SPC BENCHMARK 1™
FULL DISCLOSURE REPORT

IBM CORPORATION
IBM STORWIZE® V7000

SPC-1 V1.12

Submitted for Review: March 14, 2011
Submission Identifier: A00103

First Edition – March 2011

Trademarks

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AUDIT CERTIFICATION

Bruce McNutt
IBM Corporation
650 Harry Road C2 500
San Jose, CA 95120

March 11, 2011

The SPC Benchmark 1™ results listed below for the IBM Storwize® V7000 were produced in compliance with the SPC Benchmark 1™ 1.12 Remote Audit requirements.

SPC Benchmark 1™ 1.12 Results	
Tested Storage Configuration (TSC) Name: IBM Storwize® V7000	
Metric	**Reported Result**
SPC-1 IOPS™	53,014.29
SPC-1 Price-Performance	$7.52/SPC-1 IOPS™
Total ASU Capacity	24,433.592 GB
Data Protection Level	Protected *(Mirroring)*
Total TSC Price (including three-year maintenance)	$389,425.11

The following SPC Benchmark 1™ Remote Audit requirements were reviewed and found compliant with 1.12 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.
- SPC-1 Workload Generator commands and parameters used for the audited SPC Test Runs.

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Redwood City, CA 94062
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AUDIT CERTIFICATION *(CONT.)*

- 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 the Host System.
  - ✓ The TSC boundary within the Host System.
- The Test Results Files and resultant Summary Results Files received from IBM Corporation for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4 and 5 of the SPC-1 Benchmark Specification:
  - ✓ Data Persistence Test
  - ✓ Sustainability Test Phase
  - ✓ IOPS Test Phase
  - ✓ Response Time Ramp Test Phase
  - ✓ Repeatability Test
- The differences between the Tested Storage Configuration and Priced Storage Configuration were documented and, if applied to the Tested Storage Configuration, would not have an impact on the audited benchmark measurements.
- 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

Walter E. Baker
SPC Auditor

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LETTER OF GOOD FAITH

IBM

Vice President and Disk Storage Business Line Executive

IBM Technology & Systems Group
3039 Cornwallis Road,
Research Triangle Park, NC 27709

Phone: 1-919-543-5345
Fax: 1-919-543-2856

February 18, 2011

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 Storwize V7000.

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 1.12 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,

Doug Balog

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 650 Harry Road C2 500 San Jose, CA 95120 Phone: (408) 927-2717 FAX: 0086 28 62905793
Test Sponsor Alternate Contact	IBM Corporation – http://www.ibm.com Barry Whyte – barry.whyte@uk.ibm.com IBM Hursley Park Hursley, UK SO212JN Phone: 011-44-1-96-281-7566
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	V1.12
SPC-1 Workload Generator revision number	V2.1.0
Date Results were first used publicly	March 14, 2011
Date the FDR was submitted to the SPC	March 14, 2011
Date the priced storage configuration is available for shipment to customers	currently available
Date the TSC completed audit certification	March 11, 2011

Tested Storage Product (TSP) Description

The IBM Storwize V7000 disk system, IBM's newest midrange disk storage offering, uses IBM System Storage SAN Volume Controller technology to deliver high performance, advanced function, high availability, and modular and scalable storage capacity.

- Supports RAID 0, 1, 5, 6, and 10
- Provides SAN-attached 8 Gbps Fibre Channel (FC) host connectivity and 1 GbE iSCSI host connectivity
- Supports intermix of SAS drives, Nearline SAS drives, and Solid-state drives within the IBM Storwize V7000 Control Enclosure and IBM Storwize V7000 Expansion Enclosures (up to twenty-four 2.5-inch disk drives or twelve 3.5 inch disk drives in each Enclosure).
- Includes IBM Easy Tier technology for automatically moving heavily used data extents onto high-performance storage
- Supports attachment of other storage devices via the Fibre Channel interface, just as the SAN Volume Controller
- Supports a complete set of SAN Volume Controller functions including FlashCopy, RemoteCopy, VDisk Mirroring, thin provisioning, and a revised web-based user interface for both products new with this release

Summary of Results

SPC-1 Results	
Tested Storage Configuration (TSC) Name: IBM Storwize® V7000	
Metric	**Reported Result**
SPC-1 IOPS™	53,014.29
SPC-1 Price-Performance	$7.52/SPC-1 IOPS™
Total ASU Capacity	24,433.592 GB
Data Protection Level	Protected *(Mirroring)*
Total TSC Price (including three-year maintenance)	$389,425.11

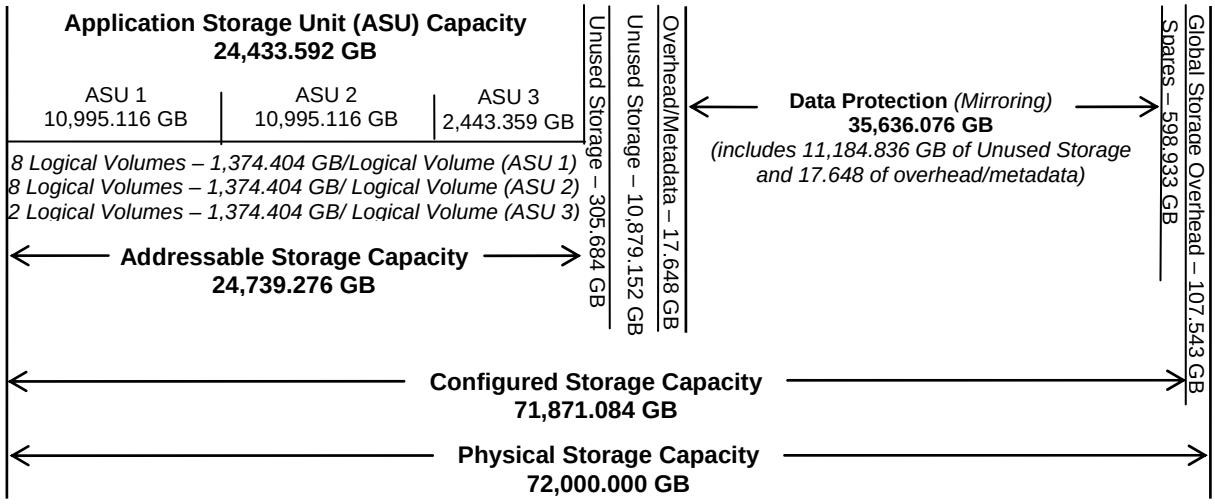
SPC-1 IOPS™ represents the maximum I/O Request Throughput at the 100% load point.

Total ASU (Application Storage Unit) **Capacity** represents the total storage capacity read and written in the course of executing the SPC-1 benchmark.

A **Data Protection Level** of **Protected** using ***Mirroring*** configures two or more identical copies of user data.

Storage Capacities, Relationships, and Utilization

The following diagram and table document the various storage capacities, used in this benchmark, and their relationships, as well as the storage utilization values required to be reported.



SPC-1 Storage Capacity Utilization	
Application Utilization	33.94%
Protected Application Utilization	68.32%
Unused Storage Ratio	30.64%

Application Utilization: Total ASU Capacity *(24,433.592 GB)* divided by Physical Storage Capacity *(72,000.000 GB)*

Protected Application Utilization: (Total ASU Capacity *(24,433.592 GB)* plus total Data Protection Capacity *(35,636.076 GB)* minus unused Data Protection Capacity *(10,879.152 GB)* divided by Physical Storage Capacity *(72,000.000 GB)*

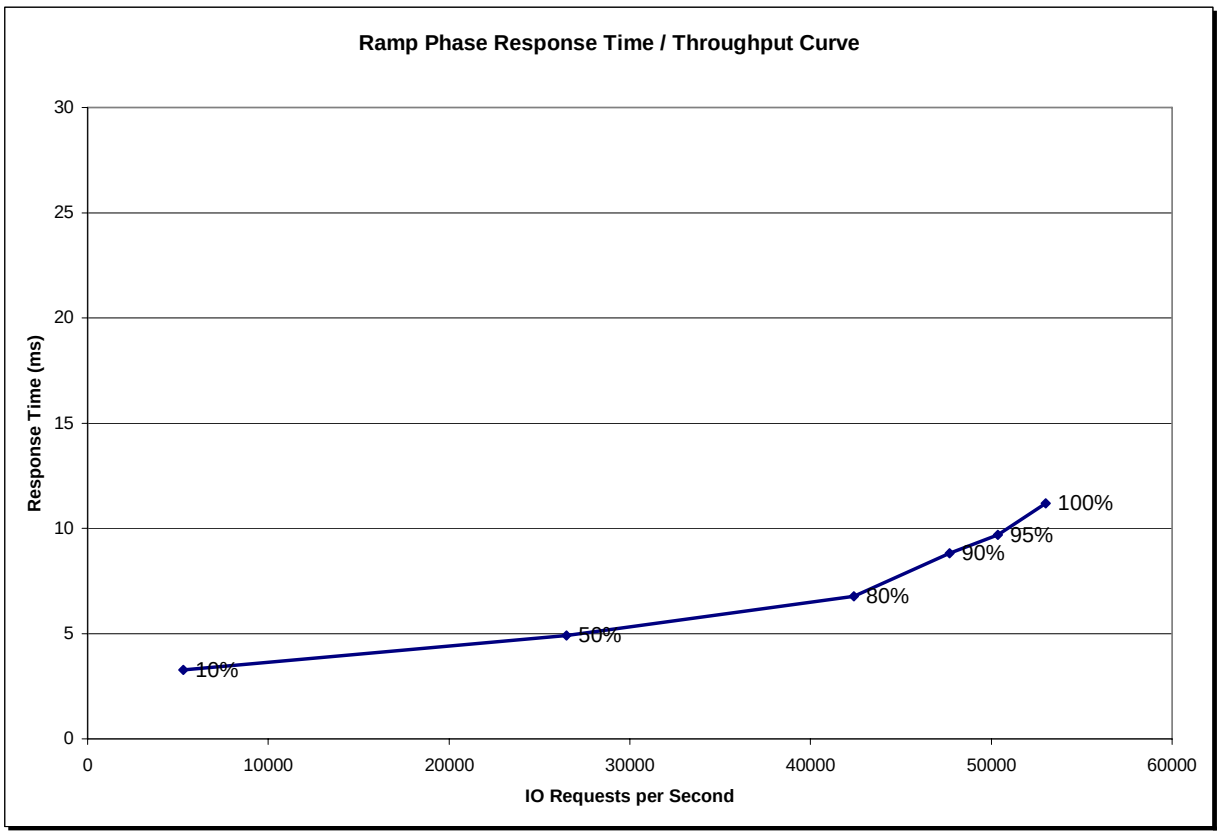
Unused Storage Ratio: Total Unused Capacity *(22,063.988 GB)* divided by Physical Storage Capacity *(72,000.000 GB)* and may not exceed 45%.

Detailed information for the various storage capacities and utilizations is available on pages 21-22 in the Full Disclosure Report.

Response Time – Throughput Curve

The Response Time-Throughput Curve illustrates the Average Response Time (milliseconds) and I/O Request Throughput at 100%, 95%, 90%, 80%, 50%, and 10% of the workload level used to generate the SPC-1 IOPS™ metric.

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



Response Time – Throughput Data

	10% Load	50% Load	80% Load	90% Load	95% Load	100% Load
I/O Request Throughput	5,302.17	26,505.06	42,396.22	47,688.07	50,357.56	53,014.29
Average Response Time (ms):						
All ASUs	3.27	4.91	6.77	8.82	9.70	11.19
ASU-1	4.04	6.05	8.41	10.53	11.50	13.03
ASU-2	3.80	6.28	9.59	12.51	13.94	16.02
ASU-3	1.40	1.90	2.04	3.56	4.02	5.16
Reads	6.19	9.62	14.16	17.20	18.81	20.97
Writes	1.36	1.84	1.95	3.35	3.76	4.82

Priced Storage Configuration Pricing

		Qty	Unit Price .	extended	% discount		discounted price
Storwize V7000 base storage enclosure (2076-124)	8 SFP (8 Gb)	1	$25,000	$25,000	39	$	15,250.00
Storwize V7000 Base SW		1	$18,000	$18,000	39	$	10,980.00
Storwize V7000 expansion enclosure (2076-224)		9	$6,000	$54,000	39	$	32,940.00
Storwize V7000 Base SW		9	$18,000	$162,000	39	$	98,820.00
SAS 1M Cables to attach Control Enclosures to Expansion Enclosures		18	$59	$1,062	39	$	647.82
2.5" 10K 300GB SAS HDD's		240	$1,099	$263,760	39	$	160,893.60
24 port fibre channel switch (2498-B24)	w/ 8 port actv, 8 SFP (8 Gb)	2	$7,890	$15,780	20	$	12,624.00
Short wave 5m fibre channel cable (1814-20A 5605)		8	$129	$1,032	20	$	825.60
Short wave 25 m fibre channel cable (1814-20A 5625)		4	$189	$756	20	$	604.80
19 inch rack (7014-T42)		1	$2,970	$2,970	50	$	1,485.00
Dual port 8 Gbps FC HBA (42D0510)		2	$1,299	$2,598	0	$	2,598.00
	HW/SW Total					$	337,668.82
Maintenance for Software							
Base SW		10	$7,200	$72,000	39	$	43,920.00
WSU for Hardware							
Storwize V7000 Controller Enclosure		1	$4,200	$4,200	39	$	2,562.00
Storwize V7000 Expansion Enclosure		9	$1,921	$17,289	39	$	10,546.29
Warranty/Maintenance Upgrade to 3 year 24x7x4 for Switch		2	$2,330	$4,660	20	$	3,728.00
	Total Warranty/Maintenance					$	60,756.29
	Grand Total					**$**	**398,425.11**

The above pricing includes hardware maintenance and software support for three years, 7 days per week, 24 hours per day. The hardware maintenance and software support provides the following:

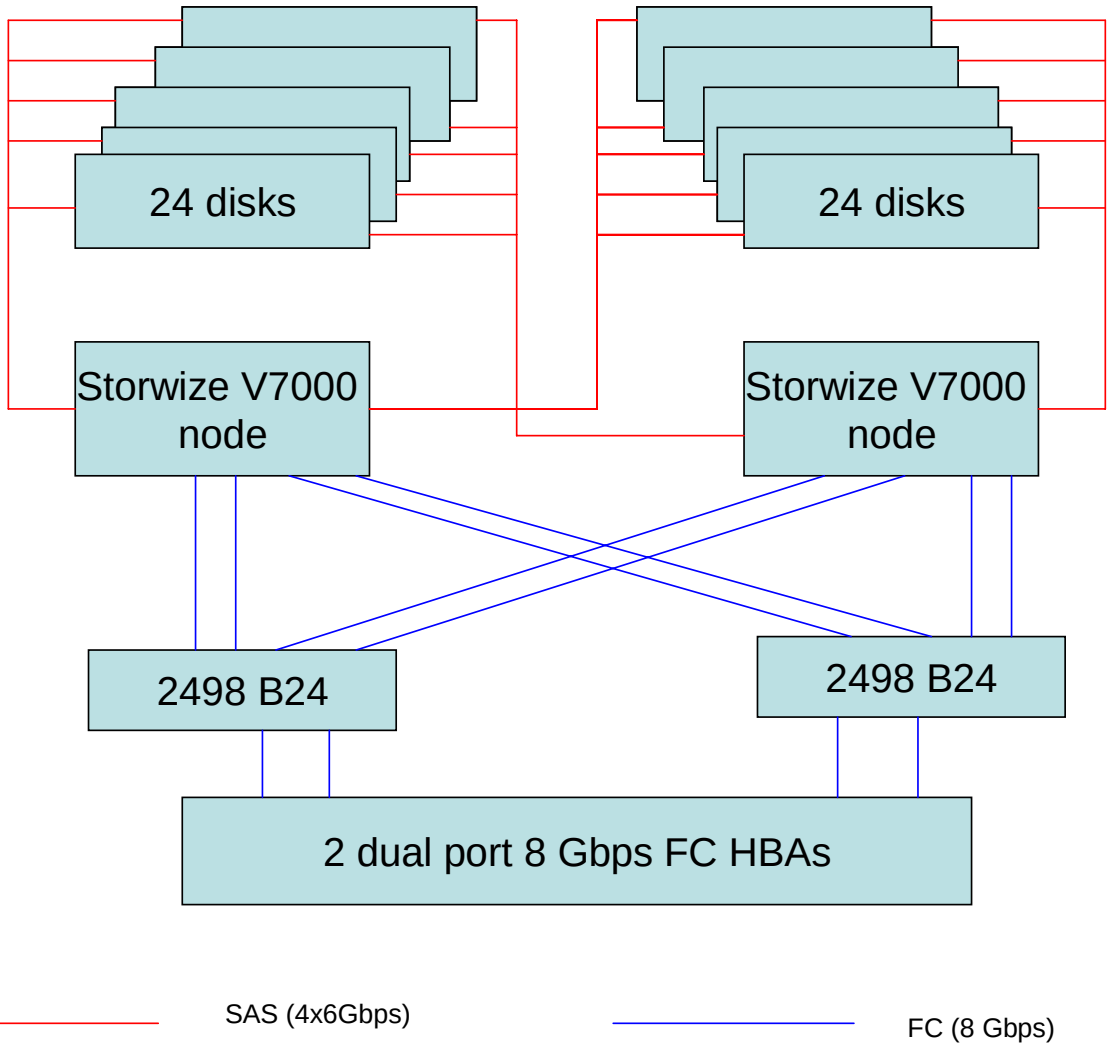
- Acknowledgement of new and existing problems with four (4) hours.
- Onsite present of a qualified maintenance engineer or provision of a customer replaceable part within four (4) hours of the above acknowledgement for any hardware failure that results in an inoperative Price Storage Configuration that can be remedied by the repair or replacement of a Priced Storage Configuration component.

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

Each of the two 2498 B24 switches in the TSC was enabled for 24 ports and configured with 20 SFPs. The benchmark measurements utilized 8 ports and 8 SFPs in each switch.

Each of the two 2498 B24 switches included in the Priced Storage Configuration was enabled for 8 ports and configured with 8 SFPs. This difference, if applied to the TSC, would not affect the reported benchmark measurements.

Priced Storage Configuration Diagram



2498 B24: 24-port fibre channel switch

24 disks: One Storwize® V7000 base storage enclosure and four Storwize® V7000 Expansion Enclosures, each with 24 10K RPM 146GB disk drives.

Priced Storage Configuration Components

Priced Storage Configuration Components:
2 – 8 Gb PCIe dual port FC HBAs
IBM Storwize® V7000 ***(2-node cluster)***
8 GB memory/cache per node *(16 GB total)*
4 – 8 Gbps switch-to-host FC connections shared by both nodes
2 – 4x6Gbps SAS connections per node
8 – 8 Gb SFPs
24 – 10K RPM 300 GB disk drives
9 – Storwize® V7000 expansion enclosures each with 24 10K RPM 300 GB disk drives
1 – 19 inch rack with 2 12-plug PDUs
2 – 24-port fibre channel switches *(2498-B24*)
8 – short wave 5m fibre channel cables
4 – 25m fibre channel cables

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

CONFIGURATION INFORMATION

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

Clause 9.4.3.4.1

A one page Benchmark Configuration (BC)/Tested Storage Configuration (TSC) diagram shall be included in the FDR…

The Benchmark Configuration (BC)/Tested Storage Configuration (TSC) is illustrated on page 18 *(Benchmark Configuration/Tested Storage Configuration Diagram).*

Storage Network Configuration

Clause 9.4.3.4.1

…

5. *If the TSC contains network storage, the diagram will include the network configuration. If a single diagram is not sufficient to illustrate both the Benchmark Configuration and network configuration in sufficient detail, the Benchmark Configuration diagram will include a high-level network illustration as shown in Figure 9-8. In that case, a separate, detailed network configuration diagram will also be included as described in Clause 9.4.3.4.2.*

Clause 9.4.3.4.2

If a storage network was configured as a part of the Tested Storage Configuration and the Benchmark Configuration diagram described in Clause 9.4.3.4.1 contains a high-level illustration of the network configuration, the Executive Summary will contain a one page topology diagram of the storage network as illustrated in Figure 9-9.

