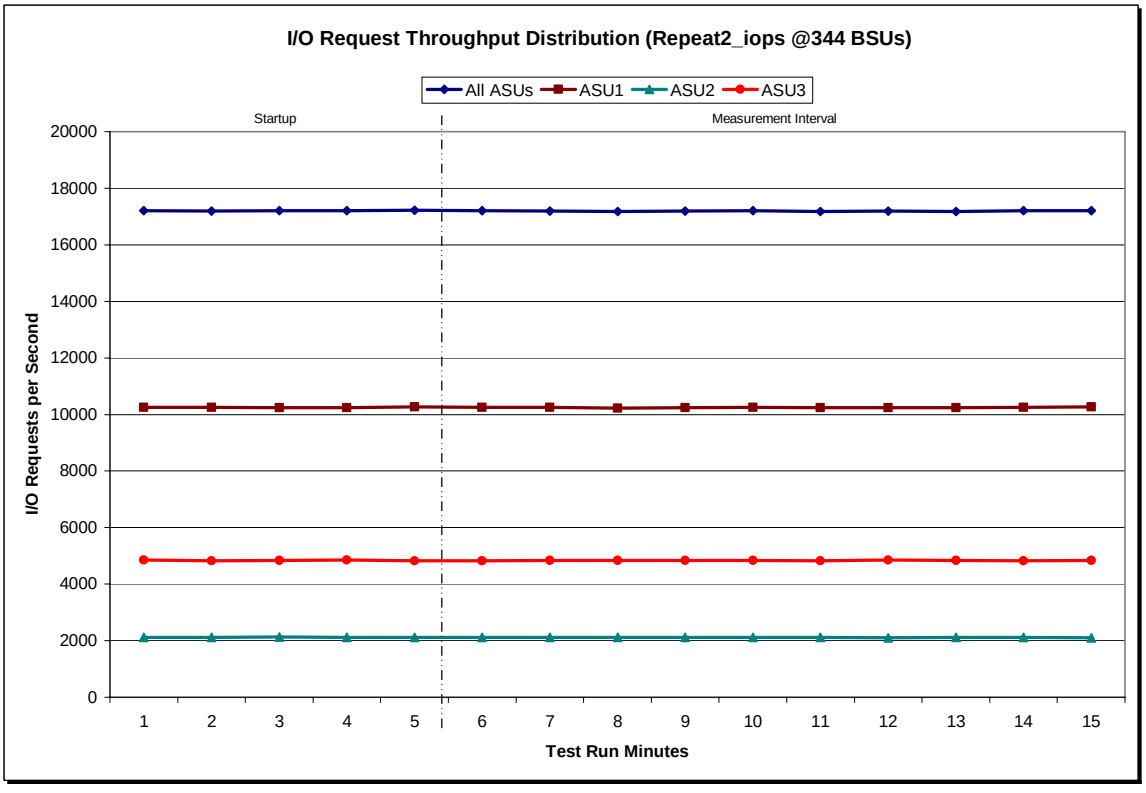
Repeatability 2 LRT –Average Response Time (ms) Distribution Graph



Repeatability 2 IOPS – I/O Request Throughput Distribution Data

344 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:27:41	18:32:42	0-4	0:05:01
Measurement Interval	18:32:42	18:42:42	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	17,208.77	10,249.13	2,112.17	4,847.47
1	17,195.63	10,250.58	2,116.10	4,828.95
2	17,202.50	10,239.78	2,124.53	4,838.18
3	17,209.80	10,231.78	2,118.43	4,859.58
4	17,215.43	10,272.03	2,114.52	4,828.88
5	17,203.98	10,258.77	2,114.90	4,830.32
6	17,198.87	10,251.95	2,111.52	4,835.40
7	17,179.97	10,220.43	2,115.73	4,843.80
8	17,198.53	10,235.95	2,120.57	4,842.02
9	17,207.33	10,248.58	2,120.47	4,838.28
10	17,182.48	10,235.68	2,117.42	4,829.38
11	17,198.83	10,242.42	2,107.13	4,849.28
12	17,176.13	10,231.40	2,112.70	4,832.03
13	17,205.35	10,257.97	2,120.13	4,827.25
14	17,200.27	10,262.10	2,104.30	4,833.87
Average	17,195.18	10,244.53	2,114.49	4,836.16

