SPC BENCHMARK 1™
FULL DISCLOSURE REPORT

X-IO TECHNOLOGIES
X-IO ISE 820 G3 ALL FLASH ARRAY

SPC-1 V1.14

Submitted for Review: March 10, 2015
Submission Identifier: A00155

First Edition – March 2015

Trademarks

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AUDIT CERTIFICATION

Ken Bates
X-IO Technologies
9950 Federal Drive, Suite 100
Colorado Springs, CO 80921

March 10, 2015

The SPC Benchmark 1™ Reported Data listed below for the X-IO ISE 820 G3 All Flash Array was produced in compliance with the SPC Benchmark 1™ v1.14 Onsite Audit requirements.

SPC Benchmark 1™ v1.14 Reported Data	
Tested Storage Product (TSP) Name: X-IO ISE 820 G3 All Flash Array	
Metric	**Reported Result**
SPC-1 IOPS™	252,981.83
SPC-1 Price-Performance	$0.32/SPC-1 IOPS™
Total ASU Capacity	2,920.578 GB
Data Protection Level	Protected 2 *(Mirroring)*
Total Price (including three-year maintenance)	$81,732.74
Currency Used	U.S. Dollars
Target Country for availability, sales and support	USA

The following SPC Benchmark 1™ Onsite Audit requirements were reviewed and found compliant with 1.14 of the SPC Benchmark 1™ specification:

- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository storage items were verified by physical inspection and information supplied by X-IO Technologies:
  - ✓ 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.
- The total Application Storage Unit (ASU) Capacity was filled with random data, using an auditor approved tool, prior to execution of the SPC-1 Tests.

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643 Bair Island Road, Suite 103
Redwood City, CA 94062
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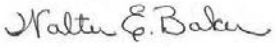
AUDIT CERTIFICATION *(CONT.)*

- An appropriate diagram of the Benchmark Configuration (BC)/Tested Storage Configuration (TSC).
- Physical verification of the components to match the above diagram.
- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters that were changed from default values.
- SPC-1 Workload Generator commands and parameters used for the audited SPC Test Runs.
- The following Host System requirements were verified by physical inspection and information supplied by X-IO Technologies:
  - ✓ 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 execution of each Test, Test Phase, and Test Run was observed and found compliant with all of the requirements and constraints of Clauses 4, 5, and 11 of the SPC-1 Benchmark Specification.
- The Test Results Files and resultant Summary Results Files received from X-IO Technologies for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4 and 5 of the SPC-1 Benchmark Specification:
  - ✓ Data Persistence Test
  - ✓ Sustainability Test Phase
  - ✓ IOPS Test Phase
  - ✓ Response Time Ramp Test Phase
  - ✓ Repeatability Test
- There was no difference between the Tested Storage Configuration (TSC) and Priced Storage Configuration.
- The submitted pricing information met all of the requirements and constraints of Clause 8 of the SPC-1 Benchmark Specification.
- The Full Disclosure Report (FDR) met all of the requirements in Clause 9 of the SPC-1 Benchmark Specification.
- This successfully audited SPC measurement is not subject to an SPC Confidential Review.

Audit Notes:

The approved use of the SPC-2 Persistence Test as a substitute for the SPC-1 Persistence Test required that 168 SPC-2 Streams be specified for the SPC-2 Persistence Test's execution. The SPC-2 Persistence Test used in the audited measurements specified 155 SPC-2 Streams. The difference of 13 Streams did not materially affect the results of the SPC-2 Persistence Test execution, which completed successfully.

Respectfully,



Walter E. Baker
SPC Auditor

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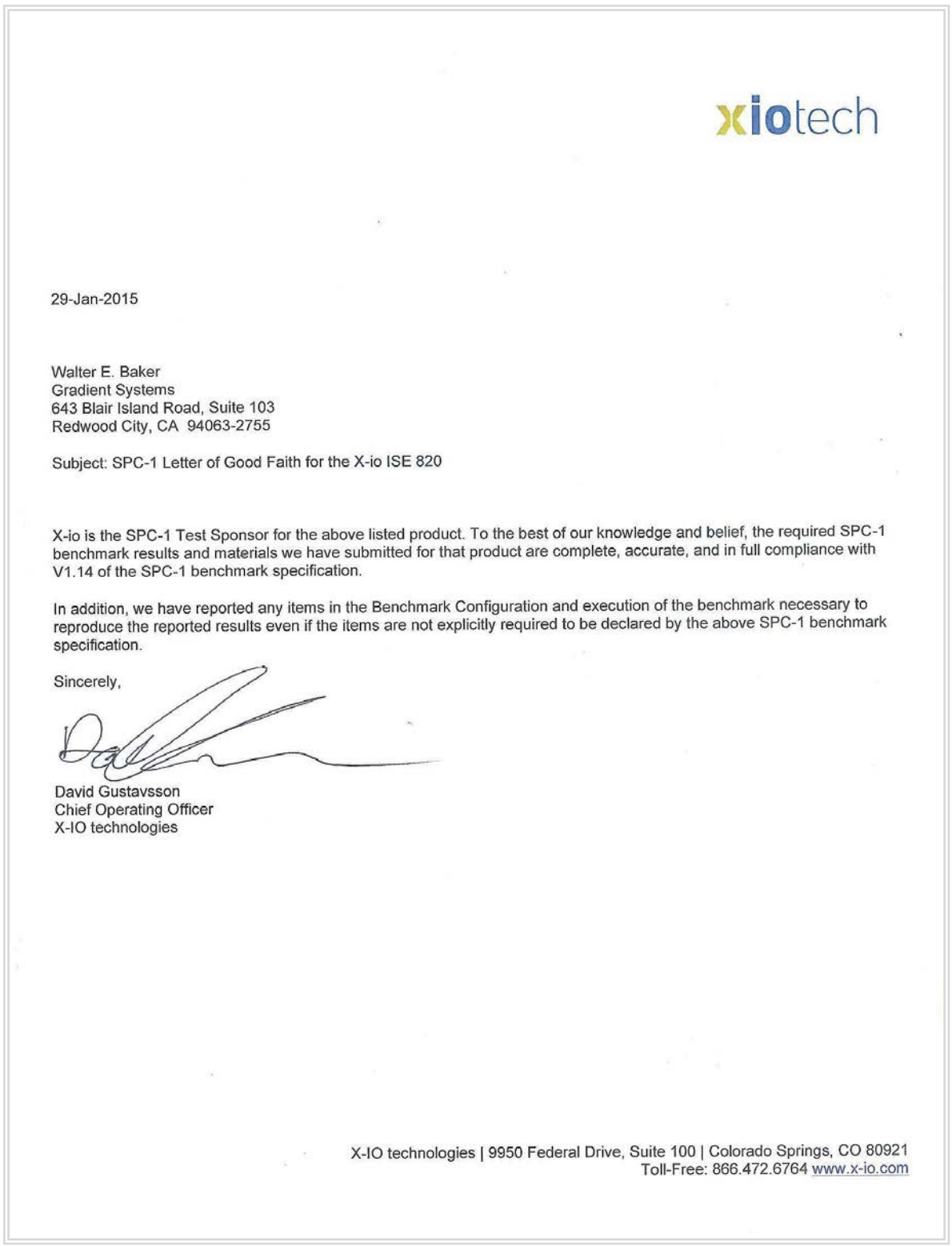
LETTER OF GOOD FAITH



xiotech

29-Jan-2015

Walter E. Baker
Gradient Systems
643 Blair Island Road, Suite 103
Redwood City, CA 94063-2755

Subject: SPC-1 Letter of Good Faith for the X-io ISE 820

X-io is the SPC-1 Test Sponsor for the above listed product. To the best of our knowledge and belief, the required SPC-1 benchmark results and materials we have submitted for that product are complete, accurate, and in full compliance with V1.14 of the SPC-1 benchmark specification.

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

Sincerely,

David Gustavsson
Chief Operating Officer
X-IO technologies

X-IO technologies | 9950 Federal Drive, Suite 100 | Colorado Springs, CO 80921
Toll-Free: 866.472.6764 www.x-io.com

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact	X-IO Technologies – http://www.x-io.com Ken Bates – Kenneth.Bates@x-io.com 9950 Federal Drive, Suite 100 Colorado Springs, CO 80921 Phone: (719) 488-2466
Test Sponsor Alternate Contact	X-IO Technologies –http://www.x-io.com Dave Gustavsson – David.Gustavsson@x-io.com 9950 Federal Drive, Suite 100 Colorado Springs, CO 80921 Phone: 719) 388-5300
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	V1.14
SPC-1 Workload Generator revision number	V2.3.0
Date Results were first used publicly	March 10, 2015
Date the FDR was submitted to the SPC	March 10, 2015
Date the Priced Storage Configuration is available for shipment to customers	currently available
Date the TSC completed audit certification	March 9, 2015

Tested Storage Product (TSP) Description

The ISE 820 G3 is a 3rd generation Intelligent Storage Element (ISE) from X-IO Technologies and is a revolutionary concept in data storage. The ISE 820 G3 is a Fibre Channel All-Flash Array (AFA) and is built on a perfectly balanced building block of performance, reliability, and scalability.

The ISE is a high-performance and highly reliable, flash-enabled storage system built for the demands of highly consolidated virtualization and VDI ecosystems, Database Management Systems and Cloud Service resources. Each ISE includes one or two sealed DataPacs (capacity modules) and dual Managed Reliability Controllers, which locally manage cache, data protection processes, and more. ISE can be configured to support both Fibre Channel and iSCSI connectivity protocols.

Developed over the course of a decade, at both Seagate and X-IO, by a core team of hardware and software designers and developers—with more than 350 patents to their collective credit—X-IO provides the basis of a carrier-grade, scale-out storage infrastructure. With a five- to seven-year operating lifespan, a standard 5-year no-cost warranty and performance that does not degrade as the system reaches 100% capacity utilization, the ISE delivers vastly superior TCO.

Summary of Results

SPC-1 Reported Data	
Tested Storage Product (TSP) Name: X-IO ISE 820 G3 All Flash Array	
Metric	**Reported Result**
SPC-1 IOPS™	252,981.83
SPC-1 Price-Performance™	$0.32/SPC-1 IOPS™
Total ASU Capacity	2,920.578 GB
Data Protection Level	Protected 2 *(mirroring)*
Total Price	$81,732.74
Currency Used	U.S. Dollars
Target Country for availability, sales and support	USA

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

SPC-1 Price-Performance™ is the ratio of **Total Price** to **SPC-1 IOPS™**.

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

A **Data Protection Level** of **Protected 2** using ***Mirroring*** configures two or more identical copies of user data.

> ***Protected 2:*** *The single point of failure of any* ***component*** *in the configuration will not result in permanent loss of access to or integrity of the SPC-1 Data Repository.*

Total Price includes the cost of the Priced Storage Configuration plus three years of hardware maintenance and software support as detailed on page 17.

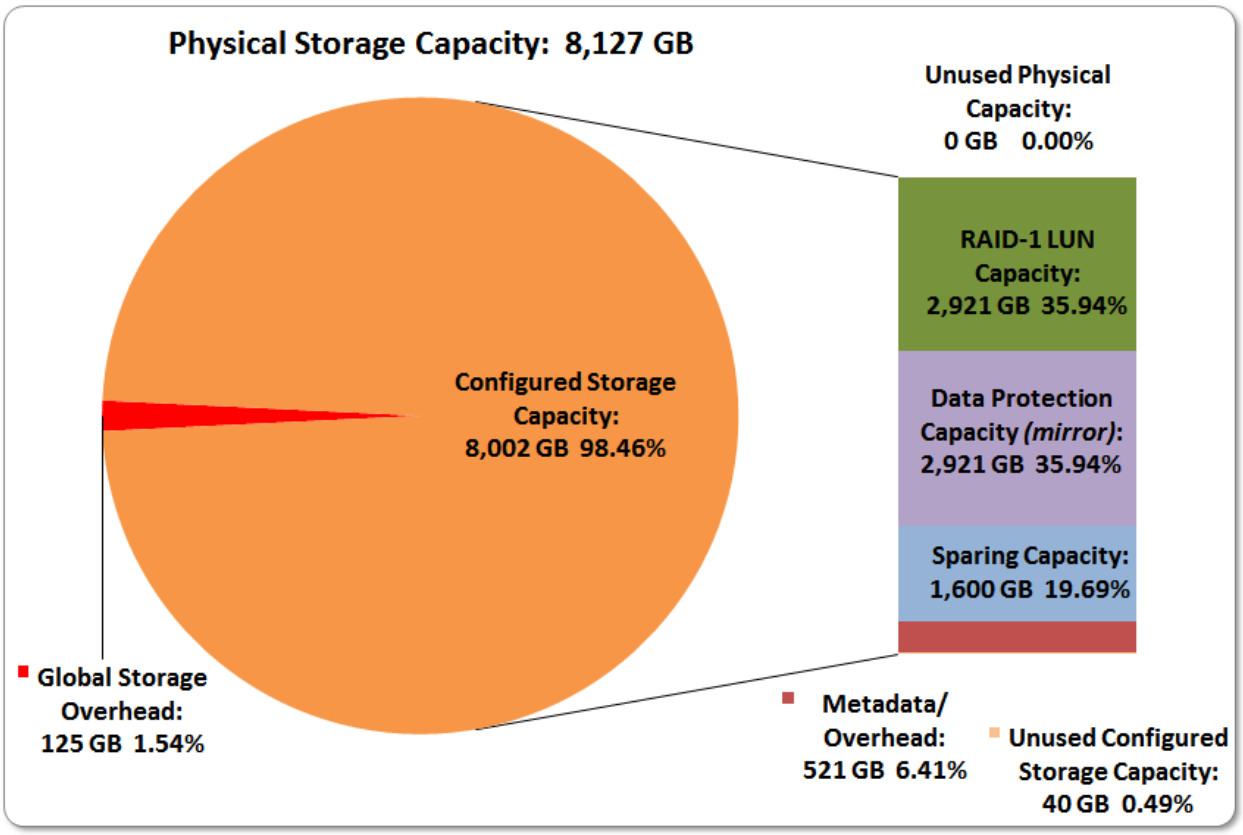
Currency Used is formal name for the currency used in calculating the **Total Price** and **SPC-1 Price-Performance™**. That currency may be the local currency of the **Target Country** or the currency of a difference country *(non-local currency)*.

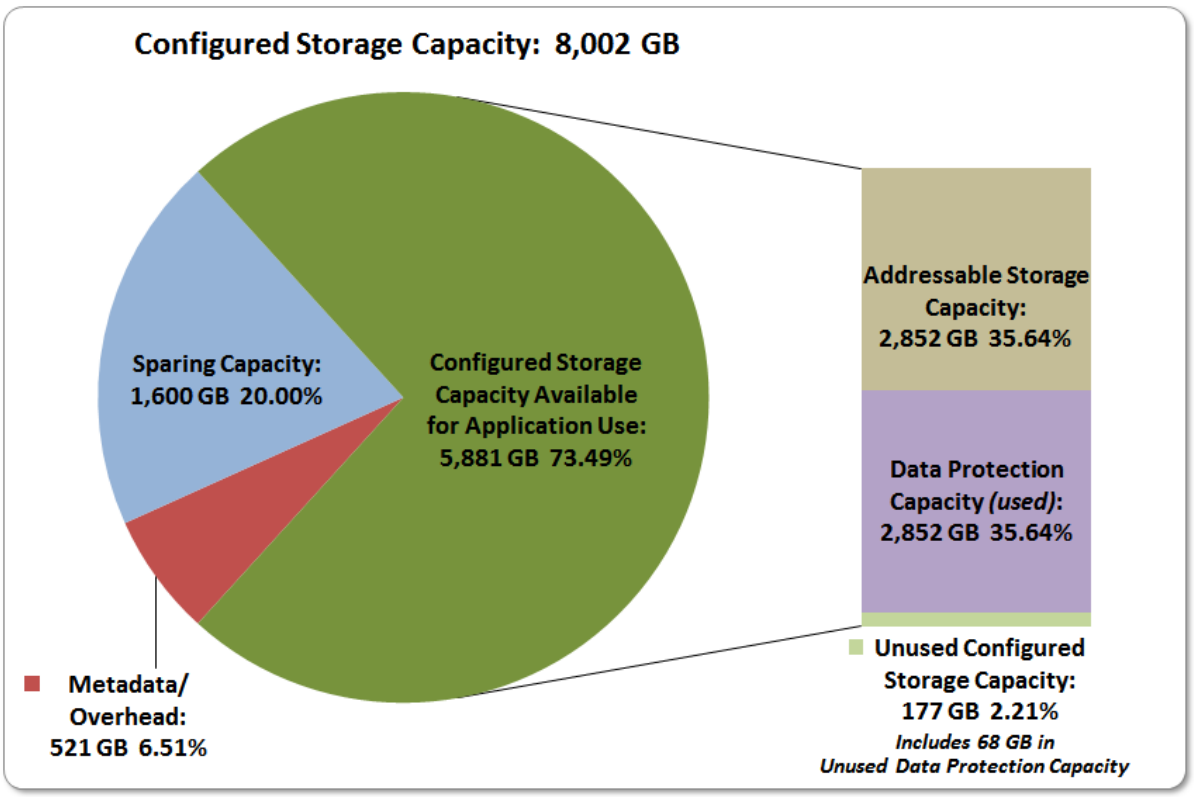
The **Target Country** is the country in which the Priced Storage Configuration is available for sale and in which the required hardware maintenance and software support is provided either directly from the Test Sponsor or indirectly via a third-party supplier.