The storage network configuration is illustrated on page 18 *(Benchmark Configuration/Tested Storage Configuration Diagram).*

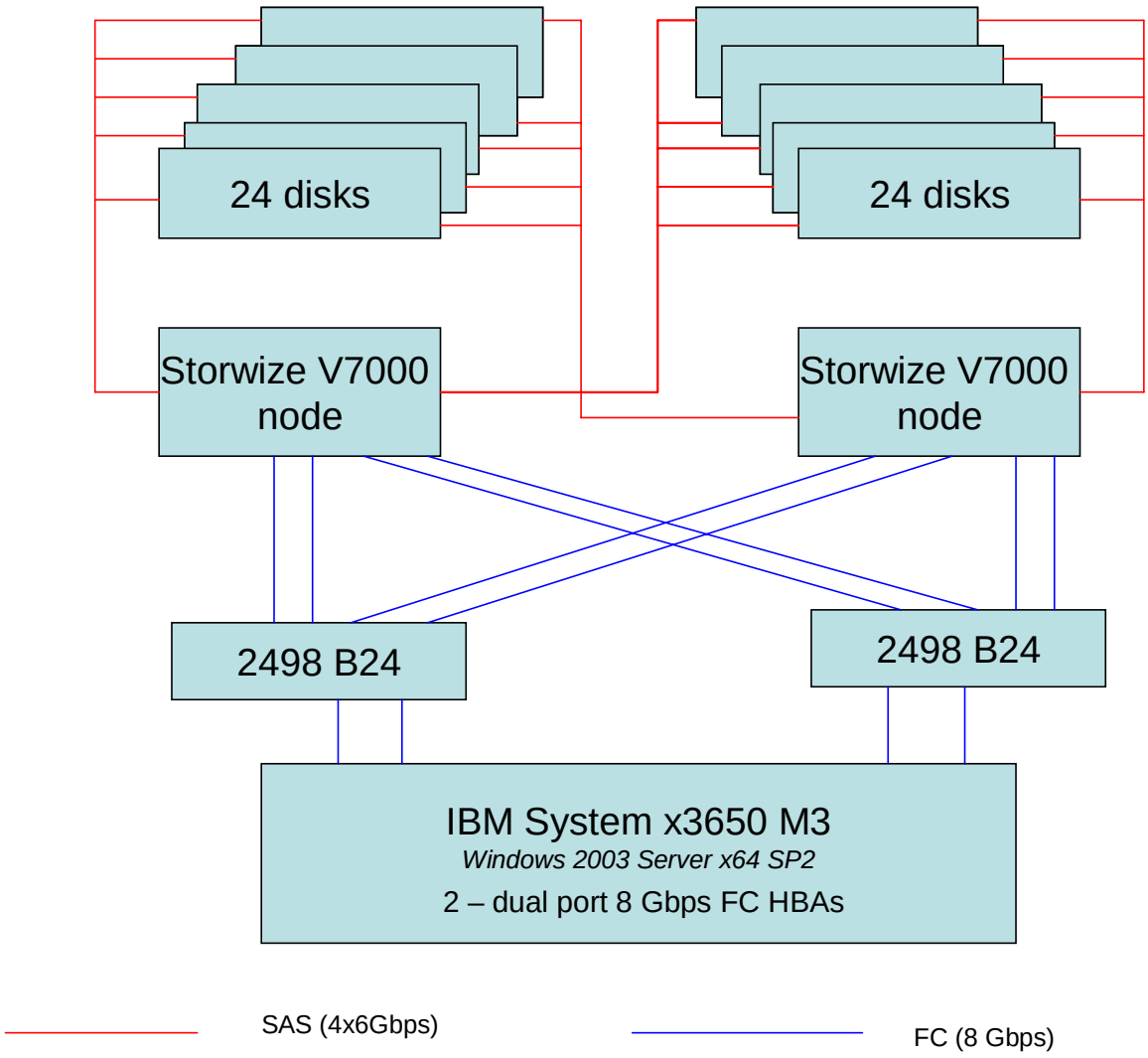
Host System and Tested Storage Configuration (TSC) Table of Components

Clause 9.4.3.4.3

The FDR will contain a table that lists the major components of each Host System and the Tested Storage Configuration (TSC). Table 9-10 specifies the content, format, and appearance of the table.

The Host System and TSC table of components may be found on page 19 *(Host System(s) and Tested Storage Configuration Components).*

Benchmark Configuration/Tested Storage Configuration Diagram



2498 B24: 24-port fibre channel switch

24 disks: One Storwize® V7000 base storage enclosure and nine Storwize® V7000 Expansion Enclosures, each with 24 10K RPM 146GB disk drives.

Host System(s) and Tested Storage Configuration Components

Host System:	Tested Storage Configuration (TSC):
IBM System X3650 M3	2 – 8 Gb PCIe dual port FC HBAs
1 – Intel Xeon 5600 2.26 GHz 6-core processor with 12 MB shared L3 cache	**IBM Storwize® V7000** ***(2-node cluster)*** 8 GB memory/cache per node *(16 GB total)* 4 – 8 Gbps switch-to-host FC connections shared by both nodes 2 – 4x6Gbps SAS connections per node 8 – 8 Gb SFPs 24 – 10K RPM 300 GB disk drives 9 – Storwize® V7000 expansion enclosures each with 24 10K RPM 300 GB disk drives
28 GB main memory	
Windows 2003 Server x64 w/SP2	
SDDDSM – Storwize® V7000 Windows driver providing multipath management	
PCIe	1 – 19 inch rack with 2 12-plug PDUs
	2 – 24-port fibre channel switches *(2498-B24*)
	8 – short wave 5m fibre channel cables
	4 – 25m fibre channel cables

Customer Tunable Parameters and Options

Clause 9.4.3.5.1

All Benchmark Configuration (BC) components with customer tunable parameter and options that have been altered from their default values must be listed in the FDR. The FDR entry for each of those components must include both the name of the component and the altered value of the parameter or option. If the parameter name is not self-explanatory to a knowledgeable practitioner, a brief description of the parameter's use must also be included in the FDR entry.

"Appendix B: Customer Tunable Parameters and Options" on page 63 contains the customer tunable parameters and options that have been altered from their default values for this benchmark.

Tested Storage Configuration (TSC) Description

Clause 9.4.3.5.2

The FDR must include sufficient information to recreate the logical representation of the TSC. In addition to customer tunable parameters and options (Clause 4.2.4.5.3), that information must include, at a minimum:

- *A diagram and/or description of the following:*
  - *All physical components that comprise the TSC. Those components are also illustrated in the BC Configuration Diagram in Clause 9.2.4.4.1 and/or the Storage Network Configuration Diagram in Clause 9.2.4.4.2.*
  - *The logical representation of the TSC, configured from the above components that will be presented to the Workload Generator.*
- *Listings of scripts used to create the logical representation of the TSC.*
- *If scripts were not used, a description of the process used with sufficient detail to recreate the logical representation of the TSC.*

"Appendix C: Tested Storage Configuration (TSC) Creation" on page 64 contains the detailed information that describes how to create and configure the logical TSC.

SPC-1 Workload Generator Storage Configuration

Clause 9.4.3.5.3

The FDR must include all SPC-1 Workload Generator storage configuration commands and parameters.

The SPC-1 Workload Generator storage configuration commands and parameters for this measurement appear in "Appendix D: SPC-1 Workload Generator Storage Commands and Parameters" on page 69.

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

Storage Capacities and Relationships

Clause 9.4.3.6.1

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

SPC-1 Storage Capacities

SPC-1 Storage Capacities		
Storage Hierarchy Component	**Units**	**Capacity**
Total ASU Capacity	Gigabytes (GB)	24,433.592
Addressable Storage Capacity	Gigabytes (GB)	24,739.276
Configured Storage Capacity	Gigabytes (GB)	71,876.084
Physical Storage Capacity	Gigabytes (GB)	72,000.000
Data Protection *(Mirroring)*	Gigabytes (GB)	35,636.076
Required Storage *(including spares)*	Gigabytes (GB)	617.187
Global Storage Overhead	Gigabytes (GB)	128.916
Total Unused Storage	Gigabytes (GB)	22,063.988

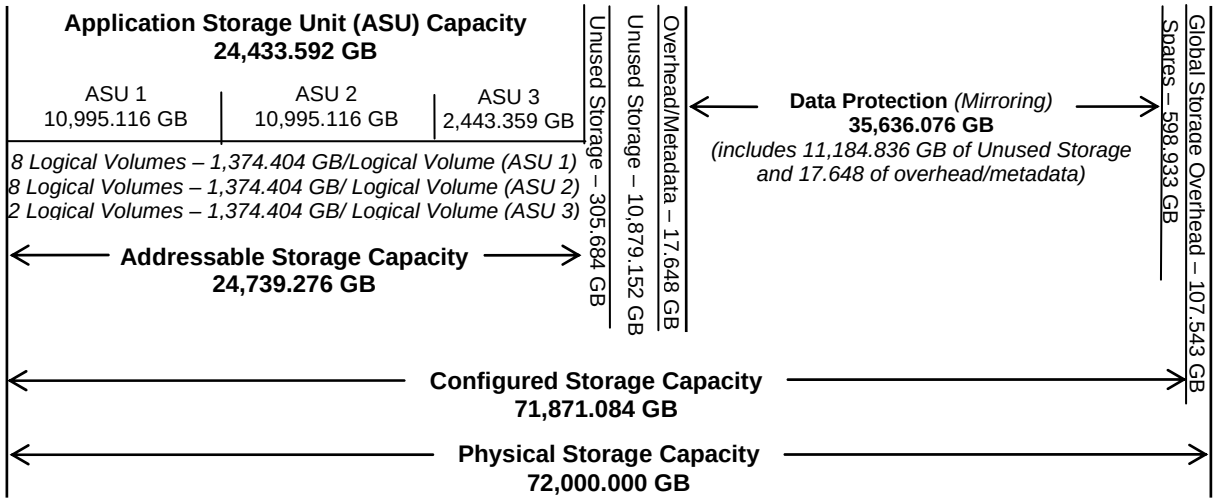
SPC-1 Storage Hierarchy Ratios

	Addressable Storage Capacity	**Configured Storage Capacity**	**Physical Storage Capacity**
Total ASU Capacity	98.76%	34.00%	33.94%
Required for Data Protection *(Mirrored)*		49.58%	49.49%
Addressable Storage Capacity		34.42%	34.36%
Required Storage *(including spares)*		0.86%	0.86%
Configured Storage Capacity			99.82%
Global Storage Overhead			0.18%
Unused Storage:			
Addressable	1.24%		
Configured		30.27%	
Physical			0.00%

The Physical Storage Capacity consisted of 72,000.000GB distributed over 240 disk drives each with a formatted capacity of 300.00 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 128.916 GB (0.18%) of Physical Storage Capacity. There was 21.758.304 GB (30.27%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 98.76% of the Addressable Storage Capacity resulting in 305.684 GB (1.24%) of Unused Storage within the Addressable Storage Capacity. The Data Protection *(mirroring)* capacity was 35,636.076 GB of which 24,756.923 GB was utilized. The total Unused Storage was 22,063.988 GB.

SPC-1 Storage Capacities and Relationships Illustration

The various storage capacities configured in the benchmark result are illustrated below (not to scale).



Logical Volume Capacity and ASU Mapping

Clause 9.4.3.6.3

A table illustrating the capacity of each ASU and the mapping of Logical Volumes to ASUs shall be provided in the FDR. … Logical Volumes shall be sequenced in the table from top to bottom per its position in the contiguous address space of each ASU. The capacity of each Logical Volume shall be stated. … In conjunction with this table, the Test Sponsor shall provide a complete description of the type of data protection (see Clause 2.4.5) used on each Logical Volume.

Logical Volume Capacity and Mapping		
ASU-1 (10,995.234 GB)	**ASU-2 (10,995.234 GB)**	**ASU-3 (2,748.808 GB)**
8 Logical Volumes 1,374.404 GB per Logical Volume (1,374.390 GB used per Logical Volume)	8 Logical Volumes 1,374.404 GB per Logical Volume (1,374.390 GB used per Logical Volume)	2 Logical Volumes 1,374.404 GB per Logical Volume (1,221.680 GB used per Logical Volume))

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

Storage Capacity Utilization

Clause 9.4.3.6.2

The FDR will include a table illustrating the storage capacity utilization values defined for Application Utilization (Clause 2.8.1), Protected Application Utilization (Clause 2.8.2), and Unused Storage Ratio (Clause 2.8.3).

Clause 2,8.1

Application Utilization is defined as Total ASU Capacity divided by Physical Storage Capacity.

Clause 2,8.2

Protected Application Utilization is defined as (Total ASU Capacity plus total Data Protection Capacity minus unused Data Protection Capacity) divided by Physical Storage Capacity.

Clause 2,8.3

Unused Storage Ratio is defined as Total Unused Capacity divided by Physical Storage Capacity and may not exceed 45%.

SPC-1 Storage Capacity Utilization	
Application Utilization	33.94%
Protected Application Utilization	68.32%
Unused Storage Ratio	30.64%

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 60 contains definitions of terms specific to the SPC-1 Tests, Test Phases, and Test Runs.

Clause 5.4.3

The Tests must be executed in the following sequence: Primary Metrics, Repeatability, and Data Persistence. That required sequence must be uninterrupted from the start of Primary Metrics to the completion of Persistence Test Run 1. Uninterrupted means the Benchmark Configuration shall not be power cycled, restarted, disturbed, altered, or adjusted during the above measurement sequence. If the required sequence is interrupted other than for the Host System/TSC power cycle between the two Persistence Test Runs, the measurement is invalid.

SPC-1 Tests, Test Phases, and Test Runs

The SPC-1 benchmark consists of the following Tests, Test Phases, and Test Runs:

- **Primary Metrics Test**
  - Sustainability Test Phase and Test Run
  - IOPS Test Phase and Test Run
  - Response Time Ramp Test Phase
    - 95% of IOPS Test Run
    - 90% of IOPS Test Run
    - 80% of IOPS Test Run
    - 50% of IOPS Test Run
    - 10% of IOPS Test Run (LRT)
- **Repeatability Test**
  - Repeatability Test Phase 1
    - 10% of IOPS Test Run (LRT)
    - IOPS Test Run
  - Repeatability Test Phase 2
    - 10% of IOPS Test Run (LRT)
    - IOPS Test Run
- **Data Persistence Test**
  - Data Persistence Test Run 1
  - Data Persistence Test Run 2

Each Test is an atomic unit that must be executed from start to finish before any other Test, Test Phase, or Test Run may be executed.

The results from each Test, Test Phase, and Test Run are listed below along with a more detailed explanation of each component.

Primary Metrics Test – Sustainability Test Phase

Clause 5.4.4.1.1

The Sustainability Test Phase has exactly one Test Run and shall demonstrate the maximum sustainable I/O Request Throughput within at least a continuous three (3) hour Measurement Interval. This Test Phase also serves to insure that the TSC has reached Steady State prior to reporting the final maximum I/O Request Throughput result (SPC-1 IOPS™).

Clause 5.4.4.1.2

The computed I/O Request Throughput of the Sustainability Test must be within 5% of the reported SPC-1 IOPS™ result.

Clause 5.4.4.1.4

The Average Response Time, as defined in Clause 5.1.1, will be computed and reported for the Sustainability Test Run and cannot exceed 30 milliseconds. If the Average Response time exceeds that 30-milliseconds constraint, the measurement is invalid.

Clause 9.4.3.7.1

For the Sustainability Test Phase the FDR shall contain:

1. *A Data Rate Distribution graph and data table.*
2. *I/O Request Throughput Distribution graph and data table.*
3. *A Response Time Frequency Distribution graph and table.*
4. *An Average Response Time Distribution graph and table.*
5. *The human readable Test Run Results File produced by the Workload Generator (may be included in an appendix).*
6. *A listing or screen image of all input parameters supplied to the Workload Generator (may be included in an appendix).*
7. *The Measured Intensity Multiplier for each I/O stream.*
8. *The variability of the Measured Intensity Multiplier, as defined in Clause 5.3.13.3.*

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 70.

