SPC BENCHMARK 1™
FULL DISCLOSURE REPORT

IBM CORPORATION
IBM SYSTEM STORAGE DS5300 (FDE)

SPC-1 V1.10.1

Submitted for Review: July 14, 2009
Submission Identifier: A00080
Revised: March 8, 2010

First Edition – July 2009

Trademarks

SPC Benchmark-1, SPC-1, SPC-1 IOPS, and SPC-1 LRT are trademarks of the Storage Performance Council. IBM, the IBM logo, and System Storage are trademarks of IBM Corporation in the United States and other countries. All other brands, trademarks, and product names are the property of their respective owners.

Table of Contents

AUDIT CERTIFICATION

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

July 13, 2009

The SPC Benchmark 1™ results listed below for the IBM System Storage DS5300 *(FDE)* were produced in compliance with the SPC Benchmark 1™ V1.10.1 Remote Audit requirements.

SPC Benchmark 1™ V1.10.1 Results	
Tested Storage Configuration (TSC) Name: IBM System Storage DS5300 *(FDE)*	
Metric	**Reported Result**
SPC-1 IOPS™	62,243.63
SPC-1 Price-Performance	$11.76/SPC-1 IOPS™
Total ASU Capacity	13,742.218 GB
Data Protection Level	Mirroring
Total TSC Price (including three-year maintenance)	$732,170

The following SPC Benchmark 1™ Remote Audit requirements were reviewed and found compliant with V1.10.1 of the SPC Benchmark 1™ specification:

- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository storage items, based on information supplied by 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).
- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters that were changed from default values.

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

AUDIT CERTIFICATION *(CONT.)*

IBM System Storage DS5300
SPC-1 Audit Certification

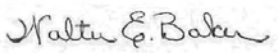
Page 2

- SPC-1 Workload Generator commands and parameters used for the audited SPC Test Runs.
- The following Host System requirements, based on information supplied by IBM Corporation:
  - ✓ The type of Host System including the number of processors and main memory.
  - ✓ The presence and version number of the SPC-1 Workload Generator on each Host System.
  - ✓ The TSC boundary within each Host System.
- The Test Results Files and resultant Summary Results Files received from 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
- The differences between the Tested Storage Configuration (TSC) used for the benchmark and Priced Storage Configuration were documented and, if applied to the TSC, would not have an impact on the reported SPC-1 performance.
- The submitted pricing information met all of the requirements and constraints of Clause 8 of the SPC-1 Benchmark Specification.
- The Full Disclosure Report (FDR) met all of the requirements in Clause 9 of the SPC-1 Benchmark Specification.
- This successfully audited SPC measurement is not subject to an SPC Confidential Review.

Audit Notes:

There were no audit notes or exceptions.

Respectfully,



Walter E. Baker
SPC Auditor

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

LETTER OF GOOD FAITH

IBM

Vice President, Disk Systems

IBM Technology & Systems Group
294 Route 100, Somers, NY 10589-3216

Phone: 914-766-3010

February 25, 2009

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 DS5300

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 1.10.1 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,

Robert Cancilla
Vice President, Disk Systems

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary 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) 799-2009
Test Sponsor Alternate Contact	IBM Corporation – http://www.ibm.com Vernon Miller – millerv@us.ibm.com KBV/9062-2 9000 South Rita Road Tucson, AZ 85744 Phone: (520) 799-4849 FAX: (520) 799-2009
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	V1.10.1
SPC-1 Workload Generator revision number	V2.00.04a
Date Results were first used publicly	July 14, 2009
Date the FDR was submitted to the SPC	July 14, 2009
Date the revised FDR was submitted to the SPC Revised Total Price and SPC-1 Price-Performance *(highlighted in red, page 11)* Corrected TSC and Priced Storage Configuration differences (page 13) Revised pricing *(highlighted in red, page 13)*	March 8, 2010
Date the TSC is available for shipment to customers	August 21, 2009
Date the TSC completed audit certification	July 13, 2009

Tested Storage Product (TSP) Description

The System Storage DS5000 series disk system is IBM's midrange disk offering, specifically designed to meet the needs of midrange/departmental storage requirements, delivering high performance, advanced function, high availability, modular and scalable storage capacity, with SAN-attached 4 Gbps Fibre Channel (FC) connectivity, and support for RAID 0, 1, 3, 5, 6, and 10, with up to 256 TB physical storage capacity.

The DS5000 series represents the seventh-generation architecture within the midrange disk family. This SPC-1 submission is the first to demonstrate the active use of HDD–based encryption (FDE).

Summary of Results

SPC-1 Results	
Tested Storage Configuration (TSC) Name: IBM System Storage DS5300 (FDE)	
Metric	**Reported Result**
SPC-1 IOPS™	62,243.63
SPC-1 Price-Performance	$14.16/SPC-1 IOPS™
Total ASU Capacity	13,742.218 GB
Data Protection Level	Mirroring
Total TSC Price (including three-year maintenance)	$881,130

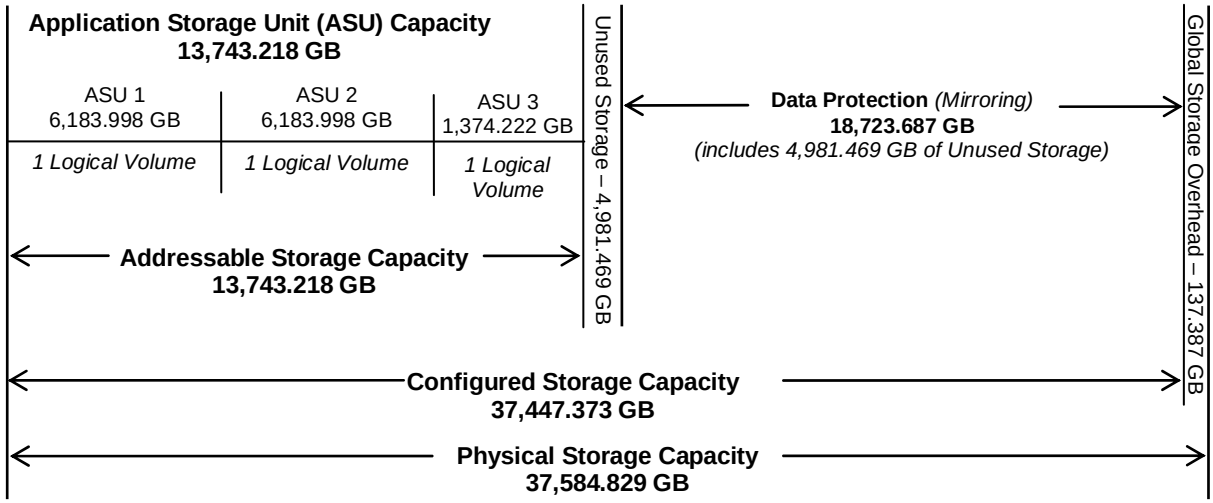
SPC-1 IOPS™ represents the maximum I/O Request Throughput at the 100% load point.

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

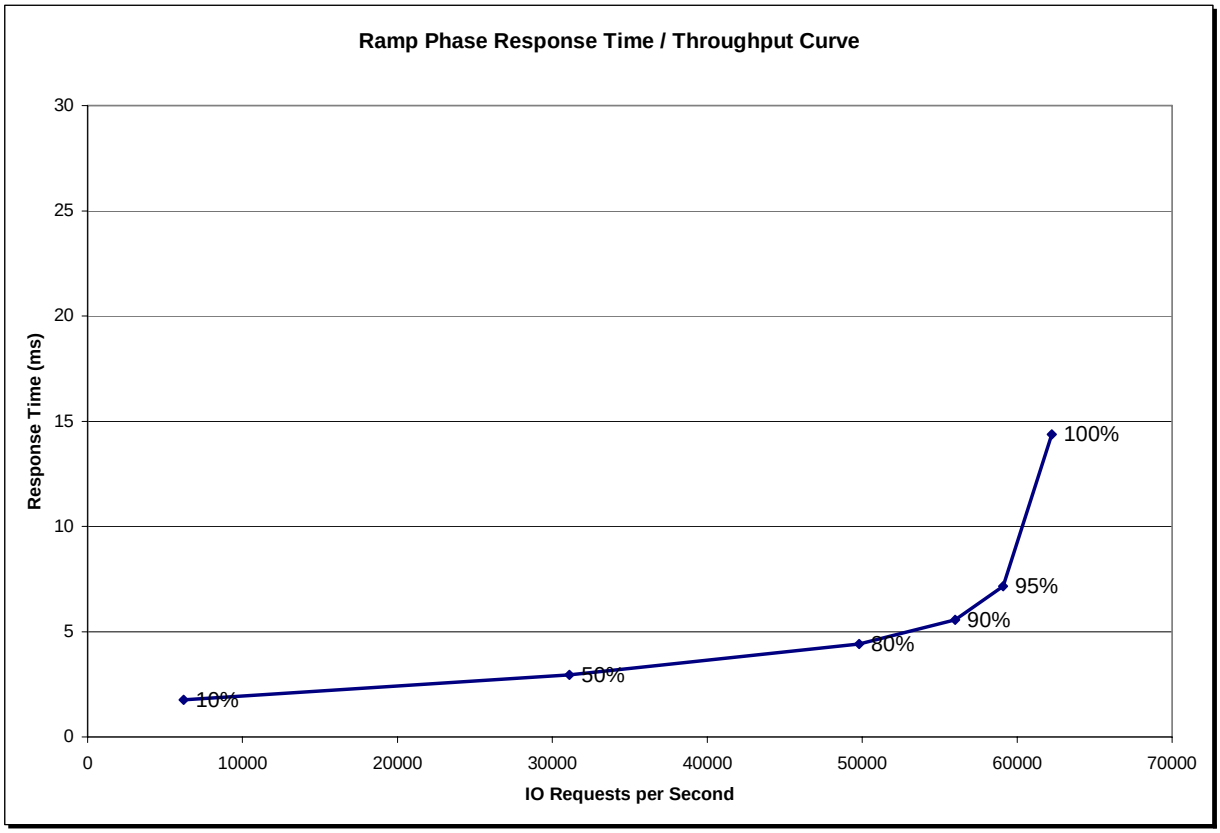
The following diagram documents the various storage capacities, used in this benchmark, and their relationships.



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	6,198.64	31,103.40	49,808.03	56,016.13	59,107.26	62,243.63
Average Response Time (ms):						
All ASUs	1.75	2.95	4.41	5.56	7.15	14.37
ASU-1	2.41	4.02	5.70	6.85	8.35	15.01
ASU-2	2.17	3.79	6.34	8.14	10.04	17.50
ASU-3	0.18	0.32	0.84	1.71	3.34	11.63
Reads	4.21	7.03	9.95	11.54	13.13	19.09
Writes	0.16	0.30	0.81	1.67	3.25	11.29

Tested Storage Configuration Pricing *(Priced Storage Configuration)*

Model Type / Feature		Description	List Price	QTY	Extended Price
1818-53A		DS5300 Dual Controller Disk System	$80,000	1	$80,000
1818-D1A		EXP5000 16 slot Expansion unit (incl 2 x 4 Gb SFPs)	$6,000	16	$96,000
	2031	8GB Cache Memory	$16,000	1	$16,000
	2052	Two Quad 8 Gbps FC Host Port Cards (each port includes SFP)	$15,000	2	$30,000
	2412	Short Wave 4Gbps SFP Transceiver Pair	$998	16	$15,968
	5605	5M LC-LC FIBER OPTIC CABLE	$129	48	$6,192
	7720	DS5000 WINDOWS HOST KIT	$1,250	1	$1,250
	8900	DS5000 8 STG PARTITION-IP0	$10,000	1	$10,000
	7358	Disk Encryption Activation	$25,000	1	$25,000
	5540	16-Pak 146.8 GB/15K DDM, FDE	$31,200	16	$499,200
39R6525		single port Qlogic PCIe - 8GbFC	$1,299	16	$20,784
			Total List		$800,394
		Std warranty 1 year 24x7x4hr response		incl	
		addtl 2 years 24x7x4			$80,736
			Grand Total		**$881,130**

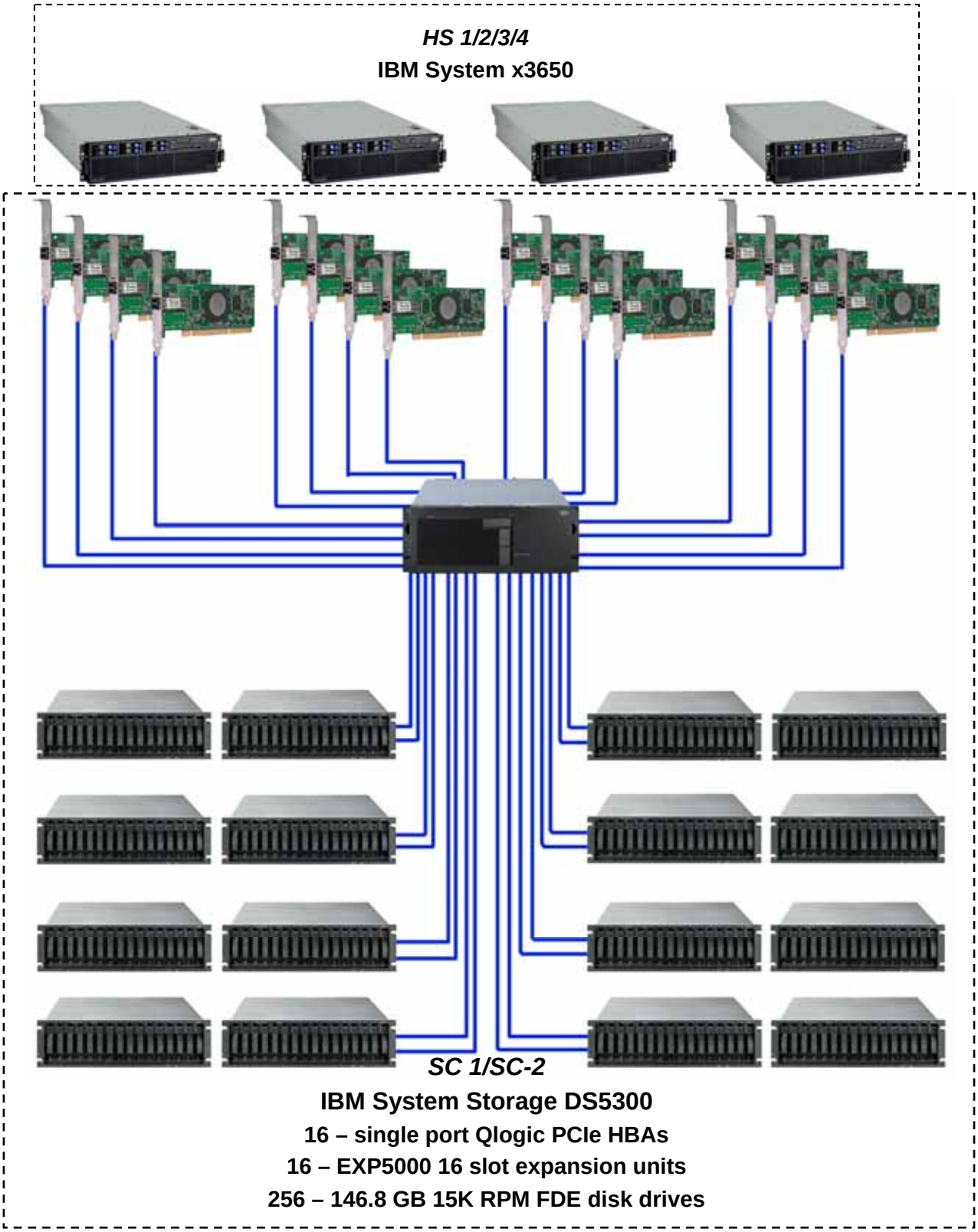
Differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration

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

- The priced disk drives are mounted in an IBM drive carrier and each disk drive is configured to self-identify as a DS5000 brand.
- The TSC was configured with 77 4Gbps SFPs, of which 64 were used. The Priced Storage Configuration included only the required 64 SFPs.

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

Benchmark Configuration/Tested Storage Configuration Diagram



Benchmark Configuration/Tested Storage Configuration Components

Host System:	Tested Storage Configuration (TSC):
HS-1/2/3/4: IBM System x3650	16 – single port Qlogic PCIe HBAs *(39R6525)*
Each Host System with:	**SC-1/SC-2: IBM System Storage DS5300** **2 – dual-active controllers with:** 8 GB cache total, 4 GB per controller 4 –Quad 8 Gbps FC Host Port Cards *(2 pair, includes 16 SFPs (8 Gbps))* 16 – 8 Gb Fibre Channel front-end connections 16 – 4 Gb Fibre Channel backend connection
2 – 3.00 GHz Dual Xeon Processors with 4 MB L2 cache	
5 GB main memory	
Windows Server 2003 Enterprise Edition 32-bit with SP2	
PCIe:	
WG	16 – 4 Gbps SFPs
	16 – EXP5000 16 slot expansion units *(each with 2 SFPs (4 Gbps))*
	256 – 146.8 GB 15K RPM FDE disk drives *(16 disk drives per expansion unit)*

In each of the following sections of this document, the appropriate Full Disclosure Report requirement, from the SPC-1 benchmark specification, is stated in italics followed by the information to fulfill the stated requirement.