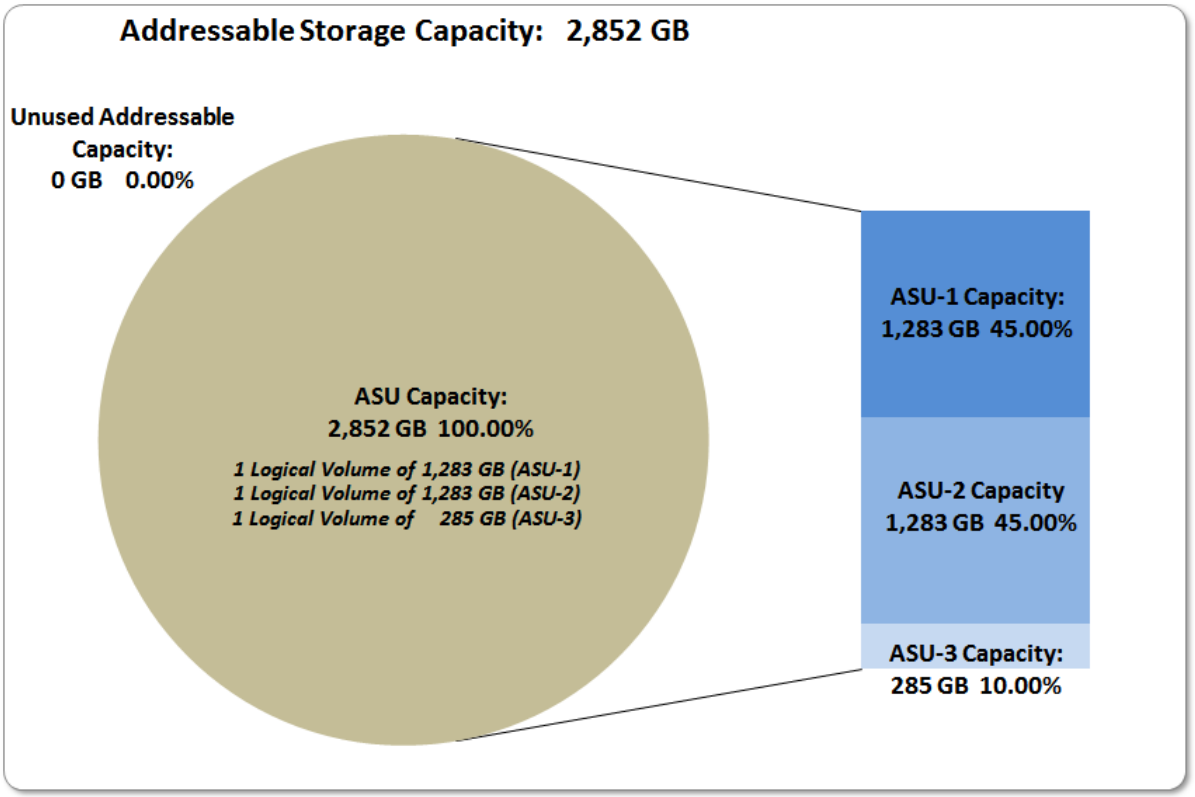
Storage Capacities, Relationships, and Utilization

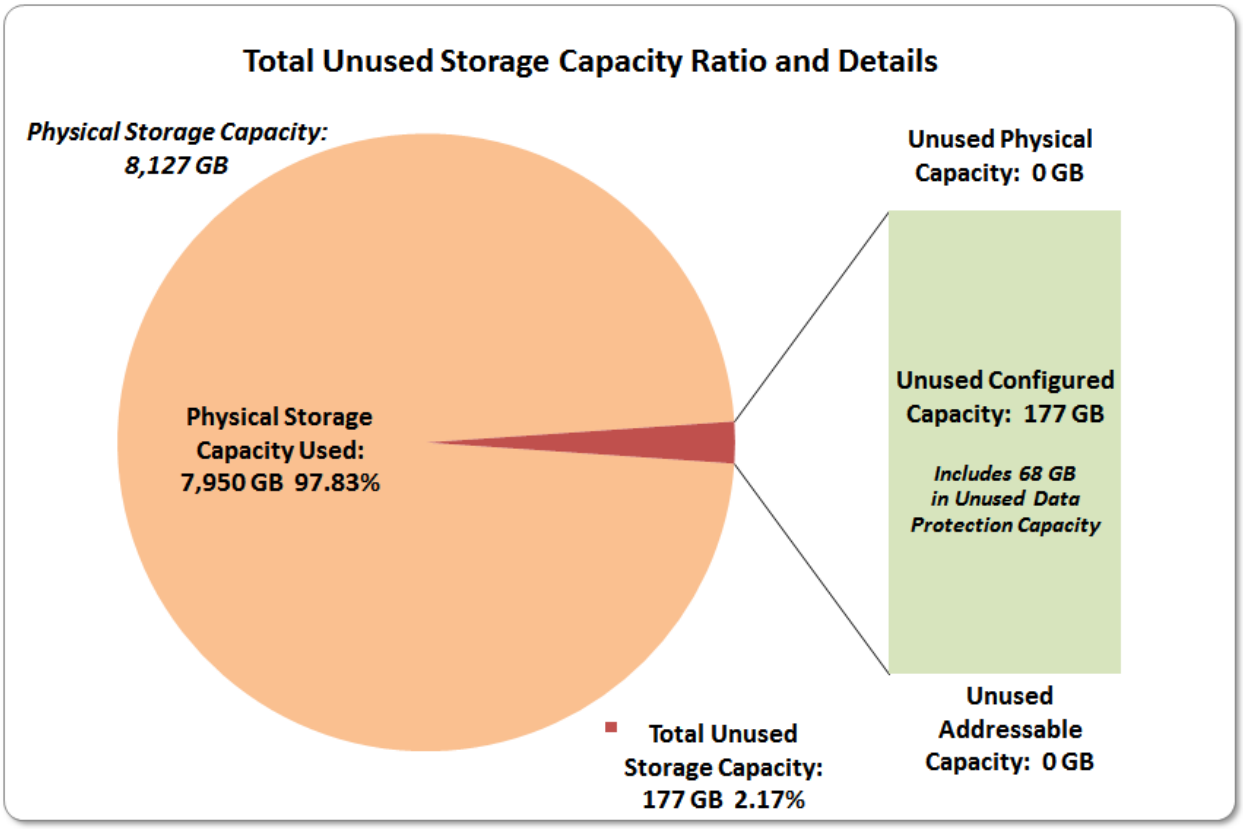
The following four charts and table document the various storage capacities, used in this benchmark, and their relationships, as well as the storage utilization values required to be reported.

The capacity values in each of the following four charts are listed as integer values, for readability, rather than the decimal values listed elsewhere in this document.




Configured Storage Capacity: 8,002 GB
Sparing Capacity:
1,600 GB 20.00%
Configured Storage Capacity Available for Application Use:
5,881 GB 73.49%
Metadata/ Overhead:
521 GB 6.51%
Addressable Storage Capacity:
2,852 GB 35.64%
Data Protection Capacity (used):
2,852 GB 35.64%
Unused Configured Storage Capacity:
177 GB 2.21%
Includes 68 GB in Unused Data Protection Capacity


Addressable Storage Capacity: 2,852 GB
Unused Addressable Capacity:
0 GB 0.00%
ASU Capacity:
2,852 GB 100.00%
1 Logical Volume of 1,283 GB (ASU-1)
1 Logical Volume of 1,283 GB (ASU-2)
1 Logical Volume of 285 GB (ASU-3)
ASU-1 Capacity:
1,283 GB 45.00%
ASU-2 Capacity
1,283 GB 45.00%
ASU-3 Capacity:
285 GB 10.00%



SPC-1 Storage Capacity Utilization	
Application Utilization	35.09%
Protected Application Utilization	70.19%
Unused Storage Ratio	2.17%

Application Utilization: Total ASU Capacity *(2,852.127 GB)* divided by Physical Storage Capacity *(8,127.017 GB)*.

Protected Application Utilization: (Total ASU Capacity *(2,852.127 GB)* plus total Data Protection Capacity *(2,920.578vGB)* minus unused Data Protection Capacity *(68,451 GB)*) divided by Physical Storage Capacity *(8,127.017 GB)*.

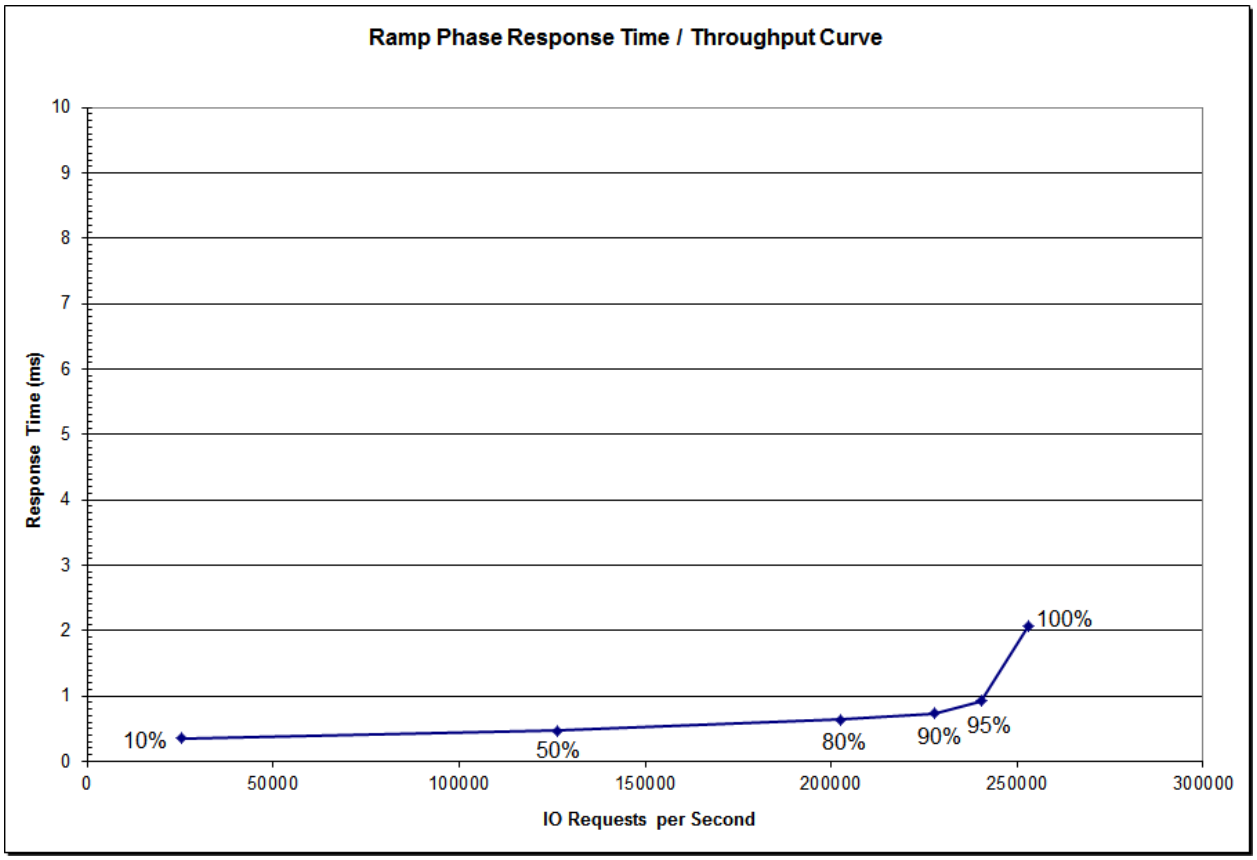
Unused Storage Ratio: Total Unused Capacity *(176.631 GB)* divided by Physical Storage Capacity *(8,127.017 GB)* and may not exceed 45%.

Detailed information for the various storage capacities and utilizations is available on pages 23-24.

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	25,311.33	126,227.48	202,389.16	227,691.75	240,336.97	252,981.83
Average Response Time (ms):						
All ASUs	0.35	0.46	0.64	0.73	0.93	2.06
ASU-1	0.36	0.47	0.64	0.73	0.91	1.98
ASU-2	0.35	0.48	0.65	0.74	0.93	2.03
ASU-3	0.34	0.44	0.64	0.74	0.97	2.24
Reads	0.37	0.51	0.67	0.76	0.92	1.90
Writes	0.34	0.44	0.62	0.72	0.94	2.16

Priced Storage Configuration Pricing

Qty	Name	Part Number	List Price	Discount	Unit price	Exteded Price
1	1 - ISE FC G3 Storage System Chassis 2 - ISE Manager Reliability Controllers each with: 4 - 4/8Gbps FC ports 40 - 6Gbps SAS connections 2 - ISE G3 All Flash DataPacs 20 - 200GB eMLC SSDs per DataPac	802820-000	$124,900.00	45.0%	$68,700.00	$68,700.00
4	Cable - 5m LC Duplex/LC Duplex Fiber Optic Patch Cord Cable - 5m LC Duplex/LC Duplex Fiber Optic Patch Cord	840056-000	$51.00	25.5%	$38.00	$152.00
2	QLogic - QLE2564CK 8Gb HBA Quad Port PCI Express	3rd party	$774.87		$774.87	$1,549.74
1	5 Year Hardware Warranty		$0.00	-	$0.00	$0.00
33	Software Maintenance - 1 month	020xxx-000	$190.00	10%	$171.00	$5,643.00
36	HW Maintenance - 1 month 4hr service uplift	020xxx-000	$175.00	10%	$158.00	$5,688.00
1	Software Warranty (90 Days)		$0.00	-	$0.00	$0.00
					Total	**$81,732.74**

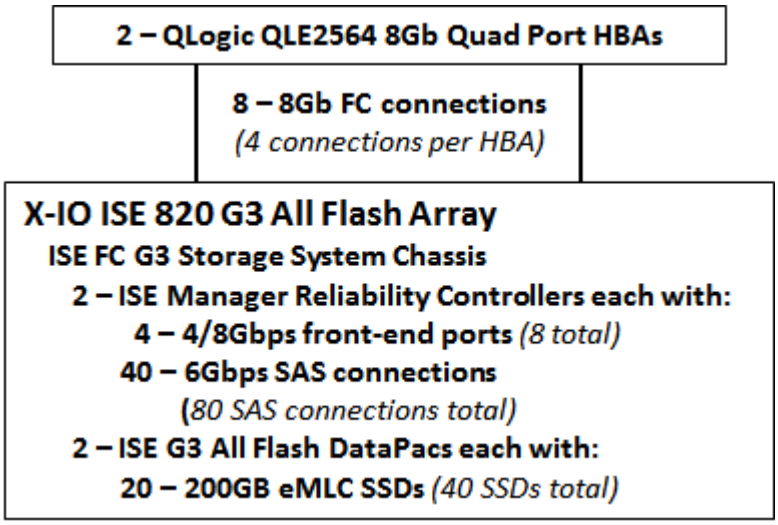
The above pricing includes hardware maintenance and software support for three years, 7 days per week, 24 hours per day. The hardware maintenance and software support provides the following:

- Acknowledgement of new and existing problems within four (4) hours.
- Onsite presence 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

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

Priced Storage Configuration Diagram



Priced Storage Configuration Components

Priced Storage Configuration:
2 – QLogic QLE2564 8Gb Quad Port HBAs
X-IO ISE 820 G3 All Flash Array 1 – ISE FC G3 Storage System Chassis 2 – ISE Manager Reliability Controllers, each with 4 – 4/8Gbps FC front-end port *(8 total and used)* 40 – 6Gbps SAS back-end connections (*80 total and used)* 2 – ISE G3 All Flash DataPacs 20 – 200GB eMLC SSDs per DataPac *(40 SSDs total)*

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 20 *(Benchmark Configuration/Tested Storage Configuration Diagram)*.

Host System(s) 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).

The Host System(s) and TSC table of components may be found on page 20 *(Host System and Tested Storage Configuration Components)*.