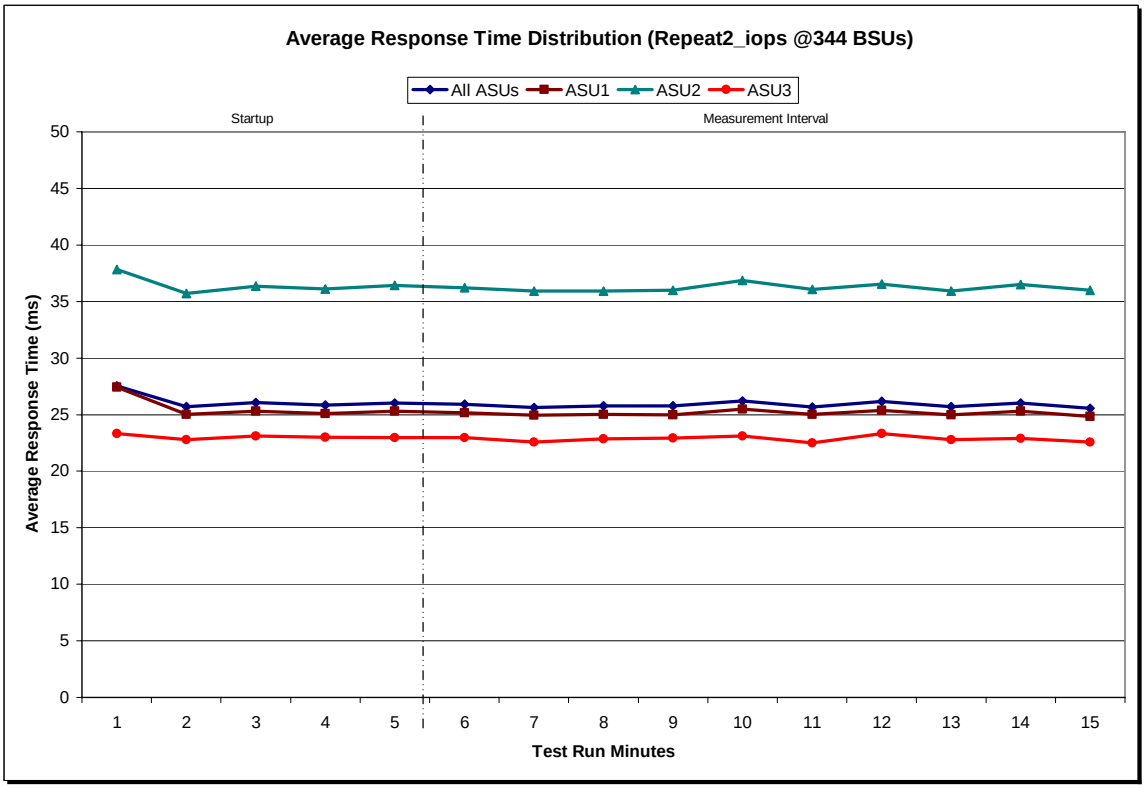
Repeatability 2 IOPS – I/O Request Throughput Distribution Graph



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

344 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:27:41	18:32:42	0-4	0:05:01
Measurement Interval	18:32:42	18:42:42	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	27.55	27.43	37.82	23.33
1	25.71	25.03	35.72	22.77
2	26.06	25.31	36.37	23.10
3	25.86	25.10	36.12	22.99
4	26.02	25.32	36.42	22.96
5	25.91	25.17	36.20	22.96
6	25.61	24.93	35.93	22.56
7	25.76	25.03	35.92	22.86
8	25.76	24.98	36.00	22.93
9	26.21	25.47	36.87	23.12
10	25.67	25.01	36.07	22.51
11	26.17	25.39	36.53	23.31
12	25.71	24.99	35.92	22.79
13	26.01	25.31	36.50	22.91
14	25.57	24.85	35.98	22.57
Average	25.84	25.11	36.19	22.85