CONFIGURATION INFORMATION

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

Clause 9.2.4.4.1

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), including the network configuration, is illustrated on page 14 *(Benchmark Configuration/Tested Storage Configuration Diagram).*

Host System Configuration

Clause 9.2.4.4.3

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

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

The details of the Host System configuration may be found on page 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)	13,742.218
Addressable Storage Capacity	Gigabytes (GB)	13,742.218
Configured Storage Capacity	Gigabytes (GB)	37,447.373
Physical Storage Capacity	Gigabytes (GB)	37,584.829
Data Protection *(Mirroring)*	Gigabytes (GB)	18,723.687
Required Storage	Gigabytes (GB)	0.000
Global Storage Overhead	Gigabytes (GB)	137.387
Total Unused Storage	Gigabytes (GB)	9,962.938

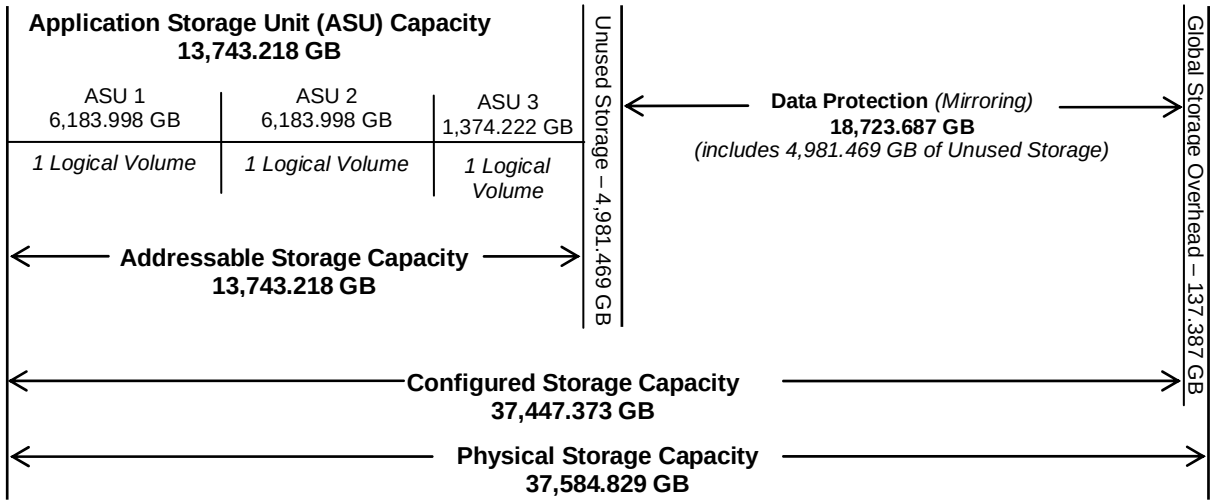
SPC-1 Storage Hierarchy Ratios

	Addressable Storage Capacity	**Configured Storage Capacity**	**Physical Storage Capacity**
Total ASU Capacity	100.00%	36.70%	36.56%
Required for Data Protection *(Mirrored)*		50.00%	49.82%
Addressable Storage Capacity		36.70%	36.56%
Required Storage		0.00%	0.00%
Configured Storage Capacity			99.63%
Global Storage Overhead			0.37%
Unused Storage:			
Addressable	0.00%		
Configured		26.71%	
Physical			0.00%

The Physical Storage Capacity consisted of 37,584.829 GB distributed over 256 disk drives each with a formatted capacity of 146.816 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 137.387 GB (0.37%) of Physical Storage Capacity. There was 9,962.938 GB (26.61%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 100% of the Addressable Storage Capacity resulting in 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 (6,183.998 GB)	**ASU-2 (6,183.998 GB)**	**ASU-3 (1,374.222 GB)**
1 Logical Volume 6,183.998 GB per Logical Volume (6,183.998 GB used per Logical Volume)	1 Logical Volume 6,183.998 GB per Logical Volume (6,183.998 GB used per Logical Volume)	1 Logical Volume 1,374.222 GB per Logical Volume (1,374.222 GB used per Logical Volume)

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

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 Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 67.

Sustainability Test Results File

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

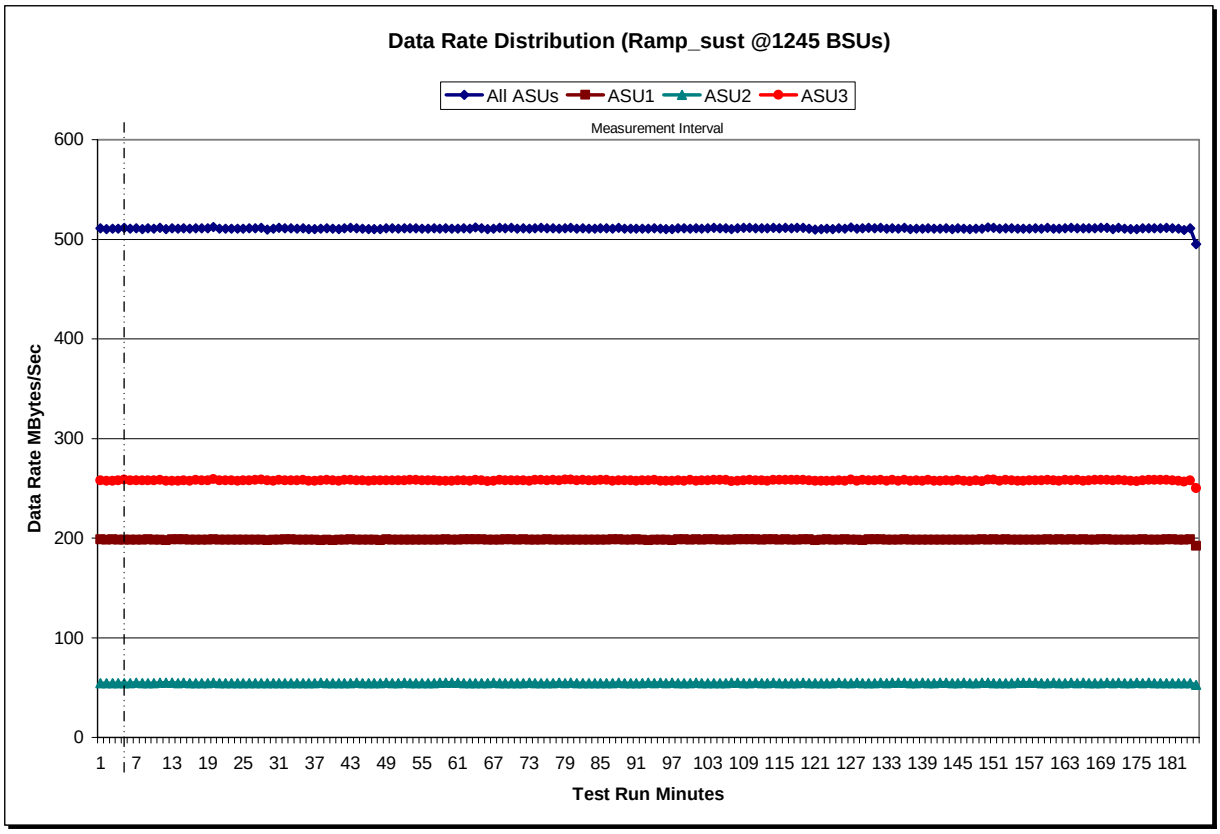
Sustainability Test Results File

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

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	9:05:20	9:10:20	0-4	0:05:00
Measurement Interval	9:10:20	12:10:20	4-184	3:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	511.11	198.65	54.58	257.87	63	511.68	198.79	54.56	258.33	126	511.77	198.49	54.50	258.78
1	510.26	198.18	54.57	257.50	64	510.94	198.75	54.34	257.85	127	510.71	198.38	54.70	257.63
2	510.77	198.78	54.44	257.55	65	510.00	198.40	54.48	257.13	128	510.86	197.97	54.51	258.38
3	510.78	198.21	54.48	258.09	66	510.62	198.30	54.74	257.58	129	511.27	198.81	54.58	257.88
4	511.59	198.44	54.58	258.57	67	511.26	198.22	54.59	258.45	130	511.15	198.70	54.58	257.86
5	510.79	198.15	54.56	258.08	68	510.95	198.56	54.60	257.80	131	511.38	198.59	54.65	258.14
6	510.95	198.47	54.66	257.82	69	511.30	198.60	54.63	258.07	132	510.55	198.44	54.47	257.64
7	510.28	198.09	54.41	257.78	70	510.39	198.30	54.33	257.76	133	511.21	198.37	54.65	258.18
8	511.17	198.62	54.54	258.02	71	511.08	198.69	54.57	257.82	134	510.64	198.36	54.71	257.56
9	510.75	198.45	54.58	257.72	72	510.59	198.26	54.72	257.61	135	511.52	198.67	54.66	258.20
10	511.25	198.34	54.79	258.13	73	511.23	198.47	54.60	258.16	136	510.26	198.32	54.43	257.51
11	509.97	198.02	54.68	257.27	74	511.29	198.44	54.44	258.41	137	510.58	198.35	54.38	257.85
12	510.96	198.75	54.67	257.53	75	511.15	198.65	54.53	257.96	138	510.70	198.42	54.91	257.37
13	510.48	198.52	54.41	257.55	76	510.92	198.13	54.58	258.21	139	511.20	198.32	54.54	258.34
14	511.21	198.54	54.65	258.03	77	510.74	198.16	54.72	257.86	140	510.58	198.46	54.47	257.65
15	510.46	198.35	54.46	257.66	78	511.21	198.21	54.42	258.57	141	510.54	198.20	54.78	257.56
16	510.99	198.15	54.56	258.28	79	511.64	198.30	54.70	258.64	142	511.06	198.31	54.68	258.08
17	511.01	198.40	54.53	258.08	80	510.63	198.42	54.47	257.74	143	510.28	198.27	54.39	257.62
18	510.93	198.47	54.62	257.83	81	511.07	198.41	54.49	258.17	144	510.93	198.20	54.45	258.28
19	512.30	198.60	54.65	259.05	82	510.42	198.13	54.48	257.81	145	510.70	198.36	54.73	257.61
20	510.55	198.12	54.57	257.87	83	510.61	198.28	54.58	257.75	146	510.02	198.32	54.48	257.22
21	510.63	198.27	54.63	257.74	84	511.11	198.33	54.43	258.35	147	510.61	198.27	54.55	257.79
22	510.76	198.35	54.54	257.87	85	511.06	198.37	54.41	258.28	148	510.66	198.75	54.70	257.21
23	510.47	198.34	54.49	257.64	86	510.45	198.73	54.30	257.41	149	511.73	198.43	54.71	258.58
24	510.56	198.39	54.40	257.76	87	511.44	198.74	54.67	258.03	150	511.62	198.67	54.39	258.57
25	510.93	198.37	54.54	258.02	88	510.67	198.46	54.39	257.82	151	510.65	198.41	54.62	257.61
26	511.15	198.20	54.56	258.39	89	510.56	198.24	54.46	257.85	152	511.16	198.53	54.49	258.13
27	511.59	198.39	54.60	258.60	90	510.70	198.60	54.60	257.50	153	510.83	198.32	54.62	257.89
28	509.87	197.86	54.22	257.79	91	510.61	198.21	54.51	257.89	154	510.50	198.21	54.71	257.58
29	510.39	198.40	54.44	257.54	92	510.70	198.04	54.73	257.93	155	510.52	198.40	54.72	257.40
30	511.37	198.35	54.58	258.44	93	511.21	198.45	54.57	258.19	156	510.78	198.25	54.67	257.85
31	511.17	198.72	54.54	257.91	94	510.74	198.34	54.77	257.63	157	511.21	198.25	54.95	258.01
32	510.81	198.51	54.39	257.91	95	510.36	198.34	54.58	257.44	158	510.70	198.23	54.51	257.95
33	510.71	198.42	54.61	257.67	96	510.33	198.04	54.66	257.63	159	511.45	198.60	54.57	258.28
34	511.05	198.48	54.44	258.13	97	511.23	198.73	54.60	257.90	160	510.58	198.10	54.72	257.76
35	510.25	198.17	54.49	257.59	98	511.03	198.85	54.54	257.64	161	510.66	198.62	54.51	257.53
36	510.30	198.27	54.40	257.62	99	510.70	198.21	54.38	258.11	162	511.07	198.21	54.47	258.39
37	510.49	198.00	54.65	257.83	100	510.91	198.59	54.78	257.54	163	511.39	198.73	54.69	257.98
38	511.06	198.27	54.40	258.39	101	510.62	198.26	54.62	257.75	164	511.03	198.24	54.53	258.26
39	510.49	198.02	54.47	258.00	102	511.07	198.55	54.48	258.05	165	511.01	198.53	54.86	257.62
40	510.24	198.36	54.40	257.48	103	511.66	198.75	54.60	258.32	166	510.92	198.44	54.50	257.98
41	511.13	198.23	54.59	258.32	104	511.01	198.18	54.57	258.27	167	511.03	198.09	54.55	258.40
42	511.27	198.54	54.64	258.10	105	511.14	198.47	54.43	258.23	168	511.34	198.52	54.47	258.35
43	510.86	198.43	54.76	257.67	106	510.12	198.34	54.69	257.09	169	511.59	198.52	54.79	258.27
44	510.55	198.20	54.51	257.84	107	510.98	198.56	54.77	257.65	170	510.21	198.13	54.33	257.75
45	510.09	198.16	54.54	257.39	108	511.25	198.53	54.63	258.10	171	511.27	198.30	54.68	258.30
46	510.22	198.07	54.42	257.73	109	511.51	198.59	54.48	258.43	172	510.59	198.22	54.51	257.86
47	510.32	197.93	54.56	257.82	110	511.08	198.54	54.72	257.82	173	510.05	198.21	54.47	257.36
48	511.20	198.67	54.71	257.83	111	510.86	198.24	54.56	258.06	174	510.18	198.30	54.67	257.21
49	510.87	198.48	54.42	257.97	112	510.80	198.61	54.58	257.61	175	511.01	198.54	54.55	257.93
50	510.62	198.35	54.34	257.93	113	511.54	198.59	54.65	258.30	176	511.19	198.23	54.72	258.24
51	511.05	198.23	54.87	257.96	114	510.85	198.18	54.51	258.16	177	510.87	198.11	54.50	258.26
52	511.13	198.31	54.45	258.36	115	511.46	198.72	54.56	258.17	178	511.02	198.12	54.57	258.34
53	511.00	198.47	54.33	258.19	116	511.14	198.41	54.56	258.16	179	511.49	198.54	54.55	258.41
54	510.58	198.16	54.54	257.88	117	511.23	198.33	54.49	258.42	180	511.05	198.60	54.44	258.00
55	510.70	198.29	54.48	257.92	118	511.50	198.55	54.77	258.18	181	510.46	198.29	54.55	257.63
56	510.82	198.45	54.53	257.83	119	510.65	198.50	54.33	257.82	182	509.33	198.33	54.31	256.69
57	510.70	198.45	54.68	257.56	120	509.61	197.92	54.43	257.26	183	510.94	198.55	54.51	257.88
58	511.07	198.67	54.74	257.66	121	510.31	198.30	54.54	257.47	184	495.10	192.24	52.87	249.99
59	510.44	198.09	54.80	257.55	122	510.53	198.57	54.60	257.36					
60	510.72	198.34	54.68	257.70	123	510.07	198.30	54.50	257.26					
61	511.13	198.63	54.54	257.96	124	511.06	198.39	54.69	257.98					
62	510.55	198.53	54.37	257.66	125	510.57	198.60	54.52	257.45					