Storage Network Configuration

Clause 9.4.3.4.1

…

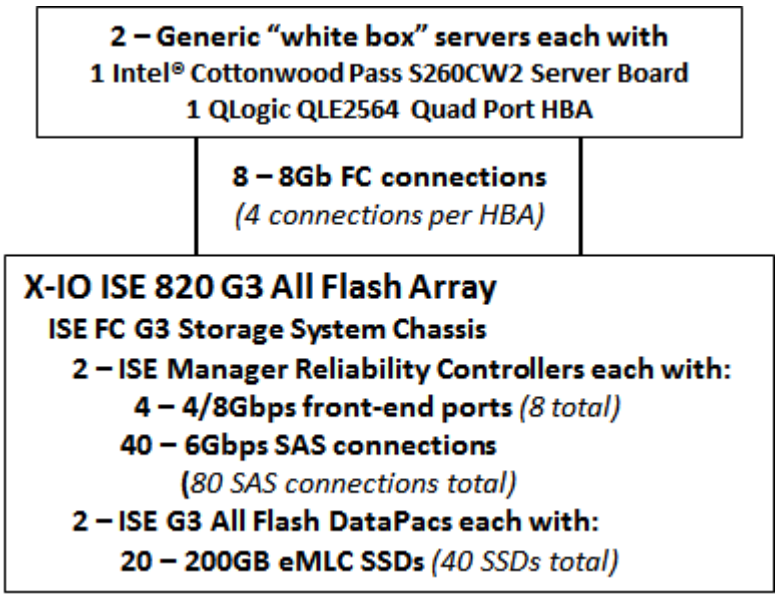
5. *If the TSC contains network storage, the diagram will include the network configuration. If a single diagram is not sufficient to illustrate both the Benchmark Configuration and network configuration in sufficient detail, the Benchmark Configuration diagram will include a high-level network illustration 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.

There was no storage network in this configuration. All of the storage was directly connected.

Benchmark Configuration/Tested Storage Configuration Diagram



Host System and Tested Storage Configuration Components

Host Systems
2 – Generic "white box" servers, each with: 1 – Intel® Cottonwood Pass S260CW2 Server Board 1 – Dual Intel® Xeon® E5-2630V3 2.4 GHz processors each with, 8 cores and 20 MB Intel® SmartCache 64 GB main memory Microsoft Windows 2008 Server R2 PCIe Gen3
Tested Storage Configuration (TSC) Components
2 – QLogic QLE2564 8Gb Quad Port HBAs
X-IO ISE 820 G3 All Flash Array 1 – ISE FC G3 Storage System Chassis 2 – ISE Manager Reliability Controllers, each with 4 – 4/8Gbps FC front-end port *(8 total and used)* 40 – 6Gbps SAS back-end connections (*80 total and used)* 2 – ISE G3 All Flash DataPacs 20 – 200GB eMLC SSDs per DataPac *(40 SSDs total)*

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 67 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 68 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 71.

ASU Pre-Fill

Clause 5.3.3

Each of the three SPC-1 ASUs (ASU-1, ASU-2 and ASU-3) is required to be completely filled with specified content prior to the execution of audited SPC-1 Tests. The content is required to consist of random data pattern such as that produced by an SPC recommended tool.

The configuration file used to complete the required ASU pre-fill appears in Appendix D: SPC-1 Workload Generator Storage Commands and Parameters on page 71.

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

Storage Capacities and Relationships

Clause 9.4.3.6.1

Two tables and four charts documenting the storage capacities and relationships of the SPC-1 Storage Hierarchy (Clause 2.1) shall be included in the FDR. … The capacity value in each chart may be listed as an integer value, for readability, rather than the decimal value listed in the table below.

SPC-1 Storage Capacities

The Physical Storage Capacity consisted of 8,127.017 GB distributed over 40 solid state storage devices (SSDs) each with a formatted capacity of 203.175 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 125.031 GB (1.54%) of the Physical Storage Capacity. There was 176.631 GB (2.21%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 10000% of the Addressable Storage Capacity resulting in 0.00 GB (0.00%) of Unused Storage within the Addressable Storage Capacity. The Data Protection *(Mirroring)* capacity was 2.920.578 GB of which 2,852.127 GB was utilized. The total Unused Storage capacity was 176.631 GB.

Note: The configured Storage Devices may include additional storage capacity reserved for system overhead, which is not accessible for application use. That storage capacity may not be included in the value presented for Physical Storage Capacity.

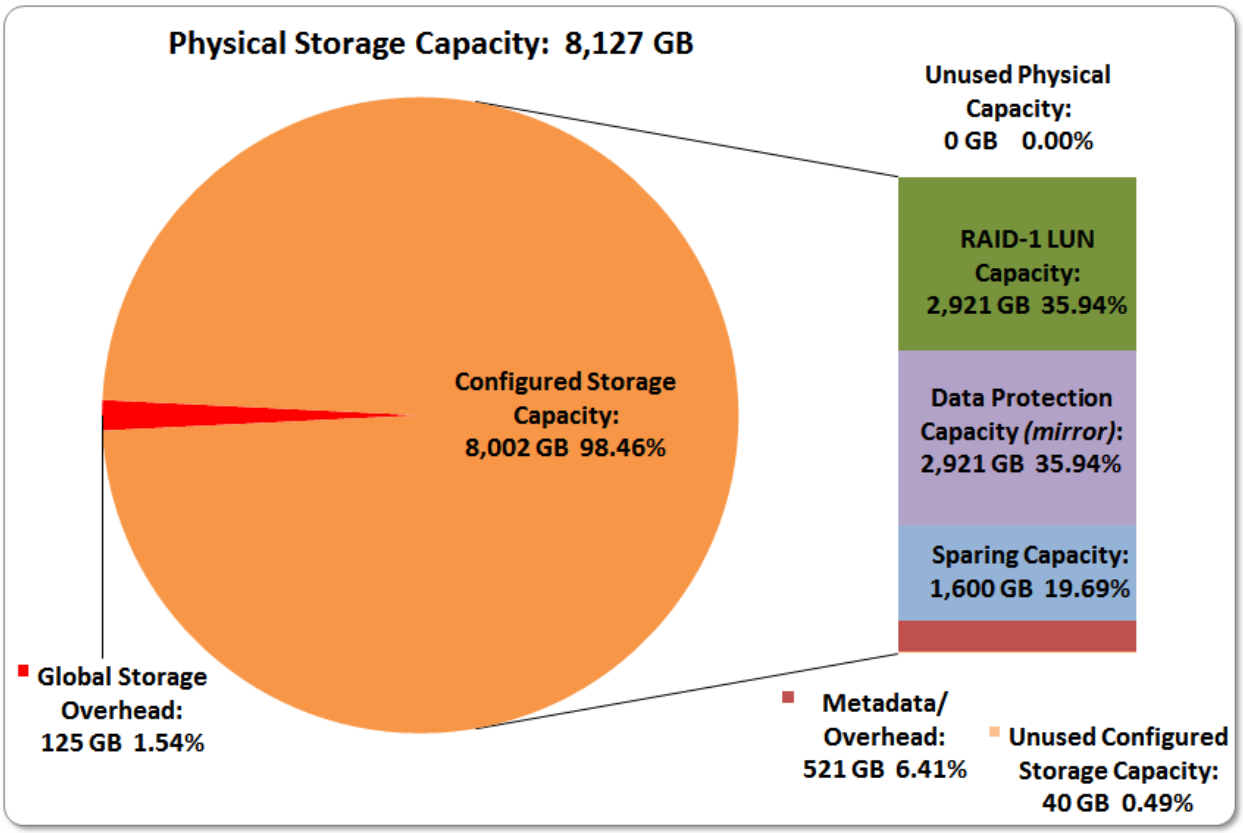
SPC-1 Storage Capacities

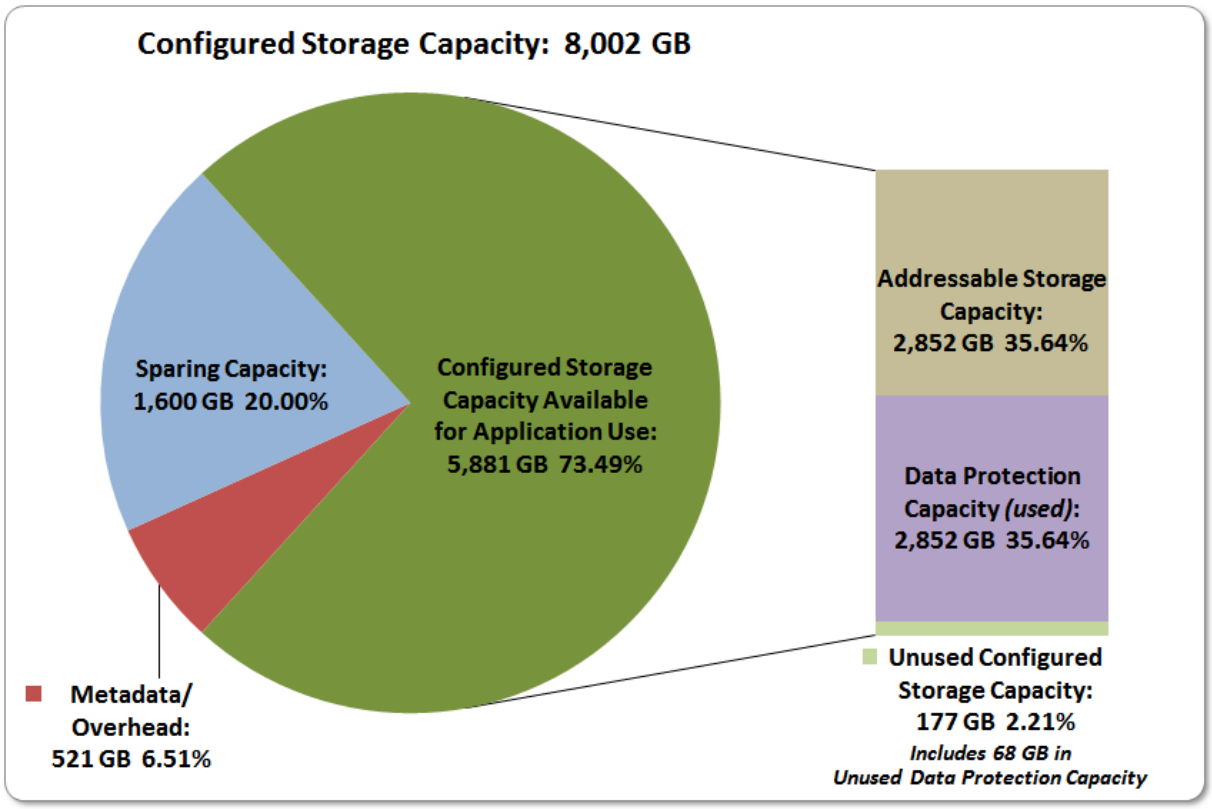
Storage Hierarchy Component	Units	Capacity
Total ASU Capacity	Gigabytes (GB)	2,852.127
Addressable Storage Capacity	Gigabytes (GB)	2,852.127
Configured Storage Capacity	Gigabytes (GB)	8,001.986
Physical Storage Capacity	Gigabytes (GB)	8,127.017
Data Protection *(Mirroring)*	Gigabytes (GB)	2.920.578
Required Storage *(sparing, metadata/overhead)*	Gigabytes (GB)	2,120.028
Global Storage Overhead	Gigabytes (GB)	125.031
Total Unused Storage	Gigabytes (GB)	176.631

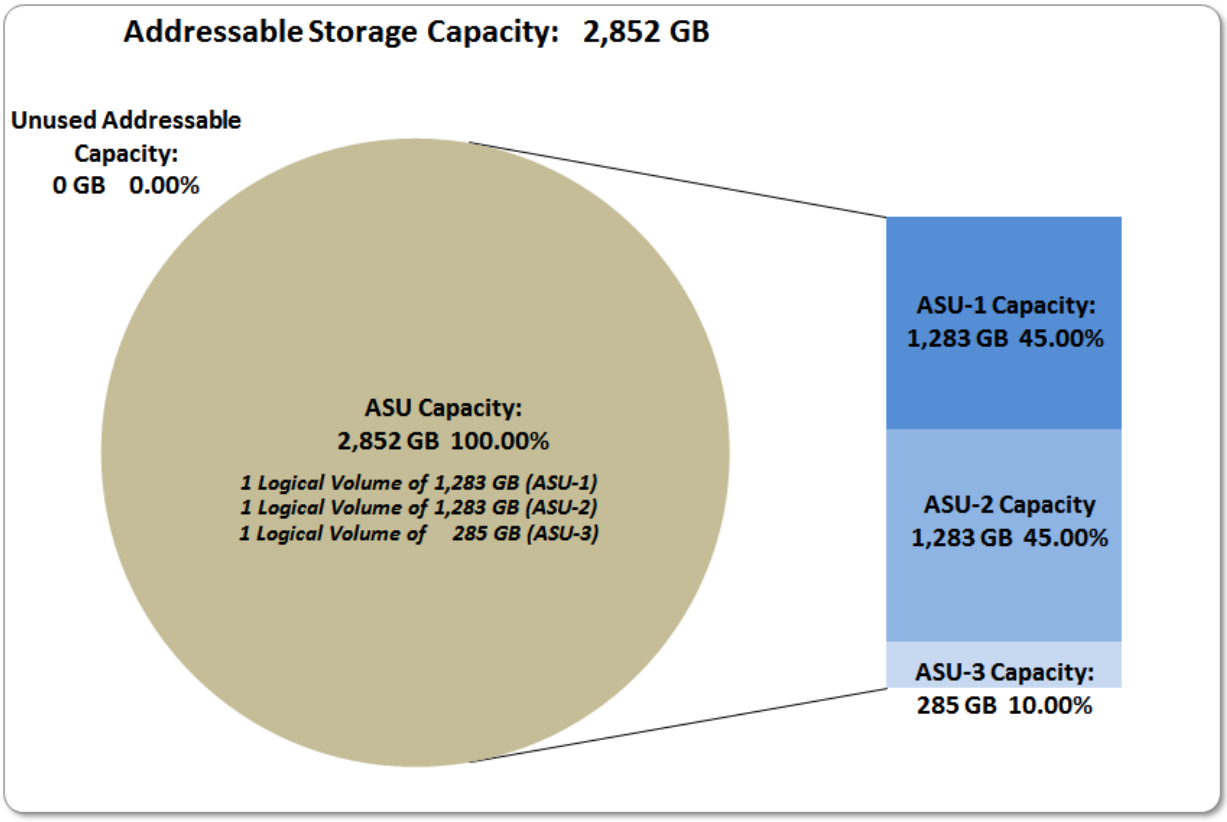
SPC-1 Storage Hierarchy Ratios

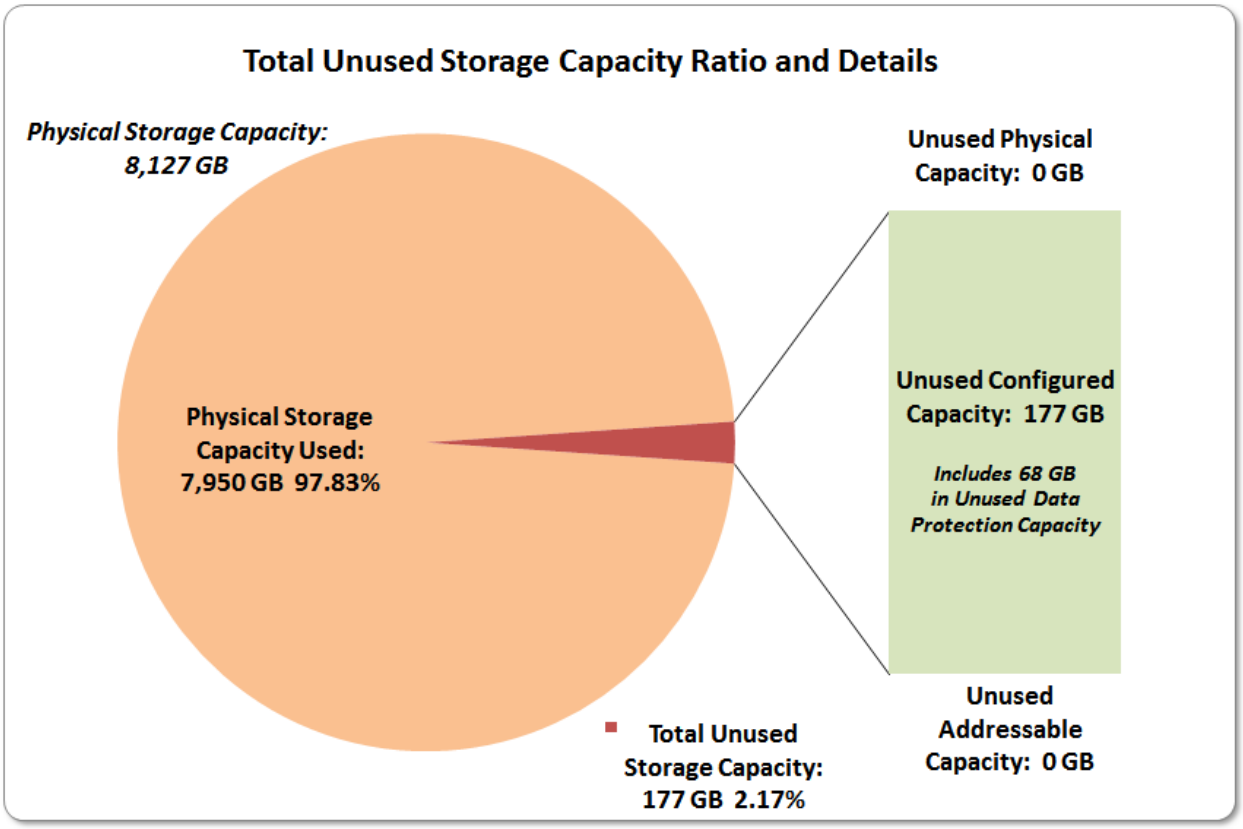
	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	35.64%	35.09%
Required for Data Protection *(Mirroring)*		36.50%	35.94%
Addressable Storage Capacity		35.64%	35.09T
Required Storage		25.49%	26.09%
Configured Storage Capacity			98.46%
Global Storage Overhead			1.54%
Unused Storage:			
Addressable	0.00%		
Configured		2.21%	
Physical			0.00%