Sustainability Test Results File

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

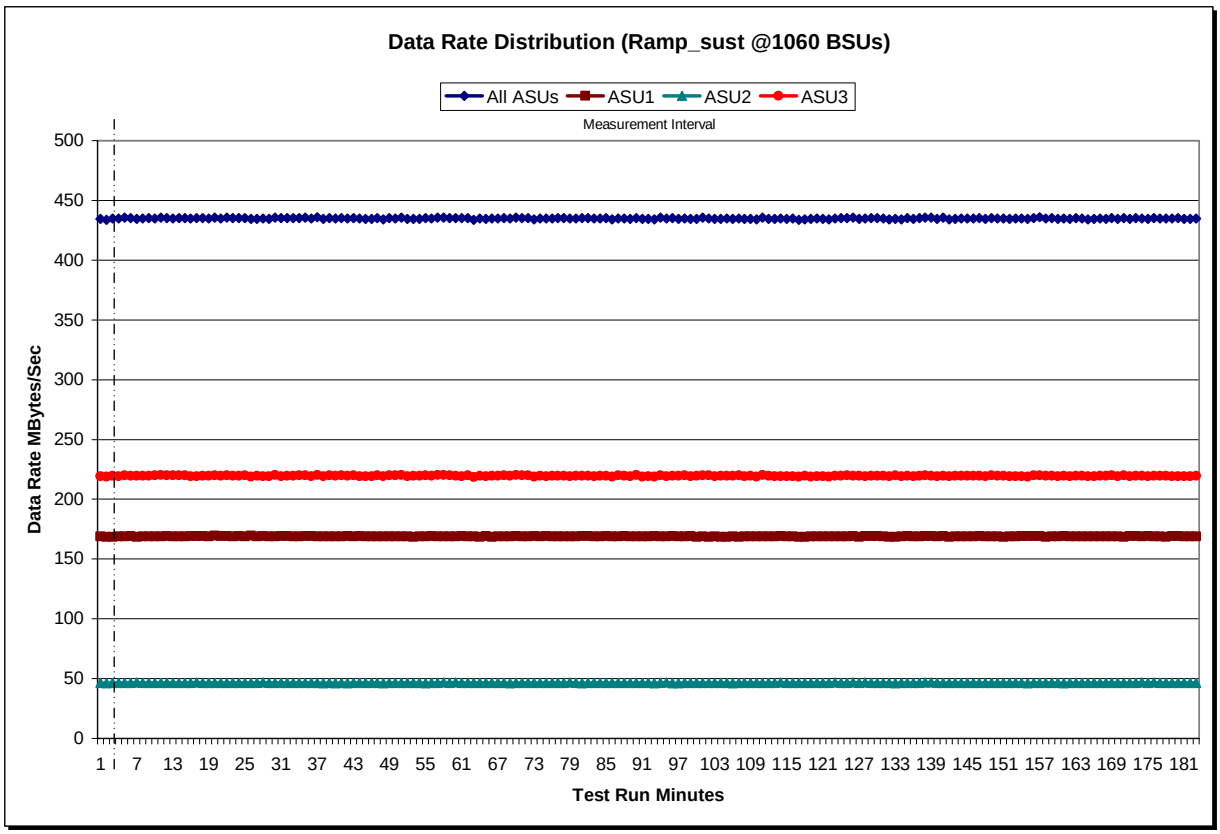
Sustainability Test Results File

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

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	17:35:28	17:38:28	0-2	0:03:00
Measurement Interval	17:38:28	20:38:28	3-182	3:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	434.61	169.00	46.31	219.30	63	434.96	168.64	46.56	219.76	126	434.60	168.64	46.51	219.45
1	433.68	168.59	46.10	219.00	64	434.63	169.19	46.34	219.10	127	434.88	169.07	46.74	219.07
2	434.91	168.64	46.58	219.69	65	434.84	168.60	46.52	219.72	128	435.10	169.01	46.52	219.57
3	434.82	168.88	46.55	219.40	66	434.86	168.92	46.47	219.48	129	435.24	169.08	46.44	219.72
4	435.41	168.91	46.41	220.09	67	435.06	168.69	46.53	219.84	130	434.78	168.93	46.39	219.46
5	435.31	169.14	46.44	219.73	68	434.68	168.87	46.25	219.56	131	434.28	168.58	46.60	219.11
6	434.62	168.44	46.70	219.48	69	435.73	169.05	46.46	220.22	132	434.44	168.52	46.07	219.84
7	434.77	168.81	46.52	219.44	70	435.04	168.75	46.43	219.86	133	434.30	168.74	46.42	219.14
8	435.10	169.00	46.39	219.71	71	435.26	168.86	46.40	219.99	134	435.12	169.17	46.51	219.45
9	435.01	168.70	46.41	219.90	72	434.11	169.08	46.27	218.76	135	434.49	168.70	46.58	219.21
10	435.66	168.97	46.49	220.20	73	434.88	168.87	46.43	219.58	136	435.03	168.99	46.53	219.51
11	435.32	169.02	46.47	219.83	74	434.73	169.03	46.34	219.36	137	435.57	169.05	46.70	219.83
12	434.93	168.68	46.47	219.78	75	435.01	168.95	46.61	219.44	138	435.49	169.08	46.78	219.63
13	435.17	168.77	46.33	220.06	76	435.15	168.87	46.52	219.76	139	434.62	168.97	46.47	219.18
14	435.17	168.93	46.47	219.77	77	435.06	168.98	46.43	219.64	140	435.39	169.24	46.43	219.72
15	434.82	169.18	46.40	219.23	78	434.86	168.81	46.68	219.37	141	434.02	168.41	46.47	219.14
16	435.03	169.07	46.62	219.34	79	434.86	168.91	46.37	219.59	142	434.66	168.83	46.35	219.48
17	435.05	169.04	46.46	219.55	80	435.06	169.08	46.25	219.73	143	434.82	168.90	46.40	219.52
18	434.72	168.83	46.26	219.63	81	435.22	169.06	46.61	219.56	144	435.01	168.92	46.43	219.66
19	435.66	169.45	46.39	219.82	82	434.67	168.83	46.45	219.39	145	434.92	168.85	46.45	219.62
20	435.00	169.02	46.50	219.48	83	434.89	168.68	46.57	219.64	146	435.22	169.13	46.48	219.61
21	435.46	169.05	46.34	220.07	84	435.17	169.03	46.51	219.63	147	434.62	168.79	46.45	219.38
22	435.09	168.78	46.56	219.75	85	434.19	168.83	46.45	218.91	148	435.32	168.89	46.49	219.94
23	435.32	169.16	46.52	219.64	86	434.97	168.75	46.35	219.87	149	434.75	168.77	46.42	219.56
24	435.19	168.97	46.29	219.92	87	435.02	169.12	46.47	219.43	150	434.74	168.60	46.50	219.64
25	434.66	169.38	46.36	218.92	88	434.61	168.89	46.45	219.27	151	434.44	168.68	46.36	219.40
26	434.63	168.73	46.48	219.42	89	435.37	168.83	46.31	220.23	152	434.89	168.99	46.60	219.29
27	434.81	169.08	46.66	219.07	90	434.31	168.87	46.42	219.02	153	434.71	169.17	46.33	219.22
28	434.56	168.91	46.55	219.11	91	434.53	168.79	46.43	219.31	154	434.34	169.28	46.18	218.87
29	435.62	168.86	46.52	220.25	92	434.24	169.03	46.24	218.96	155	435.37	169.02	46.51	219.84
30	435.04	169.24	46.50	219.30	93	435.47	168.89	46.62	219.97	156	435.79	169.11	46.56	220.12
31	435.09	169.08	46.46	219.56	94	434.99	168.99	46.66	219.35	157	434.76	168.56	46.52	219.68
32	435.06	169.00	46.31	219.75	95	435.12	169.15	46.23	219.73	158	435.18	168.95	46.53	219.70
33	435.20	168.88	46.43	219.89	96	434.66	168.93	46.18	219.55	159	434.57	168.78	46.40	219.39
34	435.51	169.24	46.31	219.96	97	434.95	168.73	46.31	219.91	160	434.91	169.03	46.18	219.70
35	434.82	169.29	46.31	219.22	98	434.63	169.10	46.42	219.11	161	434.66	168.86	46.59	219.21
36	435.75	168.83	46.48	220.44	99	434.44	168.55	46.48	219.41	162	435.16	168.97	46.50	219.70
37	434.31	168.87	46.21	219.22	100	435.51	168.79	46.60	220.12	163	434.92	168.88	46.34	219.69
38	435.09	168.88	46.45	219.77	101	434.69	168.60	46.28	219.81	164	434.22	168.70	46.47	219.06
39	434.71	168.94	46.21	219.56	102	434.48	168.87	46.52	219.09	165	434.50	168.92	46.39	219.20
40	435.31	168.95	46.57	219.79	103	434.58	168.51	46.44	219.63	166	435.00	168.81	46.45	219.73
41	434.83	169.05	46.18	219.60	104	434.76	168.57	46.46	219.73	167	434.59	168.72	46.46	219.41
42	435.12	168.82	46.39	219.90	105	434.63	168.66	46.22	219.75	168	435.28	168.74	46.46	220.08
43	434.84	169.02	46.45	219.37	106	434.86	168.61	46.46	219.79	169	434.36	168.88	46.37	219.10
44	434.31	168.67	46.27	219.36	107	434.58	168.79	46.58	219.21	170	435.20	168.62	46.58	220.00
45	434.62	168.78	46.51	219.33	108	434.53	168.75	46.37	219.41	171	434.56	169.07	46.40	219.09
46	435.11	168.68	46.45	219.98	109	434.25	168.76	46.49	219.00	172	435.12	169.13	46.51	219.48
47	434.18	168.75	46.25	219.19	110	435.52	168.78	46.52	220.22	173	434.91	168.69	46.66	219.55
48	435.07	168.84	46.42	219.81	111	434.62	168.82	46.39	219.41	174	434.65	169.02	46.32	219.32
49	435.01	168.88	46.31	219.83	112	434.58	168.86	46.40	219.33	175	435.10	168.82	46.62	219.65
50	435.71	168.84	46.42	220.45	113	434.88	169.13	46.62	219.14	176	434.84	168.84	46.48	219.51
51	434.41	168.89	46.32	219.20	114	434.49	168.80	46.41	219.28	177	434.74	168.51	46.50	219.73
52	434.42	168.63	46.32	219.47	115	434.73	168.86	46.47	219.40	178	434.83	169.14	46.47	219.23
53	434.62	168.77	46.35	219.49	116	433.91	168.41	46.59	218.91	179	435.03	169.02	46.61	219.40
54	435.15	168.83	46.22	220.10	117	434.28	168.34	46.36	219.58	180	434.57	168.93	46.37	219.26
55	434.86	169.09	46.34	219.44	118	434.50	168.96	46.51	219.04	181	434.42	168.83	46.35	219.25
56	435.59	168.70	46.58	220.31	119	434.75	168.82	46.60	219.33	182	434.91	168.92	46.53	219.45
57	435.73	168.91	46.65	220.16	120	434.58	168.92	46.33	219.33					
58	435.03	168.81	46.35	219.86	121	434.21	168.84	46.40	218.98					
59	435.06	168.74	46.84	219.49	122	434.87	168.67	46.76	219.44					
60	435.05	169.17	46.51	219.38	123	435.22	169.00	46.50	219.72					
61	435.27	168.76	46.51	220.00	124	435.09	168.75	46.33	220.01					
62	433.86	168.89	46.35	218.61	125	435.43	169.11	46.73	219.59					

Sustainability – Data Rate Distribution Graph

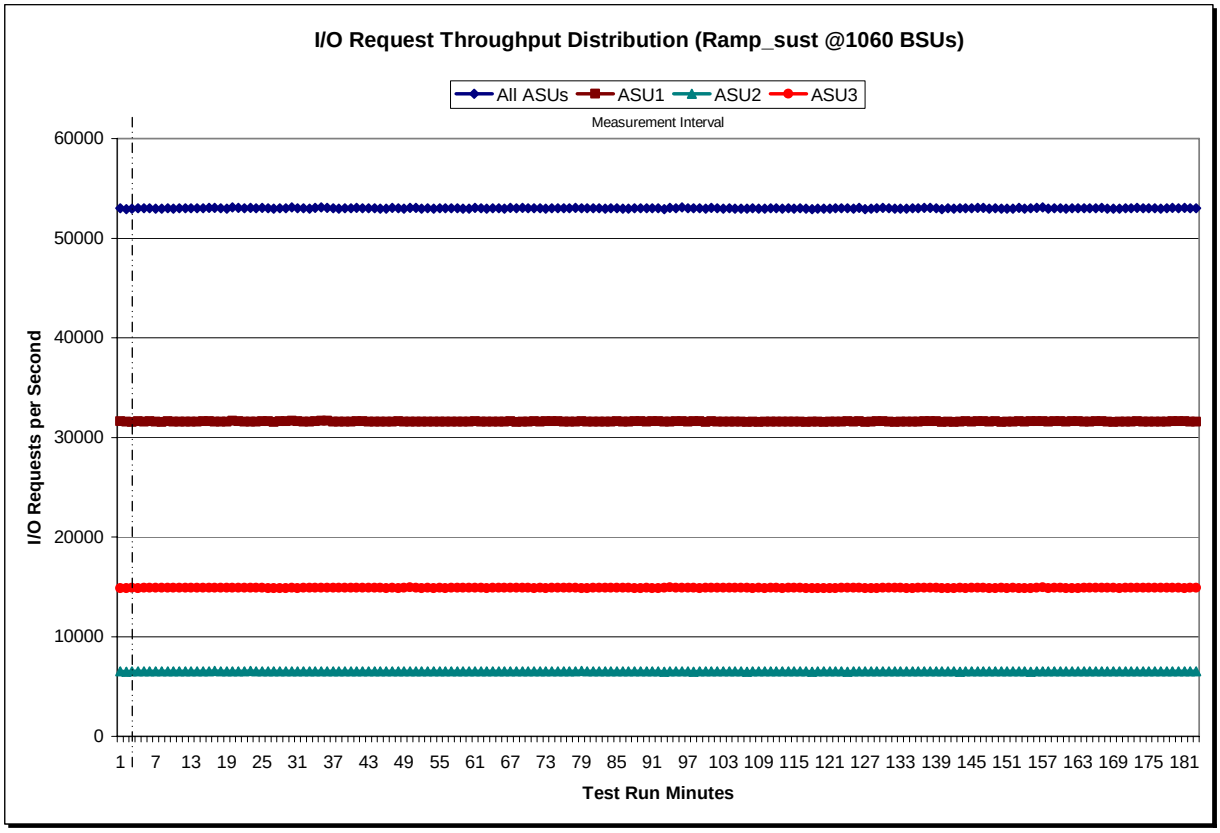


Sustainability – I/O Request Throughput Distribution Data

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	17:35:28	17:38:28	0-2	0:03:00
Measurement Interval	17:38:28	20:38:28	3-182	3:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	53,008.58	31,606.62	6,528.93	14,873.03	63	52,993.35	31,573.95	6,523.68	14,895.72	126	52,900.27	31,527.57	6,513.57	14,859.13
1	52,914.57	31,566.18	6,481.53	14,866.85	64	53,003.72	31,594.60	6,509.95	14,899.17	127	52,976.73	31,570.83	6,526.23	14,879.67
2	52,971.53	31,551.02	6,521.13	14,899.38	65	52,972.40	31,578.17	6,512.43	14,881.80	128	52,999.28	31,598.53	6,520.97	14,879.78
3	53,013.83	31,608.10	6,531.02	14,874.72	66	53,029.47	31,599.07	6,521.60	14,908.80	129	53,039.63	31,618.75	6,528.13	14,892.75
4	53,008.72	31,595.72	6,521.55	14,891.45	67	52,982.58	31,550.50	6,529.87	14,902.22	130	52,987.28	31,570.83	6,522.83	14,893.62
5	53,010.98	31,609.12	6,512.98	14,888.88	68	53,038.15	31,591.02	6,530.57	14,916.57	131	52,947.90	31,543.33	6,519.32	14,885.25
6	52,979.83	31,561.17	6,531.33	14,887.33	69	53,007.80	31,591.23	6,506.23	14,910.33	132	52,973.67	31,557.92	6,503.80	14,911.95
7	52,977.18	31,553.25	6,529.30	14,894.63	70	52,986.80	31,611.73	6,517.57	14,857.50	133	52,962.85	31,592.02	6,516.35	14,854.48
8	53,018.55	31,608.17	6,520.25	14,890.13	71	52,981.57	31,572.22	6,520.83	14,888.52	134	52,983.40	31,590.15	6,513.17	14,880.08
9	52,977.95	31,567.13	6,513.88	14,896.93	72	52,976.67	31,599.27	6,517.52	14,859.88	135	53,012.08	31,584.93	6,532.93	14,894.22
10	53,003.03	31,582.75	6,519.73	14,900.55	73	53,014.83	31,601.28	6,528.55	14,885.00	136	53,053.57	31,625.30	6,528.95	14,899.32
11	53,008.02	31,584.30	6,531.32	14,892.40	74	52,997.97	31,600.52	6,512.30	14,885.15	137	53,041.18	31,623.50	6,527.92	14,889.77
12	52,997.93	31,581.50	6,521.22	14,895.22	75	53,009.37	31,568.45	6,528.33	14,912.58	138	53,023.57	31,598.78	6,531.80	14,892.98
13	52,996.25	31,571.82	6,521.22	14,903.22	76	53,018.67	31,574.30	6,520.43	14,923.93	139	52,933.77	31,553.50	6,515.27	14,865.00
14	52,997.48	31,604.63	6,509.30	14,883.55	77	53,033.05	31,587.20	6,525.60	14,920.25	140	52,983.48	31,581.40	6,525.58	14,876.50
15	53,038.48	31,618.88	6,530.20	14,889.40	78	53,020.22	31,603.77	6,545.22	14,871.23	141	52,943.18	31,550.07	6,522.25	14,870.87
16	53,029.40	31,593.67	6,552.45	14,883.28	79	52,996.28	31,596.97	6,520.00	14,879.32	142	52,992.38	31,589.70	6,500.65	14,902.03
17	53,002.25	31,598.15	6,511.47	14,892.63	80	52,998.82	31,590.05	6,507.82	14,900.95	143	52,993.13	31,605.93	6,515.05	14,872.15
18	52,971.37	31,576.60	6,505.65	14,889.12	81	52,993.18	31,581.98	6,527.78	14,883.42	144	53,014.68	31,587.68	6,535.15	14,891.85
19	53,077.35	31,645.77	6,526.63	14,904.95	82	52,953.43	31,565.85	6,504.60	14,882.98	145	53,045.18	31,617.08	6,523.50	14,904.60
20	53,026.75	31,598.43	6,516.77	14,911.55	83	52,992.38	31,575.92	6,518.98	14,897.48	146	53,028.82	31,616.52	6,521.13	14,891.17
21	52,994.68	31,592.07	6,510.35	14,892.27	84	53,014.98	31,615.40	6,512.78	14,886.80	147	52,962.42	31,571.63	6,514.15	14,876.63
22	53,036.38	31,590.70	6,544.33	14,901.35	85	52,966.72	31,565.48	6,520.02	14,881.22	148	53,008.38	31,609.03	6,522.58	14,876.77
23	53,010.97	31,585.65	6,524.08	14,901.23	86	52,973.43	31,557.97	6,528.80	14,886.67	149	52,957.57	31,531.32	6,518.23	14,908.02
24	53,025.92	31,604.95	6,503.67	14,917.30	87	52,995.53	31,598.97	6,521.47	14,875.10	150	52,954.17	31,567.17	6,520.15	14,866.85
25	52,994.90	31,624.42	6,506.62	14,863.87	88	53,005.02	31,606.32	6,520.27	14,878.43	151	52,970.25	31,572.47	6,515.28	14,882.50
26	52,947.90	31,553.13	6,514.77	14,880.00	89	53,007.13	31,579.63	6,506.47	14,921.03	152	53,030.18	31,618.22	6,532.10	14,879.87
27	52,997.33	31,599.53	6,520.17	14,877.63	90	53,002.88	31,600.98	6,521.48	14,880.42	153	52,973.83	31,585.23	6,511.43	14,877.17
28	52,981.05	31,600.85	6,519.10	14,861.10	91	52,984.17	31,600.28	6,514.50	14,869.38	154	52,994.45	31,620.28	6,495.25	14,878.92
29	53,071.28	31,649.63	6,524.37	14,897.28	92	52,937.07	31,561.05	6,486.07	14,889.95	155	53,034.77	31,616.75	6,511.90	14,906.12
30	53,008.15	31,614.52	6,515.15	14,878.48	93	53,049.20	31,589.25	6,530.68	14,929.27	156	53,085.00	31,616.38	6,529.97	14,938.65
31	52,998.07	31,587.83	6,526.73	14,883.50	94	53,015.00	31,599.47	6,529.35	14,886.18	157	52,950.57	31,576.88	6,512.45	14,861.23
32	52,974.60	31,575.82	6,512.37	14,886.42	95	53,074.85	31,637.97	6,517.53	14,919.35	158	53,021.05	31,602.23	6,524.23	14,894.58
33	53,060.60	31,633.97	6,517.78	14,908.85	96	52,987.03	31,586.70	6,517.17	14,883.17	159	53,008.85	31,612.38	6,506.08	14,890.38
34	53,090.18	31,659.13	6,522.75	14,908.30	97	53,020.85	31,602.77	6,500.65	14,917.43	160	52,947.10	31,574.65	6,505.98	14,866.47
35	53,051.97	31,641.62	6,506.93	14,903.42	98	52,984.32	31,613.05	6,520.27	14,851.00	161	52,985.22	31,600.03	6,523.63	14,861.55
36	53,019.42	31,589.43	6,512.75	14,917.23	99	52,959.97	31,547.62	6,526.15	14,886.20	162	53,000.72	31,608.68	6,517.52	14,874.52
37	52,963.30	31,555.13	6,512.05	14,896.12	100	53,036.18	31,611.32	6,526.85	14,898.02	163	52,987.20	31,587.02	6,503.98	14,896.20
38	53,003.95	31,562.80	6,530.23	14,910.92	101	52,987.65	31,568.58	6,510.17	14,908.90	164	52,982.95	31,582.83	6,511.67	14,888.45
39	53,001.78	31,593.92	6,502.03	14,905.83	102	52,979.72	31,558.68	6,534.98	14,886.05	165	53,020.22	31,604.67	6,520.57	14,894.98
40	53,041.75	31,607.20	6,526.17	14,908.38	103	52,983.22	31,564.85	6,513.88	14,904.48	166	53,030.48	31,604.35	6,526.52	14,899.62
41	53,018.72	31,614.52	6,513.98	14,890.22	104	52,966.68	31,556.78	6,515.20	14,894.70	167	52,962.40	31,563.23	6,514.62	14,884.55
42	52,988.22	31,557.13	6,520.67	14,910.42	105	52,979.55	31,559.63	6,512.87	14,907.05	168	52,958.97	31,554.77	6,506.78	14,897.42
43	53,006.83	31,594.55	6,525.87	14,886.42	106	52,971.40	31,549.73	6,500.30	14,921.37	169	52,978.40	31,596.68	6,507.42	14,874.30
44	52,977.60	31,566.35	6,513.52	14,897.73	107	52,981.37	31,595.92	6,514.90	14,870.55	170	53,004.67	31,596.77	6,522.48	14,885.42
45	52,973.90	31,579.22	6,526.40	14,868.28	108	52,972.73	31,555.02	6,511.72	14,906.00	171	53,017.68	31,597.47	6,519.13	14,901.08
46	53,033.77	31,593.32	6,520.63	14,919.82	109	52,964.47	31,580.17	6,523.20	14,861.10	172	53,028.70	31,618.17	6,520.18	14,890.35
47	52,995.27	31,603.65	6,512.53	14,879.08	110	53,012.07	31,589.17	6,520.02	14,902.88	173	52,983.87	31,574.00	6,519.33	14,890.53
48	52,970.97	31,569.23	6,507.13	14,894.60	111	52,988.43	31,565.27	6,539.40	14,883.77	174	53,004.47	31,597.67	6,513.83	14,892.97
49	53,030.55	31,564.07	6,540.17	14,926.32	112	52,953.08	31,569.47	6,506.22	14,877.40	175	52,985.88	31,581.00	6,510.23	14,894.65
50	53,036.27	31,590.15	6,523.60	14,922.52	113	53,000.27	31,579.83	6,535.00	14,885.43	176	52,974.58	31,568.12	6,518.23	14,888.23
51	52,944.37	31,561.78	6,510.80	14,871.78	114	52,940.10	31,555.62	6,501.95	14,882.53	177	52,985.67	31,563.30	6,505.17	14,917.20
52	53,010.12	31,583.97	6,528.35	14,897.80	115	52,983.27	31,589.22	6,511.80	14,882.25	178	53,030.62	31,628.55	6,508.52	14,893.55
53	52,965.48	31,571.67	6,514.40	14,879.42	116	52,945.12	31,540.72	6,532.55	14,871.85	179	53,021.08	31,608.10	6,525.68	14,887.30
54	53,002.88	31,582.18	6,501.65	14,919.05	117	52,930.62	31,557.57	6,494.53	14,878.52	180	53,024.72	31,617.07	6,526.80	14,880.85
55	52,983.82	31,592.82	6,517.55	14,873.45	118	52,966.32	31,580.35	6,519.22	14,866.75	181	52,988.73	31,574.17	6,517.30	14,897.27
56	53,019.03	31,586.17	6,520.30	14,912.57	119	52,951.92	31,545.82	6,525.58	14,880.52	182	53,014.85	31,585.35	6,528.70	14,900.80
57	53,004.25	31,565.48	6,539.97	14,898.80	120	52,949.07	31,578.93	6,506.87	14,863.27	***Average***	***52,997.17***	***31,587.48***	***6,518.83***	***14,890.85***
58	52,979.18	31,583.65	6,505.27	14,890.27	121	52,985.72	31,591.62	6,520.05	14,874.05					
59	52,980.20	31,558.98	6,525.00	14,896.22	122	53,006.02	31,569.03	6,531.72	14,905.27					
60	53,050.52	31,629.37	6,523.52	14,897.63	123	52,986.22	31,602.25	6,500.30	14,883.67					
61	53,007.78	31,568.32	6,533.15	14,906.32	124	52,972.90	31,566.08	6,506.17	14,900.65					
62	52,965.67	31,591.70	6,515.55	14,858.42	125	53,055.23	31,613.63	6,539.02	14,902.58					