Sustainability – Data Rate Distribution Graph

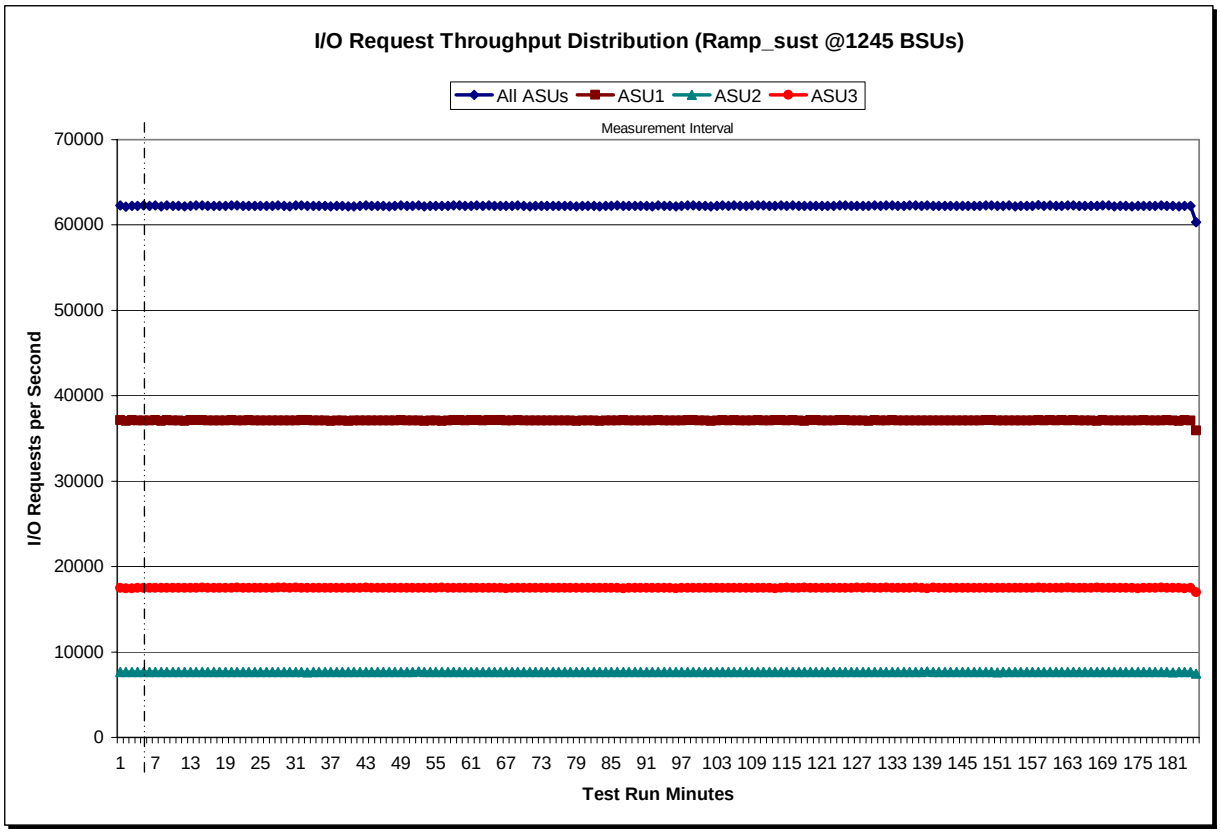


Sustainability – I/O Request Throughput Distribution Data

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	9:05:20	9:10:20	0-4	0:05:00
Measurement Interval	9:10:20	12:10:20	5-184	3:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	62,286.25	37,123.17	7,666.35	17,496.73	63	62,312.37	37,140.83	7,669.88	17,501.65	126	62,259.43	37,095.30	7,649.50	17,514.63
1	62,149.43	37,056.70	7,640.15	17,452.58	64	62,243.15	37,118.75	7,649.98	17,474.42	127	62,232.25	37,079.75	7,665.88	17,486.62
2	62,232.63	37,126.37	7,652.17	17,454.10	65	62,260.35	37,133.50	7,659.02	17,467.83	128	62,247.32	37,059.35	7,659.65	17,528.32
3	62,262.50	37,101.92	7,669.22	17,491.37	66	62,221.83	37,098.90	7,676.60	17,446.33	129	62,281.27	37,127.77	7,673.02	17,480.48
4	62,268.57	37,102.83	7,674.02	17,491.72	67	62,242.20	37,090.57	7,656.53	17,495.10	130	62,250.37	37,100.48	7,648.12	17,501.77
5	62,248.87	37,099.18	7,654.70	17,494.98	68	62,311.33	37,150.20	7,664.73	17,496.40	131	62,280.75	37,104.45	7,660.80	17,515.50
6	62,277.92	37,118.23	7,662.05	17,497.63	69	62,239.80	37,108.40	7,639.92	17,491.48	132	62,272.15	37,117.62	7,664.70	17,489.83
7	62,211.13	37,059.70	7,651.83	17,499.60	70	62,194.73	37,079.10	7,640.62	17,475.02	133	62,246.08	37,096.25	7,657.85	17,491.98
8	62,294.32	37,127.78	7,664.98	17,501.55	71	62,242.95	37,116.48	7,638.67	17,487.80	134	62,238.47	37,083.83	7,664.95	17,489.68
9	62,247.33	37,097.08	7,656.05	17,494.20	72	62,246.00	37,106.72	7,662.30	17,476.98	135	62,278.03	37,106.98	7,670.50	17,500.55
10	62,225.22	37,085.55	7,658.70	17,480.97	73	62,237.92	37,092.67	7,665.42	17,479.83	136	62,273.43	37,092.07	7,664.92	17,516.45
11	62,210.88	37,043.63	7,671.00	17,496.25	74	62,256.70	37,113.85	7,637.35	17,505.50	137	62,214.50	37,080.67	7,644.05	17,489.78
12	62,252.03	37,118.22	7,645.37	17,488.45	75	62,256.23	37,101.12	7,668.38	17,486.73	138	62,275.75	37,116.43	7,699.22	17,460.10
13	62,267.83	37,145.60	7,658.17	17,464.07	76	62,252.10	37,077.95	7,669.27	17,504.88	139	62,260.07	37,097.70	7,648.72	17,513.65
14	62,309.38	37,132.02	7,660.80	17,516.57	77	62,260.48	37,097.63	7,669.52	17,493.33	140	62,228.27	37,109.17	7,642.63	17,476.47
15	62,231.28	37,091.75	7,664.65	17,474.88	78	62,192.68	37,053.23	7,641.95	17,497.50	141	62,221.50	37,077.93	7,669.02	17,474.55
16	62,228.90	37,066.40	7,672.37	17,490.13	79	62,252.47	37,097.82	7,661.97	17,492.68	142	62,240.12	37,087.28	7,656.95	17,495.88
17	62,220.50	37,094.13	7,648.72	17,477.65	80	62,225.82	37,103.83	7,654.97	17,467.02	143	62,241.00	37,111.32	7,648.92	17,480.77
18	62,262.52	37,107.52	7,660.05	17,494.95	81	62,263.15	37,113.08	7,650.18	17,499.88	144	62,236.73	37,085.27	7,661.12	17,490.35
19	62,298.82	37,131.62	7,657.17	17,510.03	82	62,193.30	37,055.08	7,659.33	17,478.88	145	62,245.15	37,080.83	7,665.12	17,499.20
20	62,276.45	37,104.43	7,650.82	17,521.20	83	62,233.77	37,074.35	7,663.65	17,495.77	146	62,223.10	37,094.43	7,650.28	17,478.38
21	62,227.63	37,085.07	7,659.02	17,483.55	84	62,247.82	37,104.05	7,641.68	17,502.08	147	62,244.20	37,097.30	7,660.37	17,486.53
22	62,261.38	37,119.47	7,658.90	17,483.02	85	62,266.17	37,109.33	7,660.80	17,496.03	148	62,270.42	37,138.13	7,664.37	17,467.92
23	62,248.02	37,108.43	7,664.58	17,475.00	86	62,249.35	37,153.47	7,637.92	17,457.97	149	62,312.17	37,132.05	7,672.30	17,507.82
24	62,227.97	37,098.02	7,661.77	17,468.18	87	62,262.32	37,110.50	7,656.65	17,495.17	150	62,248.92	37,110.02	7,630.93	17,507.97
25	62,245.17	37,089.25	7,659.22	17,496.70	88	62,243.33	37,106.12	7,649.33	17,487.88	151	62,232.33	37,090.45	7,653.35	17,488.53
26	62,247.40	37,094.20	7,648.13	17,505.07	89	62,219.77	37,088.05	7,645.93	17,485.78	152	62,277.92	37,114.18	7,658.48	17,505.25
27	62,284.77	37,089.45	7,663.63	17,531.68	90	62,222.68	37,088.92	7,642.12	17,491.65	153	62,202.23	37,071.07	7,642.20	17,488.97
28	62,237.18	37,078.22	7,644.30	17,514.67	91	62,213.35	37,075.40	7,652.48	17,485.47	154	62,226.58	37,070.87	7,677.03	17,478.68
29	62,207.07	37,093.95	7,647.93	17,465.18	92	62,298.28	37,126.12	7,672.40	17,499.77	155	62,236.12	37,115.42	7,654.55	17,466.15
30	62,274.60	37,100.13	7,652.78	17,521.68	93	62,238.80	37,072.42	7,663.97	17,502.42	156	62,230.67	37,066.92	7,663.93	17,499.82
31	62,278.07	37,130.65	7,649.97	17,497.45	94	62,248.78	37,085.43	7,672.47	17,490.88	157	62,321.50	37,127.72	7,679.48	17,514.30
32	62,221.60	37,116.98	7,623.42	17,481.20	95	62,192.35	37,083.00	7,659.50	17,449.85	158	62,232.37	37,086.93	7,645.92	17,499.52
33	62,239.17	37,087.57	7,674.62	17,476.98	96	62,236.58	37,094.05	7,653.02	17,489.52	159	62,299.78	37,132.43	7,660.02	17,507.33
34	62,228.87	37,079.32	7,649.90	17,499.65	97	62,300.85	37,138.75	7,665.20	17,496.90	160	62,239.33	37,083.97	7,667.53	17,487.83
35	62,224.25	37,098.87	7,652.42	17,472.97	98	62,272.98	37,128.62	7,655.00	17,489.37	161	62,260.58	37,135.10	7,655.27	17,470.22
36	62,175.32	37,053.62	7,653.55	17,468.15	99	62,246.58	37,103.30	7,653.37	17,489.92	162	62,281.38	37,102.65	7,662.55	17,516.18
37	62,235.80	37,089.92	7,659.58	17,486.30	100	62,246.53	37,100.07	7,657.60	17,488.87	163	62,313.38	37,147.08	7,661.92	17,504.38
38	62,213.88	37,068.45	7,639.92	17,505.52	101	62,198.35	37,059.57	7,670.62	17,468.17	164	62,256.68	37,075.78	7,678.40	17,502.50
39	62,201.60	37,057.62	7,639.23	17,504.75	102	62,234.83	37,104.73	7,646.80	17,483.30	165	62,259.15	37,105.90	7,670.93	17,482.32
40	62,212.55	37,098.10	7,646.22	17,468.23	103	62,285.80	37,122.23	7,663.73	17,499.83	166	62,229.25	37,089.88	7,646.87	17,492.50
41	62,218.38	37,076.77	7,654.97	17,486.65	104	62,229.98	37,082.98	7,651.17	17,495.83	167	62,246.65	37,052.88	7,671.28	17,522.48
42	62,299.35	37,112.28	7,671.47	17,515.60	105	62,303.72	37,142.60	7,651.88	17,509.23	168	62,292.32	37,136.33	7,656.73	17,499.25
43	62,262.60	37,115.48	7,664.57	17,482.55	106	62,248.50	37,114.15	7,662.07	17,472.28	169	62,298.10	37,113.15	7,675.38	17,509.57
44	62,242.52	37,096.38	7,637.55	17,508.58	107	62,238.68	37,074.57	7,674.03	17,490.08	170	62,208.70	37,076.13	7,648.95	17,483.62
45	62,224.73	37,084.50	7,663.05	17,477.18	108	62,287.33	37,115.88	7,663.07	17,508.38	171	62,260.02	37,090.75	7,660.35	17,508.92
46	62,201.62	37,067.80	7,639.30	17,494.52	109	62,270.97	37,118.67	7,660.97	17,491.33	172	62,231.82	37,100.78	7,660.98	17,470.05
47	62,263.30	37,105.17	7,672.72	17,485.42	110	62,278.85	37,103.18	7,665.27	17,510.40	173	62,206.33	37,087.40	7,652.25	17,466.68
48	62,285.20	37,129.78	7,653.48	17,501.93	111	62,218.43	37,084.72	7,664.75	17,468.97	174	62,230.03	37,106.73	7,664.28	17,459.02
49	62,230.82	37,084.18	7,653.85	17,492.78	112	62,248.33	37,141.45	7,644.77	17,462.12	175	62,256.35	37,119.35	7,645.52	17,491.48
50	62,235.88	37,113.93	7,643.55	17,478.40	113	62,306.37	37,126.65	7,670.93	17,508.78	176	62,230.22	37,066.28	7,663.70	17,500.23
51	62,278.30	37,111.72	7,690.30	17,476.28	114	62,250.72	37,073.08	7,663.20	17,514.43	177	62,234.90	37,071.98	7,658.95	17,503.97
52	62,205.97	37,065.45	7,650.00	17,490.52	115	62,307.37	37,152.85	7,658.92	17,495.60	178	62,264.28	37,103.03	7,647.77	17,513.48
53	62,258.02	37,113.60	7,645.02	17,499.40	116	62,246.42	37,093.22	7,659.88	17,493.32	179	62,258.90	37,124.53	7,639.02	17,495.35
54	62,222.40	37,074.28	7,658.65	17,489.47	117	62,214.22	37,044.07	7,653.07	17,517.08	180	62,231.38	37,109.33	7,631.97	17,490.08
55	62,225.08	37,052.28	7,642.83	17,529.97	118	62,262.15	37,116.70	7,654.27	17,491.18	181	62,190.67	37,062.57	7,646.25	17,481.85
56	62,253.30	37,096.28	7,657.50	17,499.52	119	62,262.12	37,130.98	7,645.87	17,485.27	182	62,226.78	37,130.57	7,638.62	17,457.60
57	62,264.93	37,135.72	7,666.98	17,462.23	120	62,251.87	37,098.77	7,656.70	17,496.40	183	62,237.25	37,108.38	7,651.20	17,477.67
58	62,276.48	37,124.78	7,669.95	17,481.75	121	62,248.60	37,112.05	7,654.02	17,482.53	184	60,331.37	35,931.50	7,438.43	16,961.43
59	62,233.87	37,101.80	7,662.28	17,469.78	122	62,227.80	37,101.53	7,648.97	17,477.30	Average	62,238.02	37,094.15	7,655.72	17,488.15
60	62,256.97	37,130.07	7,650.23	17,476.67	123	62,265.30	37,133.35	7,638.33	17,493.62					
61	62,286.73	37,140.72	7,639.13	17,506.88	124	62,290.63	37,135.95	7,670.95	17,483.73					
62	62,226.95	37,090.18	7,642.70	17,494.07	125	62,254.25	37,097.45	7,655.22	17,501.58					

Sustainability – I/O Request Throughput Distribution Graph

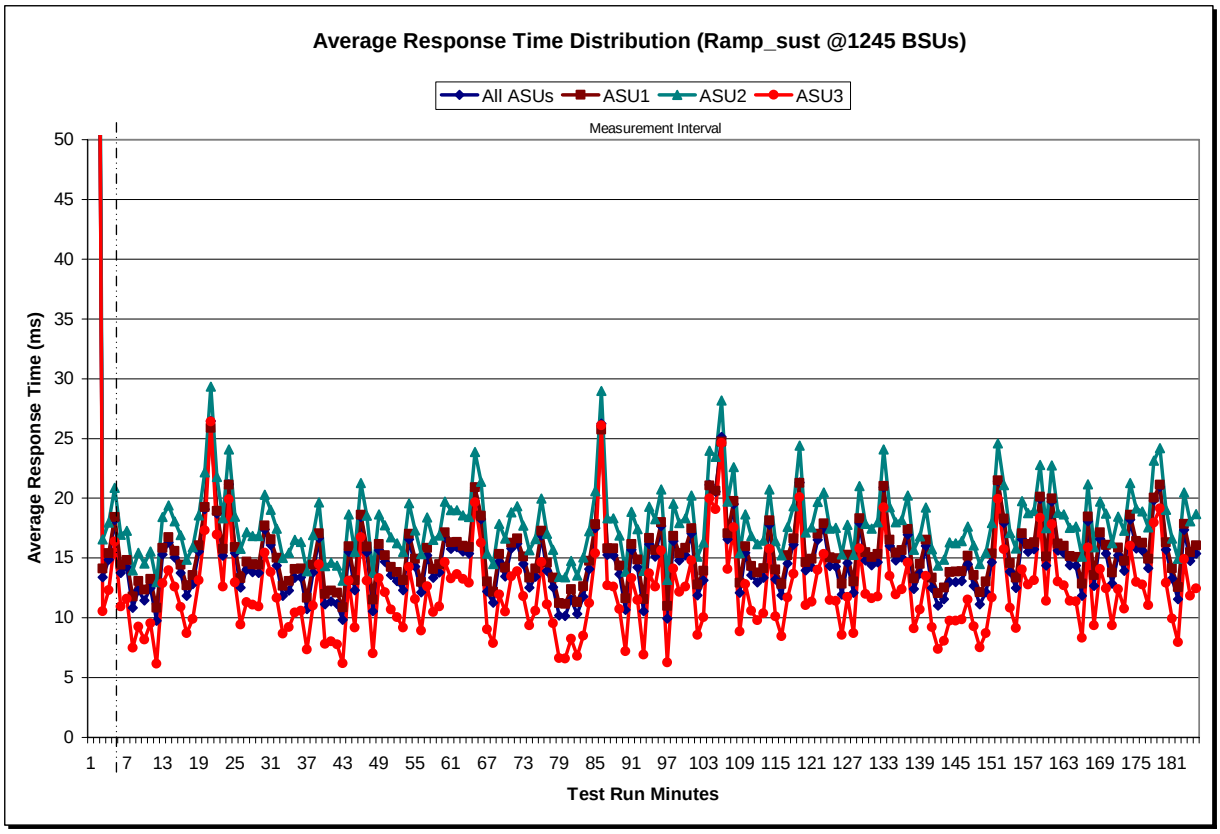


Sustainability – Average Response Time (ms) Distribution Data

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	9:05:20	9:10:20	0-4	0:05:00
Measurement Interval	9:10:20	12:10:20	4-184	3:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	369.11	359.66	399.51	375.84	63	15.39	15.92	18.42	12.93	126	14.59	15.27	17.77	11.75
1	104.26	100.52	111.90	108.85	64	20.93	20.92	23.88	19.66	127	12.09	13.02	15.28	8.72
2	13.41	14.10	16.57	10.55	65	18.24	18.53	21.37	16.27	128	17.94	18.31	21.04	15.79
3	14.85	15.41	17.95	12.30	66	12.19	13.03	15.38	9.03	129	14.80	15.49	17.86	11.98
4	18.16	18.44	20.87	16.38	67	11.26	12.17	14.51	7.89	130	14.39	15.07	17.45	11.61
5	13.76	14.44	16.96	10.93	68	14.69	15.33	17.87	11.94	131	14.66	15.33	17.98	11.78
6	14.23	14.84	17.27	11.58	69	13.45	14.17	16.64	10.52	132	20.90	21.04	24.08	19.21
7	10.85	11.78	13.98	7.50	70	15.79	16.26	18.82	13.45	133	16.01	16.53	19.25	13.49
8	12.29	13.08	15.43	9.26	71	16.21	16.65	19.32	13.91	134	14.79	15.45	18.00	11.96
9	11.44	12.34	14.53	8.17	72	14.51	15.13	17.70	11.81	135	15.05	15.65	18.19	12.39
10	12.49	13.24	15.55	9.53	73	12.51	13.34	15.67	9.36	136	16.97	17.42	20.22	14.61
11	9.77	10.82	13.00	6.14	74	13.43	14.12	16.60	10.58	137	12.40	13.28	15.70	9.11
12	15.32	15.83	18.42	12.87	75	16.86	17.27	19.99	14.63	138	13.73	14.50	16.83	10.71
13	16.29	16.74	19.41	13.96	76	13.93	14.61	17.01	11.13	139	16.01	16.54	19.21	13.48
14	15.04	15.58	18.06	12.59	77	12.57	13.36	15.68	9.53	140	12.49	13.36	15.75	9.22
15	13.75	14.43	16.93	10.91	78	10.19	11.22	13.42	6.61	141	11.03	12.06	14.38	7.37
16	11.84	12.70	14.88	8.70	79	10.15	11.17	13.38	6.57	142	11.56	12.53	14.87	8.05
17	12.83	13.58	15.91	9.89	80	11.51	12.39	14.74	8.24	143	12.99	13.83	16.29	9.77
18	15.55	16.07	18.57	13.15	81	10.32	11.32	13.53	6.80	144	13.00	13.85	16.24	9.77
19	19.07	19.26	22.18	17.32	82	11.77	12.64	15.03	8.50	145	13.07	13.89	16.41	9.87
20	26.45	25.87	29.35	26.41	83	14.07	14.76	17.23	11.23	146	14.46	15.19	17.65	11.52
21	18.74	18.94	21.79	16.96	84	17.48	17.81	20.58	15.42	147	12.67	13.56	16.04	9.30
22	15.20	15.77	18.32	12.61	85	26.24	25.73	28.96	26.11	148	11.14	12.15	14.52	7.52
23	21.16	21.15	24.08	19.91	86	15.25	15.81	18.33	12.71	149	12.12	13.05	15.44	8.70
24	15.40	15.91	18.48	12.96	87	15.21	15.81	18.33	12.58	150	14.65	15.36	17.93	11.69
25	12.52	13.30	15.77	9.44	88	13.65	14.37	16.89	10.71	151	21.43	21.49	24.57	19.93
26	14.04	14.68	17.18	11.32	89	10.66	11.64	13.87	7.19	152	17.92	18.29	21.08	15.75
27	13.81	14.48	16.86	11.08	90	15.70	16.17	18.86	13.32	153	13.84	14.59	17.08	10.84
28	13.75	14.44	16.83	10.95	91	14.24	14.88	17.41	11.48	154	12.48	13.36	15.82	9.16
29	17.40	17.72	20.30	15.46	92	10.54	11.57	13.91	6.89	155	16.54	17.06	19.76	14.04
30	16.10	16.57	19.06	13.81	93	16.17	16.68	19.30	13.73	156	15.53	16.15	18.76	12.79
31	14.37	15.02	17.47	11.65	94	15.11	15.65	18.24	12.59	157	15.75	16.32	18.94	13.13
32	11.84	12.68	15.00	8.68	95	17.66	17.99	20.75	15.61	158	19.95	20.11	22.78	18.36
33	12.28	13.06	15.45	9.21	96	9.92	10.98	13.18	6.26	159	14.37	15.12	17.51	11.42
34	13.36	14.09	16.54	10.44	97	16.41	16.85	19.55	14.11	160	19.72	19.99	22.74	17.82
35	13.40	14.11	16.35	10.59	98	14.81	15.41	17.92	12.16	161	15.63	16.19	18.78	13.05
36	10.73	11.67	13.91	7.35	99	15.23	15.83	18.32	12.60	162	15.41	16.02	18.65	12.71
37	13.78	14.44	16.92	11.01	100	17.07	17.49	20.24	14.79	163	14.40	15.16	17.54	11.43
38	16.66	17.07	19.66	14.47	101	11.88	12.78	15.12	8.57	164	14.36	15.09	17.64	11.37
39	11.11	12.00	14.33	7.81	102	13.13	13.91	16.30	10.06	165	11.86	12.85	15.14	8.32
40	11.37	12.28	14.61	8.03	103	21.11	21.05	23.98	19.99	166	18.08	18.48	21.18	15.89
41	11.15	12.09	14.35	7.77	104	20.54	20.61	23.48	19.09	167	12.68	13.58	15.91	9.36
42	9.83	10.87	13.10	6.21	105	25.12	24.71	28.19	24.63	168	16.59	17.13	19.73	14.09
43	15.50	15.98	18.65	13.10	106	16.55	17.07	19.74	14.07	169	15.38	16.08	18.73	12.45
44	12.31	13.13	15.52	9.17	107	19.50	19.78	22.62	17.55	170	12.84	13.78	16.25	9.35
45	18.42	18.62	21.27	16.73	108	12.09	12.93	15.40	8.87	171	15.22	15.88	18.45	12.40
46	15.47	15.96	18.55	13.09	109	15.43	16.00	18.63	12.81	172	13.94	14.76	17.26	10.75
47	10.53	11.52	13.76	7.02	110	13.58	14.31	16.85	10.59	173	18.21	18.61	21.27	16.02
48	15.66	16.15	18.66	13.32	111	12.95	13.77	16.17	9.78	174	15.80	16.43	19.16	13.00
49	14.68	15.24	17.73	12.14	112	13.37	14.15	16.46	10.35	175	15.61	16.26	18.90	12.77
50	13.55	14.25	16.75	10.69	113	17.79	18.13	20.72	15.77	176	14.16	14.94	17.55	11.04
51	13.07	13.84	16.23	10.06	114	13.23	14.03	16.41	10.13	177	19.85	20.06	23.14	17.96
52	12.31	13.14	15.51	9.17	115	11.89	12.82	15.24	8.45	178	20.95	21.13	24.19	19.14
53	16.56	17.03	19.57	14.25	116	14.53	15.23	17.61	11.70	179	15.68	16.29	19.04	12.92
54	14.28	14.95	17.31	11.55	117	16.12	16.62	19.33	13.67	180	13.27	14.15	16.62	9.95
55	12.14	13.00	15.32	8.93	118	21.33	21.28	24.40	20.07	181	11.57	12.58	14.95	7.95
56	15.24	15.83	18.41	12.62	119	13.95	14.67	17.14	11.05	182	17.34	17.85	20.49	14.89
57	13.36	14.06	16.53	10.47	120	14.24	14.93	17.56	11.34	183	14.77	15.48	18.06	11.83
58	13.78	14.49	16.87	10.93	121	16.51	17.03	19.70	14.02	184	15.36	16.04	18.68	12.45
59	16.75	17.12	19.73	14.65	122	17.49	17.90	20.47	15.32	Average	14.80	15.43	17.96	12.09
60	15.78	16.30	19.00	13.29	123	14.34	15.05	17.46	11.49					
61	15.92	16.35	19.02	13.65	124	14.29	14.98	17.52	11.40					
62	15.55	16.01	18.57	13.26	125	11.95	12.87	15.30	8.56					