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



Repeatability 1 (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	0.0353	0.2813	0.0701	0.2101	0.0179	0.0699	0.0347	0.2806
COV	0.017	0.006	0.014	0.006	0.031	0.007	0.015	0.005

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.*

Repeatability 1 (IOPS)
Measured Intensity Multiplier and Coefficient of Variation

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2810	0.0701	0.2099	0.0179	0.0701	0.0351	0.2809
COV	0.005	0.002	0.002	0.002	0.008	0.003	0.005	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	0.0352	0.2809	0.0703	0.2098	0.0179	0.0696	0.0352	0.2812
COV	0.011	0.004	0.007	0.006	0.022	0.012	0.022	0.004

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2811	0.0700	0.2098	0.0180	0.0700	0.0350	0.2813
COV	0.004	0.002	0.003	0.003	0.007	0.004	0.005	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 Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 69.

Data Persistence Test Results File

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

Persistence 1 Test Results File

Persistence 2 Test Results File

Data Persistence Test Results

Data Persistence Test Results	
Data Persistence Test Run Number: 1	
Total Number of Logical Blocks Written	36,211,776
Total Number of Logical Blocks Verified	33,437,056
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 IBM System Storage DS4700 Express Model, as documented in this Full Disclosure Report is currently available for customer purchase and shipment.

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 13. 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 13.

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 IBM System Storage DS4700 *Express Model*.

APPENDIX A: SPC-1 GLOSSARY

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

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

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

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

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

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

SPC-1 Data Repository Definitions

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

Application Storage Unit (ASU): The logical interface between the storage and SPC-1 Workload Generator. The three ASUs (Data, User, and Log) are typically implemented on one or more Logical Volume.

Logical Volume: The division of Addressable Storage Capacity into individually addressable logical units of storage used in the SPC-1 benchmark. Each Logical Volume is implemented as a single, contiguous address space.

Addressable Storage Capacity: The total storage (sum of Logical Volumes) that can be read and written by application programs such as the SPC-1 Workload Generator.

Configured Storage Capacity: This capacity includes the Addressable Storage Capacity and any other storage (parity disks, hot spares, etc.) necessary to implement the Addressable Storage Capacity.

Physical Storage Capacity: The formatted capacity of all storage devices physically present in the Tested Storage Configuration (TSC).

Data Protection Overhead: The storage capacity required to implement the selected level of data protection.

Required Storage: The amount of Configured Storage Capacity required to implement the Addressable Storage Configuration, excluding the storage required for the three ASUs.

Global Storage Overhead: The amount of Physical Storage Capacity that is required for storage subsystem use and unavailable for use by application programs.

Total Unused Storage: The amount of storage capacity available for use by application programs but not included in the Total ASU Capacity.

SPC-1 Data Protection Levels

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.

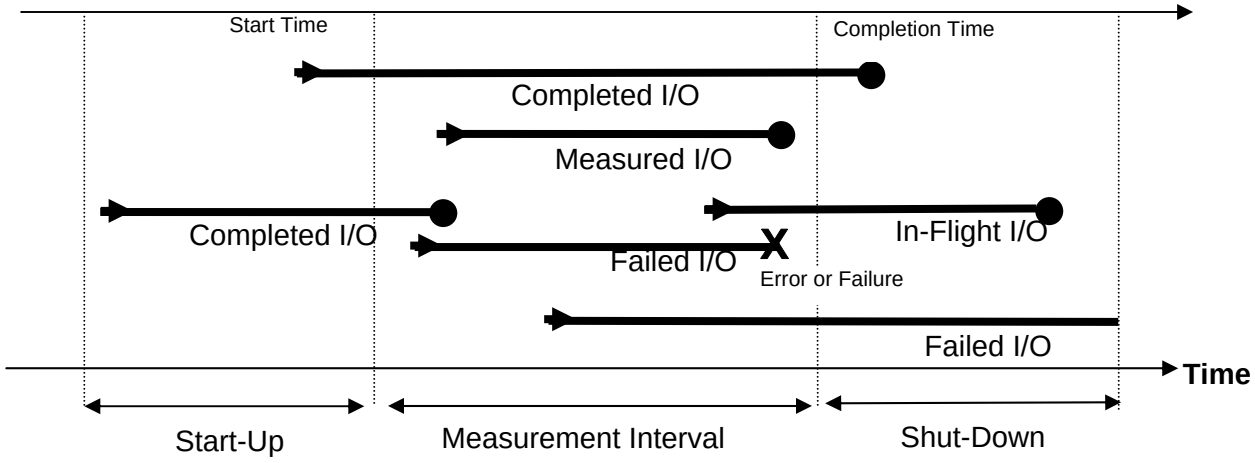
Test: A collection of Test Phases and or Test Runs sharing a common objective.