SPC-1 Storage Capacity Charts




Configured Storage Capacity: 8,002 GB
Sparing Capacity:
1,600 GB 20.00%
Configured Storage Capacity Available for Application Use:
5,881 GB 73.49%
Metadata/ Overhead:
521 GB 6.51%
Addressable Storage Capacity:
2,852 GB 35.64%
Data Protection Capacity (used):
2,852 GB 35.64%
Unused Configured Storage Capacity:
177 GB 2.21%
Includes 68 GB in Unused Data Protection Capacity


Addressable Storage Capacity: 2,852 GB
Unused Addressable Capacity:
0 GB 0.00%
ASU Capacity:
2,852 GB 100.00%
1 Logical Volume of 1,283 GB (ASU-1)
1 Logical Volume of 1,283 GB (ASU-2)
1 Logical Volume of 285 GB (ASU-3)
ASU-1 Capacity:
1,283 GB 45.00%
ASU-2 Capacity
1,283 GB 45.00%
ASU-3 Capacity:
285 GB 10.00%



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	35.09%
Protected Application Utilization	70.19%
Unused Storage Ratio	2.17%

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 (1,283.457 GB)	**ASU-2 (1,283.457 GB)**	**ASU-3 (285.213 GB)**
1 Logical Volume 1,283.457 GB per Logical Volume (1,283.457 GB used per Logical Volume)	1 Logical Volume 1,283.457 GB per Logical Volume (1,283.457 GB used per Logical Volume)	1 Logical Volume 285.213 GB per Logical Volume (285.213 GB used per Logical Volume)

The Data Protection Level used for all Logical Volumes was **Protected 2** using ***Mirroring*** as described on page 12. See "ASU Configuration" in the **IOPS Test Results File** for more detailed configuration information.

SPC-1 BENCHMARK EXECUTION RESULTS

This portion of the Full Disclosure Report documents the results of the various SPC-1 Tests, Test Phases, and Test Runs. An SPC-1 glossary on page 63 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.

"Ramp-Up" Test Runs

Clause 5.3.13

In order to warm-up caches or perform the initial ASU data migration in a multi-tier configuration, a Test Sponsor may perform a series of "Ramp-Up" Test Runs as a substitute for an initial, gradual Ramp-Up.

Clause 5.3.13.3

The "Ramp-Up" Test Runs will immediately precede the Primary Metrics Test as part of the uninterrupted SPC-1 measurement sequence.

Clause 9.4.3.7.1

If a series of "Ramp-Up" Test Runs were included in the SPC-1 measurement sequence, the FDR shall report the duration (ramp-up and measurement interval), BSU level, SPC-1 IOPS and average response time for each "Ramp-Up" Test Run in an appropriate table.

There were no "Ramp-Up" Test Runs executed.

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 eight (8) 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 9.4.3.7.2

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 73.

Sustainability Test Results File

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

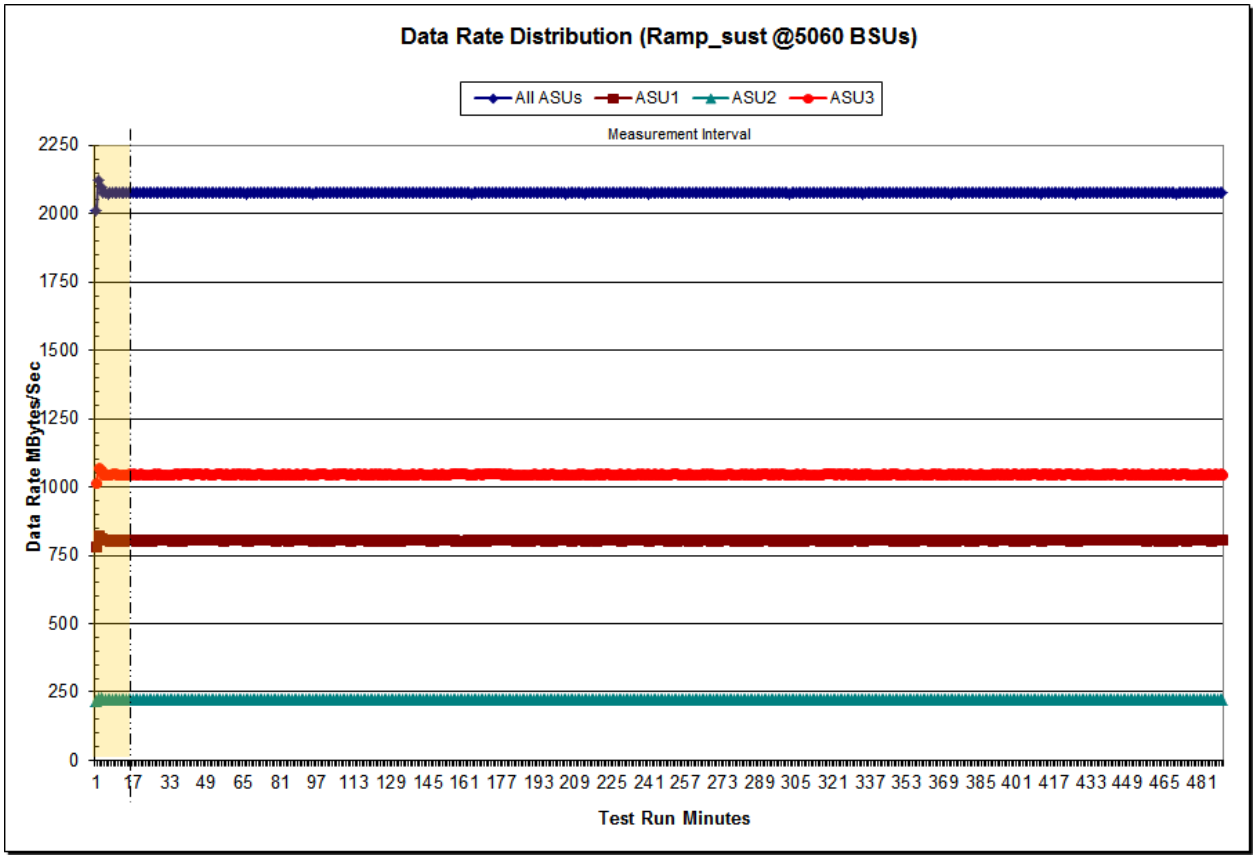
Sustainability Test Results File

Sustainability – Data Rate Distribution Data (MB/second)

The Sustainability Data Rate table of data is not embedded in this document due to its size. The table is available via the following URL:

Sustainability Data Rate Table

Sustainability – Data Rate Distribution Graph

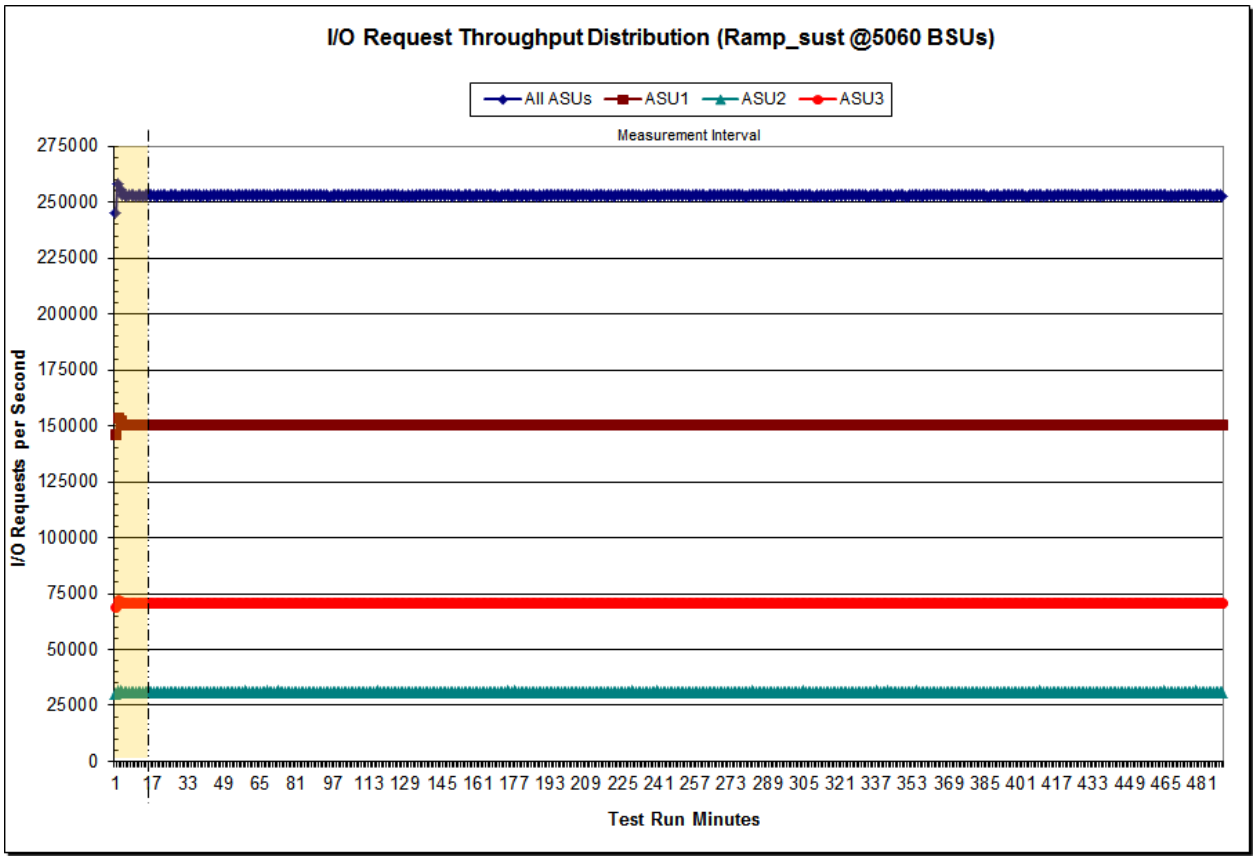


Sustainability – I/O Request Throughput Distribution Data

The Sustainability I/O Request Throughput table of data is not embedded in this document due to its size. The table is available via the following URL:

Sustainability I/O Request Throughput Table

Sustainability – I/O Request Throughput Distribution Graph

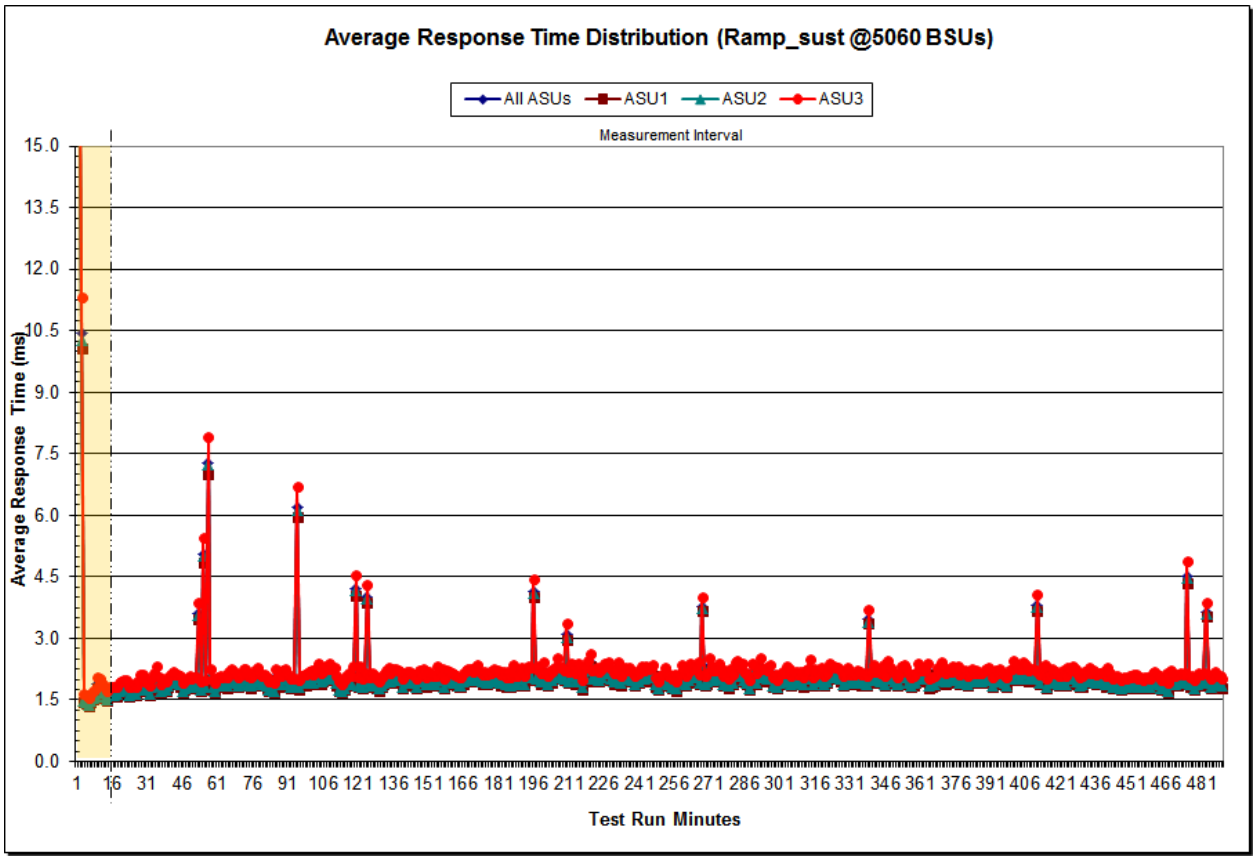


Sustainability – Average Response Time (ms) Distribution Data

The Sustainability Average Response Time table of data is not embedded in this document due to its size. The table is available via the following URL:

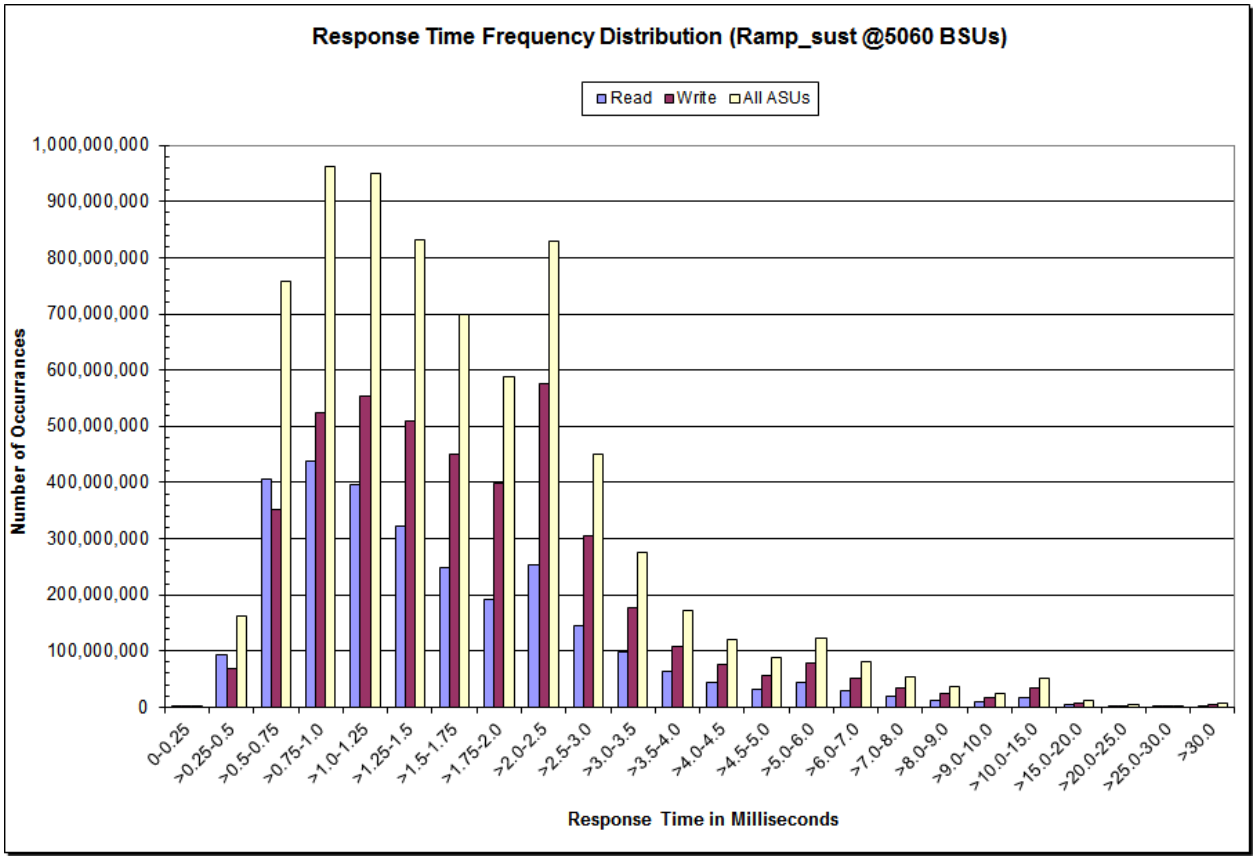
Sustainability Average Response Time Table

Sustainability – Average Response Time (ms) Distribution Graph



Sustainability – Response Time Frequency Distribution Data

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 5.3.15.2

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 5.3.15.3

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	0.001	0.000	0.001	0.000	0.002	0.001	0.001	0,000

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 9.4.3.7.3

For the IOPS Test Phase the FDR shall contain:

1. *I/O Request Throughput Distribution (data and graph).*
2. *A Response Time Frequency Distribution.*
3. *An Average Response Time Distribution.*
4. *The human readable Test Run Results File produced by the Workload Generator.*
5. *A listing or screen image of all input parameters supplied to the Workload Generator.*
6. *The total number of I/O Requests completed in the Measurement Interval as well as the number of I/O Requests with a Response Time less than or equal to 30 milliseconds and the number of I/O Requests with a Response Time greater than 30 milliseconds.*

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in Appendix E: SPC-1 Workload Generator Input Parameters on Page 73.

IOPS Test Results File

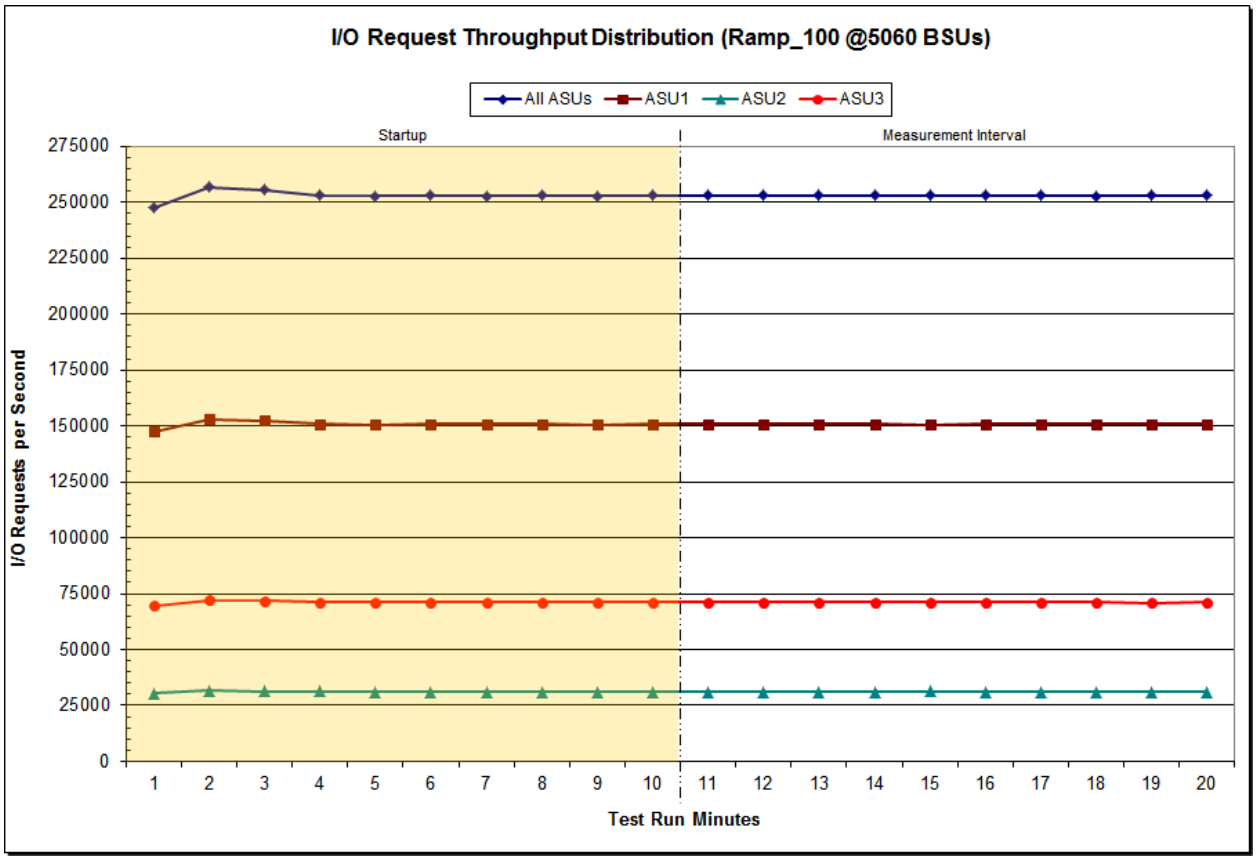
A link to the test results file generated from the IOPS Test Run is listed below.

IOPS Test Results File

IOPS Test Run – I/O Request Throughput Distribution Data

5,060 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:38:57	17:48:58	0-9	0:10:01
Measurement Interval	17:48:58	17:58:58	10-19	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	247,413.82	147,411.98	30,447.60	69,554.23
1	256,806.63	153,123.35	31,578.35	72,104.93
2	255,626.63	152,339.88	31,435.07	71,851.68
3	253,060.32	150,815.97	31,164.25	71,080.10
4	252,875.78	150,673.35	31,136.60	71,065.83
5	252,935.55	150,795.97	31,104.73	71,034.85
6	252,880.70	150,705.63	31,124.02	71,051.05
7	253,039.38	150,816.42	31,107.00	71,115.97
8	252,919.80	150,666.90	31,127.00	71,125.90
9	252,945.98	150,694.60	31,134.00	71,117.38
10	252,953.65	150,782.88	31,100.35	71,070.42
11	252,974.30	150,757.40	31,086.47	71,130.43
12	253,053.88	150,819.78	31,153.97	71,080.13
13	252,994.33	150,761.52	31,114.18	71,118.63
14	252,941.02	150,669.40	31,163.95	71,107.67
15	253,114.68	150,880.40	31,146.52	71,087.77
16	253,009.38	150,773.82	31,091.83	71,143.73
17	252,848.03	150,707.78	31,098.83	71,041.42
18	252,968.63	150,818.43	31,148.48	71,001.72
19	252,960.35	150,764.27	31,122.03	71,074.05
Average	***252,981.83***	***150,773.57***	***31,122.66***	***71,085.60***

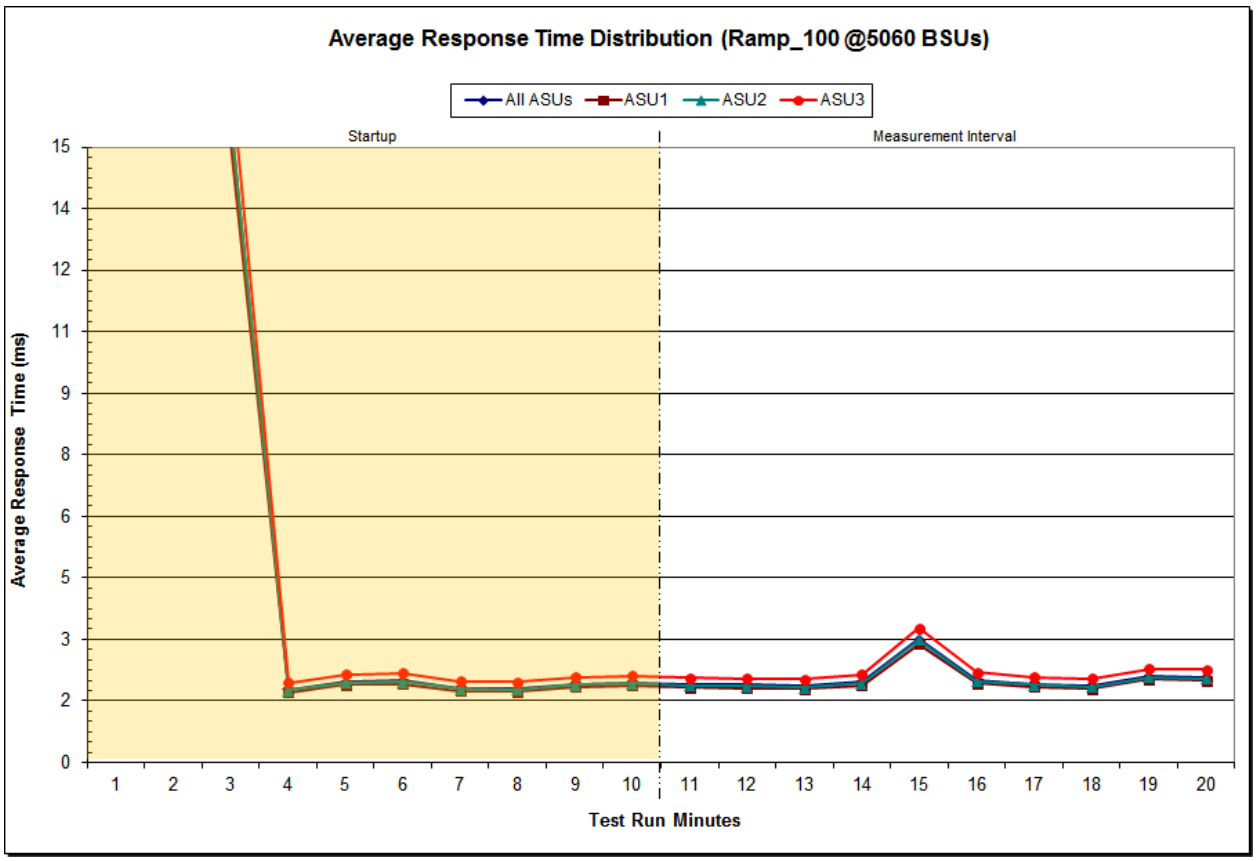
IOPS Test Run – I/O Request Throughput Distribution Graph



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

5,060 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:38:57	17:48:58	0-9	0:10:01
Measurement Interval	17:48:58	17:58:58	10-19	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	23.62	22.91	23.54	25.17
1	20.51	19.77	20.56	22.05
2	15.68	15.10	15.74	16.86
3	1.78	1.71	1.76	1.94
4	1.97	1.89	1.94	2.15
5	1.99	1.91	1.97	2.17
6	1.81	1.74	1.79	1.98
7	1.79	1.72	1.77	1.95
8	1.91	1.84	1.89	2.08
9	1.95	1.87	1.92	2.12
10	1.90	1.83	1.88	2.07
11	1.89	1.81	1.86	2.05
12	1.86	1.79	1.83	2.03
13	1.96	1.88	1.93	2.14
14	3.01	2.89	2.99	3.27
15	2.01	1.93	1.98	2.20
16	1.91	1.84	1.89	2.08
17	1.87	1.80	1.85	2.04
18	2.10	2.02	2.08	2.29
19	2.07	1.99	2.04	2.26
Average	***2.06***	***1.98***	***2.03***	***2.24***

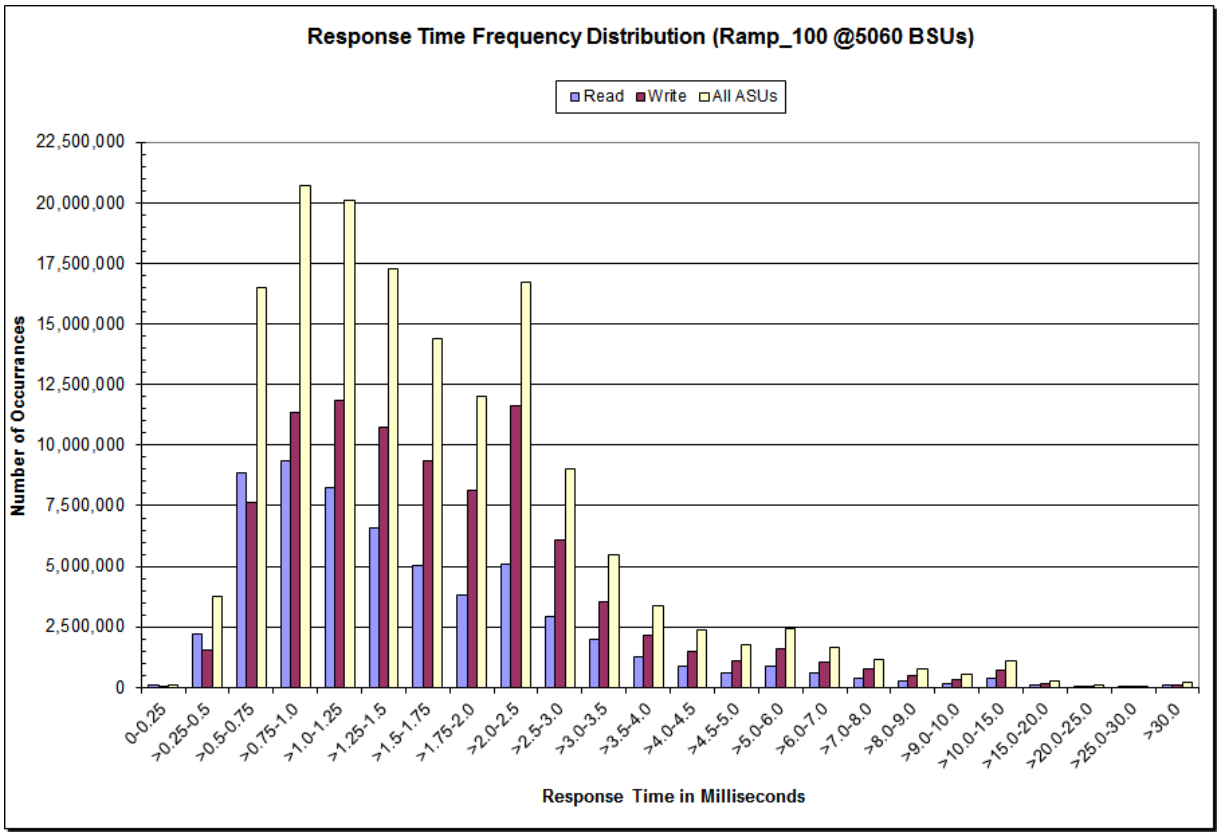
IOPS Test Run – Average Response Time (ms) Distribution Graph



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	85,991	2,221,720	8,871,514	9,378,640	8,242,434	6,578,206	5,010,974	3,839,607
Write	8,101	1,540,768	7,618,925	11,324,889	11,864,249	10,715,631	9,365,127	8,153,721
All ASUs	94,092	3,762,488	16,490,439	20,703,529	20,106,683	17,293,837	14,376,101	11,993,328
ASU1	87,654	2,689,502	11,171,173	13,173,261	12,312,016	10,249,736	8,251,668	6,672,154
ASU2	3,558	454,463	2,125,298	2,632,459	2,521,734	2,146,155	1,754,175	1,439,464
ASU3	2,880	618,523	3,193,968	4,897,809	5,272,933	4,897,946	4,370,258	3,881,710
Response Time (ms)	**>2.0-2.5**	**>2.5-3.0**	**>3.0-3.5**	**>3.5-4.0**	**>4.0-4.5**	**>4.5-5.0**	**>5.0-6.0**	**>6.0-7.0**
Read	5,088,959	2,936,595	1,980,468	1,257,290	875,712	621,678	872,458	578,686
Write	11,622,919	6,107,793	3,516,644	2,141,678	1,501,166	1,115,357	1,578,868	1,068,095
All ASUs	16,711,878	9,044,388	5,497,112	3,398,968	2,376,878	1,737,035	2,451,326	1,646,781
ASU1	9,071,955	4,925,727	3,072,875	1,917,778	1,339,397	970,715	1,367,026	916,285
ASU2	1,969,991	1,066,062	664,221	413,711	289,569	210,287	294,771	196,930
ASU3	5,669,932	3,052,599	1,760,016	1,067,479	747,912	556,033	789,529	533,566
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	391,371	263,343	181,110	376,313	93,048	28,335	13,526	75,715
Write	741,292	509,163	350,675	711,353	169,458	51,126	23,238	123,080
All ASUs	1,132,663	772,506	531,785	1,087,666	262,506	79,461	36,764	198,795
ASU1	626,371	425,932	293,173	602,731	146,364	44,359	20,761	113,739
ASU2	135,288	91,898	63,418	129,828	31,656	9,484	4,538	24,555
ASU3	371,004	254,676	175,194	355,107	84,486	25,618	11,465	60,501

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
151,787,009	151,588.,214	198,795

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 5.3.15.2

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 5.3.15.3

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	0.007	0.0350	0.2810
COV	0.002	0.000	0.001	0.000	0.003	0.001	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 16.