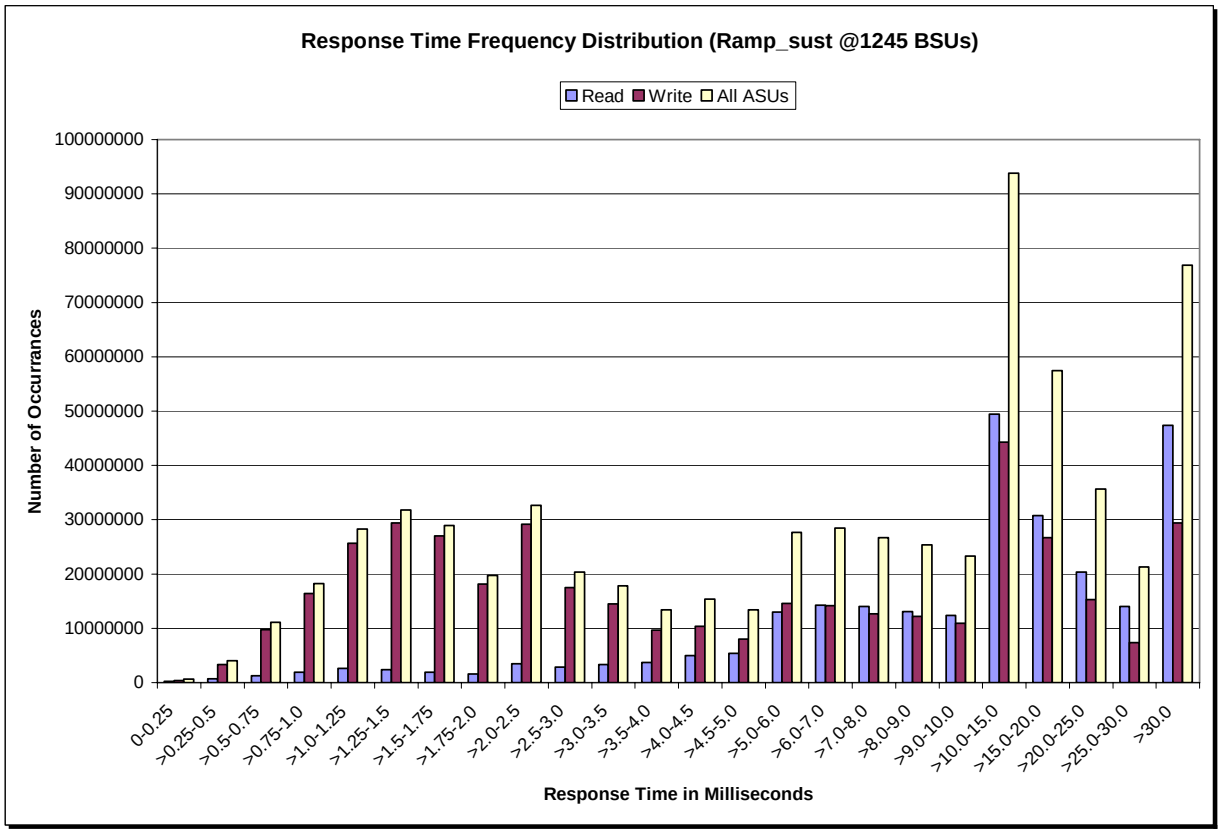
Sustainability – Average Response Time (ms) Distribution Graph



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	275,926	694,503	1,284,258	1,870,972	2,577,926	2,397,264	1,915,722	1,547,829
Write	360,154	3,336,961	9,771,473	16,378,414	25,696,736	29,364,121	27,040,318	18,178,692
All ASUs	636,080	4,031,464	11,055,731	18,249,386	28,274,662	31,761,385	28,956,040	19,726,521
ASU1	470,614	2,291,979	5,652,088	9,021,954	13,727,353	15,061,872	13,422,944	9,048,946
ASU2	64,713	456,535	1,303,461	2,159,865	3,332,769	3,645,662	3,236,311	2,195,407
ASU3	100,753	1,282,950	4,100,182	7,067,567	11,214,540	13,053,851	12,296,785	8,482,168
Response Time (ms)	**>2.0-2.5**	**>2.5-3.0**	**>3.0-3.5**	**>3.5-4.0**	**>4.0-4.5**	**>4.5-5.0**	**>5.0-6.0**	**>6.0-7.0**
Read	3,514,116	2,853,348	3,359,829	3,715,016	5,007,379	5,349,870	13,024,404	14,225,360
Write	29,131,881	17,536,044	14,484,113	9,645,350	10,371,500	8,012,675	14,600,865	14,219,484
All ASUs	32,645,997	20,389,392	17,843,942	13,360,366	15,378,879	13,362,545	27,625,269	28,444,844
ASU1	15,312,656	9,845,620	9,133,178	7,461,787	8,986,676	8,290,288	17,998,176	18,784,905
ASU2	3,715,154	2,265,756	1,929,585	1,382,317	1,532,119	1,318,461	2,789,999	2,974,423
ASU3	13,618,187	8,278,016	6,781,179	4,516,262	4,860,084	3,753,796	6,837,094	6,685,516
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	14,061,390	13,106,205	12,355,695	49,479,360	30,725,617	20,376,912	13,992,419	47,408,570
Write	12,649,413	12,230,222	10,924,439	44,317,405	26,694,096	15,316,337	7,353,101	29,436,894
All ASUs	26,710,803	25,336,427	23,280,134	93,796,765	57,419,713	35,693,249	21,345,520	76,845,464
ASU1	17,821,366	16,636,024	15,432,131	61,316,456	37,330,838	23,538,984	14,711,389	49,318,573
ASU2	2,925,957	2,908,811	2,670,453	11,344,274	7,271,958	4,796,768	3,147,126	13,313,888
ASU3	5,963,480	5,791,592	5,177,550	21,136,035	12,816,917	7,357,497	3,487,005	14,213,003

Sustainability – Response Time Frequency Distribution Graph



Sustainability – Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

IM – Intensity Multiplier: *The ratio of I/Os for each I/O stream relative to the total I/Os for all I/O streams (ASU1-1 – ASU3-1) as required by the benchmark specification.*

Clauses 5.1.0 and 5.3.13.2

MIM – Measured Intensity Multiplier: *The Measured Intensity Multiplier represents the ratio of measured I/Os for each I/O stream relative to the total I/Os measured for all I/O streams (ASU1-1 – ASU3-1). This value may differ from the corresponding Expected Intensity Multiplier by no more than 5%.*

Clause 5.3.13.3

COV – Coefficient of Variation: *This measure of variation for the Measured Intensity Multiplier cannot exceed 0.2.*

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0175	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.03	0.001	0.002	0.001	0.004	0.002	0.003	0.001

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 t the Workload Generator.*
6. *The total number of I/O Requests completed in the Measurement Interval as well as the number of I/O Requests with a Response Time less than or equal to 30 milliseconds and the number of I/O Requests with a Response Time greater than 30 milliseconds.*

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 67.

IOPS Test Results File

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

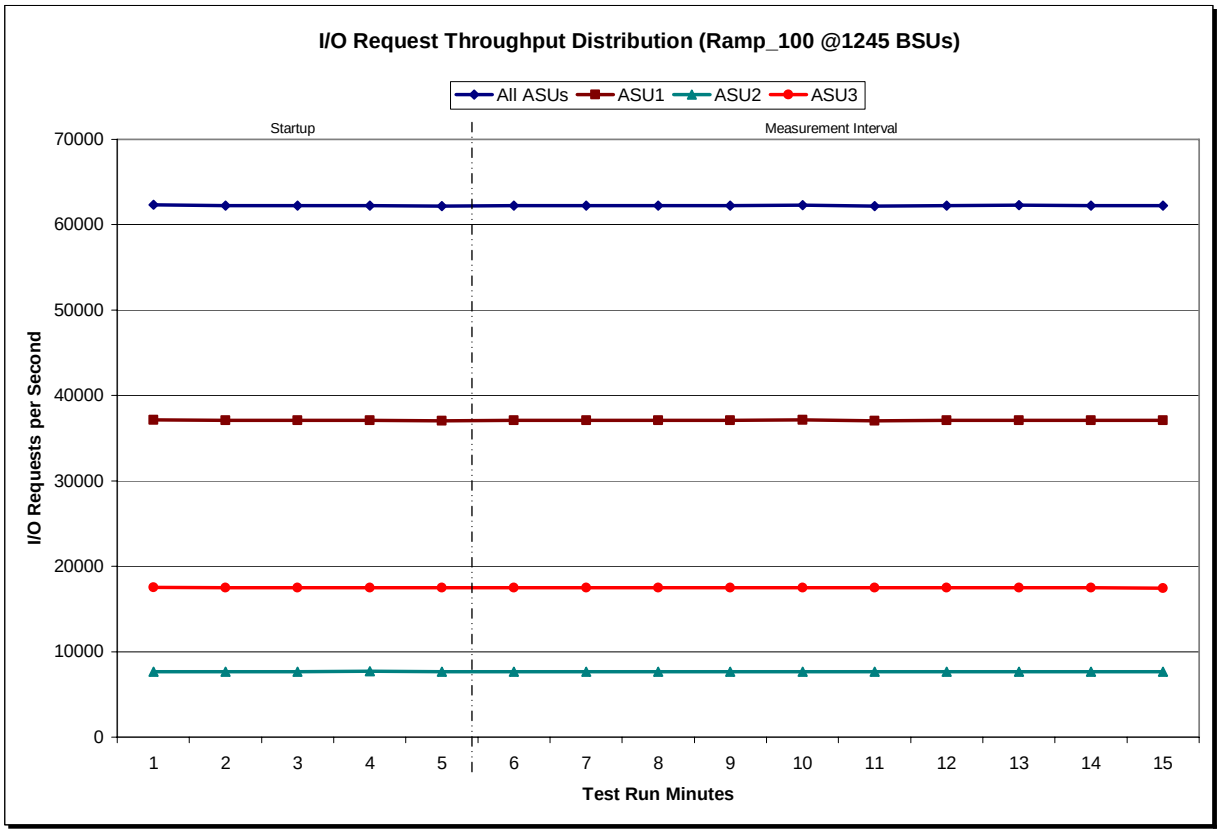
IOPS Test Results File

IOPS Test Run – I/O Request Throughput Distribution Data

1245 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:11:01	12:16:02	0-4	0:05:01
Measurement Interval	12:16:02	12:26:02	3-14	0:10:00

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	62,320.60	37,135.45	7,664.78	17,520.37
1	62,219.25	37,069.85	7,672.73	17,476.67
2	62,257.65	37,111.67	7,650.25	17,495.73
3	62,259.62	37,085.75	7,686.23	17,487.63
4	62,186.30	37,053.30	7,662.78	17,470.22
5	62,248.57	37,114.38	7,665.45	17,468.73
6	62,240.37	37,106.68	7,648.60	17,485.08
7	62,219.17	37,070.25	7,651.98	17,496.93
8	62,225.27	37,084.23	7,669.92	17,471.12
9	62,280.00	37,126.80	7,667.32	17,485.88
10	62,210.03	37,057.68	7,640.07	17,512.28
11	62,254.52	37,095.42	7,667.48	17,491.62
12	62,290.60	37,111.35	7,670.10	17,509.15
13	62,250.80	37,097.80	7,646.97	17,506.03
14	62,216.97	37,108.62	7,650.92	17,457.43
Average	62,243.63	37,097.32	7,657.88	17,488.43

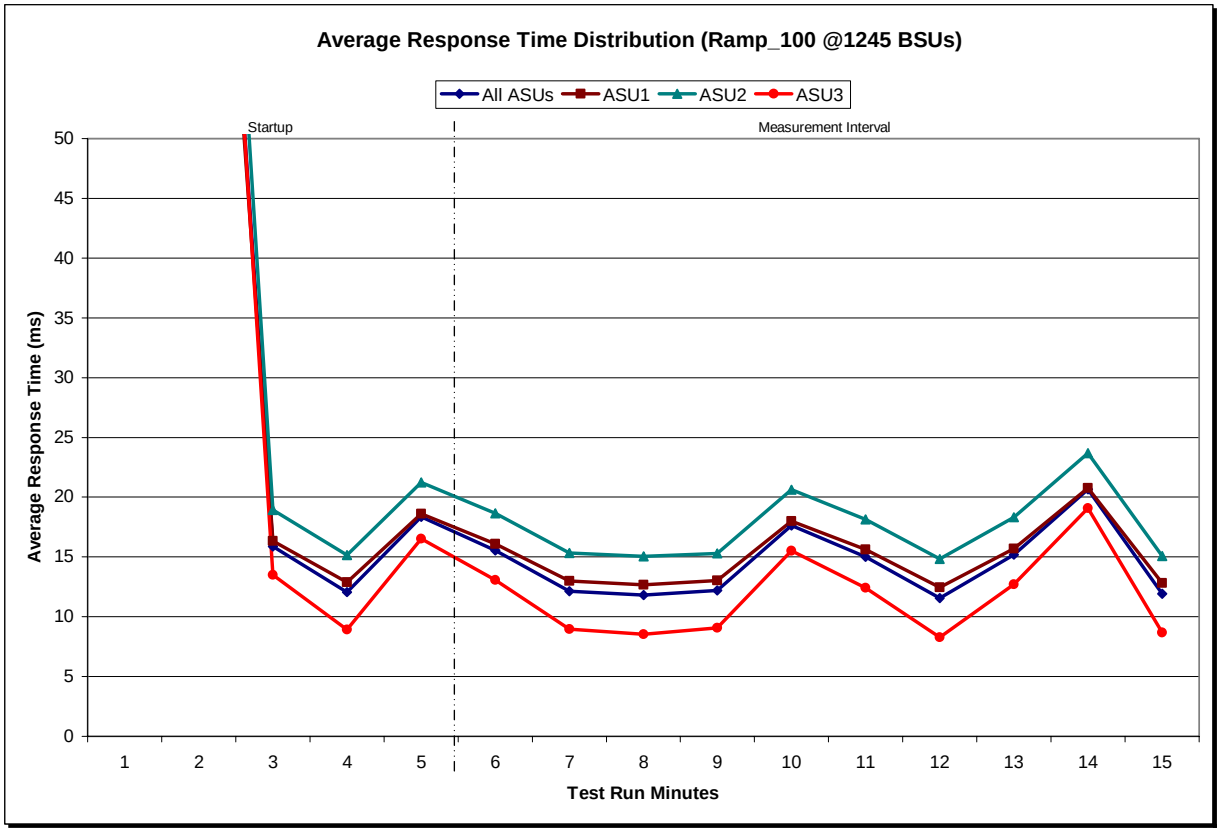
IOPS Test Run – I/O Request Throughput Distribution Graph