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

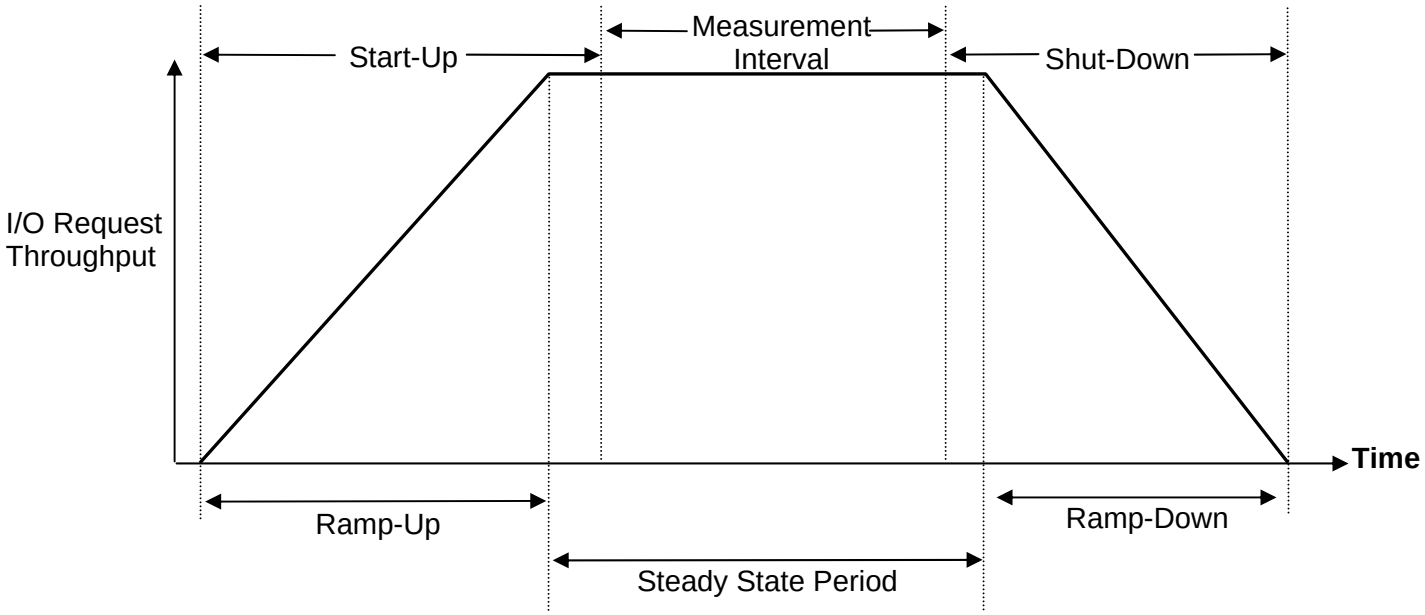
period, Shut-Down period, and Ramp-Down period as illustrated in the "SPC-1 Test Run Components" below. All SPC-1 Test Runs shall have a Steady State period and a Measurement Interval.