Sustainability – I/O Request Throughput Distribution Graph

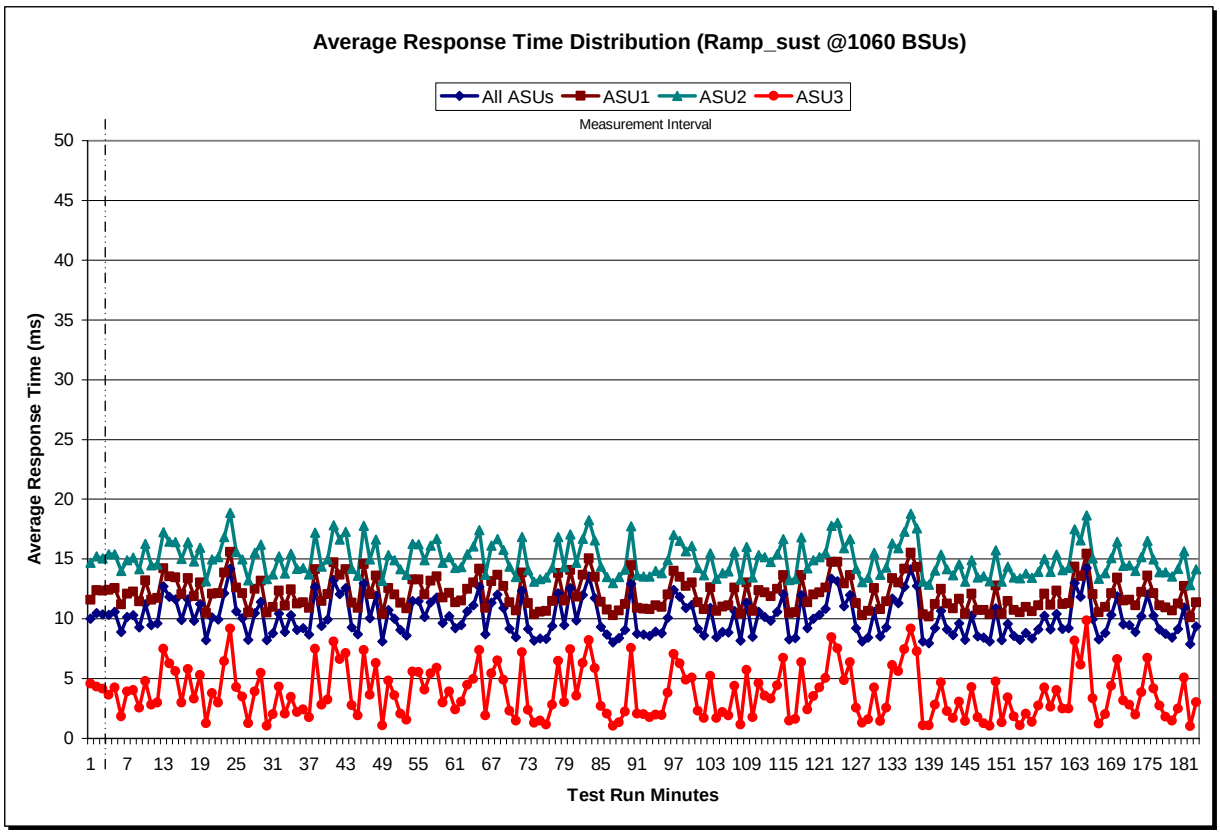


Sustainability – Average Response Time (ms) Distribution Data

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	17:35:28	17:38:28	0-2	0:03:00
Measurement Interval	17:38:28	20:38:28	3-182	3:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	10.00	11.58	14.68	4.58	63	11.13	13.02	16.04	4.97	126	9.21	11.32	14.17	2.57
1	10.47	12.40	15.21	4.32	64	12.68	14.20	17.44	7.39	127	8.11	10.30	13.06	1.30
2	10.37	12.35	15.06	4.13	65	8.71	10.89	13.68	1.91	128	8.44	10.65	13.42	1.57
3	10.32	12.40	15.41	3.65	66	11.35	13.16	16.13	5.44	129	10.59	12.56	15.53	4.23
4	10.58	12.57	15.42	4.25	67	12.04	13.70	16.66	6.50	130	8.53	10.80	13.68	1.45
5	8.90	11.18	13.99	1.85	68	10.92	12.75	15.77	4.91	131	9.29	11.45	14.28	2.55
6	10.14	12.10	14.89	3.91	69	9.19	11.38	14.36	2.30	132	11.70	13.39	16.30	6.12
7	10.30	12.27	15.12	4.03	70	8.46	10.70	13.50	1.47	133	11.31	13.02	15.92	5.63
8	9.27	11.44	14.15	2.55	71	12.36	13.88	16.85	7.19	134	12.67	14.18	17.27	7.46
9	11.22	13.22	16.25	4.79	72	9.15	11.31	14.08	2.39	135	14.13	15.51	18.79	9.16
10	9.48	11.59	14.47	2.82	73	8.16	10.37	13.09	1.28	136	12.75	14.32	17.57	7.28
11	9.62	11.73	14.53	2.98	74	8.36	10.58	13.34	1.47	137	8.11	10.38	13.12	1.08
12	12.71	14.23	17.25	7.50	75	8.32	10.64	13.46	1.14	138	7.96	10.20	12.87	1.07
13	11.84	13.52	16.45	6.27	76	9.39	11.49	14.27	2.81	139	9.20	11.22	14.05	2.80
14	11.62	13.46	16.41	5.61	77	12.13	13.83	16.85	6.49	140	10.64	12.48	15.37	4.67
15	9.89	12.08	15.02	3.00	78	9.48	11.52	14.32	3.02	141	9.09	11.27	14.14	2.26
16	11.63	13.38	16.40	5.80	79	12.57	14.07	17.05	7.44	142	8.64	10.88	13.65	1.69
17	9.83	11.88	14.81	3.32	80	9.87	11.85	14.70	3.56	143	9.60	11.65	14.57	3.05
18	11.22	13.03	15.95	5.31	81	11.99	13.69	16.72	6.30	144	8.23	10.43	13.09	1.43
19	8.22	10.48	13.15	1.25	82	13.52	15.05	18.24	8.22	145	10.25	12.10	14.89	4.29
20	10.11	12.09	14.96	3.77	83	11.74	13.51	16.57	5.88	146	8.54	10.72	13.45	1.76
21	9.94	12.14	15.14	3.00	84	9.33	11.42	14.36	2.69	147	8.41	10.72	13.56	1.25
22	12.14	13.87	16.83	6.43	85	8.66	10.77	13.51	2.05	148	8.10	10.38	13.12	1.04
23	14.19	15.60	18.85	9.17	86	8.02	10.30	12.98	1.03	149	10.88	12.77	15.74	4.75
24	10.62	12.60	15.57	4.27	87	8.40	10.69	13.49	1.32	150	8.19	10.39	13.12	1.35
25	10.06	12.13	14.96	3.51	88	9.06	11.25	14.10	2.22	151	9.57	11.48	14.36	3.42
26	8.24	10.51	13.21	1.26	89	12.93	14.48	17.75	7.54	152	8.56	10.71	13.46	1.85
27	10.46	12.49	15.52	3.93	90	8.76	10.90	13.64	2.07	153	8.23	10.53	13.40	1.07
28	11.39	13.19	16.20	5.47	91	8.68	10.82	13.55	2.00	154	8.82	10.99	13.80	2.03
29	8.21	10.53	13.33	1.05	92	8.58	10.79	13.52	1.76	155	8.36	10.61	13.43	1.36
30	8.79	10.97	13.73	2.02	93	8.92	11.14	14.02	1.98	156	9.11	11.14	13.94	2.72
31	10.45	12.35	15.21	4.33	94	8.79	10.98	13.81	1.94	157	10.25	12.09	15.02	4.27
32	8.87	11.08	13.79	2.04	95	10.07	12.03	14.91	3.82	158	9.10	11.15	13.95	2.61
33	10.29	12.45	15.45	3.45	96	12.42	14.00	17.04	7.05	159	10.39	12.35	15.37	4.04
34	9.09	11.28	14.18	2.21	97	11.84	13.51	16.53	6.26	160	9.13	11.25	14.08	2.48
35	9.20	11.36	14.24	2.40	98	10.91	12.75	15.66	4.91	161	9.20	11.32	14.25	2.49
36	8.67	10.89	13.70	1.77	99	11.16	13.02	16.08	5.06	162	13.01	14.37	17.48	8.16
37	12.66	14.16	17.19	7.49	100	9.19	11.39	14.25	2.31	163	11.85	13.57	16.56	6.15
38	9.41	11.50	14.37	2.82	101	8.59	10.80	13.63	1.69	164	14.27	15.44	18.66	9.86
39	9.94	12.07	14.99	3.22	102	10.89	12.62	15.47	5.21	165	9.99	12.07	15.04	3.36
40	13.24	14.71	17.83	8.11	103	8.46	10.64	13.36	1.69	166	8.28	10.55	13.35	1.24
41	12.06	13.68	16.63	6.61	104	8.88	11.02	13.83	2.20	167	8.81	10.98	13.81	2.02
42	12.55	14.14	17.26	7.13	105	8.87	11.12	13.97	1.89	168	10.33	12.15	15.07	4.39
43	9.29	11.35	14.19	2.78	106	10.65	12.59	15.61	4.38	169	11.88	13.43	16.44	6.62
44	8.71	10.91	13.62	1.92	107	8.18	10.43	13.27	1.15	170	9.52	11.51	14.42	3.16
45	12.95	14.57	17.78	7.38	108	11.34	13.04	16.02	5.72	171	9.48	11.59	14.46	2.82
46	10.05	12.08	14.97	3.62	109	8.51	10.66	13.45	1.76	172	8.91	11.12	13.99	1.98
47	11.93	13.60	16.63	6.31	110	10.57	12.39	15.32	4.62	173	10.24	12.24	15.16	3.84
48	8.12	10.40	13.16	1.08	111	10.14	12.20	15.14	3.55	174	12.03	13.59	16.51	6.75
49	10.74	12.58	15.34	4.83	112	9.82	11.88	14.75	3.31	175	10.24	12.13	14.98	4.17
50	10.00	12.03	14.89	3.59	113	10.57	12.48	15.40	4.41	176	9.11	11.13	13.88	2.72
51	9.07	11.32	14.16	2.06	114	12.06	13.64	16.67	6.72	177	8.73	10.94	13.88	1.81
52	8.60	10.88	13.67	1.55	115	8.28	10.47	13.23	1.47	178	8.44	10.67	13.53	1.46
53	11.48	13.28	16.27	5.58	116	8.39	10.56	13.31	1.64	179	9.16	11.27	14.17	2.47
54	11.48	13.30	16.23	5.55	117	11.99	13.66	16.80	6.36	180	10.96	12.76	15.67	5.08
55	10.14	12.03	14.89	4.06	118	9.20	11.36	14.23	2.42	181	7.89	10.12	12.80	1.02
56	11.36	13.17	16.14	5.45	119	10.00	12.04	14.92	3.52	182	9.36	11.36	14.14	3.03
57	11.79	13.54	16.69	5.92	120	10.34	12.22	15.15	4.23	***Average***	***10.12***	***12.09***	***14.99***	***3.80***
58	9.67	11.78	14.69	2.99	121	10.83	12.59	15.51	5.04					
59	10.21	12.16	15.15	3.93	122	13.37	14.77	17.79	8.45					
60	9.21	11.37	14.26	2.41	123	13.13	14.75	18.04	7.54					
61	9.48	11.52	14.32	3.04	124	11.05	12.96	15.91	4.88					
62	10.61	12.51	15.42	4.48	125	11.98	13.66	16.65	6.36					

Sustainability – Average Response Time (ms) Distribution Graph



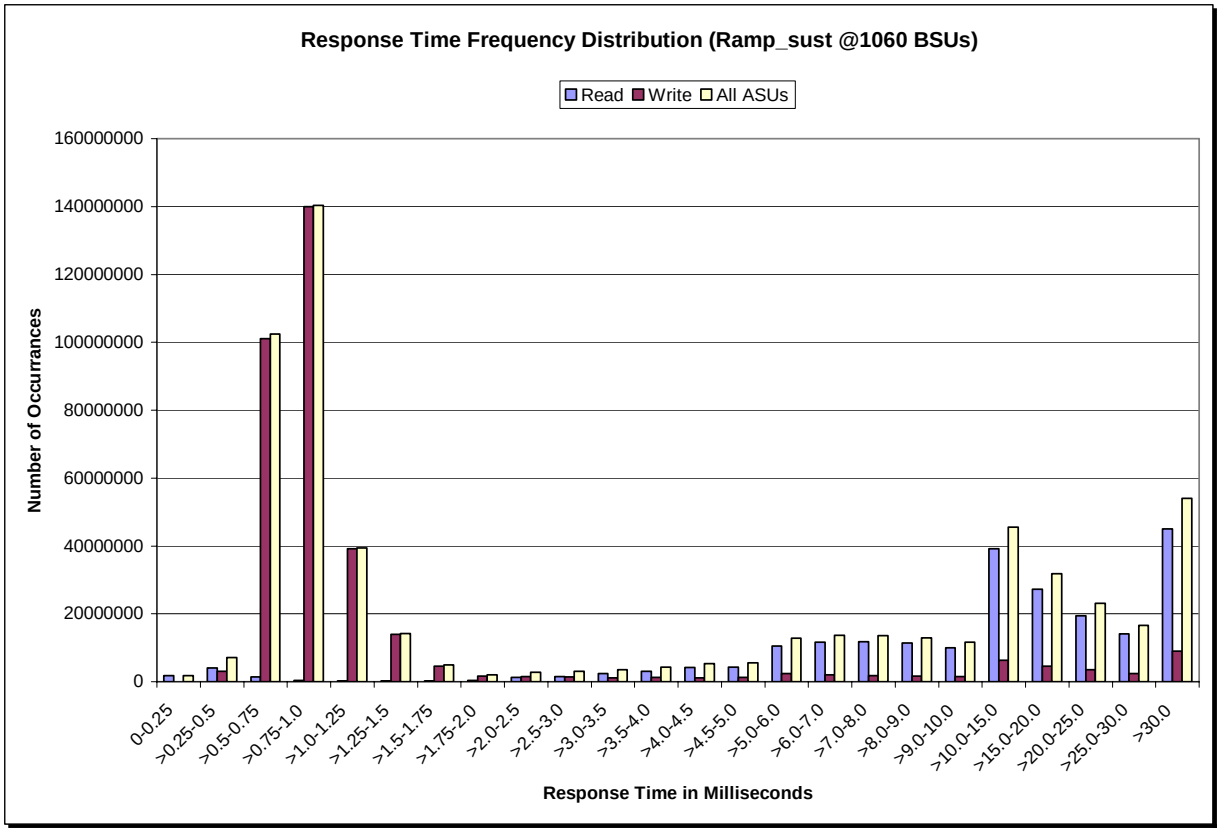
Sustainability – Response Time Frequency Distribution Data

Response Time (ms)	0-0.25	>0.25-0.5	>0.5-0.75	>0.75-1.0	>1.0-1.25	>1.25-1.5	>1.5-1.75	>1.75-2.0
Read	1,714,911	4,036,130	1,411,032	335,797	220,491	255,678	286,719	372,360
Write	19,763	3,100,669	101,082,874	140,007,987	39,168,618	13,981,095	4,605,289	1,648,020
All ASUs	1,734,674	7,136,799	102,493,906	140,343,784	39,389,109	14,236,773	4,892,008	2,020,380
ASU1	1,571,065	4,724,932	46,582,236	60,972,375	16,566,799	5,766,330	2,022,874	1,013,571
ASU2	155,332	1,142,117	11,500,450	14,104,437	3,666,689	1,230,130	402,690	170,315
ASU3	8,277	1,269,750	44,411,220	65,266,972	19,155,621	7,240,313	2,466,444	836,494

Response Time (ms)	>2.0-2.5	>2.5-3.0	>3.0-3.5	>3.5-4.0	>4.0-4.5	>4.5-5.0	>5.0-6.0	>6.0-7.0
Read	1,207,371	1,569,912	2,396,638	3,043,273	4,186,334	4,331,930	10,468,437	11,678,089
Write	1,544,625	1,411,296	1,175,914	1,234,778	1,123,262	1,236,168	2,353,865	2,021,941
All ASUs	2,751,996	2,981,208	3,572,552	4,278,051	5,309,596	5,568,098	12,822,302	13,700,030
ASU1	1,805,224	2,099,101	2,772,746	3,382,582	4,320,307	4,431,673	10,321,400	11,210,498
ASU2	219,355	235,926	268,692	338,126	485,989	581,833	1,442,121	1,572,730
ASU3	727,417	646,181	531,114	557,343	503,300	554,592	1,058,781	916,802

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	11,786,703	11,390,410	10,070,221	39,201,491	27,263,318	19,435,314	14,124,267	44,966,960
Write	1,765,605	1,593,331	1,540,953	6,360,081	4,563,667	3,595,721	2,421,789	9,057,863
All ASUs	13,552,308	12,983,741	11,611,174	45,561,572	31,826,985	23,031,035	16,546,056	54,024,823
ASU1	11,151,658	10,628,829	9,345,097	36,638,369	25,267,735	17,926,788	12,731,509	37,890,789
ASU2	1,595,045	1,624,178	1,559,093	6,018,344	4,473,118	3,459,162	2,671,136	11,486,262
ASU3	805,605	730,734	706,984	2,904,859	2,086,132	1,645,085	1,143,411	4,647,772

Sustainability – Response Time Frequency Distribution Graph



Sustainability – Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.13.2

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

Clause 5.3.13.3

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

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

Primary Metrics Test – IOPS Test Phase

Clause 5.4.4.2

The IOPS Test Phase consists of one Test Run at the 100% load point with a Measurement Interval of ten (10) minutes. The IOPS Test Phase immediately follows the Sustainability Test Phase without any interruption or manual intervention.

The IOPS Test Run generates the SPC-1 IOPS™ primary metric, which is computed as the I/O Request Throughput for the Measurement Interval of the IOPS Test Run.

The Average Response Time is computed for the IOPS Test Run and cannot exceed 30 milliseconds. If the Average Response Time exceeds the 30 millisecond constraint, the measurement is invalid.

Clause 9.4.3.7.2

For the IOPS Test Phase the FDR shall contain:

1. *I/O Request Throughput Distribution (data and graph).*
2. *A Response Time Frequency Distribution.*
3. *An Average Response Time Distribution.*
4. *The human readable Test Run Results File produced by the Workload Generator.*
5. *A listing or screen image of all input parameters supplied 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 70.