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

1245 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:11:01	12:16:02	0-4	0:05:01
Measurement Interval	12:16:02	12:26:02	3-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	339.29	331.10	363.16	346.22
1	106.74	103.25	116.09	110.03
2	15.87	16.34	18.95	13.50
3	12.06	12.90	15.14	8.94
4	18.34	18.60	21.24	16.52
5	15.56	16.10	18.63	13.06
6	12.14	12.99	15.32	8.95
7	11.79	12.66	15.05	8.52
8	12.20	13.05	15.28	9.06
9	17.63	18.00	20.61	15.52
10	15.03	15.61	18.12	12.43
11	11.57	12.44	14.84	8.29
12	15.18	15.71	18.33	12.69
13	20.65	20.75	23.68	19.09
14	11.93	12.80	15.09	8.69
Average	14.37	15.01	17.50	11.63

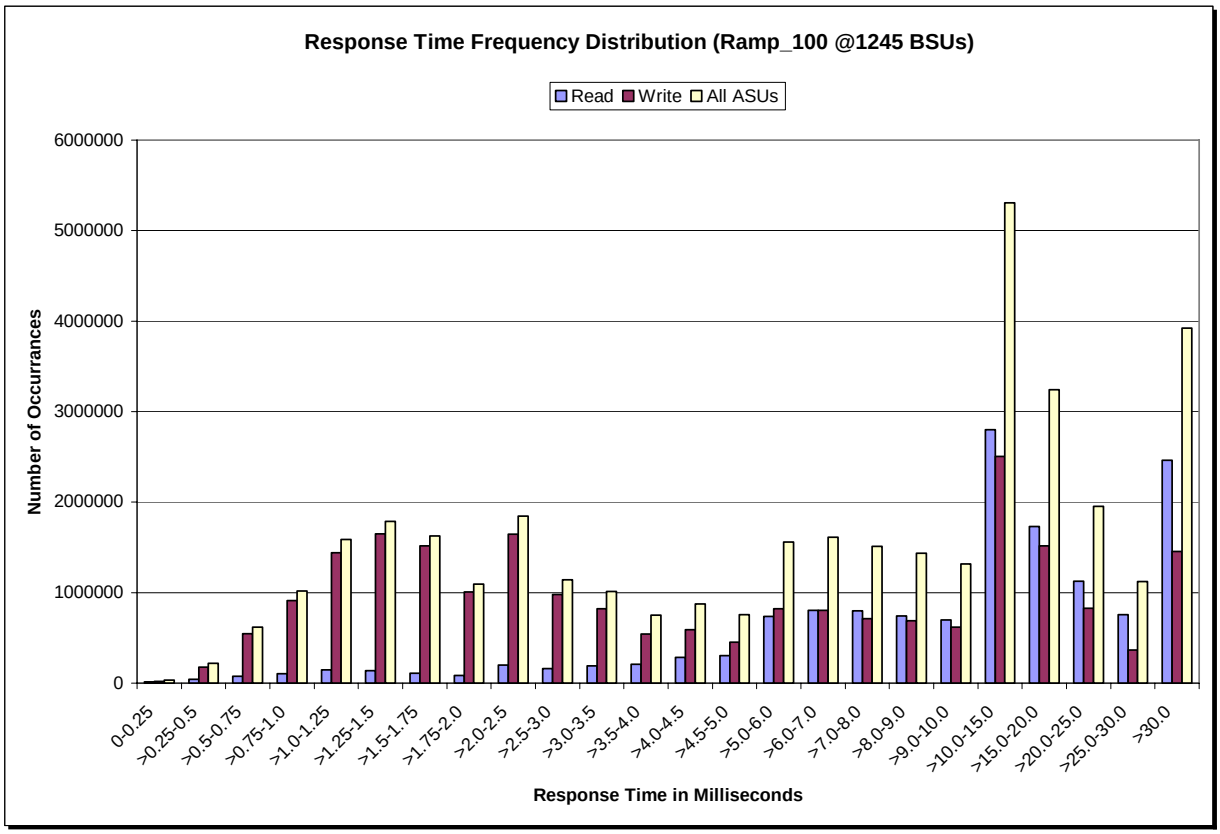
IOPS Test Run – Average Response Time (ms) Distribution Graph



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	16464	40,928	74,184	105,971	147,015	135,971	109,356	86,436
Write	18712	177,486	545,494	911,463	1,441,798	1,649,324	1,517,111	1,006,028
All ASUs	35176	218,414	619,678	1,017,434	1,588,813	1,785,295	1,626,467	1,092,464
ASU1	26586	125,423	316,323	503,518	769,875	846,229	753,256	500,729
ASU2	3458	25,076	73,462	120,766	188,015	205,597	182,043	121,476
ASU3	5132	67,915	229,893	393,150	630,923	733,469	691,168	470,259
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	199,708	161,769	191,029	209,516	284,757	302,160	737,999	805,781
Write	1,643,625	980,461	821,856	541,873	591,605	452,482	821,564	804,610
All ASUs	1,843,333	1,142,230	1,012,885	751,389	876,362	754,642	1,559,563	1,610,391
ASU1	863,878	551,142	517,946	419,988	511,818	468,008	1,017,685	1,063,844
ASU2	208,941	126,988	109,965	77,551	87,535	74,861	157,851	168,387
ASU3	770,514	464,100	384,974	253,850	277,009	211,773	384,027	378,160
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	797,729	743,524	700,564	2,799,379	1,728,644	1,127,731	755,769	2,465,017
Write	711,831	690,539	618,734	2,507,479	1,514,909	827,649	363,990	1,456,889
All ASUs	1,509,560	1,434,063	1,319,298	5,306,858	3,243,553	1,955,380	1,119,759	3,921,906
ASU1	1,008,932	942,997	875,772	3,469,541	2,105,468	1,292,269	779,631	2,526,744
ASU2	165,974	164,890	151,201	642,424	409,871	264,392	167,727	696,109
ASU3	334,654	326,176	292,325	1,194,893	728,214	398,719	172,401	699,053

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
37,344,913	33,423,007	3,921,906

IOPS Test Run – Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

IM – Intensity Multiplier: *The ratio of I/Os for each I/O stream relative to the total I/Os for all I/O streams (ASU1-1 – ASU3-1) as required by the benchmark specification.*

Clauses 5.1.0 and 5.3.13.2

MIM – Measured Intensity Multiplier: *The Measured Intensity Multiplier represents the ratio of measured I/Os for each I/O stream relative to the total I/Os measured for all I/O streams (ASU1-1 – ASU3-1). This value may differ from the corresponding Expected Intensity Multiplier by no more than 5%.*

Clause 5.3.13.3

COV – Coefficient of Variation: *This measure of variation for the Measured Intensity Multiplier cannot exceed 0.2.*

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0349	0.2811	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.002	0.001	0.002	0.001	0.002	0.001	0.003	0.001

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 Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 67.

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 - 1245 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:11:01	12:16:02	0-4	0:05:01
Measurement Interval	12:16:02	12:26:02	5-14	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	62,320.60	37,135.45	7,664.78	17,520.37
1	62,219.25	37,069.85	7,672.73	17,476.67
2	62,257.65	37,111.67	7,650.25	17,495.73
3	62,259.62	37,085.75	7,686.23	17,487.63
4	62,186.30	37,053.30	7,662.78	17,470.22
5	62,248.57	37,114.38	7,665.45	17,468.73
6	62,240.37	37,106.68	7,648.60	17,485.08
7	62,219.17	37,070.25	7,651.98	17,496.93
8	62,225.27	37,084.23	7,669.92	17,471.12
9	62,280.00	37,126.80	7,667.32	17,485.88
10	62,210.03	37,057.68	7,640.07	17,512.28
11	62,254.52	37,095.42	7,667.48	17,491.62
12	62,290.60	37,111.35	7,670.10	17,509.15
13	62,250.80	37,097.80	7,646.97	17,506.03
14	62,216.97	37,108.62	7,650.92	17,457.43
Average	62,243.63	37,097.32	7,657.88	17,488.43

95% Load Level - 1182 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:26:39	12:31:40	0-4	0:05:01
Measurement Interval	12:31:40	12:41:40	5-14	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	59,108.62	35,225.95	7,262.92	16,619.75
1	59,164.37	35,275.33	7,287.32	16,601.72
2	59,131.57	35,214.53	7,300.07	16,616.97
3	59,101.15	35,226.88	7,268.80	16,605.47
4	59,126.70	35,239.18	7,275.42	16,612.10
5	59,089.27	35,220.40	7,263.07	16,605.80
6	59,135.48	35,251.87	7,263.93	16,619.68
7	59,068.03	35,182.57	7,280.77	16,604.70
8	59,139.17	35,243.60	7,278.73	16,616.83
9	59,154.57	35,259.45	7,265.58	16,629.53
10	59,100.98	35,216.75	7,287.52	16,596.72
11	59,126.78	35,257.82	7,255.75	16,613.22
12	59,066.62	35,214.18	7,257.57	16,594.87
13	59,083.97	35,221.40	7,272.17	16,590.40
14	59,107.77	35,222.88	7,272.02	16,612.87
Average	59,107.26	35,229.09	7,269.71	16,608.46

90% Load Level - 1120 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:42:17	12:47:18	0-4	0:05:01
Measurement Interval	12:47:18	12:57:18	5-14	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	56,084.10	33,428.47	6,903.90	15,751.73
1	55,989.05	33,342.50	6,906.72	15,739.83
2	55,994.65	33,403.62	6,867.73	15,723.30
3	55,971.20	33,369.10	6,877.07	15,725.03
4	56,010.33	33,387.25	6,893.57	15,729.52
5	55,975.77	33,365.43	6,876.63	15,733.70
6	56,027.03	33,422.02	6,866.83	15,738.18
7	55,998.40	33,382.70	6,891.02	15,724.68
8	56,020.45	33,381.38	6,886.00	15,753.07
9	56,020.83	33,381.13	6,895.82	15,743.88
10	55,981.95	33,383.65	6,880.00	15,718.30
11	56,100.22	33,422.53	6,894.43	15,783.25
12	56,010.67	33,368.55	6,888.62	15,753.50
13	56,049.83	33,383.65	6,912.72	15,753.47
14	55,976.12	33,354.58	6,899.77	15,721.77
Average	56,016.13	33,384.56	6,889.18	15,742.38

80% Load Level - 996 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:57:55	13:02:56	0-4	0:05:01
Measurement Interval	13:02:56	13:12:56	5-14	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	49,841.98	29,700.78	6,127.92	14,013.28
1	49,756.42	29,666.13	6,121.12	13,969.17
2	49,755.40	29,646.93	6,122.53	13,985.93
3	49,797.28	29,654.77	6,143.97	13,998.55
4	49,783.98	29,654.28	6,131.95	13,997.75
5	49,759.03	29,648.88	6,116.35	13,993.80
6	49,835.68	29,714.68	6,136.55	13,984.45
7	49,797.62	29,668.28	6,133.87	13,995.47
8	49,847.43	29,726.75	6,111.90	14,008.78
9	49,775.38	29,647.80	6,131.33	13,996.25
10	49,816.45	29,700.13	6,118.07	13,998.25
11	49,821.03	29,695.62	6,138.05	13,987.37
12	49,815.53	29,696.28	6,145.27	13,973.98
13	49,793.40	29,678.22	6,127.48	13,987.70
14	49,818.73	29,694.27	6,117.68	14,006.78
Average	49,808.03	29,687.09	6,127.66	13,993.28

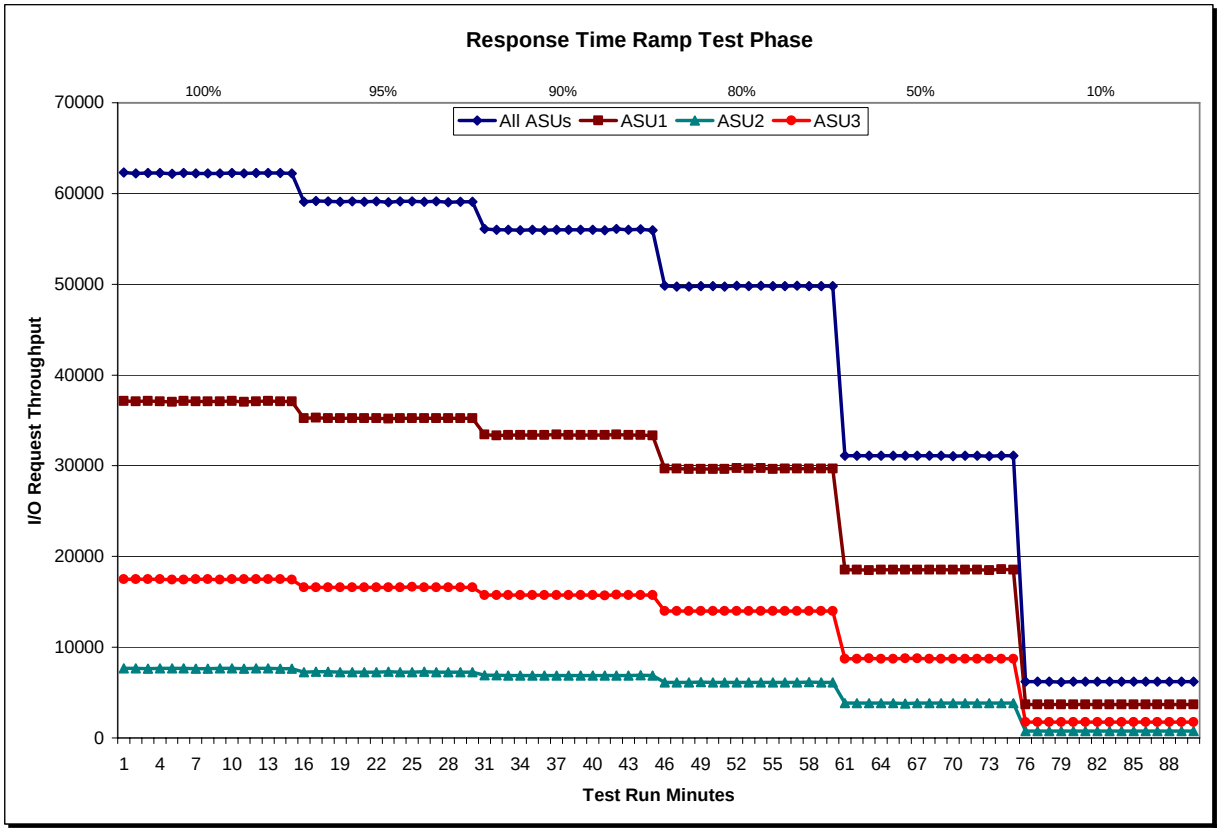
50% Load Level - 622 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:13:31	13:18:32	0-4	0:05:01
Measurement Interval	13:18:32	13:28:32	5-14	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	31,114.42	18,551.82	3,818.57	8,744.03
1	31,088.37	18,533.42	3,818.72	8,736.23
2	31,093.60	18,503.55	3,825.88	8,764.17
3	31,102.47	18,535.63	3,818.68	8,748.15
4	31,109.68	18,535.18	3,826.10	8,748.40
5	31,128.33	18,546.62	3,814.28	8,767.43
6	31,104.25	18,534.97	3,819.27	8,750.02
7	31,110.63	18,535.22	3,829.13	8,746.28
8	31,115.88	18,544.38	3,834.78	8,736.72
9	31,082.97	18,539.30	3,820.28	8,723.38
10	31,096.40	18,534.32	3,820.37	8,741.72
11	31,097.12	18,529.88	3,818.28	8,748.95
12	31,055.73	18,509.60	3,818.95	8,727.18
13	31,122.78	18,574.77	3,821.98	8,726.03
14	31,119.85	18,556.03	3,827.85	8,735.97
Average	31,103.40	18,540.51	3,822.52	8,740.37

10% Load Level - 124 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:29:05	13:34:06	0-4	0:05:01
Measurement Interval	13:34:06	13:44:06	5-14	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	6,205.57	3,690.82	767.68	1,747.07
1	6,211.88	3,693.25	764.97	1,753.67
2	6,212.95	3,699.20	763.27	1,750.48
3	6,180.87	3,680.28	761.77	1,738.82
4	6,196.87	3,692.28	764.35	1,740.23
5	6,196.10	3,692.92	759.47	1,743.72
6	6,202.52	3,688.38	764.00	1,750.13
7	6,205.65	3,693.97	763.78	1,747.90
8	6,204.53	3,688.52	772.05	1,743.97
9	6,189.32	3,691.72	760.22	1,737.38
10	6,194.42	3,693.13	760.93	1,740.35
11	6,197.33	3,695.00	770.68	1,731.65
12	6,203.92	3,690.43	760.53	1,752.95
13	6,192.92	3,691.28	763.73	1,737.90
14	6,199.65	3,694.83	762.17	1,742.65
Average	6,198.64	3,692.02	763.76	1,742.86

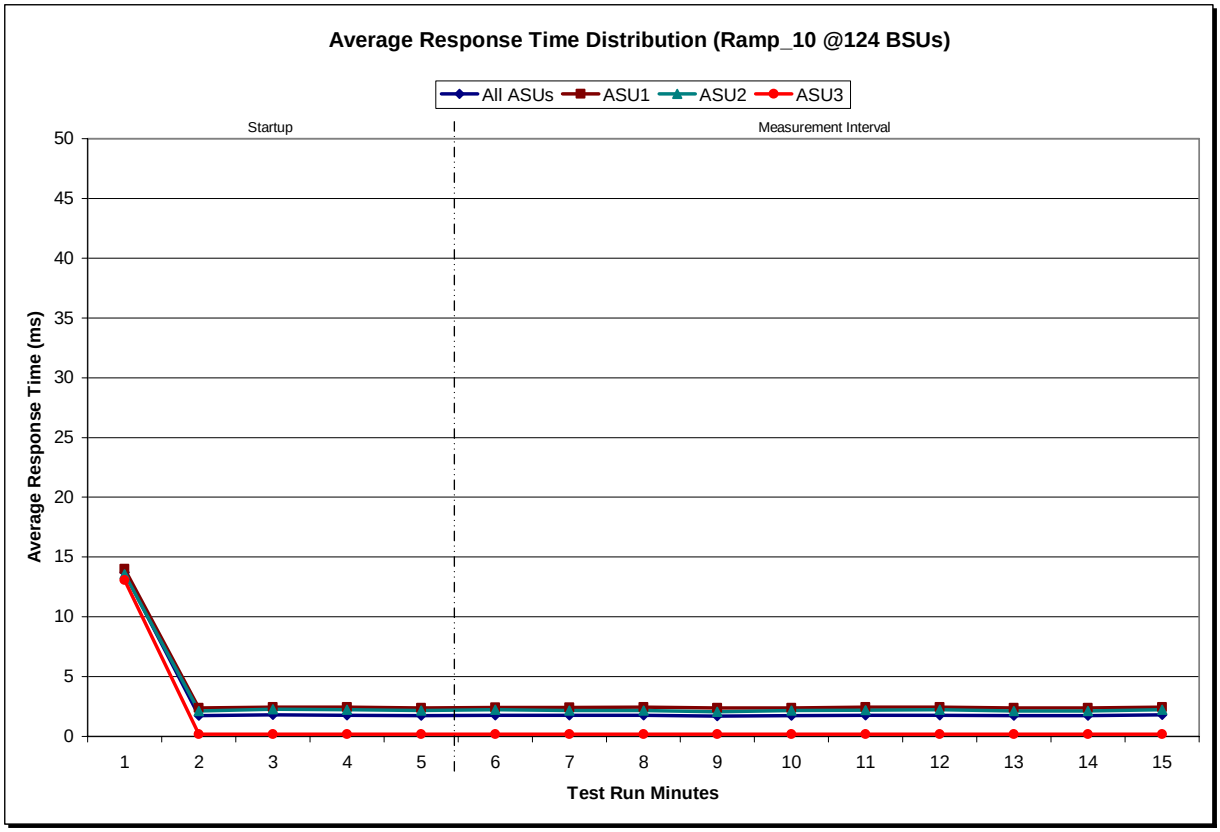
Response Time Ramp Distribution (IOPS) Graph