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

Windows 2003 Registry Changes

```
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\
ql2300\Device\MaximumSGList=0xff
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\
ql2300\Device\NumberOfRequests=0xfe
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\
Disk\TimeOutValue=0x78
HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\
ql2300\Device\DriverParameters=UseSameNN=1
```

Automatic Cache Read Ahead

ReadAheadMultiplier: changed from default of 1(on) to new value of 0(off)

Storage Array Cache Block Size

Cache Block Size: changed from default of 4K to new value of 16K

RDAC Failover Options

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

Host Bus Adapter Options

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

Host Bus Adapter Settings		
Item	**Default**	**New Value**
Adapter Settings:		
Loop Reset Delay	5	8
Apapter Hard Loop ID	Disabled	Enabled
Hard Loop ID (unique for each)	0	eg. 22
Fibre Channel Tape Support	Enabled	Disabled
Advanced Adapter Settings:		
Execution Throttle	16	256
LUNs per Target	8	0
Login Retry Count	8	30
Port Down Retry Count	8	70
Link Down Timeout	30	60

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

The storage management utility, **SANtricity**, was used to create eight volume groups on the storage subsystem, each volume group contains a RAID1 (mirrored) volume. The eight RAID1 volumes are visible by each of the attached hosts. The **SANtricity** script, **"3994_8_4plus4.script"**, is listed below.

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

1. Run the attached script "doSPC.bat", which performs the following steps.
    - Use diskpar.exe to set the starting offset for each of the storage system volumes.
    - Starting offset is 65536. Use all of the remaining capacity in the partition.
    - Convert all of the storage system volumes to Dynamic Disks using the **"convertDynamic.script"**.
    - The following step are done using the **"createVolumes.script"**.
        - Create a Windows Striped (RAID 0) volume using all eight 32MB volumes.
        - Delete the large volume on each of the Dynamic Disks.
        - Create a Windows Striped (RAID 0) volume for ASU 3.
            - Select all eight volumes.
            - Set capacity to 23404MB.
            - Assign drive letter "N" to the volume. Do not format the volume.
        - Create the Windows Striped (RAID0) volume for ASU 1.
            - Select all eight volumes.
            - Set capacity to 105318MB.
            - Assign drive letter "L" to the volume. Do not format the volume.
        - Create the Windows Striped (RAID 0) volume for ASU 2.
            - Select all eight volumes.
            - Set capacity to 105318MB.
            - Assign drive letter "M" to the volume. Do not format the volume.
2. Reboot the two Host Systems.
3. After reboot completes, start Disk Administrator on each of the two Host Systems.
4. Import foreign disks, or reactivate the Windows stripe sets as necessary. On the second Host System, assign drive letters to the stripe sets as they were assigned in the script above.

All of the scripts and related parameter files are listed below.