IOPS Test Results File

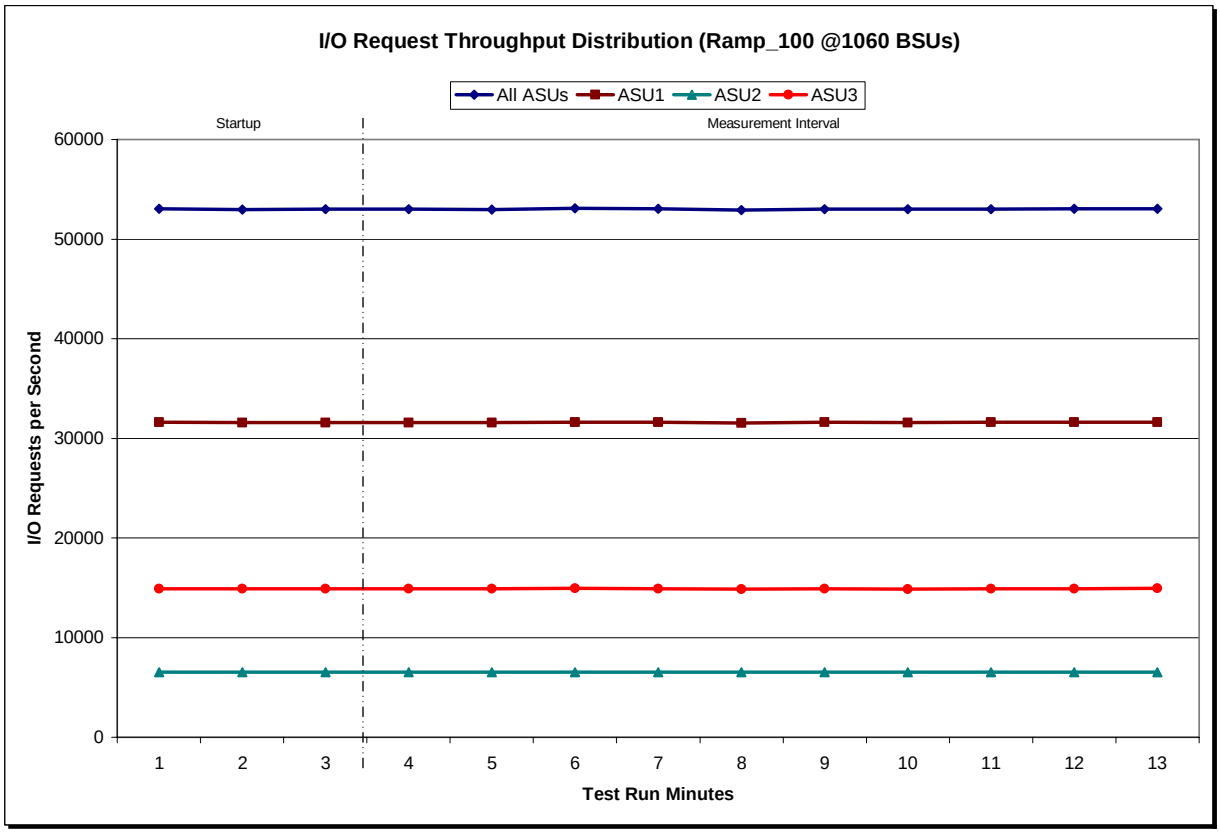
A link to the test results file generated from the IOPS Test Run is listed below.

IOPS Test Results File

IOPS Test Run – I/O Request Throughput Distribution Data

1060 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:38:35	20:41:36	0-2	0:03:01
Measurement Interval	20:41:36	20:51:36	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	53,030.42	31,619.90	6,527.90	14,882.62
1	52,955.73	31,556.98	6,503.68	14,895.07
2	52,988.97	31,590.15	6,513.97	14,884.85
3	52,994.98	31,571.42	6,507.97	14,915.60
4	52,978.13	31,573.43	6,507.90	14,896.80
5	53,069.75	31,625.28	6,508.23	14,936.23
6	53,045.35	31,638.77	6,506.52	14,900.07
7	52,929.12	31,553.73	6,503.58	14,871.80
8	53,009.20	31,600.23	6,509.68	14,899.28
9	52,983.55	31,593.22	6,519.37	14,870.97
10	53,021.88	31,602.47	6,530.40	14,889.02
11	53,051.28	31,624.33	6,513.22	14,913.73
12	53,059.67	31,612.73	6,521.38	14,925.55
Average	***53,014.29***	***31,599.56***	***6,512.83***	***14,901.91***

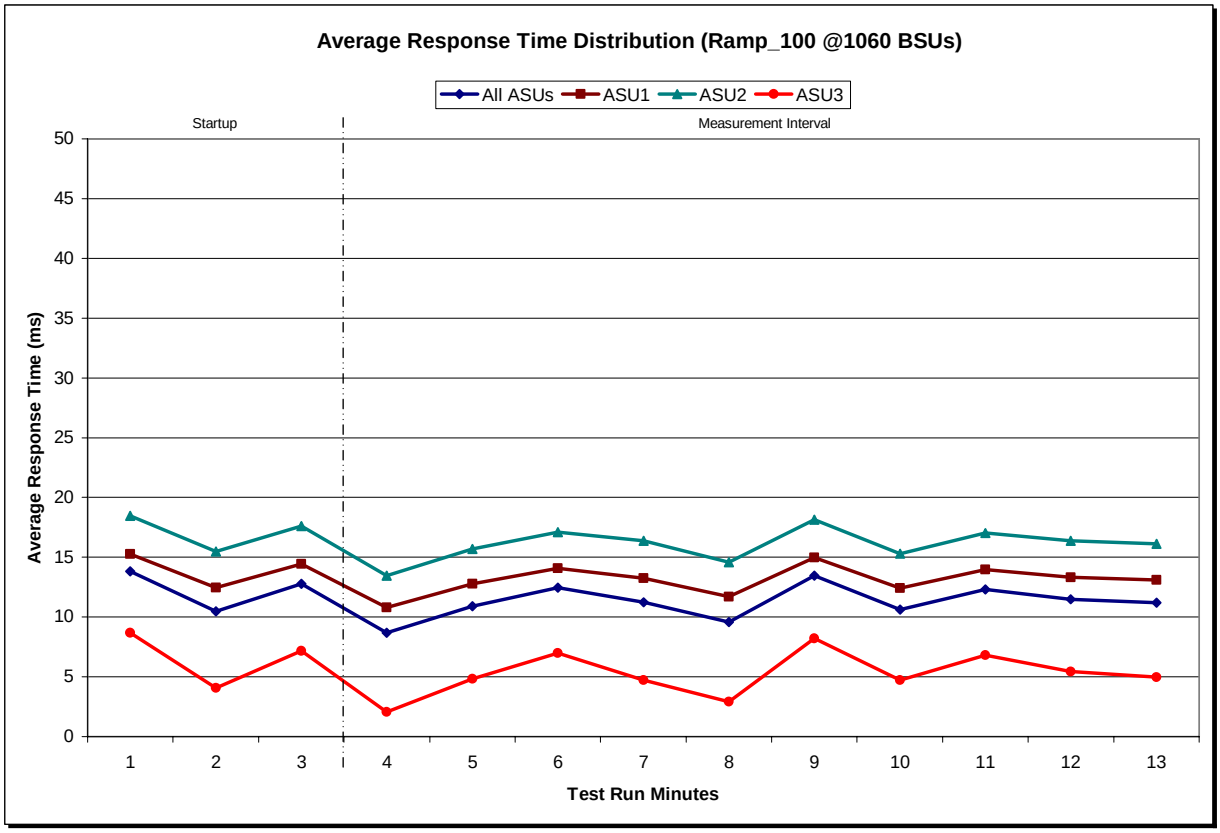
IOPS Test Run – I/O Request Throughput Distribution Graph



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

1060 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:38:35	20:41:36	0-2	0:03:01
Measurement Interval	20:41:36	20:51:36	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	13.82	15.27	18.47	8.69
1	10.48	12.47	15.47	4.07
2	12.77	14.43	17.59	7.16
3	8.66	10.80	13.47	2.05
4	10.89	12.77	15.71	4.82
5	12.44	14.06	17.10	6.98
6	11.23	13.23	16.39	4.73
7	9.59	11.71	14.57	2.91
8	13.47	14.98	18.15	8.20
9	10.61	12.43	15.30	4.71
10	12.32	13.95	17.02	6.80
11	11.48	13.31	16.37	5.45
12	11.18	13.10	16.13	4.96
Average	***11.19***	***13.03***	***16.02***	***5.16***

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



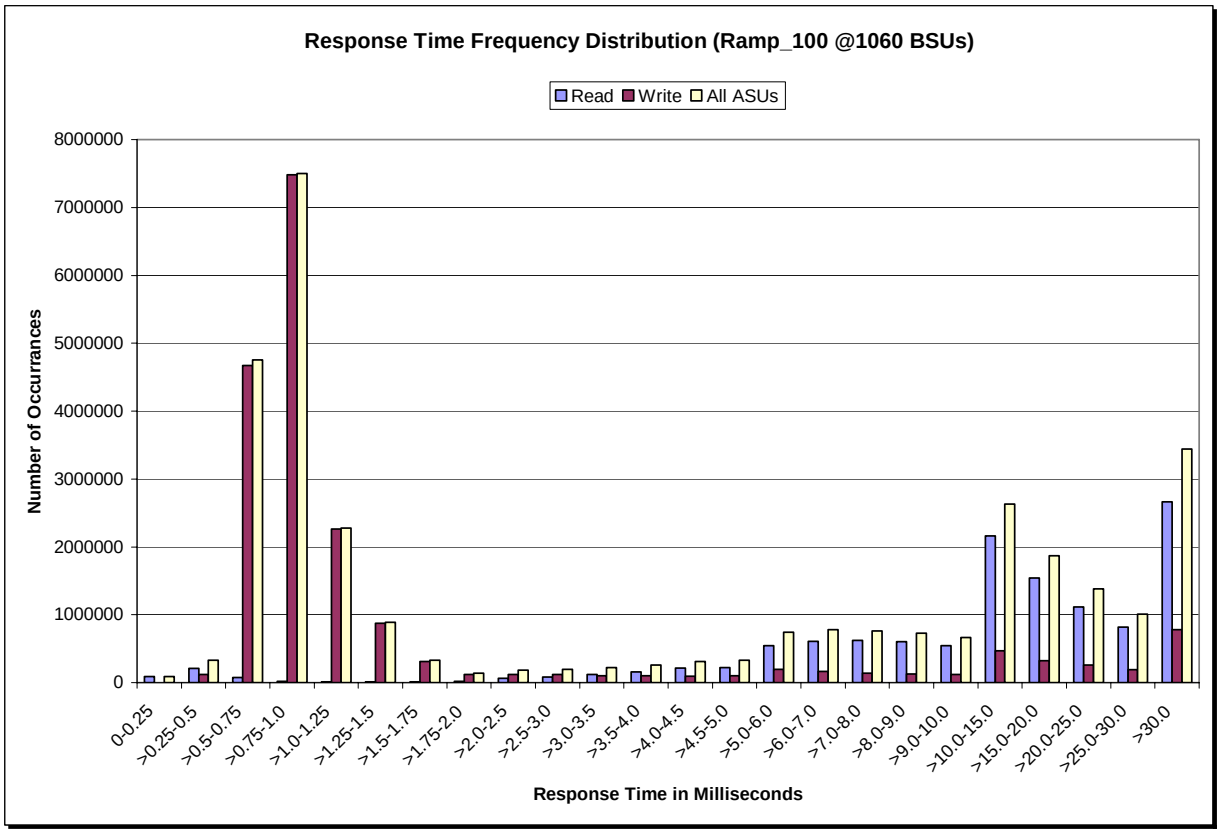
IOPS Test Run – Response Time Frequency Distribution Data

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	87,194	211,226	76,826	19,406	12,907	14,120	15,250	19,343
Write	1,162	120,557	4,674,856	7,480,917	2,261,245	874,634	311,642	120,363
All ASUs	88,356	331,783	4,751,682	7,500,323	2,274,152	888,754	326,892	139,706
ASU1	79,622	227,937	2,145,281	3,275,578	970,887	369,006	136,731	67,400
ASU2	8,290	53,190	540,563	757,663	211,418	76,910	27,433	12,341
ASU3	444	50,656	2,065,838	3,467,082	1,091,847	442,838	162,728	59,965

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	61,924	80,615	123,303	156,015	216,543	224,286	543,839	611,094
Write	122,925	117,680	98,852	104,145	95,284	103,990	198,177	166,931
All ASUs	184,849	198,295	222,155	260,160	311,827	328,276	742,016	778,025
ASU1	111,328	127,897	159,379	191,449	239,939	247,218	569,634	613,750
ASU2	15,952	16,869	17,970	21,487	29,102	34,164	83,011	88,183
ASU3	57,569	53,529	44,806	47,224	42,786	46,894	89,371	76,092

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	621,001	603,883	543,769	2,162,745	1,543,260	1,116,762	817,333	2,661,603
Write	140,956	124,448	119,752	468,766	324,799	262,888	190,745	778,154
All ASUs	761,957	728,331	663,521	2,631,511	1,868,059	1,379,650	1,008,078	3,439,757
ASU1	608,857	581,219	521,298	2,074,671	1,463,380	1,058,405	762,657	2,355,849
ASU2	88,222	89,598	86,814	342,160	256,590	201,924	156,934	690,822
ASU3	64,878	57,514	55,409	214,680	148,089	119,321	88,487	393,086

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
31,808,115	28,368,358	3,439,757

IOPS Test Run – Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.13.2

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

Clause 5.3.13.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2811	0.0700	0.2099	0.0180	0.0699	0.0350	0.2811
COV	0.002	0.001	0.002	0.001	0.005	0.002	0.002	0.001

Primary Metrics Test – Response Time Ramp Test Phase

Clause 5.4.4.3

The Response Time Ramp Test Phase consists of five Test Runs, one each at 95%, 90%, 80%, 50%, and 10% of the load point (100%) used to generate the SPC-1 IOPS™ primary metric. Each of the five Test Runs has a Measurement Interval of ten (10) minutes. The Response Time Ramp Test Phase immediately follows the IOPS Test Phase without any interruption or manual intervention.

The five Response Time Ramp Test Runs, in conjunction with the IOPS Test Run (100%), demonstrate the relationship between Average Response Time and I/O Request Throughput for the Tested Storage Configuration (TSC) as illustrated in the response time/throughput curve on page 13.

In addition, the Average Response Time measured during the 10% Test Run is the value for the SPC-1 LRT™ metric. That value represents the Average Response Time of a lightly loaded TSC.

Clause 9.4.3.7.3

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

1. *A Response Time Ramp Distribution.*
2. *The human readable Test Run Results File produced by the Workload Generator for each Test Run within the Response Time Ramp Test Phase.*
3. *For the 10% Load Level Test Run (SPC-1 LRT™ metric) an Average Response Time Distribution.*
4. *A listing or screen image of all input parameters supplied to the Workload Generator.*

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 70.

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 - 1060 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:38:35	20:41:36	0-2	0:03:01
Measurement Interval	20:41:36	20:51:36	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	53,030.42	31,619.90	6,527.90	14,882.62
1	52,955.73	31,556.98	6,503.68	14,895.07
2	52,988.97	31,590.15	6,513.97	14,884.85
3	52,994.98	31,571.42	6,507.97	14,915.60
4	52,978.13	31,573.43	6,507.90	14,896.80
5	53,069.75	31,625.28	6,508.23	14,936.23
6	53,045.35	31,638.77	6,506.52	14,900.07
7	52,929.12	31,553.73	6,503.58	14,871.80
8	53,009.20	31,600.23	6,509.68	14,899.28
9	52,983.55	31,593.22	6,519.37	14,870.97
10	53,021.88	31,602.47	6,530.40	14,889.02
11	53,051.28	31,624.33	6,513.22	14,913.73
12	53,059.67	31,612.73	6,521.38	14,925.55
Average	53,014.29	31,599.56	6,512.83	14,901.91

95% Load Level - 1007 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:51:41	20:54:42	0-2	0:03:01
Measurement Interval	20:54:42	21:05:05	3-12	0:10:23

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	50,334.68	30,033.00	6,176.17	14,125.52
1	50,334.80	30,000.42	6,192.48	14,141.90
2	50,349.48	30,022.55	6,167.98	14,158.95
3	50,363.20	30,004.65	6,203.10	14,155.45
4	50,378.23	30,055.97	6,191.08	14,131.18
5	50,360.35	30,028.42	6,187.35	14,144.58
6	50,407.48	30,046.13	6,190.85	14,170.50
7	50,301.53	30,004.93	6,187.05	14,109.55
8	50,334.83	30,003.55	6,192.82	14,138.47
9	50,388.10	30,034.33	6,189.00	14,164.77
10	50,332.35	29,986.07	6,188.07	14,158.22
11	50,381.23	30,008.43	6,220.85	14,151.95
12	50,328.28	29,993.62	6,186.53	14,148.13
Average	50,357.56	30,016.61	6,193.67	14,147.28

90% Load Level - 954 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:05:11	21:08:12	0-2	0:03:01
Measurement Interval	21:08:12	21:18:12	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	47,695.95	28,419.40	5,863.83	13,412.72
1	47,700.05	28,427.52	5,865.87	13,406.67
2	47,639.23	28,419.58	5,854.22	13,365.43
3	47,716.90	28,464.22	5,877.18	13,375.50
4	47,699.20	28,396.12	5,887.72	13,415.37
5	47,673.57	28,430.13	5,862.87	13,380.57
6	47,709.68	28,417.38	5,880.33	13,411.97
7	47,671.08	28,408.70	5,866.73	13,395.65
8	47,634.52	28,401.80	5,858.75	13,373.97
9	47,623.63	28,364.73	5,874.32	13,384.58
10	47,715.43	28,432.83	5,885.22	13,397.38
11	47,751.43	28,451.60	5,877.33	13,422.50
12	47,685.22	28,403.07	5,864.67	13,417.48
Average	47,688.07	28,417.06	5,873.51	13,397.50

80% Load Level - 848 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:18:17	21:21:18	0-2	0:03:01
Measurement Interval	21:21:18	21:31:18	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	42,431.52	25,290.92	5,220.88	11,919.72
1	42,369.18	25,247.42	5,227.03	11,894.73
2	42,425.08	25,282.47	5,219.07	11,923.55
3	42,430.32	25,286.93	5,210.47	11,932.92
4	42,392.08	25,264.02	5,218.75	11,909.32
5	42,365.47	25,270.73	5,192.93	11,901.80
6	42,382.65	25,243.05	5,218.57	11,921.03
7	42,375.15	25,265.07	5,207.27	11,902.82
8	42,408.65	25,276.25	5,219.07	11,913.33
9	42,417.70	25,277.35	5,211.80	11,928.55
10	42,393.75	25,269.38	5,216.73	11,907.63
11	42,405.82	25,250.90	5,229.82	11,925.10
12	42,390.63	25,256.27	5,211.72	11,922.65
Average	42,396.22	25,266.00	5,213.71	11,916.52

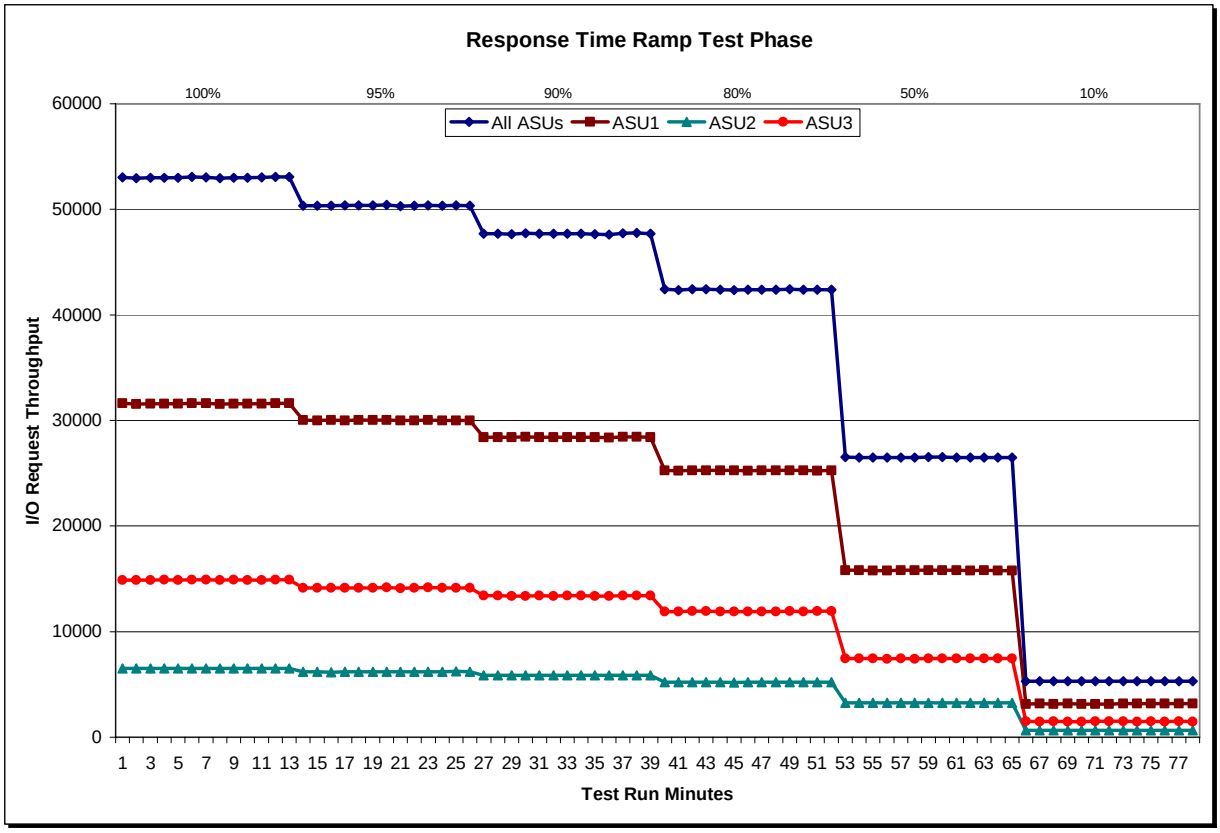
50% Load Level - 530 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:31:23	21:34:24	0-2	0:03:01
Measurement Interval	21:34:24	21:44:24	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	26,529.45	15,821.42	3,267.47	7,440.57
1	26,493.47	15,803.40	3,249.85	7,440.22
2	26,493.10	15,786.55	3,267.25	7,439.30
3	26,479.42	15,792.65	3,255.77	7,431.00
4	26,504.38	15,814.47	3,250.28	7,439.63
5	26,497.90	15,801.25	3,260.98	7,435.67
6	26,525.72	15,810.53	3,255.83	7,459.35
7	26,543.98	15,812.70	3,281.13	7,450.15
8	26,512.20	15,816.12	3,254.00	7,442.08
9	26,482.65	15,794.10	3,248.62	7,439.93
10	26,513.17	15,809.07	3,254.87	7,449.23
11	26,490.50	15,780.23	3,255.13	7,455.13
12	26,500.70	15,777.63	3,256.15	7,466.92
Average	26,505.06	15,800.88	3,257.28	7,446.91