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 9.4.3.7.4

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 73.

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 table and graph for completeness.

100% Load Level: 5,060 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:38:57	17:48:58	0-9	0:10:01
Measurement Interval	17:48:58	17:58:58	10-19	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	247,413.82	147,411.98	30,447.60	69,554.23
1	256,806.63	153,123.35	31,578.35	72,104.93
2	255,626.63	152,339.88	31,435.07	71,851.68
3	253,060.32	150,815.97	31,164.25	71,080.10
4	252,875.78	150,673.35	31,136.60	71,065.83
5	252,935.55	150,795.97	31,104.73	71,034.85
6	252,880.70	150,705.63	31,124.02	71,051.05
7	253,039.38	150,816.42	31,107.00	71,115.97
8	252,919.80	150,666.90	31,127.00	71,125.90
9	252,945.98	150,694.60	31,134.00	71,117.38
10	252,953.65	150,782.88	31,100.35	71,070.42
11	252,974.30	150,757.40	31,086.47	71,130.43
12	253,053.88	150,819.78	31,153.97	71,080.13
13	252,994.33	150,761.52	31,114.18	71,118.63
14	252,941.02	150,669.40	31,163.95	71,107.67
15	253,114.68	150,880.40	31,146.52	71,087.77
16	253,009.38	150,773.82	31,091.83	71,143.73
17	252,848.03	150,707.78	31,098.83	71,041.42
18	252,968.63	150,818.43	31,148.48	71,001.72
19	252,960.35	150,764.27	31,122.03	71,074.05
Average	***252,981.83***	***150,773.57***	***31,122.66***	***71,085.60***

95% Load Level: 4,807 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:59:52	18:09:53	0-9	0:10:01
Measurement Interval	18:09:53	18:19:53	10-19	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	240,576.80	143,436.77	29,595.30	67,544.73
1	240,387.22	143,272.60	29,560.68	67,553.93
2	240,375.30	143,235.20	29,562.07	67,578.03
3	240,420.05	143,280.65	29,544.13	67,595.27
4	240,389.78	143,252.90	29,546.05	67,590.83
5	240,323.92	143,181.92	29,574.50	67,567.50
6	240,351.30	143,237.38	29,568.50	67,545.42
7	240,315.68	143,244.23	29,530.87	67,540.58
8	240,357.78	143,266.72	29,579.70	67,511.37
9	240,348.42	143,252.57	29,551.48	67,544.37
10	240,295.22	143,182.80	29,544.92	67,567.50
11	240,339.45	143,224.67	29,555.13	67,559.65
12	240,281.17	143,227.17	29,559.80	67,494.20
13	240,359.35	143,280.03	29,535.88	67,543.43
14	240,331.72	143,248.68	29,567.67	67,515.37
15	240,349.55	143,236.52	29,549.45	67,563.58
16	240,353.72	143,256.43	29,557.07	67,540.22
17	240,322.78	143,262.38	29,580.28	67,480.12
18	240,349.03	143,260.00	29,552.58	67,536.45
19	240,387.75	143,252.92	29,612.32	67,522.52
Average	***240,336.97***	***143,243.16***	***29,561.51***	***67,532.30***

90% Load Level: 4,554 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:20:44	18:30:45	0-9	0:10:01
Measurement Interval	18:30:45	18:40:45	10-19	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	228,006.88	135,934.80	28,021.98	64,050.10
1	227,659.68	135,735.32	28,011.27	63,913.10
2	227,700.40	135,670.55	28,011.33	64,018.52
3	227,785.47	135,769.27	27,996.45	64,019.75
4	227,661.55	135,715.87	28,010.45	63,935.23
5	227,832.82	135,827.23	28,015.58	63,990.00
6	227,646.88	135,707.87	28,008.75	63,930.27
7	227,715.25	135,655.28	28,043.35	64,016.62
8	227,679.90	135,675.43	28,020.65	63,983.82
9	227,800.48	135,775.80	28,017.17	64,007.52
10	227,706.28	135,755.38	28,017.38	63,933.52
11	227,613.03	135,588.53	28,029.05	63,995.45
12	227,647.77	135,686.43	28,006.22	63,955.12
13	227,749.10	135,717.43	28,007.70	64,023.97
14	227,700.72	135,645.93	28,038.93	64,015.85
15	227,726.05	135,730.92	27,970.07	64,025.07
16	227,627.00	135,698.40	27,988.35	63,940.25
17	227,851.32	135,795.95	28,056.10	63,999.27
18	227,669.97	135,680.30	28,001.68	63,987.98
19	227,626.23	135,655.22	27,983.53	63,987.48
Average	***227,691.75***	***135,695.45***	***28,009.90***	***63,986.40***

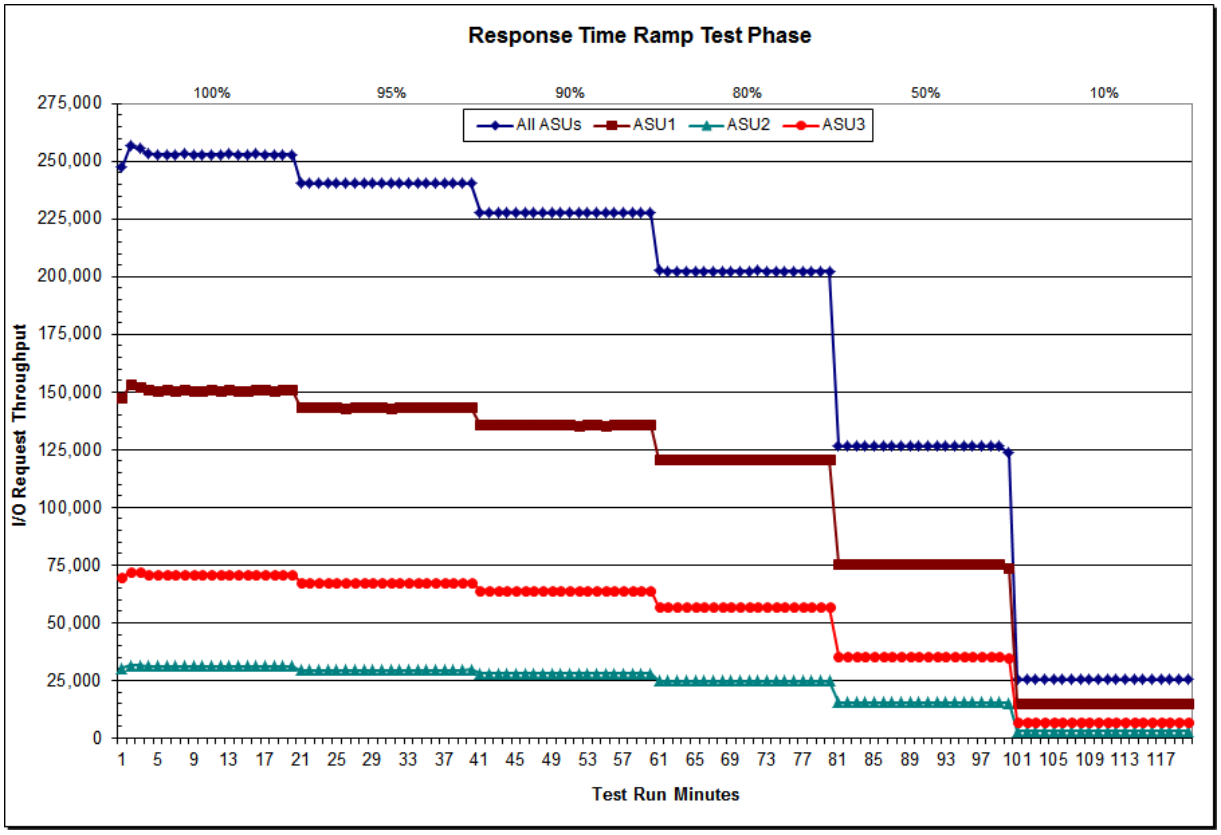
80% Load Level: 4,048 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:41:33	18:51:34	0-9	0:10:01
Measurement Interval	18:51:34	19:01:34	10-19	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	202,552.33	120,770.30	24,877.92	56,904.12
1	202,412.78	120,641.62	24,899.08	56,872.08
2	202,329.82	120,623.65	24,903.23	56,802.93
3	202,417.42	120,703.77	24,840.48	56,873.17
4	202,468.23	120,726.72	24,874.83	56,866.68
5	202,408.50	120,654.87	24,903.75	56,849.88
6	202,368.40	120,617.55	24,942.00	56,808.85
7	202,393.65	120,654.65	24,870.10	56,868.90
8	202,383.93	120,612.68	24,882.87	56,888.38
9	202,431.78	120,646.27	24,877.33	56,908.18
10	202,322.32	120,610.52	24,875.38	56,836.42
11	202,485.40	120,681.25	24,911.02	56,893.13
12	202,379.75	120,571.58	24,919.37	56,888.80
13	202,259.22	120,565.38	24,874.63	56,819.20
14	202,336.53	120,607.90	24,867.62	56,861.02
15	202,410.33	120,631.38	24,918.27	56,860.68
16	202,419.47	120,651.32	24,890.42	56,877.73
17	202,454.40	120,676.08	24,894.73	56,883.58
18	202,438.73	120,658.75	24,929.32	56,850.67
19	202,385.42	120,615.25	24,911.83	56,858.33
Average	***202,389.16***	***120,626.94***	***24,899.26***	***56,862.96***

Response Time Ramp Distribution (IOPS) Data *(continued)*

50% Load Level: 2,530 BSUs	Start	Stop	Interval	Duration	10% Load Level: 560 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:02:14	19:12:15	0-9	0:10:01	Start-Up/Ramp-Up	19:22:42	19:32:43	0-9	0:10:01
Measurement Interval	19:12:15	19:22:15	10-19	0:10:00	Measurement Interval	19:32:43	19:42:43	10-19	0:10:00
(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3	*(60 second intervals)*	All ASUs	ASU-1	ASU-2	ASU-3
0	126,601.38	75,484.53	15,543.47	35,573.38	**0**	25,308.45	15,094.28	3,110.33	7,103.83
1	126,578.35	75,453.87	15,575.50	35,548.98	**1**	25,288.02	15,077.20	3,115.22	7,095.60
2	126,571.23	75,421.60	15,592.95	35,556.68	**2**	25,281.67	15,085.45	3,102.03	7,094.18
3	126,440.22	75,360.12	15,560.82	35,519.28	**3**	25,305.88	15,080.33	3,111.28	7,114.27
4	126,605.15	75,463.55	15,567.43	35,574.17	**4**	25,293.43	15,076.42	3,112.42	7,104.60
5	126,522.72	75,384.85	15,561.82	35,576.05	**5**	25,311.58	15,091.15	3,112.33	7,108.10
6	126,426.65	75,387.63	15,527.12	35,511.90	**6**	25,300.43	15,076.95	3,115.27	7,108.22
7	126,566.58	75,397.03	15,586.48	35,583.07	**7**	25,325.98	15,067.52	3,116.30	7,142.17
8	126,488.85	75,371.72	15,568.38	35,548.75	**8**	25,273.28	15,053.40	3,113.77	7,106.12
9	126,492.15	75,409.67	15,578.93	35,503.55	**9**	25,331.58	15,110.12	3,109.00	7,112.47
10	126,528.48	75,427.55	15,549.95	35,550.98	**10**	25,317.90	15,088.58	3,110.22	7,119.10
11	126,574.27	75,444.68	15,571.82	35,557.77	**11**	25,308.32	15,102.65	3,095.93	7,109.73
12	126,517.85	75,428.42	15,574.98	35,514.45	**12**	25,320.20	15,088.45	3,107.78	7,123.97
13	126,467.75	75,309.08	15,575.28	35,583.38	13	25,303.30	15,074.18	3,118.27	7,110.85
14	126,532.22	75,420.18	15,563.13	35,548.90	14	25,303.68	15,080.37	3,108.60	7,114.72
15	126,515.15	75,354.78	15,575.68	35,584.68	15	25,325.13	15,101.47	3,103.30	7,120.37
16	126,582.22	75,447.93	15,568.58	35,565.70	16	25,301.33	15,085.02	3,095.60	7,120.72
17	126,485.02	75,390.25	15,581.72	35,513.05	17	25,290.68	15,064.38	3,114.55	7,111.75
18	126,512.75	75,427.60	15,535.15	35,550.00	18	25,334.98	15,097.37	3,127.98	7,109.63
19	123,559.08	73,609.48	15,198.73	34,750.87	19	25,307.73	15,077.15	3,122.58	7,108.00
Average	***126,227.48***	***75,226.00***	***15,529.50***	***35,471.98***	***Average***	***25,311.33***	***15,085.96***	***3,110.48***	***7,114.88***

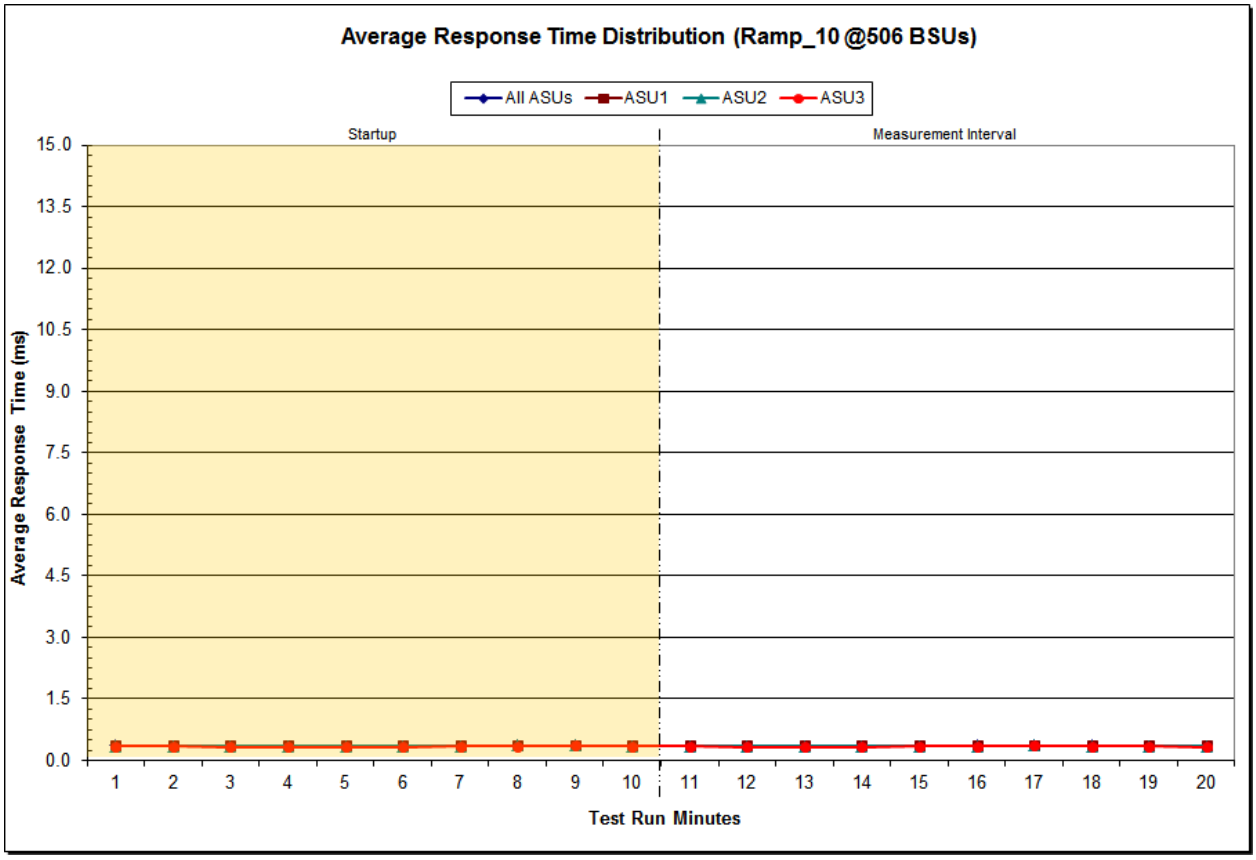
Response Time Ramp Distribution (IOPS) Graph



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

506 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:22:42	19:32:43	0-9	0:10:01
Measurement Interval	19:32:43	19:42:43	10-19	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.35	0.36	0.34	0.35
1	0.35	0.36	0.34	0.34
2	0.35	0.36	0.35	0.33
3	0.35	0.35	0.34	0.33
4	0.35	0.35	0.34	0.33
5	0.35	0.35	0.34	0.33
6	0.35	0.36	0.35	0.34
7	0.36	0.36	0.35	0.35
8	0.36	0.36	0.35	0.35
9	0.35	0.36	0.34	0.34
10	0.35	0.35	0.34	0.34
11	0.35	0.35	0.34	0.33
12	0.35	0.35	0.34	0.33
13	0.35	0.35	0.34	0.33
14	0.35	0.35	0.34	0.34
15	0.35	0.36	0.35	0.34
16	0.36	0.36	0.35	0.35
17	0.35	0.36	0.35	0.35
18	0.35	0.35	0.34	0.34
19	0.35	0.35	0.34	0.33
Average	***0.35***	***0.36***	***0.35***	***0.34***

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 5.3.15.2

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 5.3.15.3

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	0.2812	0.0699	0.2099	0.0180	0.0699	0.0350	0.2811
COV	0.005	0.001	0.004	0.0901	0.007	0.003	0.006	0.001

Repeatability Test

Clause 5.4.5

The Repeatability Test demonstrates the repeatability and reproducibility of the SPC-1 IOPS™ primary metric and the 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 9.4.3.7.5

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 73.