"3994_8_4plus4.script"

```
set controller[a] mode=active;
set controller[b] mode=active;
```

```
create volume drives[ 10,1 10,2 10,3 10,4 10,5 10,6 10,7 10,8 ]
RAIDLevel=1
segmentSize=512
userLabel="LUN_0"
capacity=256gb
owner=A;

create volume drives[ 10,9 10,10 10,11 10,12 10,13 10,14 10,15 10,16 ]
RAIDLevel=1
segmentSize=512
userLabel="LUN_1"
capacity=256gb
owner=A;

create volume drives[ 11,1 11,2 11,3 11,4 11,5 11,6 11,7 11,8 ]
RAIDLevel=1
segmentSize=512
userLabel="LUN_2"
capacity=256gb
owner=A;

create volume drives[ 11,9 11,10 11,11 11,12 11,13 11,14 11,15 11,16 ]
RAIDLevel=1
segmentSize=512
userLabel="LUN_3"
capacity=256gb
owner=A;

create volume drives[ 20,1 20,2 20,3 20,4 20,5 20,6 20,7 20,8 ]
RAIDLevel=1
segmentSize=512
userLabel="LUN_4"
capacity=256gb
owner=B;

create volume drives[ 20,9 20,10 20,11 20,12 20,13 20,14 20,15 20,16 ]
RAIDLevel=1
segmentSize=512
userLabel="LUN_5"
capacity=256gb
owner=B;

create volume drives[ 21,1 21,2 21,3 21,4 21,5 21,6 21,7 21,8 ]
RAIDLevel=1
segmentSize=512
userLabel="LUN_6"
capacity=256gb
owner=B;

create volume drives[ 21,9 21,10 21,11 21,12 21,13 21,14 21,15 21,16 ]
RAIDLevel=1
segmentSize=512
userLabel="LUN_7"
capacity=256gb
owner=B;
```

```
set volume["LUN_0"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = False readAheadMultiplier = 0;
set volume["LUN_1"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = False readAheadMultiplier = 0;
set volume["LUN_2"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = False readAheadMultiplier = 0;
set volume["LUN_3"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = False readAheadMultiplier = 0;
set volume["LUN_4"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = False readAheadMultiplier = 0;
set volume["LUN_5"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = False readAheadMultiplier = 0;
set volume["LUN_6"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = False readAheadMultiplier = 0;
set volume["LUN_7"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = False readAheadMultiplier = 0;



set storageArray cacheFlushStop=80 cacheFlushStart=80 cacheBlockSize=16;

set storageArray defaultHostType="Windows 2000/Server 2003 Non-Clustered";

set controller[a] HostNVSRAMByte[0x01, 0x17]=0x01;
set controller[b] HostNVSRAMByte[0x01, 0x17]=0x01;

/* Setup for RDAC failover environment */

set controller[a] HostNVSRAMByte[0x00, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x01, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x02, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x03, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x04, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x05, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x06, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x07, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x08, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x09, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x0a, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x0b, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x0c, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x0d, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x0e, 0x24]=0x00;
set controller[a] HostNVSRAMByte[0x0f, 0x24]=0x00;

set controller[b] HostNVSRAMByte[0x00, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x01, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x02, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x03, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x04, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x05, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x06, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x07, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x08, 0x24]=0x00;
```

```
set controller[b] HostNVSRAMByte[0x09, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x0a, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x0b, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x0c, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x0d, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x0e, 0x24]=0x00;
set controller[b] HostNVSRAMByte[0x0f, 0x24]=0x00;
```

"**doSPC.bat**"

```
@echo ********************************************************
@echo * Warning make sure your boot device is PhysicalDrive 0 *
@echo *                                                       *
@echo * diskpar is now a part of this script                  *
@echo ********************************************************
timeout /t 60

@rem diskpar.bat
c:\bench\diskpar.exe -s 1 < diskpar.txt
c:\bench\diskpar.exe -s 2 < diskpar.txt
c:\bench\diskpar.exe -s 3 < diskpar.txt
c:\bench\diskpar.exe -s 4 < diskpar.txt
c:\bench\diskpar.exe -s 5 < diskpar.txt
c:\bench\diskpar.exe -s 6 < diskpar.txt
c:\bench\diskpar.exe -s 7 < diskpar.txt
c:\bench\diskpar.exe -s 8 < diskpar.txt


timeout /t 15 /NOBREAK
diskpart /s convertDynamic.script
timeout /t 15 /NOBREAK
diskpart /s createVolumes.script
```

"**diskpart.txt**"

```
y
y
65536
262106
```

"**convertDynamic.script**"

```
select disk 1
convert dynamic noerr
select disk 2
convert dynamic noerr
select disk 3
convert dynamic noerr
select disk 4
convert dynamic noerr
select disk 5
convert dynamic noerr
select disk 6
convert dynamic noerr
select disk 7
```

```
convert dynamic noerr
select disk 8
convert dynamic noerr
```

"**createVolumes.script**"

```
create volume stripe disk=1,2,3,4,5,6,7,8

list volume

select volume 0
delete volume noerr
select volume 1
delete volume noerr
select volume 2
delete volume noerr
select volume 3
delete volume noerr
select volume 4
delete volume noerr
select volume 5
delete volume noerr
select volume 6
delete volume noerr
select volume 7
delete volume noerr


create volume stripe size=23404 disk=1,2,3,4,5,6,7,8
assign letter=N
create volume stripe size=105318 disk=1,2,3,4,5,6,7,8
assign letter=L
create volume stripe size=105318 disk=1,2,3,4,5,6,7,8
assign letter=M
```

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

The contents of the SPC-1 Workload Generator command and parameter files used for the Primary Metrics and Repeatability Tests are listed below. Immediately following those files is the SPC-1 Workload Generator command and parameter file used for the Persistence Test.