10% Load Level - 106 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:44:28	21:47:29	0-2	0:03:01
Measurement Interval	21:47:29	21:57:29	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	5,296.18	3,151.60	651.67	1,492.92
1	5,294.68	3,160.37	648.82	1,485.50
2	5,292.45	3,153.17	650.42	1,488.87
3	5,301.30	3,162.50	653.10	1,485.70
4	5,292.50	3,155.03	654.03	1,483.43
5	5,290.72	3,145.00	651.13	1,494.58
6	5,293.80	3,158.47	646.67	1,488.67
7	5,308.53	3,167.10	650.40	1,491.03
8	5,299.03	3,162.98	656.33	1,479.72
9	5,303.42	3,165.07	649.48	1,488.87
10	5,310.00	3,172.28	654.47	1,483.25
11	5,311.25	3,168.98	648.72	1,493.55
12	5,311.12	3,177.93	650.80	1,482.38
Average	5,302.17	3,163.54	651.51	1,487.12

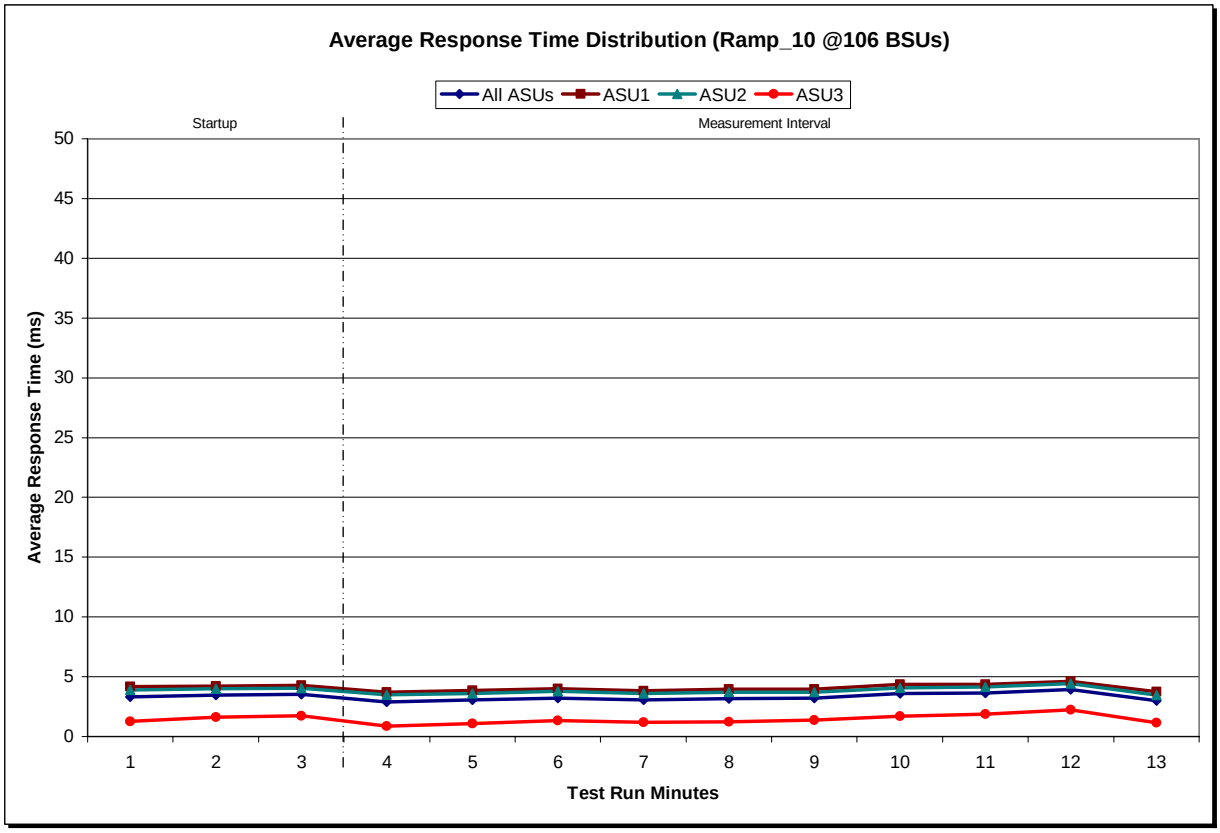
Response Time Ramp Distribution (IOPS) Graph



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

106 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:44:28	21:47:29	0-2	0:03:01
Measurement Interval	21:47:29	21:57:29	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	3.31	4.17	3.89	1.25
1	3.45	4.20	3.98	1.62
2	3.53	4.28	4.02	1.73
3	2.89	3.71	3.50	0.88
4	3.05	3.85	3.61	1.09
5	3.21	3.99	3.78	1.33
6	3.06	3.83	3.60	1.18
7	3.17	3.97	3.72	1.23
8	3.20	3.96	3.72	1.36
9	3.58	4.37	4.07	1.70
10	3.64	4.37	4.14	1.87
11	3.91	4.60	4.42	2.24
12	2.98	3.74	3.46	1.14
Average	***3.27***	***4.04***	***3.80***	***1.40***

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



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

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.13.2

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

Clause 5.3.13.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0351	0.2812	0.0701	0.2102	0.0180	0.0699	0.0350	0.2805
COV	0.008	0.003	0.007	0.002	0.012	0.006	0.011	0.004

Repeatability Test

Clause 5.4.5

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

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

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

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

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

Clause 9.4.3.7.4

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

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

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 70.

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	***53,014.29***
Repeatability Test Phase 1	52,989.86
Repeatability Test Phase 2	52,992.05

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

	SPC-1 LRT™
Primary Metrics	***3.27 ms***
Repeatability Test Phase 1	2.79 ms
Repeatability Test Phase 2	2.98 ms

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

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

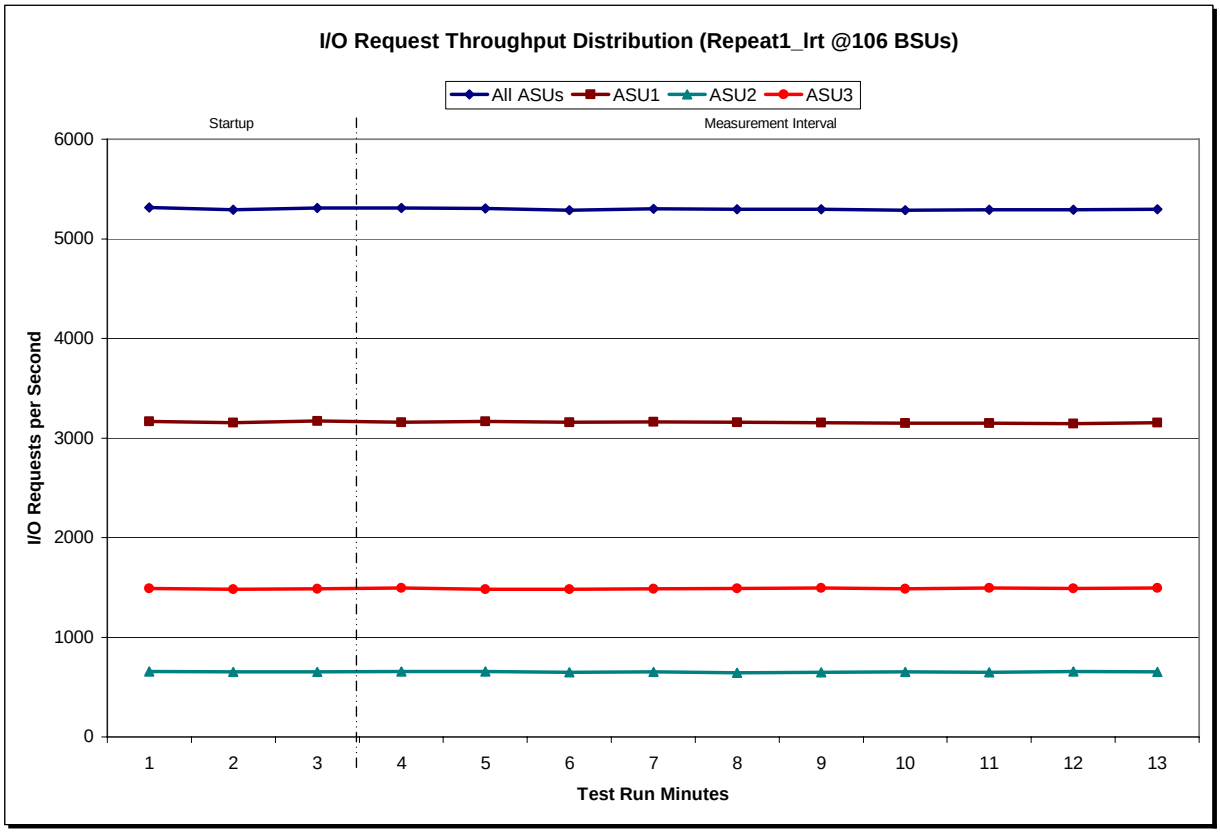
Repeatability Test Phase 1, Test Run 1 (LRT)
Repeatability Test Phase 1, Test Run 2 (IOPS)
Repeatability Test Phase 2, Test Run 1 (LRT)
Repeatability Test Phase 2, Test Run 2 (IOPS)

Repeatability 1 LRT – I/O Request Throughput Distribution Data

106 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:57:39	22:00:39	0-2	0:03:00
Measurement Interval	22:00:39	22:10:39	3-12	0:10:00

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	5,313.37	3,167.63	655.57	1,490.17
1	5,289.90	3,155.03	651.33	1,483.53
2	5,309.83	3,169.30	652.62	1,487.92
3	5,309.35	3,159.28	657.47	1,492.60
4	5,305.32	3,167.17	657.27	1,480.88
5	5,287.12	3,155.57	649.25	1,482.30
6	5,301.47	3,161.63	652.07	1,487.77
7	5,294.20	3,157.95	645.12	1,491.13
8	5,296.78	3,151.23	648.92	1,496.63
9	5,287.65	3,150.90	651.10	1,485.65
10	5,293.35	3,151.03	649.55	1,492.77
11	5,292.90	3,145.35	656.38	1,491.17
12	5,296.93	3,151.53	650.35	1,495.05
Average	***5,296.51***	***3,155.17***	***651.75***	***1,489.60***

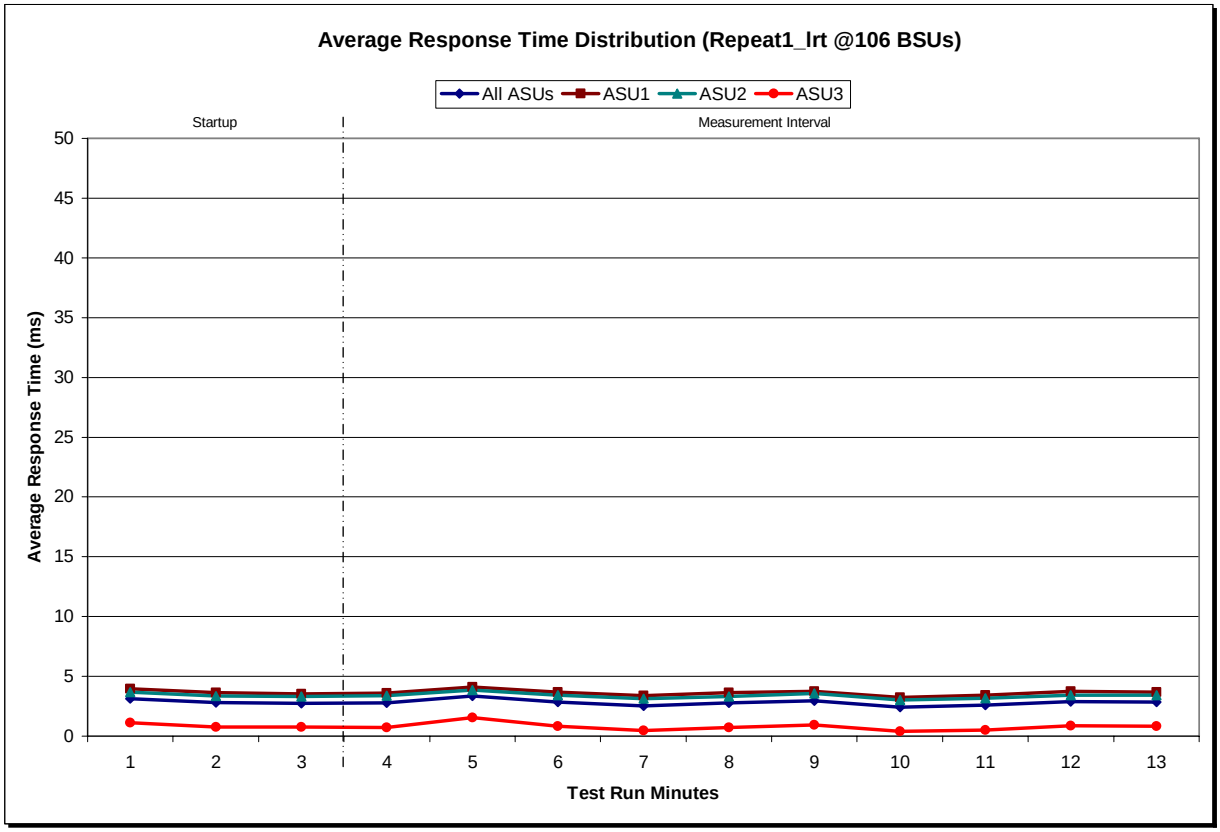
Repeatability 1 LRT – I/O Request Throughput Distribution Graph



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

106 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:57:39	22:00:39	0-2	0:03:00
Measurement Interval	22:00:39	22:10:39	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	3.12	3.94	3.68	1.12
1	2.81	3.65	3.36	0.77
2	2.74	3.54	3.32	0.76
3	2.77	3.61	3.38	0.73
4	3.35	4.10	3.84	1.54
5	2.84	3.66	3.43	0.84
6	2.52	3.37	3.15	0.46
7	2.77	3.62	3.30	0.72
8	2.94	3.76	3.55	0.95
9	2.42	3.25	3.02	0.38
10	2.58	3.43	3.18	0.51
11	2.89	3.73	3.41	0.88
12	2.84	3.68	3.41	0.82
Average	***2.79***	***3.62***	***3.37***	***0.78***

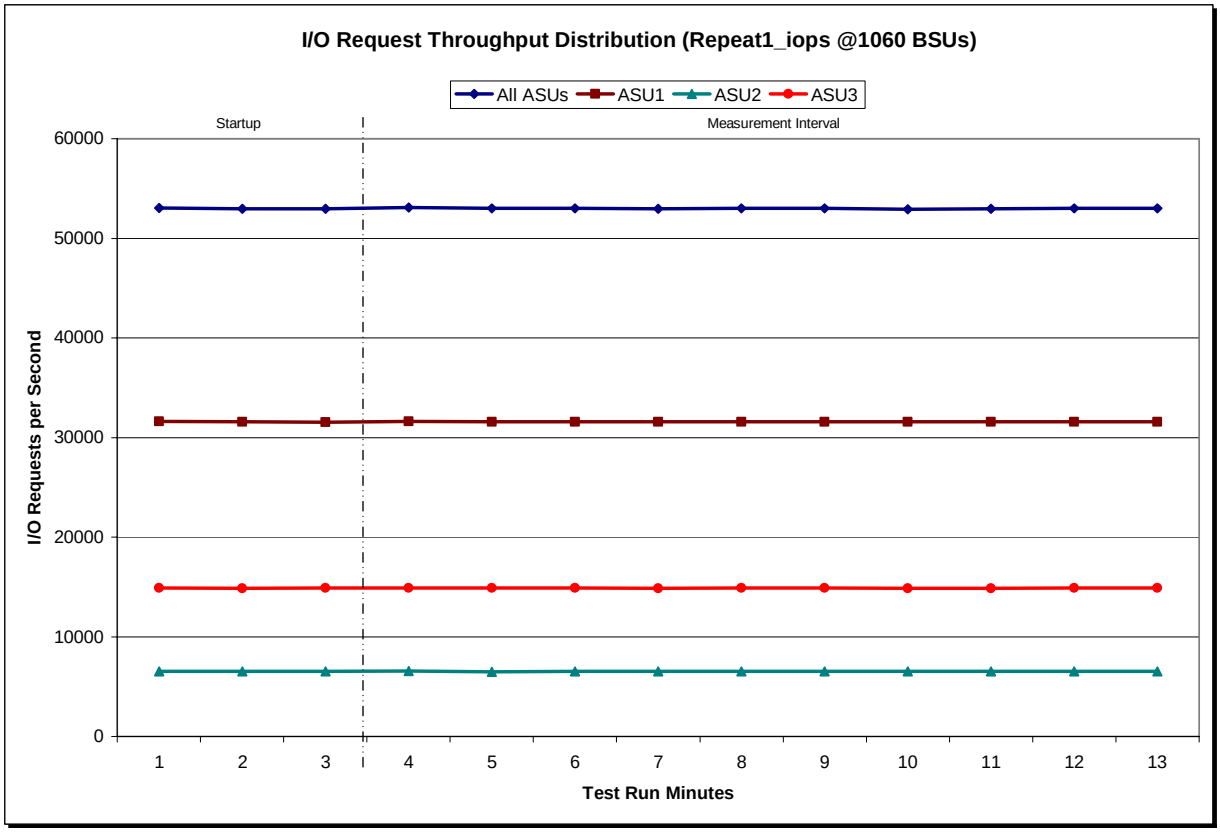
Repeatability 1 LRT –Average Response Time (ms) Distribution Graph



Repeatability 1 IOPS – I/O Request Throughput Distribution Data

1060 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	22:10:44	22:13:45	0-2	0:03:01
Measurement Interval	22:13:45	22:23:45	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	53,047.37	31,616.48	6,535.87	14,895.02
1	52,962.45	31,583.00	6,510.58	14,868.87
2	52,961.13	31,551.87	6,513.23	14,896.03
3	53,075.68	31,622.05	6,544.35	14,909.28
4	52,982.80	31,574.07	6,500.85	14,907.88
5	53,004.47	31,568.38	6,523.78	14,912.30
6	52,944.63	31,583.90	6,515.80	14,844.93
7	52,986.83	31,573.60	6,508.67	14,904.57
8	52,983.62	31,573.83	6,517.50	14,892.28
9	52,936.83	31,559.70	6,505.62	14,871.52
10	52,963.70	31,561.63	6,527.48	14,874.58
11	53,016.57	31,583.62	6,522.57	14,910.38
12	53,003.50	31,585.37	6,517.98	14,900.15
Average	***52,989.86***	***31,578.62***	***6,518.46***	***14,892.79***