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	***252,981.83***
Repeatability Test Phase 1	253,019.21
Repeatability Test Phase 2	252,971.16

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	***0.35 ms***
Repeatability Test Phase 1	0.35 ms
Repeatability Test Phase 2	0.35 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 plus one (1) millisecond (ms).

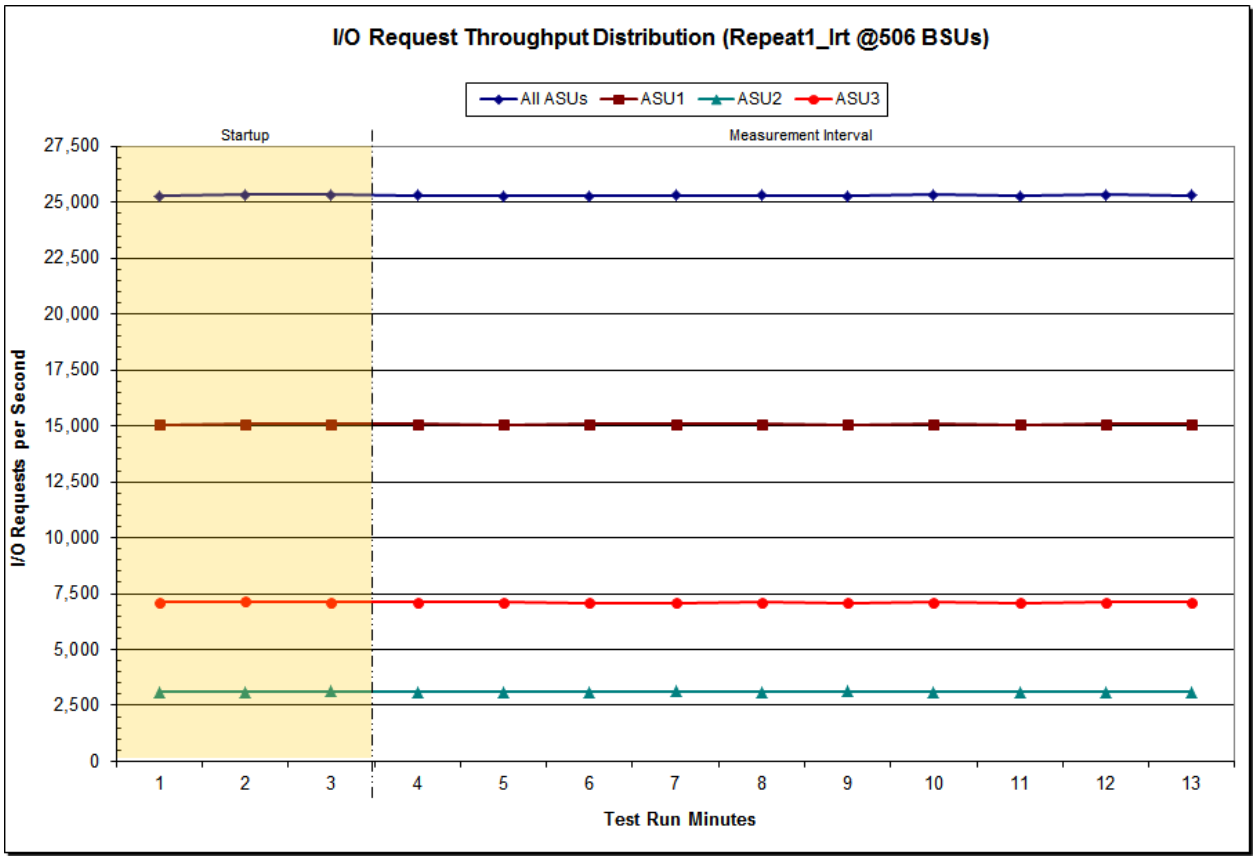
A link to the test result file generated from each Repeatability Test Run is listed below.

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

506 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:43:26	19:46:26	0-3	0:03:00
Measurement Interval	19:46:26	19:56:26	4-13	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	25,288.03	15,060.05	3,111.90	7,116.08
1	25,330.90	15,083.37	3,115.17	7,132.37
2	25,332.68	15,078.45	3,129.18	7,125.05
3	25,299.60	15,072.20	3,114.18	7,113.22
4	25,286.33	15,068.78	3,100.40	7,117.15
5	25,270.78	15,077.22	3,101.58	7,091.98
6	25,316.10	15,097.25	3,118.63	7,100.22
7	25,294.12	15,077.50	3,113.93	7,102.68
8	25,264.68	15,061.17	3,123.60	7,079.92
9	25,330.77	15,097.93	3,105.22	7,127.62
10	25,265.82	15,066.27	3,108.08	7,091.47
11	25,331.92	15,098.15	3,109.02	7,124.75
12	25,306.27	15,078.97	3,115.08	7,112.22
Average	***25,296.64***	***15,079.54***	***3,110.97***	***7,106.12***

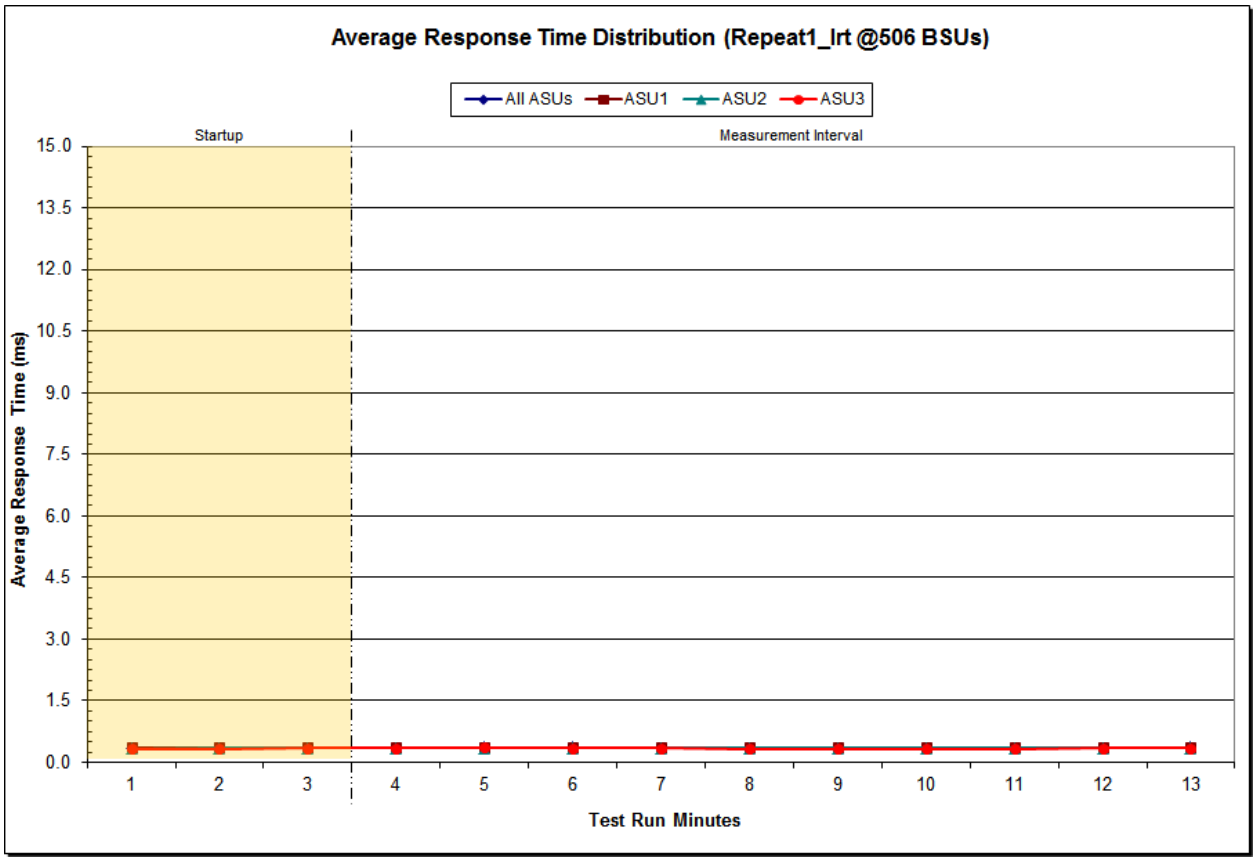
Repeatability 1 LRT – I/O Request Throughput Distribution Graph



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

506 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:43:26	19:46:26	0-3	0:03:00
Measurement Interval	19:46:26	19:56:26	4-13	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.34	0.35	0.33	0.33
1	0.35	0.36	0.34	0.33
2	0.35	0.36	0.35	0.34
3	0.35	0.36	0.35	0.34
4	0.36	0.36	0.35	0.35
5	0.36	0.36	0.35	0.35
6	0.35	0.36	0.35	0.34
7	0.35	0.35	0.34	0.33
8	0.35	0.35	0.34	0.33
9	0.35	0.35	0.34	0.33
10	0.35	0.35	0.34	0.33
11	0.35	0.36	0.35	0.34
12	0.36	0.36	0.35	0.35
Average	***0.35***	***0.36***	***0.35***	***0.34***

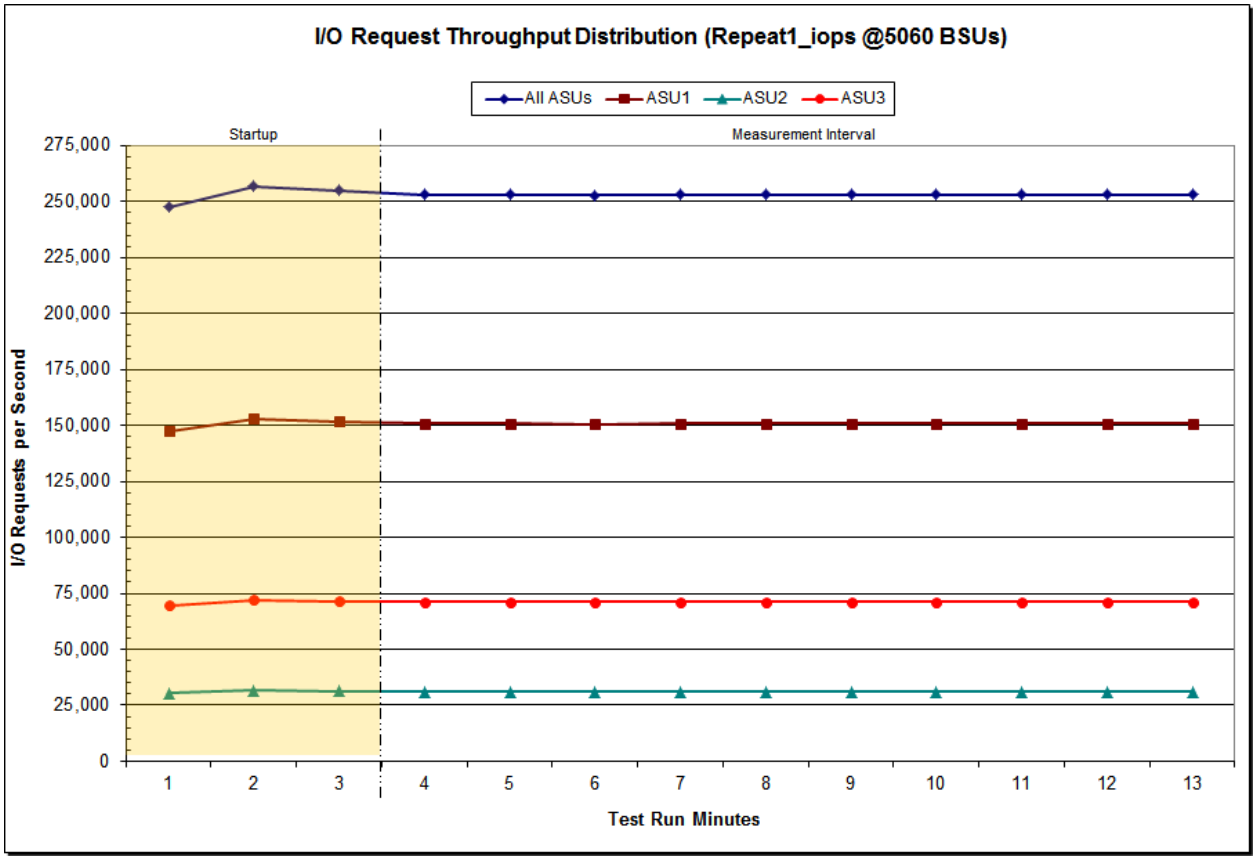
Repeatability 1 LRT –Average Response Time (ms) Distribution Graph



Repeatability 1 IOPS – I/O Request Throughput Distribution Data

5,060 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:57:23	20:00:24	0-3	0:03:01
Measurement Interval	20:00:24	20:10:24	4-13	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	247,629.80	147,569.17	30,466.98	69,593.65
1	256,857.65	153,079.52	31,590.07	72,188.07
2	254,900.75	151,929.90	31,388.53	71,582.32
3	252,996.30	150,763.07	31,074.93	71,158.30
4	253,090.77	150,836.18	31,156.55	71,098.03
5	252,879.75	150,684.80	31,143.18	71,051.77
6	253,083.35	150,849.67	31,094.73	71,138.95
7	253,059.07	150,828.52	31,132.93	71,097.62
8	253,054.97	150,853.42	31,133.65	71,067.90
9	253,015.02	150,810.97	31,117.57	71,086.48
10	253,013.52	150,812.08	31,123.08	71,078.35
11	252,960.78	150,768.45	31,125.18	71,067.15
12	253,038.58	150,784.90	31,122.25	71,131.43
Average	***253,019.21***	***150,799.21***	***31,122.41***	***71,097.60***