Host System 1– Master JVM

```
* spc1_metrics.cfg

host=master
slaves=(bm2850d_s1,bm2850d_s2,bm2850d_s3,bm2850c_s1,bm2850c_s2,bm2850c_s3)

javaparms="-Xmx512m -Xms512m"

*64 73 Gb Drives
sd=asu1_1,lun=\\.\L:,size=883471417344
sd=asu2_1,lun=\\.\M:,size=883471417344
sd=asu3_1,lun=\\.\N:,size=196326981632

eof
```

Host System 1– Slave 1 JVM

```
*slave1.parm

host=bm2850d_s1
master=bm2850d

*64 73 Gb Drives
sd=asu1_1,lun=\\.\L:,size=883471417344
sd=asu2_1,lun=\\.\M:,size=883471417344
sd=asu3_1,lun=\\.\N:,size=196326981632

eof
```

Host System 1– Slave 2 JVM

```
*slave2.parm

host=bm2850d_s2
master=bm2850d

*64 73 Gb Drives
sd=asu1_1,lun=\\.\L:,size=883471417344
sd=asu2_1,lun=\\.\M:,size=883471417344
sd=asu3_1,lun=\\.\N:,size=196326981632

eof
```

Host System 1– Slave 3 JVM

```
*slave3.parm

host=bm2850d_s3
master=bm2850d

*64 73 Gb Drives
sd=asu1_1,lun=\\.\L:,size=883471417344
sd=asu2_1,lun=\\.\M:,size=883471417344
sd=asu3_1,lun=\\.\N:,size=196326981632

eof
```

Host System 2– Slave 1 JVM

```
*slave1.parm

host=bm2850c_s1
master=bm2850d

*64 73 Gb Drives
sd=asu1_1,lun=\\.\L:,size=883471417344
sd=asu2_1,lun=\\.\M:,size=883471417344
sd=asu3_1,lun=\\.\N:,size=196326981632

eof
```

Host System 2– Slave 2 JVM

```
*slave2.parm

host=bm2850c_s2
master=bm2850d

*64 73 Gb Drives
sd=asu1_1,lun=\\.\L:,size=883471417344
sd=asu2_1,lun=\\.\M:,size=883471417344
sd=asu3_1,lun=\\.\N:,size=196326981632

eof
```

Host System 2– Slave 3 JVM

```
*slave3.parm

host=bm2850c_s3
master=bm2850d

*64 73 Gb Drives
sd=asu1_1,lun=\\.\L:,size=883471417344
sd=asu2_1,lun=\\.\M:,size=883471417344
sd=asu3_1,lun=\\.\N:,size=196326981632

eof
```

Persistence Test *(1 Host System, 1 JVM)*

```
* spc1_persist.cfg

javaparms="-Xmx512m -Xms512m"

*64 73 Gb Drives
sd=asu1_1,lun=\\.\L:,size=883471417344
sd=asu2_1,lun=\\.\M:,size=883471417344
sd=asu3_1,lun=\\.\N:,size=196326981632

eof
```

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

The **run.spc1.cmd** command file was used to execute the required SPC-1 Primary Metrics and Repeatability Tests as well as Persistence Test Run 1.

"run.spc1.cmd"

```
copy spc1_metrics.cfg spc1.cfg

java -Xmx512m -Xms512m metrics -b 344 -s 300

java -Xmx512m -Xms512m repeat1 -b 344 -s 300

java -Xmx512m -Xms512m repeat2 -b 344 -s 300

copy spc1_persist.cfg spc1.cfg

java -Xmx512m -Xms512m persist1 -b 344
```

The **persist.cmd** command file was used to execute Persistence Test Run 2.

"persist.cmd" – Persistence Test Run 2

```
java -Xmx512m -Xms512m persist2
```