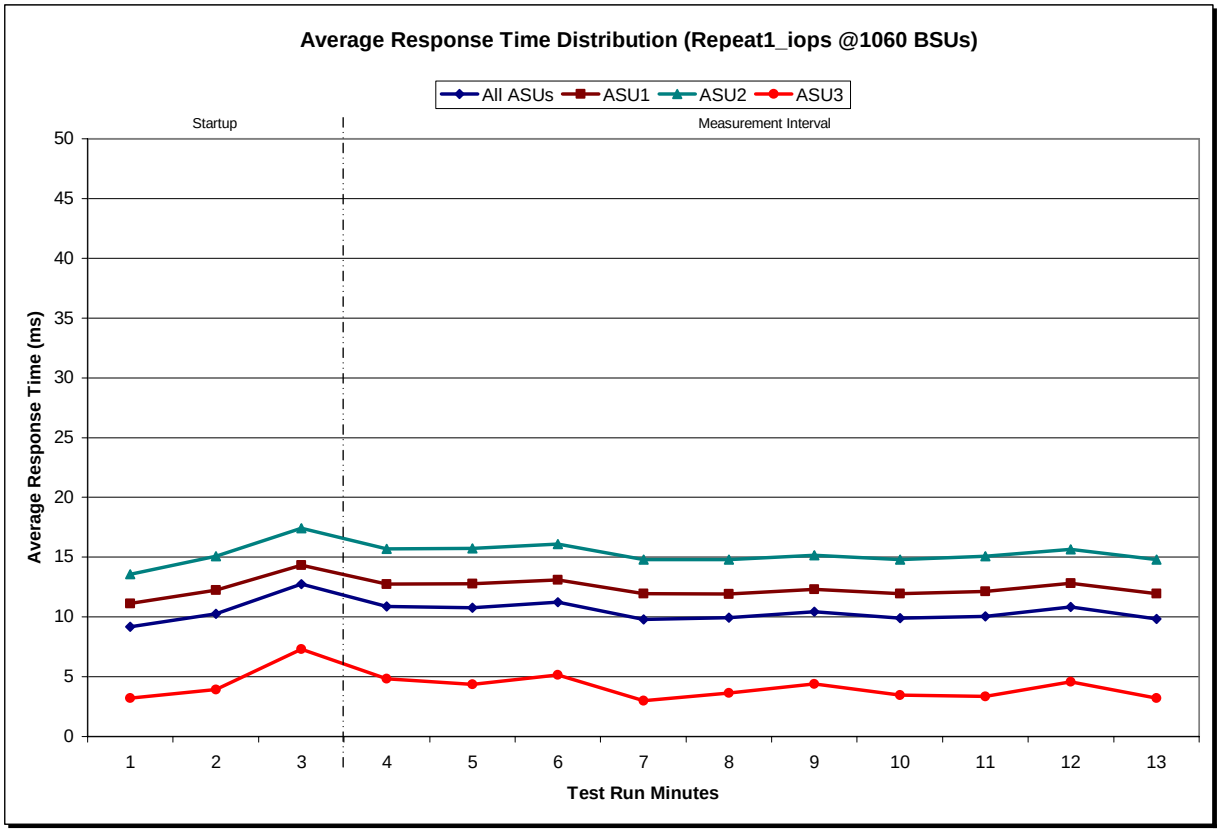
Repeatability 1 IOPS – I/O Request Throughput Distribution Graph



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

1060 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	22:10:44	22:13:45	0-2	0:03:01
Measurement Interval	22:13:45	22:23:45	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	9.19	11.11	13.58	3.20
1	10.25	12.23	15.08	3.92
2	12.73	14.33	17.41	7.29
3	10.89	12.75	15.69	4.83
4	10.76	12.77	15.74	4.36
5	11.24	13.12	16.10	5.14
6	9.77	11.94	14.79	2.97
7	9.94	11.91	14.79	3.64
8	10.45	12.33	15.17	4.39
9	9.90	11.93	14.81	3.44
10	10.03	12.14	15.07	3.36
11	10.85	12.82	15.65	4.57
12	9.83	11.94	14.80	3.20
Average	***10.37***	***12.36***	***15.26***	***3.99***

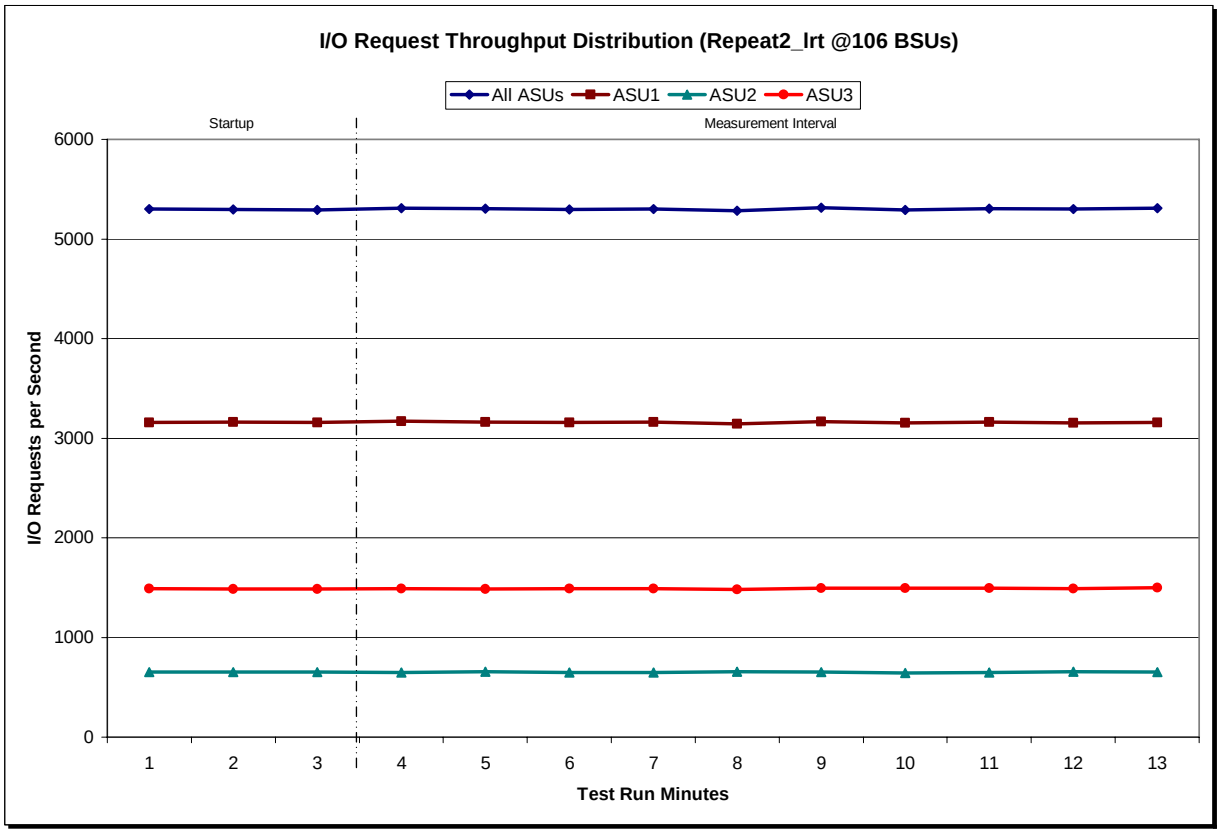
Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph



Repeatability 2 LRT – I/O Request Throughput Distribution Data

106 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	22:23:55	22:26:55	0-2	0:03:00
Measurement Interval	22:26:55	22:36:55	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	5,301.58	3,158.10	651.42	1,492.07
1	5,297.03	3,160.02	651.08	1,485.93
2	5,293.67	3,158.28	650.97	1,484.42
3	5,310.08	3,169.67	650.08	1,490.33
4	5,303.35	3,162.22	654.68	1,486.45
5	5,295.27	3,155.90	649.55	1,489.82
6	5,298.33	3,160.88	648.22	1,489.23
7	5,283.45	3,144.98	654.75	1,483.72
8	5,311.43	3,166.05	652.10	1,493.28
9	5,290.17	3,151.32	644.82	1,494.03
10	5,305.80	3,163.85	648.05	1,493.90
11	5,300.62	3,155.30	655.68	1,489.63
12	5,310.05	3,158.02	652.53	1,499.50
Average	***5,300.86***	***3,158.82***	***651.05***	***1,490.99***

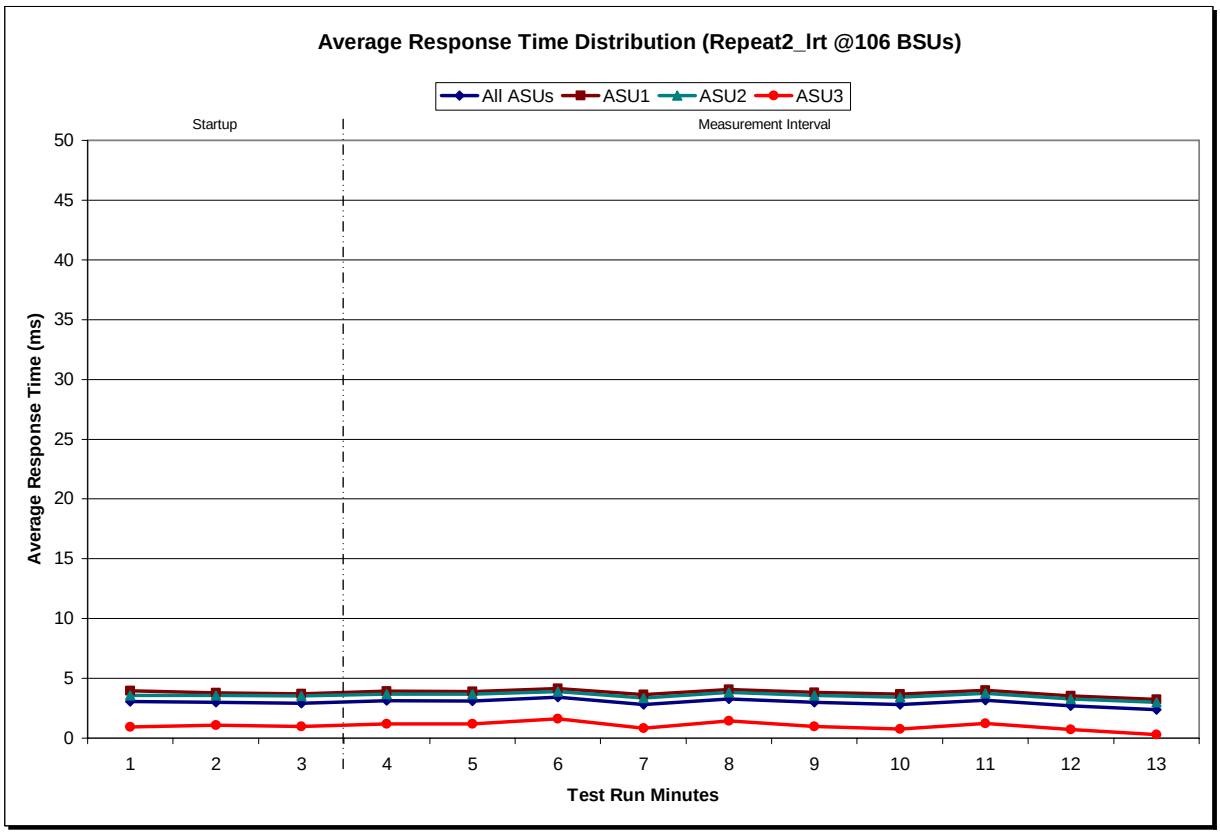
Repeatability 2 LRT – I/O Request Throughput Distribution Graph



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

106 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	22:23:55	22:26:55	0-2	0:03:00
Measurement Interval	22:26:55	22:36:55	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	3.05	3.95	3.56	0.93
1	2.99	3.77	3.55	1.07
2	2.91	3.71	3.53	0.96
3	3.12	3.92	3.68	1.19
4	3.10	3.88	3.67	1.20
5	3.40	4.14	3.90	1.64
6	2.82	3.65	3.36	0.83
7	3.29	4.05	3.81	1.44
8	2.98	3.80	3.57	0.98
9	2.81	3.65	3.42	0.76
10	3.18	3.99	3.74	1.22
11	2.70	3.52	3.28	0.71
12	2.37	3.24	2.98	0.30
Average	***2.98***	***3.78***	***3.54***	***1.03***

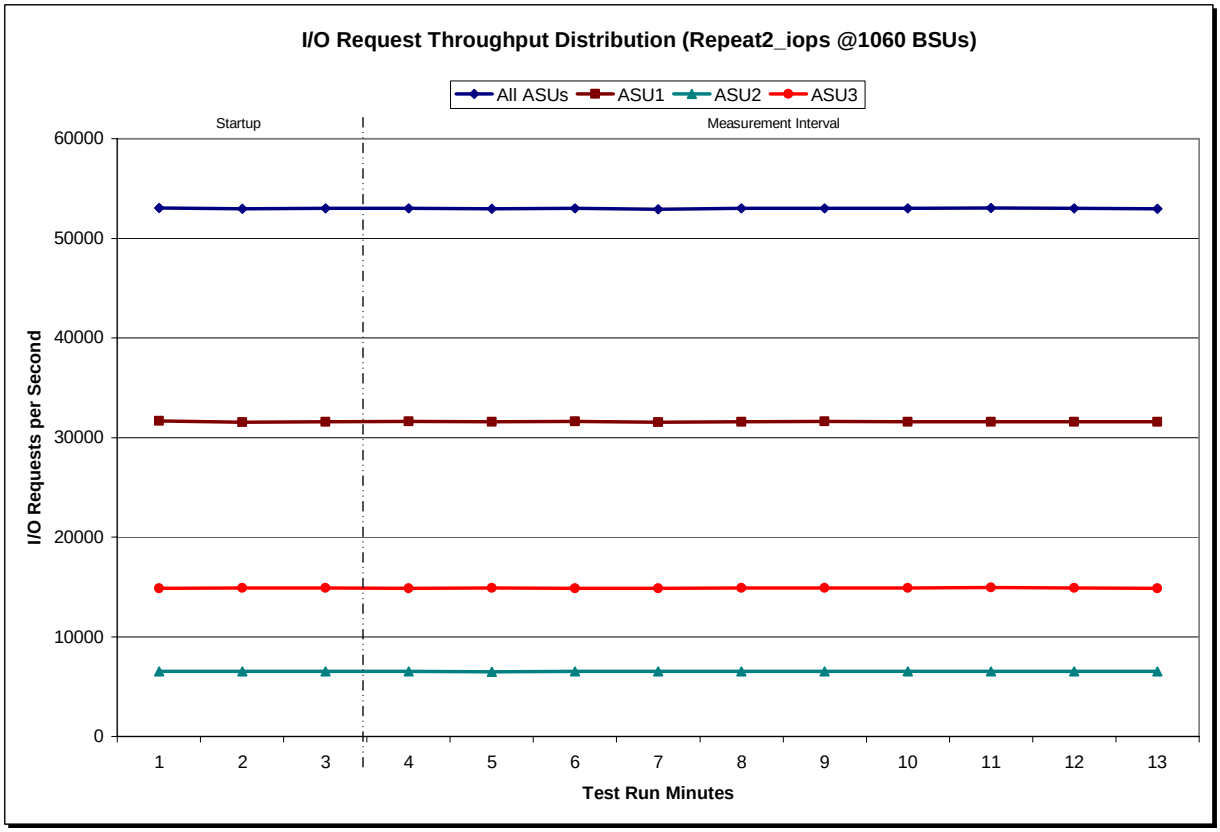
Repeatability 2 LRT –Average Response Time (ms) Distribution Graph



Repeatability 2 IOPS – I/O Request Throughput Distribution Data

1060 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	22:37:00	22:40:01	0-2	0:03:01
Measurement Interval	22:40:01	22:50:01	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	53,053.18	31,651.70	6,520.90	14,880.58
1	52,958.73	31,550.08	6,515.92	14,892.73
2	52,990.53	31,562.50	6,525.95	14,902.08
3	52,990.83	31,600.27	6,509.82	14,880.75
4	52,948.82	31,562.42	6,492.18	14,894.22
5	53,015.45	31,611.28	6,525.20	14,878.97
6	52,934.37	31,554.50	6,518.03	14,861.83
7	53,001.25	31,562.07	6,521.75	14,917.43
8	52,994.70	31,599.18	6,505.32	14,890.20
9	53,007.73	31,586.15	6,519.22	14,902.37
10	53,060.00	31,589.85	6,540.82	14,929.33
11	52,997.52	31,576.77	6,508.15	14,912.60
12	52,969.85	31,561.83	6,527.65	14,880.37
Average	***52,992.05***	***31,580.43***	***6,516.81***	***14,894.81***

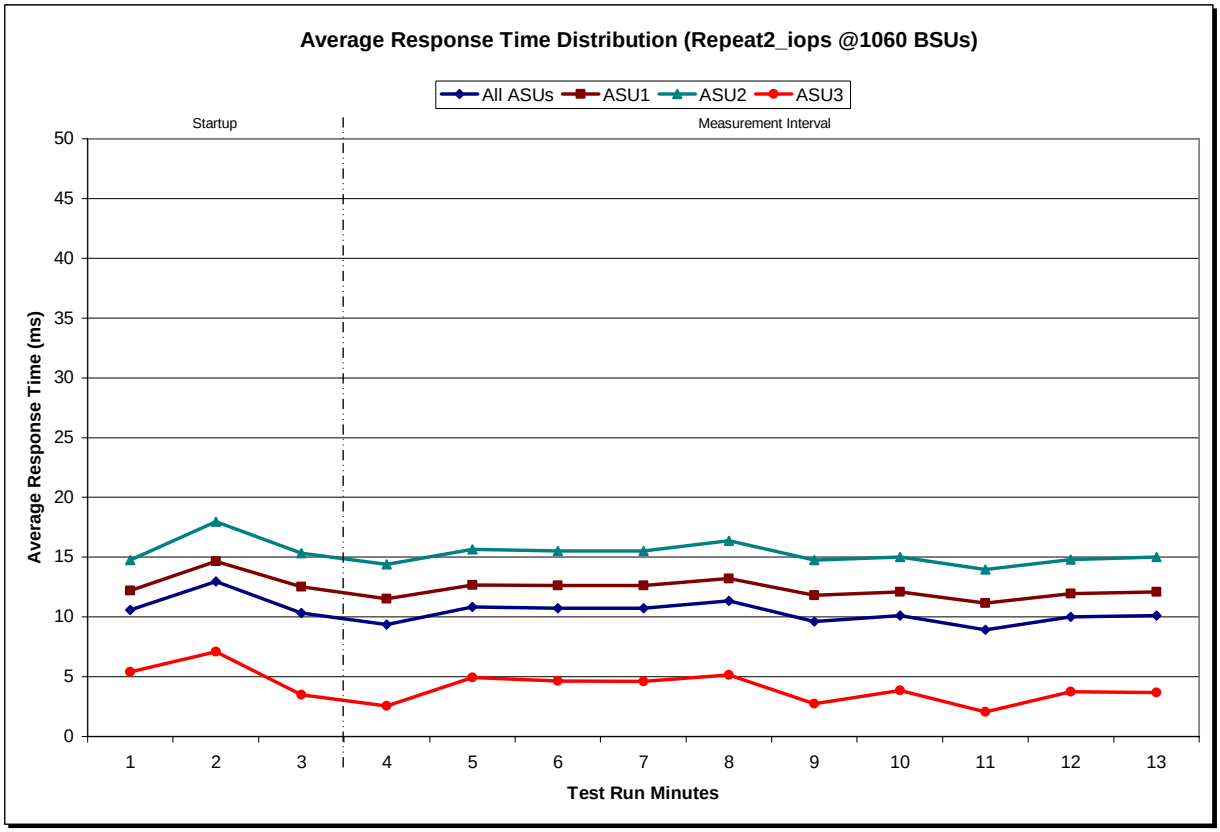
Repeatability 2 IOPS – I/O Request Throughput Distribution Graph



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

1060 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	22:37:00	22:40:01	0-2	0:03:01
Measurement Interval	22:40:01	22:50:01	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	10.59	12.19	14.76	5.38
1	12.94	14.67	17.95	7.10
2	10.33	12.51	15.35	3.50
3	9.36	11.52	14.41	2.55
4	10.85	12.66	15.67	4.92
5	10.74	12.63	15.50	4.65
6	10.73	12.63	15.50	4.60
7	11.34	13.23	16.40	5.14
8	9.61	11.80	14.75	2.74
9	10.13	12.10	15.00	3.84
10	8.94	11.15	13.98	2.04
11	9.99	11.96	14.80	3.75
12	10.10	12.11	15.01	3.68
Average	***10.18***	***12.18***	***15.10***	***3.79***

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



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

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.13.2

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

Clause 5.3.13.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0351	0.2808	0.0700	0.2098	0.0181	0.0701	0.0349	0.2812
COV	0.007	0.002	0.005	0.003	0.015	0.006	0.010	0.004

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	0.0351	0.2810	0.0699	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.002	0.001	0.002	0.001	0.002	0.002	0.002	0.001

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2808	0.0701	0.2101	0.0180	0.0698	0.0350	0.2813
COV	0.007	0.002	0.007	0.004	0.012	0.008	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	0.2810	0.0700	0.2099	0.0180	0.0699	0.0351	0.2811
COV	0.004	0.001	0.001	0.001	0.005	0.002	0.002	0.001

Data Persistence Test

Clause 6

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

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

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

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

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

Clause 9.4.3.8

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

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

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 70.