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

124 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:29:05	13:34:06	0-4	0:05:01
Measurement Interval	13:34:06	13:44:06	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	13.70	14.02	13.58	13.08
1	1.72	2.37	2.14	0.18
2	1.78	2.45	2.26	0.17
3	1.77	2.43	2.22	0.18
4	1.74	2.39	2.17	0.17
5	1.77	2.43	2.22	0.18
6	1.75	2.41	2.16	0.18
7	1.77	2.44	2.17	0.18
8	1.71	2.36	2.07	0.17
9	1.74	2.39	2.16	0.17
10	1.78	2.45	2.19	0.18
11	1.78	2.43	2.23	0.17
12	1.73	2.39	2.12	0.18
13	1.73	2.38	2.12	0.17
14	1.78	2.45	2.24	0.18
Average	1.75	2.41	2.17	0.18

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



SPC-1 LRT™ (10%) – Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

IM – Intensity Multiplier: *The ratio of I/Os for each I/O stream relative to the total I/Os for all I/O streams (ASU1-1 – ASU3-1) as required by the benchmark specification.*

Clauses 5.1.0 and 5.3.13.2

MIM – Measured Intensity Multiplier: *The Measured Intensity Multiplier represents the ratio of measured I/Os for each I/O stream relative to the total I/Os measured for all I/O streams (ASU1-1 – ASU3-1). This value may differ from the corresponding Expected Intensity Multiplier by no more than 5%.*

Clause 5.3.13.3

COV – Coefficient of Variation: *This measure of variation for the Measured Intensity Multiplier cannot exceed 0.2.*

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0352	0.2807	0.0698	0.2100	0.0180	0.0701	0.0351	0.2812
COV	0.010	0.003	0.005	0.002	0.012	0.007	0.005	0.003

Repeatability Test

Clause 5.4.5

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

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

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

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

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

Clause 9.2.4.7.4

The following content shall appear in the FDR for each Test Run in the two Repeatability Test Phases:

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

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 67.

Repeatability Test Results File

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

	SPC-1 IOPS™
Primary Metrics	***62,243.63***
Repeatability Test Phase 1	62,254.18
Repeatability Test Phase 2	62,253.60

The SPC-1 IOPS™ values in the above table were generated using 100% of the specified Business Scaling Unit (BSU) load level. Each of the Repeatability Test Phase values for SPC-1 IOPS™ must greater than 95% of the reported SPC-1 IOPS™ Primary Metric.

	SPC-1 LRT™
Primary Metrics	***1.75 ms***
Repeatability Test Phase 1	1.77 ms
Repeatability Test Phase 2	1.77 ms

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

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

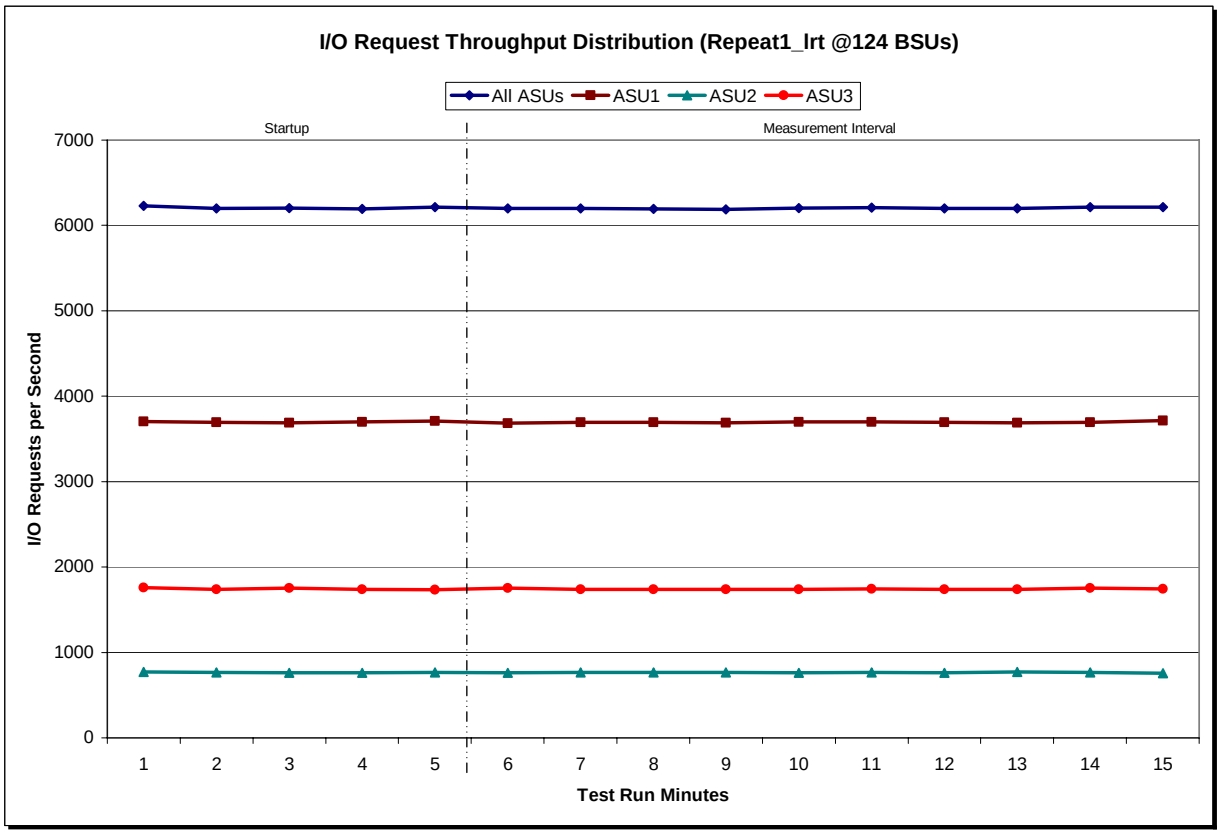
Repeatability Test Phase 1, Test Run 1 (LRT)
Repeatability Test Phase 1, Test Run 2 (IOPS)
Repeatability Test Phase 2, Test Run 1 (LRT)
Repeatability Test Phase 2, Test Run 2 (IOPS)

Repeatability 1 LRT – I/O Request Throughput Distribution Data

124 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:44:43	13:49:43	0-4	0:05:00
Measurement Interval	13:49:43	13:59:43	3-14	0:10:00

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	6,230.02	3,702.48	770.70	1,756.83
1	6,197.47	3,696.12	764.40	1,736.95
2	6,204.00	3,690.42	760.97	1,752.62
3	6,193.35	3,696.98	759.30	1,737.07
4	6,213.20	3,710.82	767.00	1,735.38
5	6,199.37	3,685.73	761.75	1,751.88
6	6,199.07	3,695.28	764.45	1,739.33
7	6,196.10	3,692.60	764.73	1,738.77
8	6,189.55	3,688.77	764.37	1,736.42
9	6,201.53	3,699.57	760.83	1,741.13
10	6,208.85	3,698.20	767.07	1,743.58
11	6,197.43	3,694.22	762.50	1,740.72
12	6,198.12	3,691.47	768.63	1,738.02
13	6,211.53	3,693.58	766.45	1,751.50
14	6,216.02	3,715.93	758.05	1,742.03
Average	6,201.76	3,695.54	763.88	1,742.34

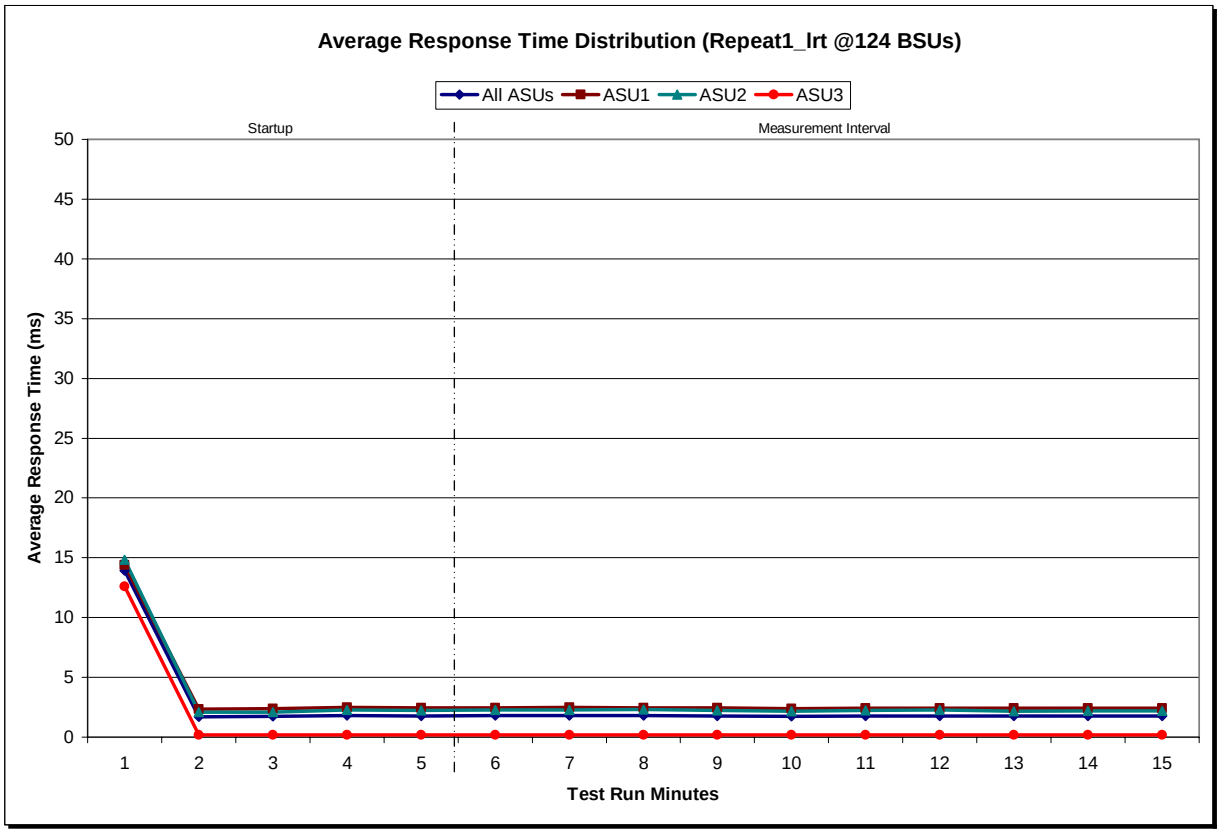
Repeatability 1 LRT – I/O Request Throughput Distribution Graph



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

124 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:44:43	13:49:43	0-4	0:05:00
Measurement Interval	13:49:43	13:59:43	3-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	13.95	14.41	14.82	12.59
1	1.70	2.34	2.10	0.18
2	1.72	2.39	2.08	0.17
3	1.80	2.47	2.26	0.18
4	1.78	2.43	2.24	0.18
5	1.79	2.46	2.28	0.18
6	1.81	2.48	2.26	0.18
7	1.79	2.45	2.30	0.18
8	1.78	2.44	2.23	0.18
9	1.74	2.38	2.17	0.17
10	1.77	2.42	2.24	0.18
11	1.77	2.41	2.27	0.18
12	1.76	2.41	2.17	0.18
13	1.75	2.41	2.20	0.18
14	1.76	2.42	2.18	0.18
Average	1.77	2.43	2.23	0.18

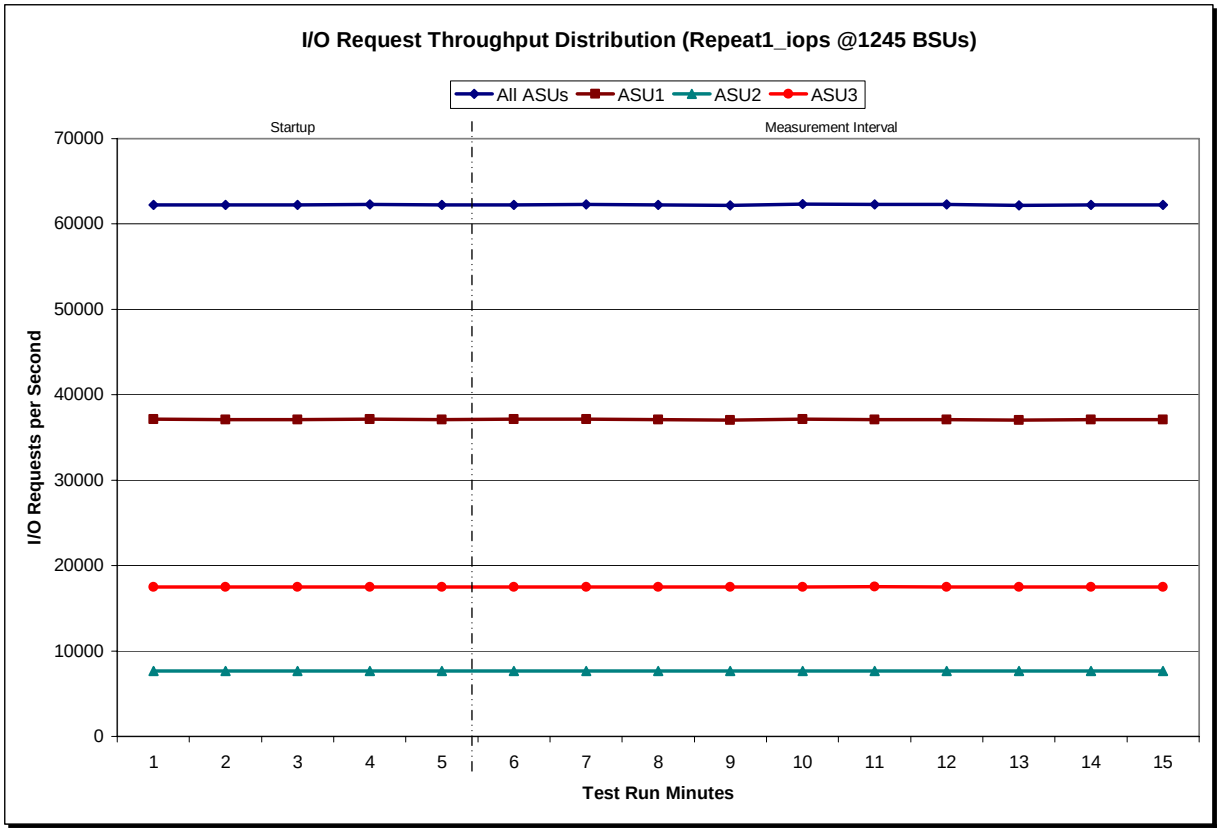
Repeatability 1 LRT –Average Response Time (ms) Distribution Graph



Repeatability 1 IOPS – I/O Request Throughput Distribution Data

1245 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:00:20	14:05:21	0-4	0:05:01
Measurement Interval	14:05:21	14:15:21	3-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	62,261.57	37,118.58	7,654.83	17,488.15
1	62,232.58	37,111.18	7,647.88	17,473.52
2	62,235.83	37,085.23	7,656.52	17,494.08
3	62,277.83	37,123.92	7,653.17	17,500.75
4	62,239.02	37,107.62	7,647.60	17,483.80
5	62,242.42	37,116.82	7,647.97	17,477.63
6	62,286.08	37,119.88	7,657.02	17,509.18
7	62,255.27	37,089.03	7,663.33	17,502.90
8	62,199.60	37,042.03	7,664.65	17,492.92
9	62,322.08	37,151.47	7,668.85	17,501.77
10	62,268.87	37,091.82	7,660.80	17,516.25
11	62,275.07	37,108.47	7,662.62	17,503.98
12	62,196.60	37,047.32	7,648.12	17,501.17
13	62,232.12	37,085.13	7,662.60	17,484.38
14	62,263.73	37,112.58	7,647.22	17,503.93
Average	62,254.18	37,096.46	7,658.32	17,499.41