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	123,042,856
Total Number of Logical Blocks Verified	95,601,632
Total Number of Logical Blocks that Failed Verification	0
Time Duration for Writing Test Logical Blocks	10 minutes
Size in Bytes of each Logical Block	512
Number of Failed I/O Requests in the process of the Test	0

In some cases the same address was the target of multiple writes, which resulted in more Logical Blocks Written than Logical Blocks Verified. In the case of multiple writes to the same address, the pattern written and verified must be associated with the last write to that address.

PRICED STORAGE CONFIGURATION AVAILABILITY DATE

Clause 9.2.4.9

The committed delivery data for general availability (Availability Date) of all products that comprise the Priced Storage Configuration must be reported. When the Priced Storage Configuration includes products or components with different availability dates, the reported Availability Date for the Priced Storage Configuration must be the date at which all components are committed to be available.

The IBM Storwize® V7000 as documented in this Full Disclosure Report is currently available for customer purchase and shipment.

PRICING INFORMATION

Clause 9.4.3.3.6

The Executive Summary shall contain a pricing spreadsheet as documented in Clause 8.3.1.

Pricing information may found in the Priced Storage Configuration Pricing section on page 14.

TESTED STORAGE CONFIGURATION (TSC) AND PRICED STORAGE CONFIGURATION DIFFERENCES

Clause 9.4.3.3.7

The Executive Summary shall contain a pricing a list of all differenced between the Tested Storage Configuration (TSC) and the Priced Storage Configuration.

A list of all differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration may be found in the Executive Summary portion of this document on page 14.

ANOMALIES OR IRREGULARITIES

Clause 9.4.3.10

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

There were no anomalies or irregularities encountered during the SPC-1 Remote Audit of the IBM Storwize® V7000 .

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

Protected: This level will ensure data protection in the event of a single point of failure of any configured storage device. A brief description of the data protection utilized is included in the Executive Summary.

Unprotected: No claim of data protection is asserted in the event of a single point of failure.

SPC-1 Test Execution Definitions

Average Response Time: The sum of the Response Times for all Measured I/O Requests divided by the total number of Measured I/O Requests.

Completed I/O Request: An I/O Request with a Start Time and a Completion Time (see "I/O Completion Types" below).

Completion Time: The time recorded by the Workload Generator when an I/O Request is satisfied by the TSC as signaled by System Software.

Data Rate: The data transferred in all Measured I/O Requests in an SPC-1 Test Run divided by the length of the Test Run in seconds.

Expected I/O Count: For any given I/O Stream and Test Phase, the product of 50 times the BSU level, the duration of the Test Phase in seconds, and the Intensity Multiplier for that I/O Stream.

Failed I/O Request: Any I/O Request issued by the Workload Generator that could not be completed or was signaled as failed by System Software. A Failed I/O Request has no Completion Time (see "I/O Completion Types" below).

I/O Request Throughput: The total number of Measured I/O requests in an SPC-1 Test Run divided by the duration of the Measurement Interval in seconds.

In-Flight I/O Request: An I/O Request issued by the I/O Command Generator to the TSC that has a recorded Start Time, but does not complete within the Measurement Interval (see "I/O Completion Types" below).

Measured I/O Request: A Completed I/O Request with a Completion Time occurring within the Measurement Interval (see "I/O Completion Types" below).

Measured Intensity Multiplier: The percentage of all Measured I/O Requests that were issued by a given I/O Stream.

Measurement Interval: The finite and contiguous time period, after the TSC has reached Steady State, when data is collected by a Test Sponsor to generate an SPC-1 test result or support an SPC-1 test result.

Ramp-Up: The time required for the Benchmark Configuration (BC) to produce Steady State throughput after the Workload Generator begins submitting I/O Requests to the TSC for execution.

Ramp-Down: The time required for the BC to complete all I/O Requests issued by the Workload Generator. The Ramp-Down period begins when the Workload Generator ceases to issue new I/O Requests to the TSC.

Response Time: The Response Time of a Measured I/O Request is its Completion Time minus its Start Time.

Start Time: The time recorded by the Workload Generator when an I/O Request is submitted, by the Workload Generator, to the System Software for execution on the Tested Storage Configuration (TSC).

Start-Up: The period that begins after the Workload Generator starts to submit I/O requests to the TSC and ends at the beginning of the Measurement Interval.

Shut-Down: The period between the end of the Measurement Interval and the time when all I/O Requests issued by the Workload Generator have completed or failed.

Steady State: The consistent and sustainable throughput of the TSC. During this period the load presented to the TSC by the Workload Generator is constant.

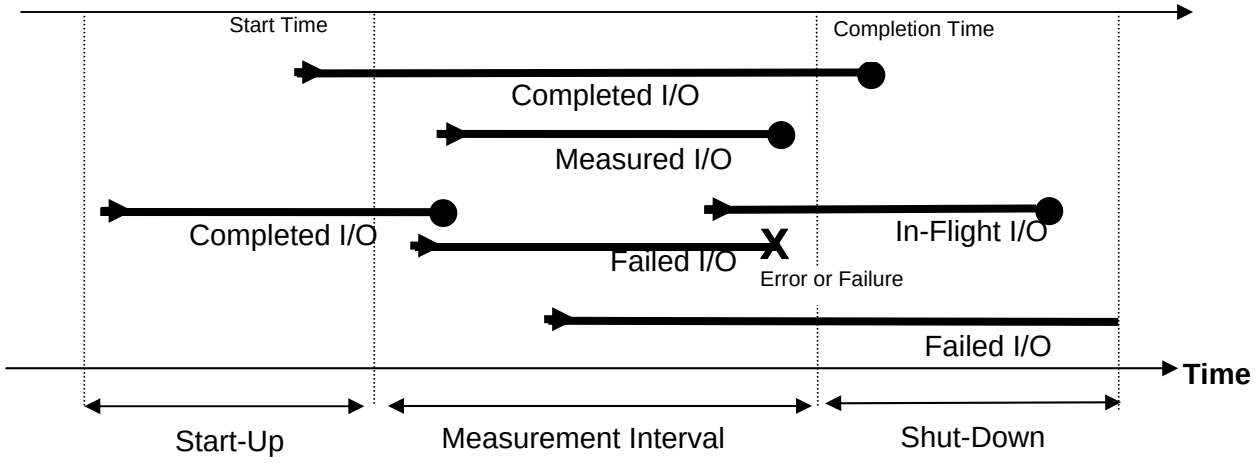
Test: A collection of Test Phases and or Test Runs sharing a common objective.

Test Run: The execution of SPC-1 for the purpose of producing or supporting an SPC-1 test result. SPC-1 Test Runs may have a finite and measured Ramp-Up period, Start-Up

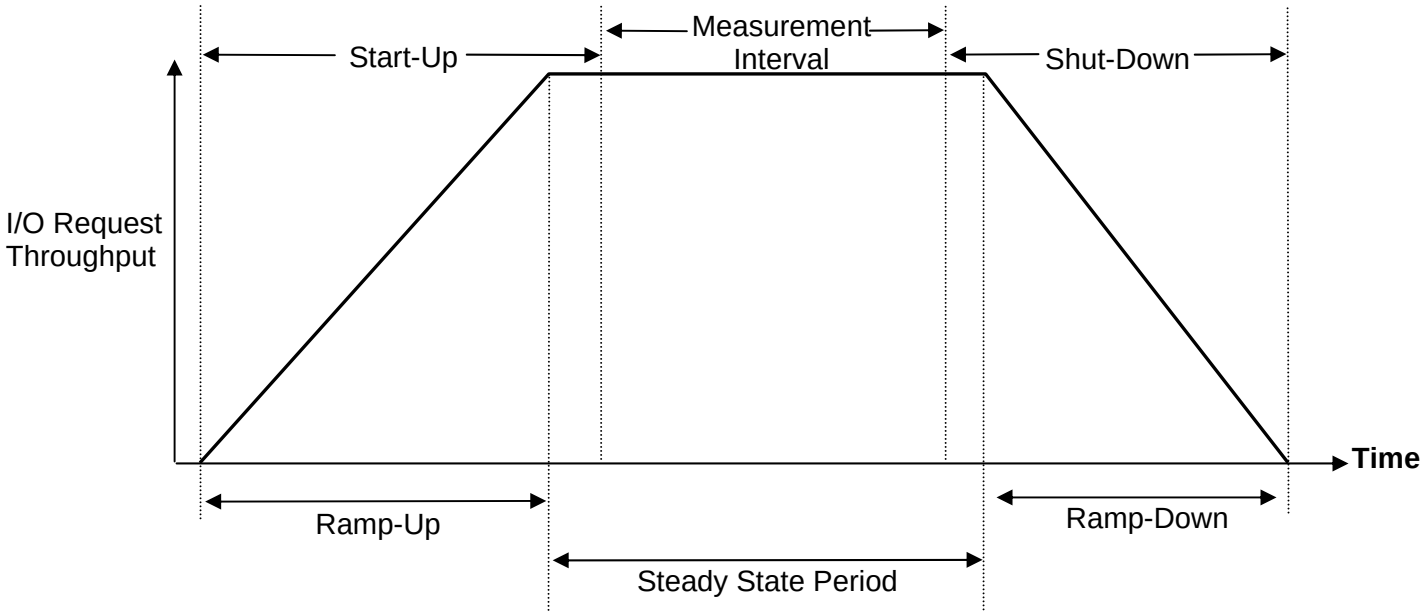
period, Shut-Down period, and Ramp-Down period as illustrated in the "SPC-1 Test Run Components" below. All SPC-1 Test Runs shall have a Steady State period and a Measurement Interval.

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

I/O Completion Types



SPC-1 Test Run Components



APPENDIX B: CUSTOMER TUNABLE PARAMETERS AND OPTIONS

There were no customer tunable parameters or options changed from their default values for these benchmark measurements.

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

IBM Storwize® V7000 Configuration

Each script listed below with the ***cyg*** file descriptor is submitted using PuTTY, a well known freeware package. In each of those scripts ***$plink*** is replace with the command ***plink name_of_cluster***, where ***name_of_cluster*** is a saved network location for the TSC.

The ***cyg*** scripts require the installation of Cygwin (http://www.cygwin.com/) and are executed as standard shell scripts in a Cygwin command window on the Host System.

The ***ds5020_tbird.configure*** script uses SANtricity Storage Manager CLI facility and is executed from a Window command window as follows:

SMcli {ip address} -f ds5020_tbird.configure

All of the referenced scripts appear at the end of this section.

Create RAID-10 Arrays and MDisks

The 240 disk drives are organized into RAID-10 arrays (*14 disks per array)* using the script ***do_chains_14disk.cyg***. This results in 17 MDisks as seen by the V7000.

Create the VDisks

The MDisks are presented "1 to 1" as 17 VDisks, using the script ***mk17vd_seq_2node.cyg***.

Create the host paths

Execution of the ***mkhost.cyg*** script creats a list of host paths.

Assign primary and alternate host paths

Each VDisk is assigned two primary and two alternate host paths using the ***mapfcs17_all.cyg***, which assigns paths from the list created in the previous step.

Windows Configuration

In Windows, multipath management was provided by SDDDSM, which is included as the driver for the Storwize V7000.

The Windows Diskpart command line utility was used to execute a script, ***dpmake.bat***, to create the Windows logical volumes used in the benchmark measurements.The ***dpmake.bat*** script was created by execution of the Cygwin script, ***mkdiskpart.cyg***, in a Cygwin command window as follows:

mkdiskpart.cyg 3 19 dpmake.bat

The resulting ***dpmake.bat*** script contained the Diskpart commands to:

- Scan the Windows "physical disks"

- Create 18 logical volumes using a stripe size of 77,102 MiB across "physical disks" 3-19 for a total capacity of 1,310,734 MiB per logical volume
- Assign drive letters E-V to the 18 striped logical volumes

All of the referenced scripts appear at the end of this section.

do_chains_14disk.cyg

```
#!/usr/bin/bash
# run in cygwin command line
# Creates 17 RAID-10 arrays of 14 disks each, using equal numbers of disks from each
chain
$plink svctask mkmdiskgrp -name thebiggroup -ext 256
drives=`$plink svcinfo lsdrive -nohdr | awk '{ print $1 }'`
for d in $drives
do
svctask chdrive -use candidate $d
done
c_enc=( -1 -1 -1 -1 -1   -2 -2 -2 -2 -2 )
n=0
for cnum in 1 2
do
  chain=`$plink svcinfo lssasfabric -nohdr -delim : |  \
    grep "^[^:]*:[^:]*:[^:]*:[^:]*:[^:]*:$cnum:[^:]*:[^:]*:[^:]*:[^:]*:lode1" | cut
-d: -f1 - | sort -n -`
  for i in $chain
  do
    c_enc[$n]=$i
    let n="n+1"
  done
done
arrcount=0
s0=0
e0=0
while [[ $arrcount -le 16 ]]
  do
  devlist0=`for d in 0 1 2 3 4 5 6; do let s="(s0+d)%24 + 1"; let e="e0+(s0+d)/24";
\
    $plink svcinfo lsenclosureslot -slot $s ${c_enc[$e]} 2>/dev/null | \
    awk '(FNR==8) { print $2 }'; done | awk -v ORS="" '{ print (FNR==1?"":":") $1 }'
`
    echo $devlist0
  devlist1=`for d in 0 1 2 3 4 5 6; do let s="(s0+d)%24 + 1"; let e="e0+(s0+d)/24";
\
    $plink svcinfo lsenclosureslot -slot $s ${c_enc[5+$e]} 2>/dev/null | \
    awk '(FNR==8) { print $2 }'; done | awk -v ORS="" '{ print (FNR==1?"":":") $1 }'
`
    echo $devlist1
  $plink  svctask mkarray -createsync -level raid10 -drive $devlist0:$devlist1 -name
md$arrcount thebiggroup
  let e0="e0+(s0+7)/24"
  let s0="(s0+7)%24"
  let arrcount="arrcount+1"
  done
sparedr=`$plink svcinfo lsenclosureslot -slot 24 ${c_enc[4]} | grep drive_id | awk
'{ print $2 }'`
$plink svctask chdrive -use spare $sparedr
sparedr=`$plink svcinfo lsenclosureslot -slot 24 ${c_enc[9]} | grep drive_id | awk
'{ print $2 }'`
```

```
$plink svctask chdrive -use spare $sparedr
```

mk17vd_seq_2node.cyg

```
#!/usr/bin/bash
#execute in cygwin command line
i=0
while [[ $i -le 16 ]]
    do
    let lode="1 + ((i%8) / 4)"
    iogrp=0
    capbytes=`$plink svcinfo lsmdisk -bytes md$i | grep capacity | awk  '{print
$2}'`
    let cap="(capbytes-536870912)/1073741824"
    $plink svctask mkvdisk -vtype seq -mdisk md$i \
       -size $cap -unit gb -mdiskgrp thebiggroup -iogrp io_grp$iogrp \
       -name vd$i -node lode$lode
    let i="i+1"
    done
```

mkhost.cyg

```
$plink svctask mkhost -force -name fcs0 -hbawwpn 2100001B3283C44C
$plink svctask mkhost -force -name fcs1 -hbawwpn 2100001B3283664C
$plink svctask mkhost -force -name fcs2 -hbawwpn 2101001B32A3C44C
$plink svctask mkhost -force -name fcs3 -hbawwpn 2101001B32A3664C
```

mapfcs17_all.cyg

```
i=0
while [[ $i -le 16 ]]
    do
    $plink svctask mkvdiskhostmap -force -host fcs0 vd$i
    $plink svctask mkvdiskhostmap -force -host fcs1 vd$i
    $plink svctask mkvdiskhostmap -force -host fcs2 vd$i
    $plink svctask mkvdiskhostmap -force -host fcs3 vd$i
    let i="i+1"
    done
```

mkdiskpart.cyg

```
#!/usr/bin/bash
# run in cygwin command line
#Makes batch input to create 18 striped volumes from specified disks with the
diskpart utility.
if [[ $# -lt 3 ]]
  then
  echo "usage: mkdiskpart N1 N2 <name of batch file>."
  return
  fi
letter=( E F G H I J K L M N O P Q R S T U V )
echo "rescan" > $3
i=$1
while [[ $i -le $2 ]]
do
  echo "select disk $i" >> $3
  echo "clean" >> $3
  echo "convert dynamic align=65536" >> $3
  if [[ $i -eq $1 ]]
  then
    disklist=$i
  else
```

```
      disklist=$disklist,$i
    fi
    let i="i+1"
  done
  echo "select volume 0" >> $3
  i=0
  while [[ $i -le 17 ]]
  do
    echo "create volume stripe size=77102 disk=$disklist" >> $3
    echo "assign letter ${letter[$i]}" >> $3
    let i="i+1"
  done
  echo "exit" >> $3
```

dpmake.bat

```
  rescan
  select disk 3
  clean
  convert dynamic align=65536
  select disk 4
  clean
  convert dynamic align=65536
  select disk 5
  clean
  convert dynamic align=65536
  select disk 6
  clean
  convert dynamic align=65536
  select disk 7
  clean
  convert dynamic align=65536
  select disk 8
  clean
  convert dynamic align=65536
  select disk 9
  clean
  convert dynamic align=65536
  select disk 10
  clean
  convert dynamic align=65536
  select disk 11
  clean
  convert dynamic align=65536
  select disk 12
  clean
  convert dynamic align=65536
  select disk 13
  clean
  convert dynamic align=65536
  select disk 14
  clean
  convert dynamic align=65536
  select disk 15
  clean
  convert dynamic align=65536
  select disk 16
  clean
  convert dynamic align=65536
  select disk 17
  clean
  convert dynamic align=65536
```

```
select disk 18
clean
convert dynamic align=65536
select disk 19
clean
convert dynamic align=65536
select volume 0
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter E
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter F
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter G
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter H
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter I
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter J
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter K
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter L
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter M
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter N
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter O
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter P
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter Q
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter R
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter S
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter T
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter U
create volume stripe size=77102 disk=3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19
assign letter V
```

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, Repeatability and Persistence Tests, is listed below.

```
javaparms="-Xms384m -Xmx768m -Xss128k"
sd=default,size=1374389534720
sd=asu1_1,lun=\\.\E:
sd=asu1_2,lun=\\.\F:
sd=asu1_3,lun=\\.\G:
sd=asu1_4,lun=\\.\H:
sd=asu1_5,lun=\\.\I:
sd=asu1_6,lun=\\.\J:
sd=asu1_7,lun=\\.\K:
sd=asu1_8,lun=\\.\L:
sd=asu2_1,lun=\\.\M:
sd=asu2_2,lun=\\.\N:
sd=asu2_3,lun=\\.\O:
sd=asu2_4,lun=\\.\P:
sd=asu2_5,lun=\\.\Q:
sd=asu2_6,lun=\\.\R:
sd=asu2_7,lun=\\.\S:
sd=asu2_8,lun=\\.\T:
sd=asu3_1,size=1221679586417,lun=\\.\U:
sd=asu3_2,size=1221679586417,lun=\\.\V:
```

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.

```
date /T > caplist.txt
time /T >> caplist.txt
plink spc1clus svcinfo lsdrive >> caplist.txt
plink spc1clus svcinfo lsmdisk -bytes >> caplist.txt
type hostcap.bat | diskpart >> caplist.txt
java -Xmx768m -Xms384m -Xss128k metrics -b 1060
java -Xmx768m -Xms384m -Xss128k repeat1 -b 1060
java -Xmx768m -Xms384m -Xss128k repeat2 -b 1060
java -Xmx1280m -Xms1280m -Xss64k persist1 -b 1060
date /T > caplist2.txt
time /T >> caplist2.txt
plink spc1clus svcinfo lsdrive >> caplist2.txt
plink spc1clus svcinfo lsmdisk -bytes >> caplist2.txt
type hostcap.bat | diskpart >> caplist2.txt
```

Persistence Test Run 2

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

```
java -Xmx1280m -Xms1280m -Xss64k persist2
```