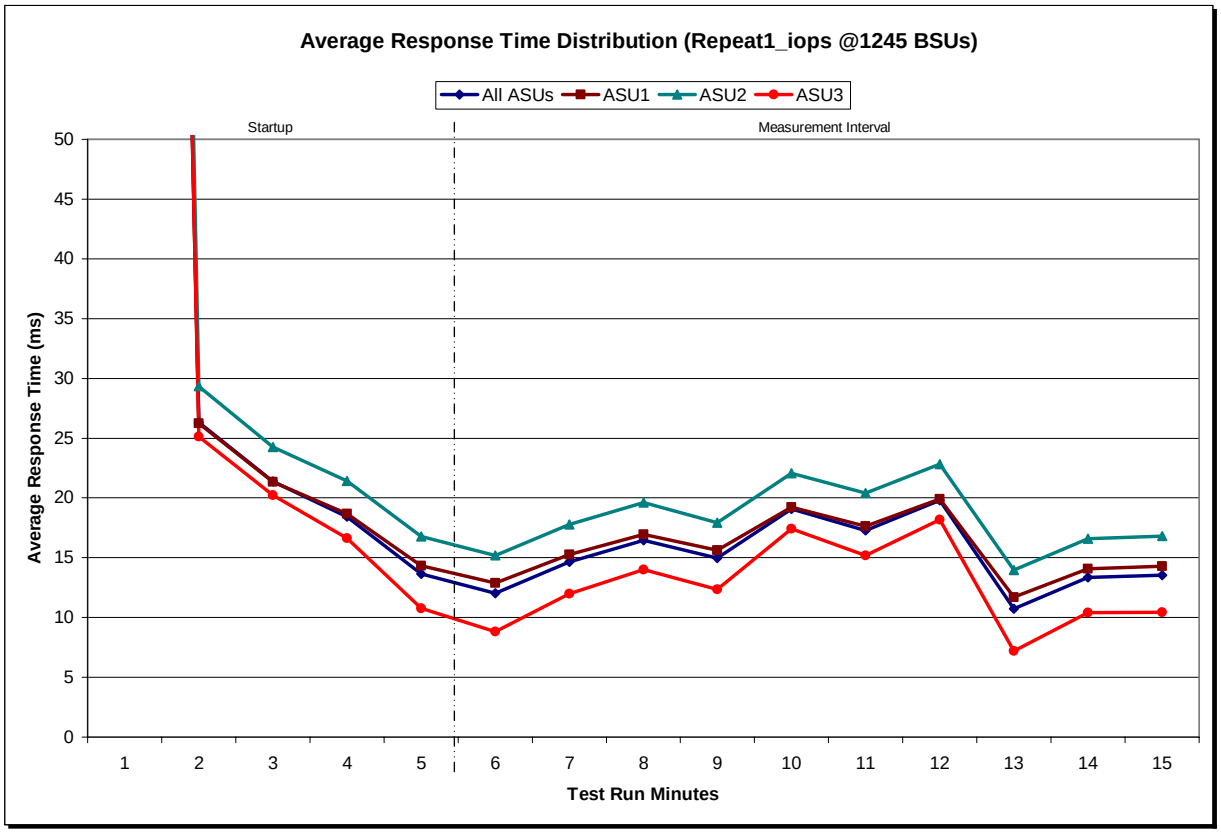
Repeatability 1 IOPS – I/O Request Throughput Distribution Graph



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

1245 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:00:20	14:05:21	0-4	0:05:01
Measurement Interval	14:05:21	14:15:21	3-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	304.13	296.61	324.26	311.28
1	26.31	26.25	29.35	25.11
2	21.39	21.35	24.28	20.23
3	18.44	18.67	21.43	16.64
4	13.63	14.33	16.78	10.77
5	12.02	12.87	15.18	8.82
6	14.66	15.27	17.77	12.00
7	16.46	16.96	19.63	14.02
8	14.99	15.62	17.94	12.36
9	19.07	19.23	22.08	17.41
10	17.29	17.64	20.41	15.18
11	19.78	19.91	22.81	18.19
12	10.72	11.70	13.98	7.19
13	13.36	14.09	16.60	10.40
14	13.52	14.29	16.80	10.44
Average	15.19	15.76	18.32	12.60

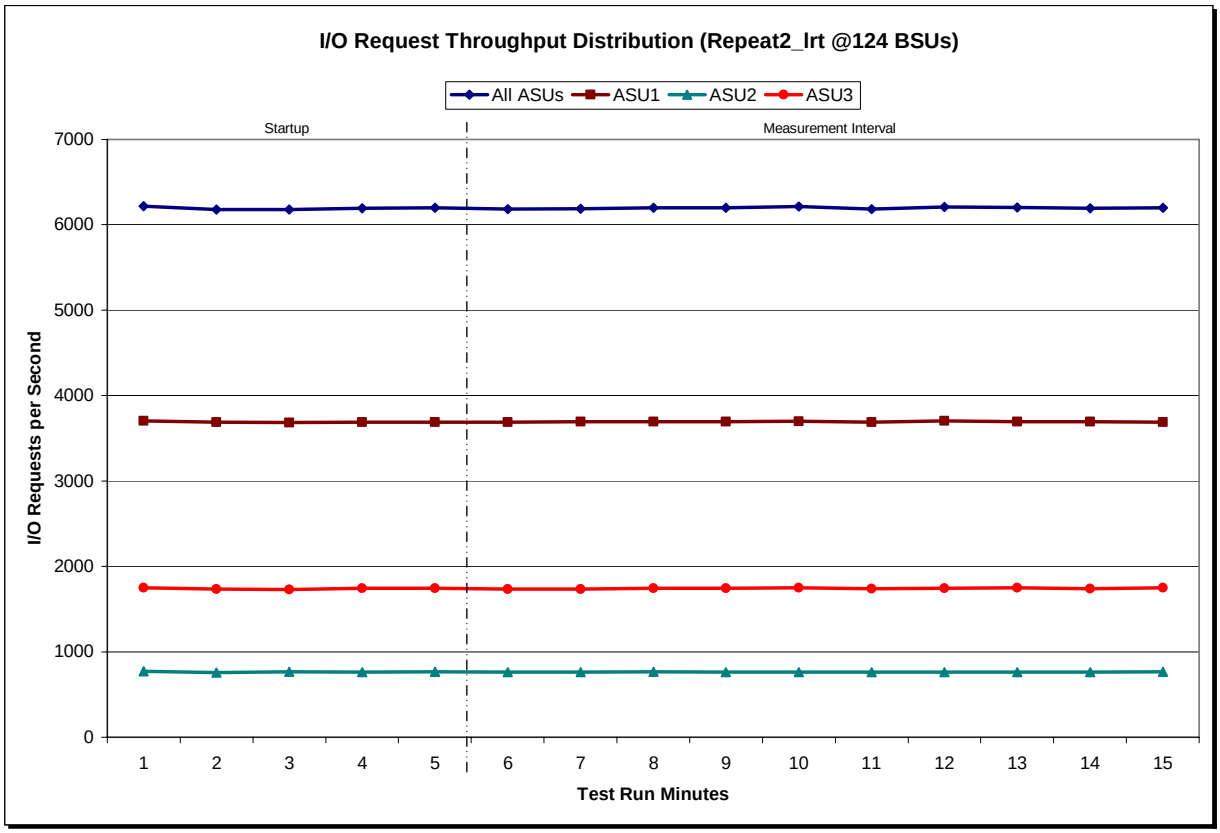
Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph



Repeatability 2 LRT – I/O Request Throughput Distribution Data

124 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:15:59	14:20:59	0-4	0:05:00
Measurement Interval	14:20:59	14:30:59	3-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	6,220.17	3,702.08	769.82	1,748.27
1	6,181.03	3,690.47	757.85	1,732.72
2	6,178.65	3,684.70	763.80	1,730.15
3	6,194.17	3,686.53	762.55	1,745.08
4	6,196.43	3,687.95	765.93	1,742.55
5	6,186.07	3,688.82	763.08	1,734.17
6	6,187.85	3,693.48	758.65	1,735.72
7	6,200.13	3,693.25	764.73	1,742.15
8	6,197.95	3,692.27	762.05	1,743.63
9	6,212.18	3,698.42	763.05	1,750.72
10	6,185.25	3,687.75	760.32	1,737.18
11	6,210.93	3,705.43	762.08	1,743.42
12	6,204.90	3,694.98	760.58	1,749.33
13	6,195.12	3,693.60	761.27	1,740.25
14	6,200.58	3,687.07	767.00	1,746.52
Average	6,198.10	3,693.51	762.28	1,742.31

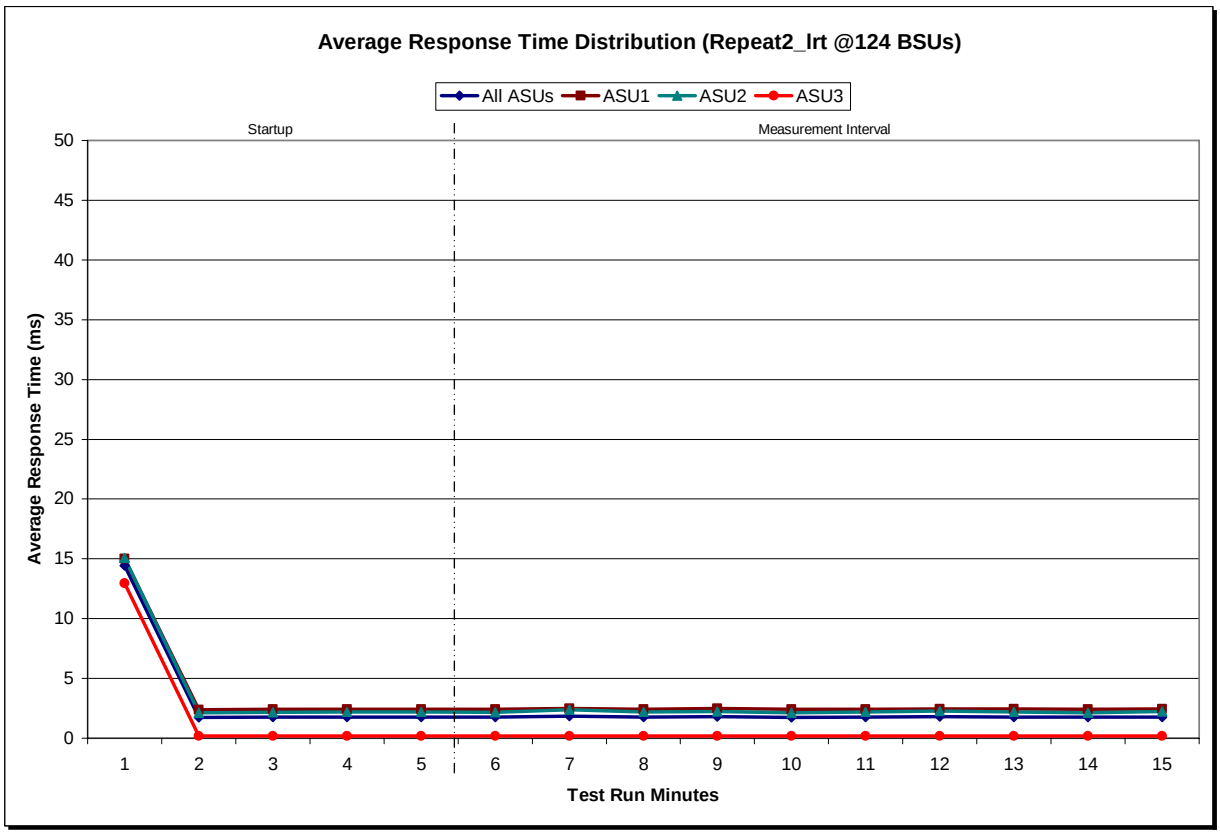
Repeatability 2 LRT – I/O Request Throughput Distribution Graph



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

124 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:15:59	14:20:59	0-4	0:05:00
Measurement Interval	14:20:59	14:30:59	3-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	14.44	15.01	15.09	12.95
1	1.72	2.36	2.11	0.17
2	1.75	2.41	2.16	0.18
3	1.77	2.43	2.20	0.18
4	1.76	2.42	2.19	0.17
5	1.75	2.41	2.15	0.17
6	1.83	2.50	2.36	0.19
7	1.75	2.41	2.19	0.18
8	1.79	2.47	2.22	0.19
9	1.74	2.40	2.11	0.17
10	1.77	2.42	2.21	0.18
11	1.78	2.44	2.26	0.18
12	1.77	2.43	2.19	0.18
13	1.75	2.40	2.14	0.19
14	1.77	2.43	2.23	0.18
Average	1.77	2.43	2.20	0.18

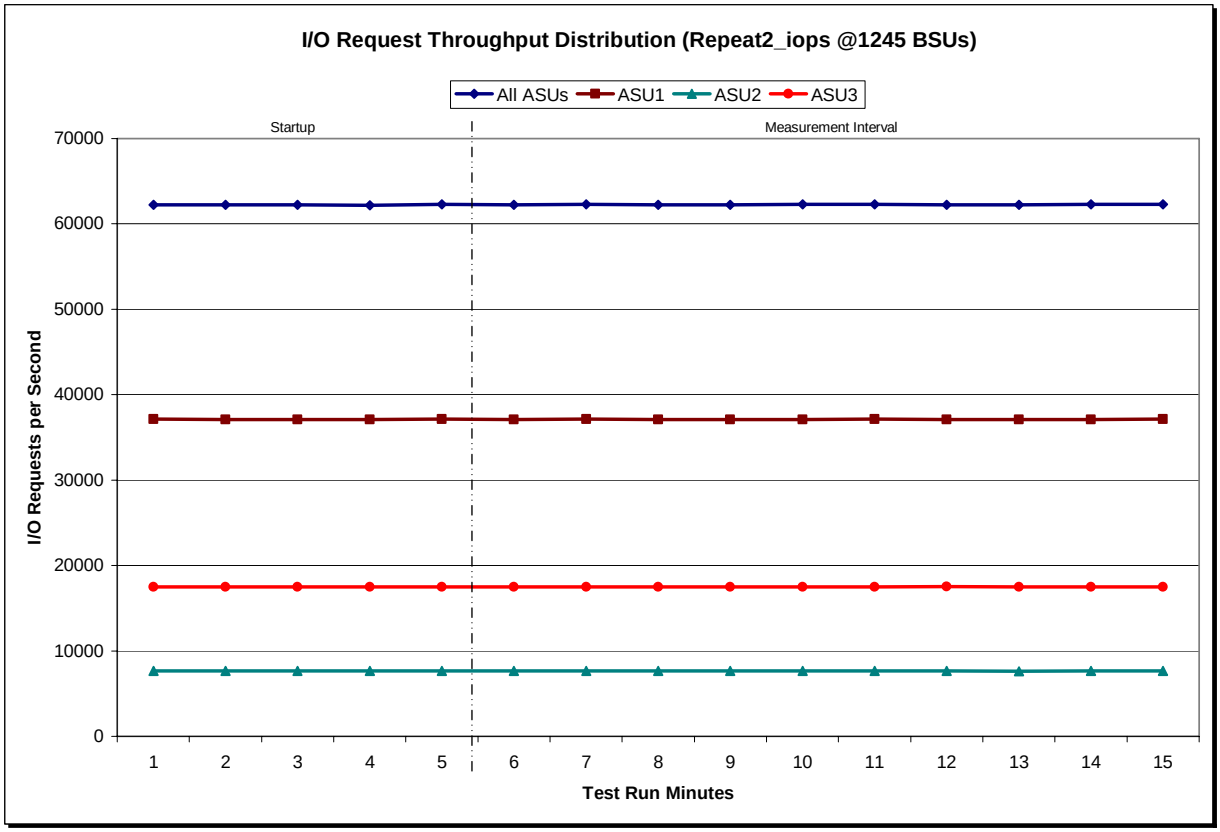
Repeatability 2 LRT –Average Response Time (ms) Distribution Graph



Repeatability 2 IOPS – I/O Request Throughput Distribution Data

1245 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:31:36	14:36:37	0-4	0:05:01
Measurement Interval	14:36:37	14:46:37	3-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	62,261.72	37,131.40	7,639.30	17,491.02
1	62,253.13	37,111.02	7,654.90	17,487.22
2	62,231.13	37,110.07	7,645.10	17,475.97
3	62,205.20	37,086.42	7,641.47	17,477.32
4	62,297.13	37,126.35	7,682.80	17,487.98
5	62,230.17	37,114.83	7,638.77	17,476.57
6	62,283.97	37,116.73	7,657.10	17,510.13
7	62,231.25	37,071.77	7,679.62	17,479.87
8	62,218.47	37,090.12	7,654.43	17,473.92
9	62,270.58	37,108.85	7,664.52	17,497.22
10	62,266.58	37,145.20	7,653.55	17,467.83
11	62,254.00	37,086.72	7,653.97	17,513.32
12	62,228.13	37,104.87	7,634.67	17,488.60
13	62,280.88	37,100.18	7,673.92	17,506.78
14	62,271.95	37,126.55	7,676.02	17,469.38
Average	62,253.60	37,106.58	7,658.66	17,488.36

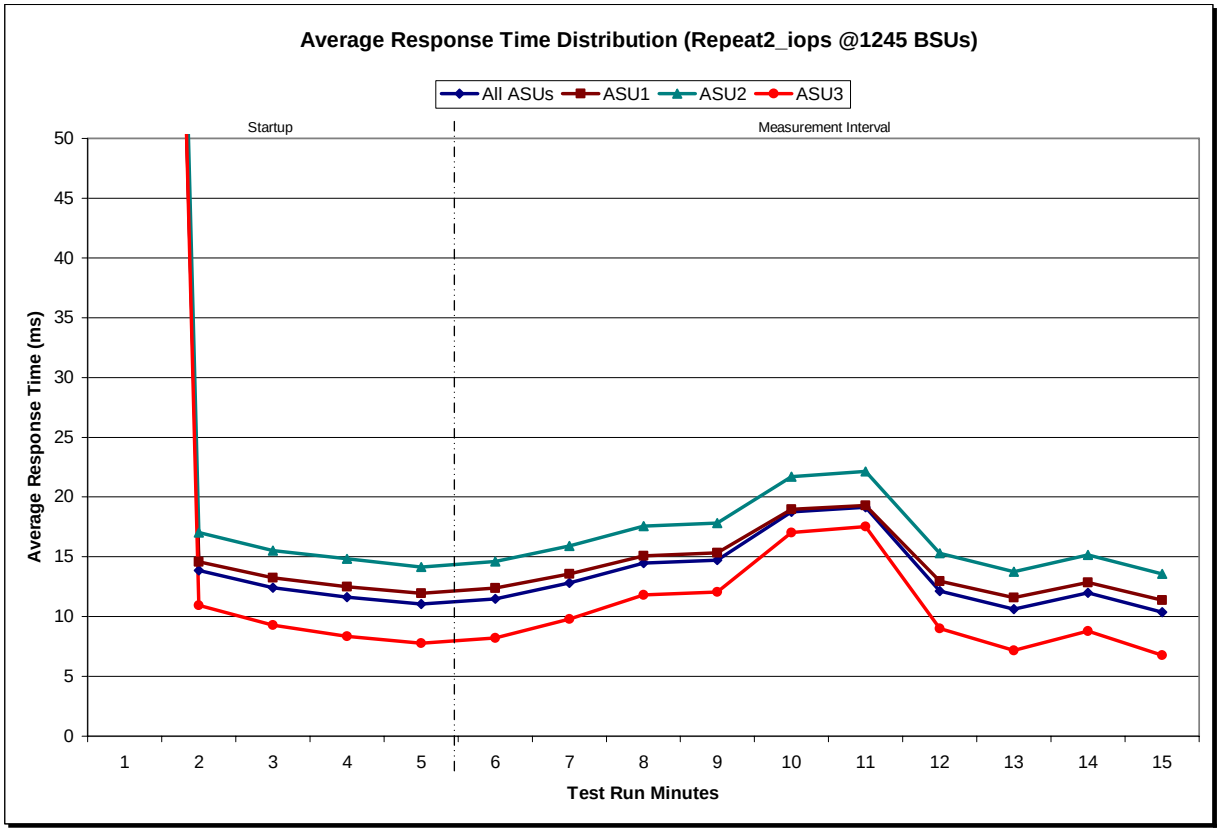
Repeatability 2 IOPS – I/O Request Throughput Distribution Graph



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

1245 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:31:36	14:36:37	0-4	0:05:01
Measurement Interval	14:36:37	14:46:37	3-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	240.60	234.22	253.26	248.63
1	13.85	14.56	17.01	10.95
2	12.41	13.25	15.52	9.28
3	11.63	12.51	14.82	8.36
4	11.06	11.96	14.16	7.78
5	11.48	12.39	14.60	8.21
6	12.80	13.59	15.91	9.77
7	14.46	15.07	17.58	11.80
8	14.73	15.35	17.82	12.07
9	18.76	18.97	21.71	17.01
10	19.15	19.29	22.15	17.55
11	12.14	12.97	15.28	9.01
12	10.62	11.60	13.74	7.17
13	11.98	12.84	15.16	8.78
14	10.35	11.37	13.58	6.76
Average	13.65	14.34	16.75	10.81

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



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

Clause 3.4.3

IM – Intensity Multiplier: *The ratio of I/Os for each I/O stream relative to the total I/Os for all I/O streams (ASU1-1 – ASU3-1) as required by the benchmark specification.*

Clauses 5.1.0 and 5.3.13.2

MIM – Measured Intensity Multiplier: *The Measured Intensity Multiplier represents the ratio of measured I/Os for each I/O stream relative to the total I/Os measured for all I/O streams (ASU1-1 – ASU3-1). This value may differ from the corresponding Expected Intensity Multiplier by no more than 5%.*

Clause 5.3.13.3

COV – Coefficient of Variation: *This measure of variation for the Measured Intensity Multiplier cannot exceed 0.2.*

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0351	0.2807	0.0699	0.2103	0.0181	0.0701	0.0350	0.2809
COV	0.008	0.003	0.007	0.004	0.014	0.006	0.008	0.003

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2809	0.0700	0.2100	0.0180	0.0700	0.0350	0.2811
COV	0.004	0.001	0.002	0.001	0.005	0.001	0.001	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	0.0349	0.2812	0.0700	0.2098	0.0180	0.0700	0.0350	0.2811
COV	0.010	0.003	0.006	0.003	0.011	0.005	0.007	0.002

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2811	0.0700	0.2100	0.0180	0.0700	0.0350	0.2809
COV	0.003	0.001	0.002	0.001	0.004	0.002	0.003	0.001

Data Persistence Test

Clause 6

The Data Persistence Test demonstrates the Tested Storage Configuration (TSC):

- *Is capable of maintain data integrity across a power cycle.*
- *Ensures the transfer of data between Logical Volumes and host systems occurs without corruption or loss.*

The SPC-1 Workload Generator will write 16 block I/O requests at random over the total Addressable Storage Capacity of the TSC for ten (10) minutes at a minimum of 25% of the load used to generate the SPC-1 IOP™ primary metric. The bit pattern selected to be written to each block as well as the address of the block will be retained in a log file.

The Benchmark Configuration will be shutdown and restarted using a power off/power on cycle at the end of the above sequence of write operations. In addition, any caches employing battery backup must be flushed/emptied.

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

Clause 9.2.4.8

The following content shall appear in this section of the FDR:

1. *A listing or screen image of all input parameters supplied to the Workload Generator.*
2. *For the successful Data Persistence Test Run, a table illustrating key results. The content, appearance, and format of this table are specified in Table 9-12. Information displayed in this table shall be obtained from the Test Run Results File referenced below in #3.*
3. *For the successful Data Persistence Test Run, the human readable Test Run Results File produced by the Workload Generator.*

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 67.

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	52,734,368
Total Number of Logical Blocks Verified	47,234,368
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 DS5300 as documented in this Full Disclosure Report will become available on August 21, 2009 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 DS5300.

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.

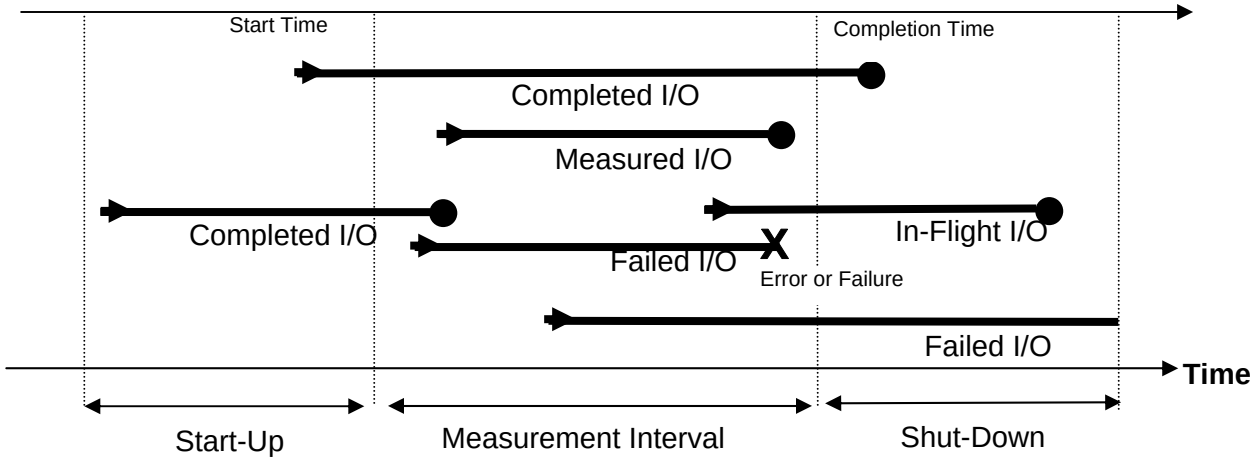
Test: A collection of Test Phases and or Test Runs sharing a common objective.

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

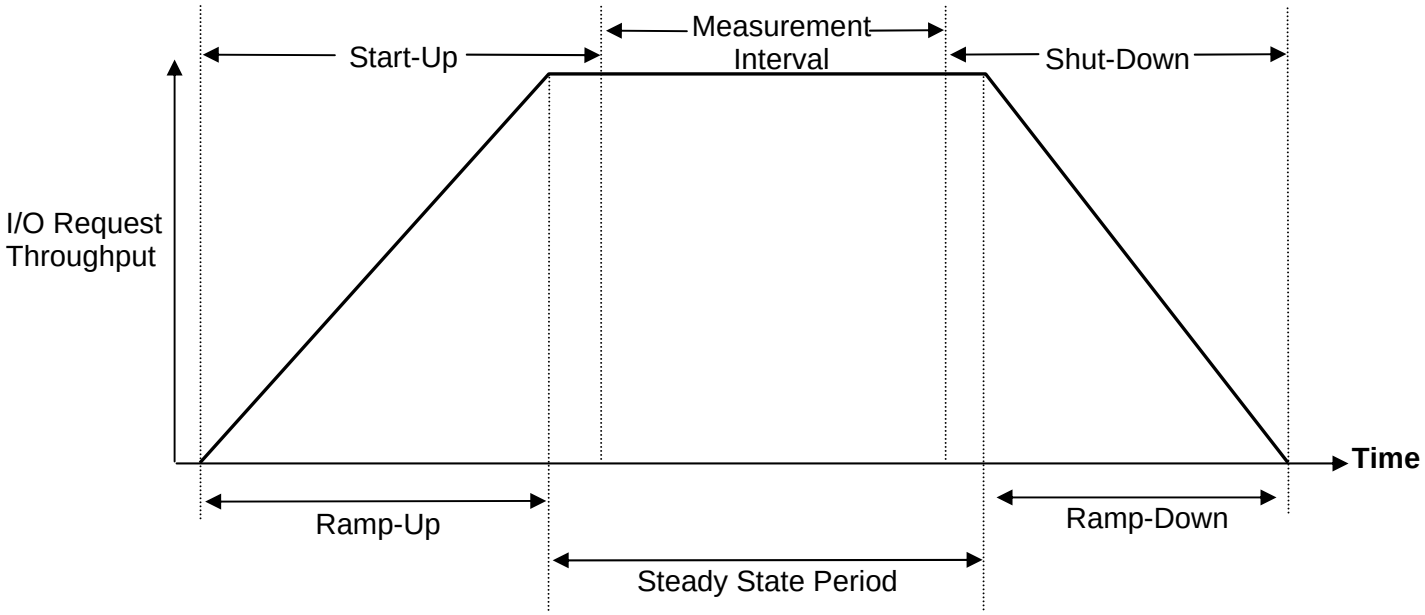
period, Shut-Down period, and Ramp-Down period as illustrated in the "SPC-1 Test Run Components" below. All SPC-1 Test Runs shall have a Steady State period and a Measurement Interval.

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\
mppdsm\Parameters\DeviceSettings\Array#...\LoadBalancePolicy=0
```

Storage Array Cache Flush Settings

Start Flush: changed from default of 80 to new value of 50

Stop Flush: changed from default of 80 to new value of 50

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
Adapter 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	510
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 sixteen volume groups on the storage subsystem, each volume group contains a single volume. The SANtricity script is included in this section. These sixteen volumes are visible by each of the attached hosts. There are four hosts used in this benchmark. One host is the "master". The other three are "slave" hosts. Each host is configured with four JVM's. The steps that follow are required to define the Windows partitions, volumes, and stripe sets that will be used by the SPC-1 benchmark. Steps 1-8 below are performed on only one of the hosts.

1. 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.
2. Start Windows Disk Administrator.
3. Convert all of the storage system volumes to Dynamic Disks.
4. Create a Windows Striped (RAID 0) volume using all sixteen 32MB volumes.
5. Delete the large volume on each of the Dynamic Disks.
6. Create a Windows Striped (RAID 0) volume for ASU 3.
   a. Select all sixteen volumes.
   b. Set capacity to 81910MB.
   c. Assign drive letter "N" to the volume. Do not format the volume.
7. Create the Windows Striped (RAID0) volume for ASU 1.
   a. Select all sixteen volumes.
   b. Set capacity to 368595MB.
   c. Assign drive letter "L" to the volume. Do not format the volume.
8. Create the Windows Striped (RAID 0) volume for ASU 2.
   a. Select all sixteen volumes.
   b. Set capacity to 368595MB.
   c. Assign drive letter "M" to the volume. Do not format the volume.
9. Reboot all four host systems.
10. After reboot completes, start Disk Administrator on each of the host systems.
11. Import foreign disks, or reactive the Windows stripe sets as necessary. On each host, assign drive letters to the stripe sets as they were assigned in steps 6, 7, and 8.

spc1_xbb2_16_8plus8r1_128kseg_16tray_secure

```
/* 01/27/09 - 16 8+8 drive groups for XBB-2         */
/* *** FDE security enabled drives ***              */
/* capacity=899gb is used with 146GB drives         */

create volume drives[ 10,1 10,2  30,1 30,2  50,1 50,2  70,1 70,2  10,3 10,4  30,3
30,4  50,3 50,4  70,3 70,4 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_0"
volumeGroupUserLabel="VolumeGroup_0"
capacity=899 gb
securityType=enabled
owner = A;

create volume drives[ 10,5 10,6  30,5 30,6  50,5 50,6  70,5 70,6  10,7 10,8  30,7
30,8  50,7 50,8  70,7 70,8 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_1"
volumeGroupUserLabel="VolumeGroup_1"
capacity=899 gb
securityType=enabled
owner = A;

create volume drives[ 10,9 10,10  30,9 30,10  50,9 50,10  70,9 70,10  10,11 10,12
30,11 30,12  50,11 50,12  70,11 70,12 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_2"
volumeGroupUserLabel="VolumeGroup_2"
capacity=899 gb
securityType=enabled
owner = A;

create volume drives[ 10,13 10,14  30,13 30,14  50,13 50,14  70,13 70,14  10,15
10,16  30,15 30,16  50,15 50,16  70,15 70,16 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_3"
volumeGroupUserLabel="VolumeGroup_3"
capacity=899 gb
securityType=enabled
owner = A;

create volume drives[ 11,1 11,2  31,1 31,2  51,1 51,2  71,1 71,2  11,3 11,4  31,3
31,4  51,3 51,4  71,3 71,4 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_4"
volumeGroupUserLabel="VolumeGroup_4"
capacity=899 gb
securityType=enabled
owner = A;

create volume drives[ 11,5 11,6  31,5 31,6  51,5 51,6  71,5 71,6  11,7 11,8  31,7
31,8  51,7 51,8  71,7 71,8 ]
RAIDLevel=1
segmentSize=128
```

```
userLabel="LUN_5"
volumeGroupUserLabel="VolumeGroup_5"
capacity=899 gb
securityType=enabled
owner = A;

create volume drives[ 11,9 11,10  31,9 31,10  51,9 51,10  71,9 71,10  11,11 11,12
31,11 31,12  51,11 51,12  71,11 71,12 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_6"
volumeGroupUserLabel="VolumeGroup_6"
capacity=899 gb
securityType=enabled
owner = A;

create volume drives[ 11,13 11,14  31,13 31,14  51,13 51,14  71,13 71,14  11,15
11,16  31,15 31,16  51,15 51,16  71,15 71,16 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_7"
volumeGroupUserLabel="VolumeGroup_7"
capacity=899 gb
securityType=enabled
owner = A;

create volume drives[ 20,1 20,2  40,1 40,2  60,1 60,2  80,1 80,2  20,3 20,4  40,3
40,4  60,3 60,4  80,3 80,4 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_8"
volumeGroupUserLabel="VolumeGroup_8"
capacity=899 gb
securityType=enabled
owner = b;

create volume drives[ 20,5 20,6  40,5 40,6  60,5 60,6  80,5 80,6  20,7 20,8  40,7
40,8  60,7 60,8  80,7 80,8 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_9"
volumeGroupUserLabel="VolumeGroup_9"
capacity=899 gb
securityType=enabled
owner = b;

create volume drives[ 20,9 20,10  40,9 40,10  60,9 60,10  80,9 80,10  20,11 20,12
40,11 40,12  60,11 60,12  80,11 80,12 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_10"
volumeGroupUserLabel="VolumeGroup_10"
capacity=899 gb
securityType=enabled
owner = b;

create volume drives[ 20,13 20,14  40,13 40,14  60,13 60,14  80,13 80,14  20,15
20,16  40,15 40,16  60,15 60,16  80,15 80,16 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_11"
volumeGroupUserLabel="VolumeGroup_11"
capacity=899 gb
```

```
securityType=enabled
owner = b;

create volume drives[ 21,1 21,2  41,1 41,2  61,1 61,2  81,1 81,2  21,3 21,4  41,3
41,4  61,3 61,4  81,3 81,4 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_12"
volumeGroupUserLabel="VolumeGroup_12"
capacity=899 gb
securityType=enabled
owner = b;

create volume drives[ 21,5 21,6  41,5 41,6  61,5 61,6  81,5 81,6  21,7 21,8  41,7
41,8  61,7 61,8  81,7 81,8 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_13"
volumeGroupUserLabel="VolumeGroup_13"
capacity=899 gb
securityType=enabled
owner = b;

create volume drives[ 21,9 21,10  41,9 41,10  61,9 61,10  81,9 81,10  21,11 21,12
41,11 41,12  61,11 61,12  81,11 81,12 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_14"
volumeGroupUserLabel="VolumeGroup_14"
capacity=899 gb
securityType=enabled
owner = b;

create volume drives[ 21,13 21,14  41,13 41,14  61,13 61,14  81,13 81,14  21,15
21,16  41,15 41,16  61,15 61,16  81,15 81,16 ]
RAIDLevel=1
segmentSize=128
userLabel="LUN_15"
volumeGroupUserLabel="VolumeGroup_15"
capacity=899 gb
securityType=enabled
owner = b;

set volume["LUN_0"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_1"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_2"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_3"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_4"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_5"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_6"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_7"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_8"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_9"]  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
```

```
set volume["LUN_10"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_11"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_12"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_13"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_14"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;
set volume["LUN_15"] mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = True readAheadMultiplier = 0;

set storageArray cacheBlockSize  = 16;
set storageArray cacheFlushStart = 50 cacheFlushStop  = 50;

set storageArray defaultHostType = "Windows 2000/Server 2003/Server 2008 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;
```

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

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

```
* spc1_iops.cfg

host=master
slaves=(bm3650a_s1,bm3650a_s2,bm3650a_s3,bm3650a_s4,bm3650b_s1,bm3650b_s2,bm
3650b_s3,bm3650b_s4,bm3650c_s1,bm3650c_s2,bm3650c_s3,bm3650c_s4,bm3650d_s1,b
m3650d_s2,bm3650d_s3,bm3650d_s4)

javaparms="-Xmx512m -Xms512m"

sd=asu1_1,lun=\\.\L:,size=6183997931520
sd=asu2_1,lun=\\.\M:,size=6183997931520
sd=asu3_1,lun=\\.\N:,size=1374221762560

eof
```

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

```
* spc1_persist.cfg

javaparms="-Xmx512m -Xms512m"

sd=asu1_1,lun=\\.\L:,size=6183997931520
sd=asu2_1,lun=\\.\M:,size=6183997931520
sd=asu3_1,lun=\\.\N:,size=1374221762560

eof
```

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

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

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

```
copy /Y spc1_iops.cfg spc1.cfg

java -Xmx640m -Xms640m metrics -b 1245 -s 300

java -Xmx640m -Xms640m repeat1 -b 1245 -s 300

java -Xmx640m -Xms640m repeat2 -b 1245 -s 300

copy /Y spc1_persist.cfg spc1.cfg

java -Xmx640m -Xms640m persist1 -b 1245

java -Xmx640m -Xms640m persist2
```

Persistence Test Run 2

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

```
rem copy /Y spc1_iops.cfg spc1.cfg

rem java -Xmx640m -Xms640m metrics -b 1245 -s 300

rem java -Xmx640m -Xms640m repeat1 -b 1245 -s 300

rem java -Xmx640m -Xms640m repeat2 -b 1245 -s 300

rem copy /Y spc1_persist.cfg spc1.cfg

rem java -Xmx640m -Xms640m persist1 -b 1245

java -Xmx640m -Xms640m persist2
```

Slave JVM Initiation

Each of the four Slave JVMs on each Host System was initiated by a command and corresponding parameter file. An example of the command and corresponding parameter file appear below. The Slave designation (slave1, slave2, etc.) and Host System designation (bm3650a, bm3650b, etc.) is differs appropriately in each specific pair of files.

Slave1.cmd

```
java –Xmx256m –Xms256m spc1 –fslave1.parm
```

Slave1.parm

```
*slave1.parm

host=bm3650a_s1
master=bm3650b

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

eof
```