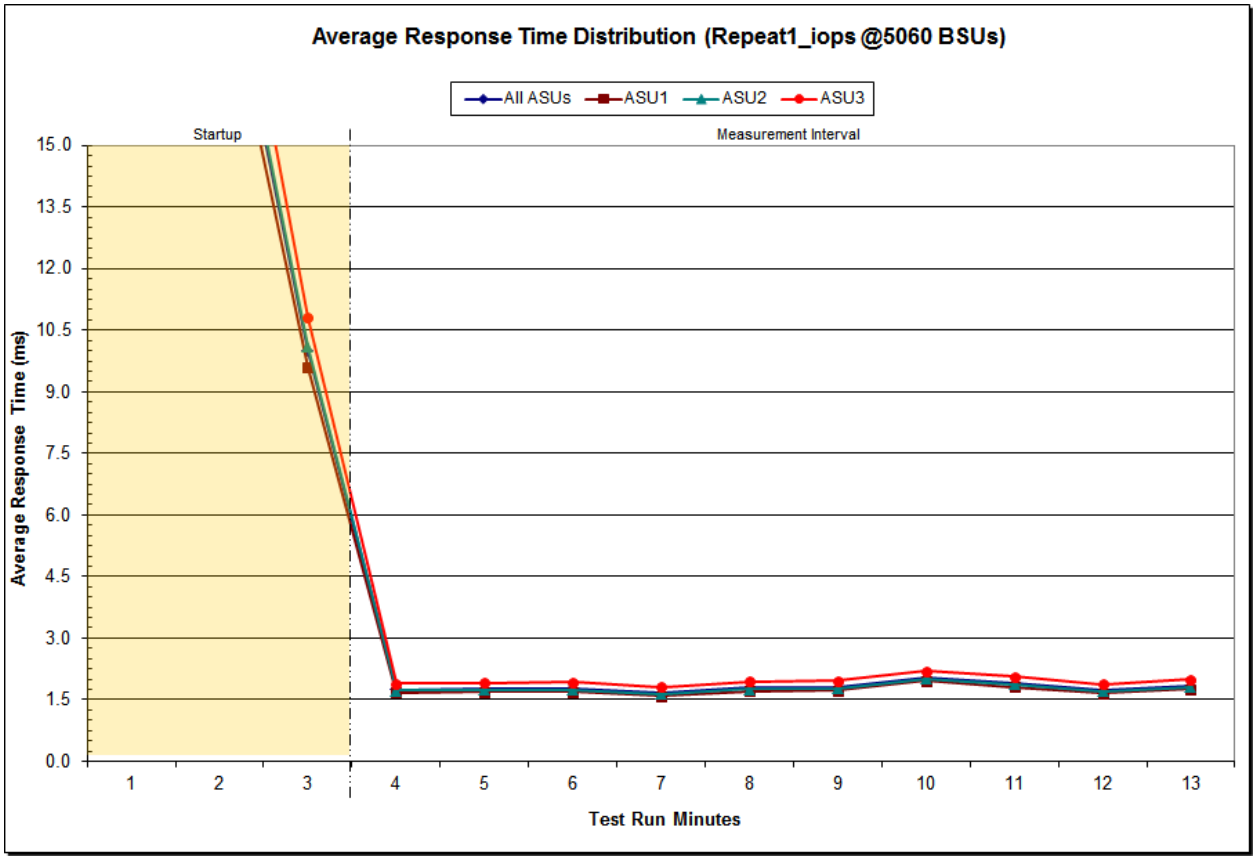
Repeatability 1 IOPS – I/O Request Throughput Distribution Graph



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

5,060 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:57:23	20:00:24	0-3	0:03:01
Measurement Interval	20:00:24	20:10:24	4-13	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	21.06	20.53	21.03	22.21
1	20.61	19.77	20.87	22.28
2	10.00	9.60	10.09	10.81
3	1.74	1.67	1.72	1.89
4	1.77	1.70	1.75	1.92
5	1.77	1.70	1.75	1.92
6	1.66	1.60	1.64	1.81
7	1.78	1.71	1.76	1.94
8	1.80	1.72	1.77	1.96
9	2.03	1.95	2.01	2.20
10	1.89	1.82	1.87	2.07
11	1.73	1.66	1.70	1.88
12	1.83	1.76	1.80	2.00
Average	***1.80***	***1.73***	***1.78***	***1.96***

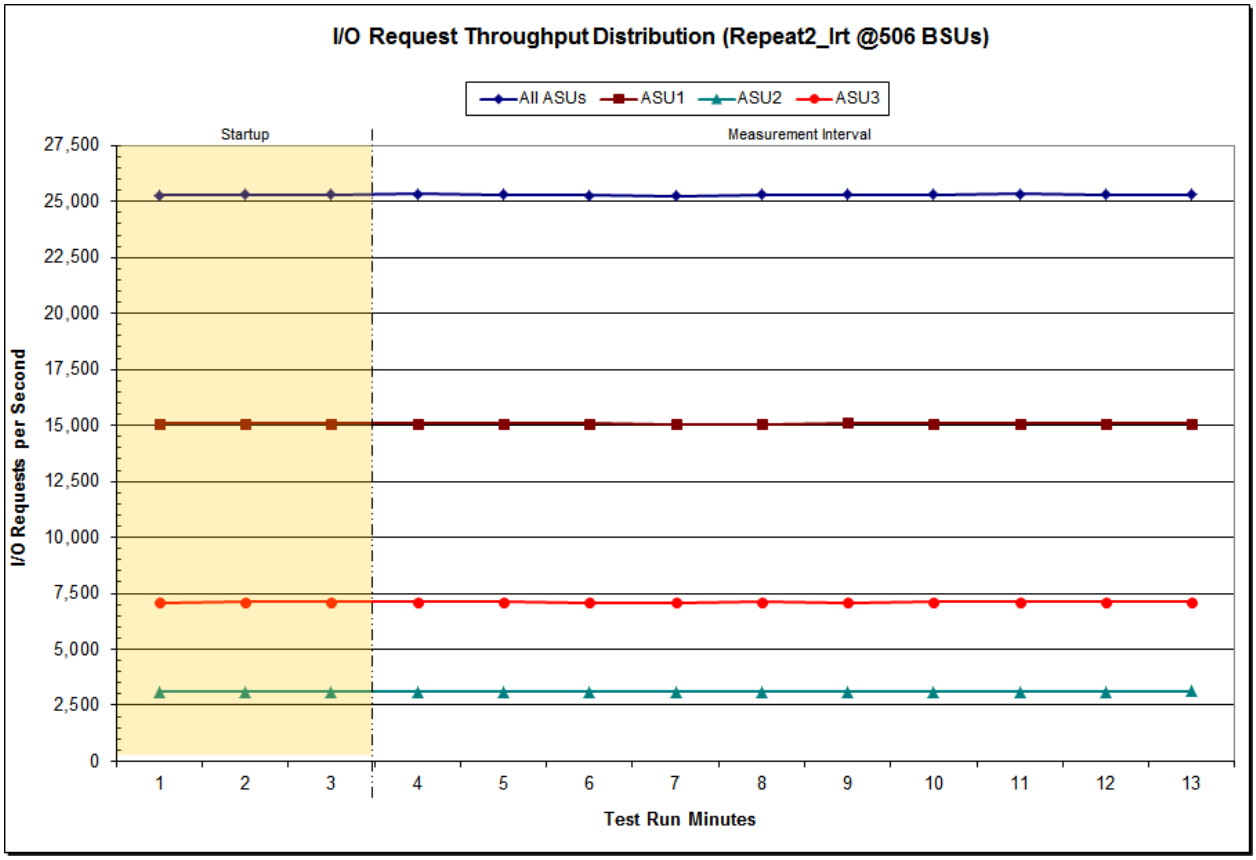
Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph



Repeatability 2 LRT – I/O Request Throughput Distribution Data

506 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:11:06	20:14:06	0-3	0:03:00
Measurement Interval	20:14:06	20:24:06	4-13	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	25,277.37	15,081.05	3,103.05	7,093.27
1	25,319.87	15,100.32	3,111.25	7,108.30
2	25,318.62	15,089.57	3,113.55	7,115.50
3	25,338.25	15,097.60	3,114.60	7,126.05
4	25,300.67	15,089.13	3,108.83	7,102.70
5	25,274.67	15,069.63	3,105.82	7,099.22
6	25,245.35	15,052.83	3,104.75	7,087.77
7	25,298.72	15,068.68	3,111.75	7,118.28
8	25,305.17	15,103.12	3,105.85	7,096.20
9	25,306.88	15,070.68	3,106.40	7,129.80
10	25,334.50	15,099.57	3,109.50	7,125.43
11	25,313.05	15,083.73	3,102.13	7,127.18
12	25,300.57	15,077.33	3,117.23	7,106.00
Average	***25,301.78***	***15,081.23***	***3,108.69***	***7,111.86***

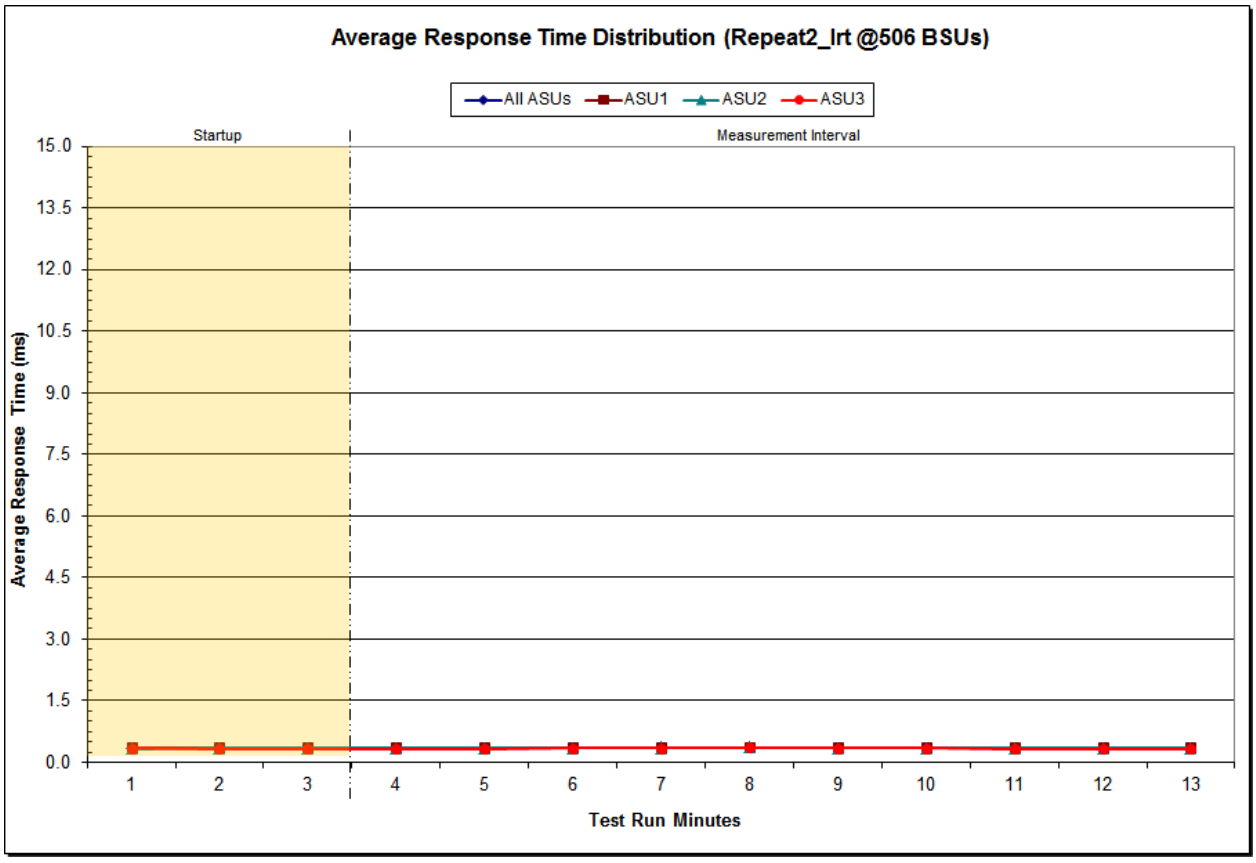
Repeatability 2 LRT – I/O Request Throughput Distribution Graph



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

506 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:11:06	20:14:06	0-3	0:03:00
Measurement Interval	20:14:06	20:24:06	4-13	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.35	0.35	0.33	0.34
1	0.35	0.35	0.34	0.33
2	0.35	0.36	0.35	0.33
3	0.35	0.35	0.34	0.33
4	0.35	0.35	0.34	0.33
5	0.35	0.35	0.34	0.34
6	0.35	0.36	0.35	0.35
7	0.36	0.36	0.35	0.35
8	0.35	0.36	0.35	0.34
9	0.35	0.35	0.34	0.34
10	0.35	0.35	0.34	0.33
11	0.35	0.35	0.34	0.33
12	0.35	0.35	0.34	0.33
Average	***0.35***	***0.36***	***0.34***	***0.34***

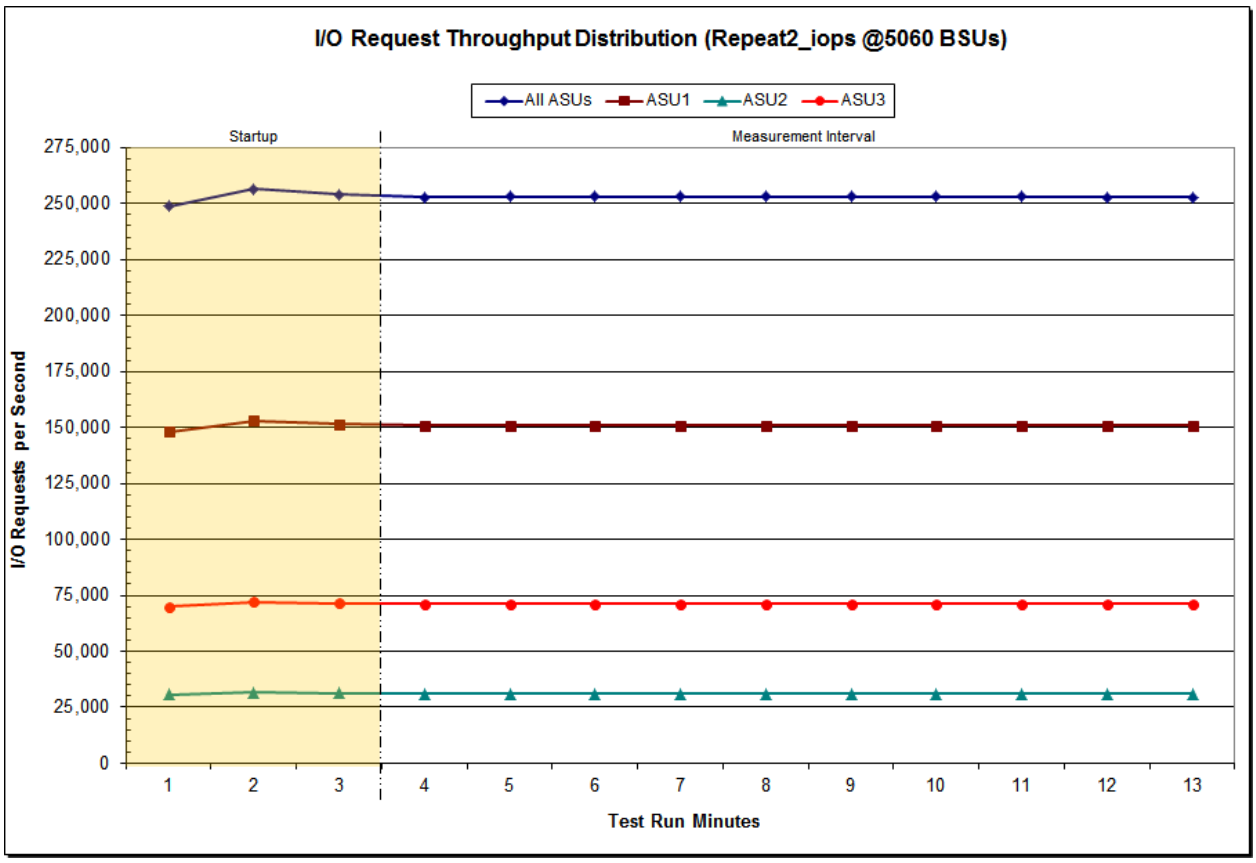
Repeatability 2 LRT –Average Response Time (ms) Distribution Graph



Repeatability 2 IOPS – I/O Request Throughput Distribution Data

5,060 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:24:58	20:27:59	0-3	0:03:01
Measurement Interval	20:27:59	20:37:59	4-13	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	248,633.68	148,160.65	30,613.98	69,859.05
1	256,528.13	152,934.00	31,554.37	72,039.77
2	253,974.70	151,377.43	31,208.67	71,388.60
3	252,928.83	150,789.28	31,095.20	71,044.35
4	253,051.93	150,869.57	31,122.13	71,060.23
5	252,968.38	150,778.87	31,133.12	71,056.40
6	253,009.08	150,804.98	31,122.08	71,082.02
7	252,997.02	150,789.55	31,114.38	71,093.08
8	252,971.12	150,802.82	31,114.65	71,053.65
9	252,981.27	150,749.18	31,105.57	71,126.52
10	252,961.70	150,769.10	31,108.90	71,083.70
11	252,916.17	150,775.10	31,099.60	71,041.47
12	252,926.07	150,760.63	31,107.92	71,057.52
Average	***252,971.16***	***150,788.91***	***31,112.36***	***71,069.89***

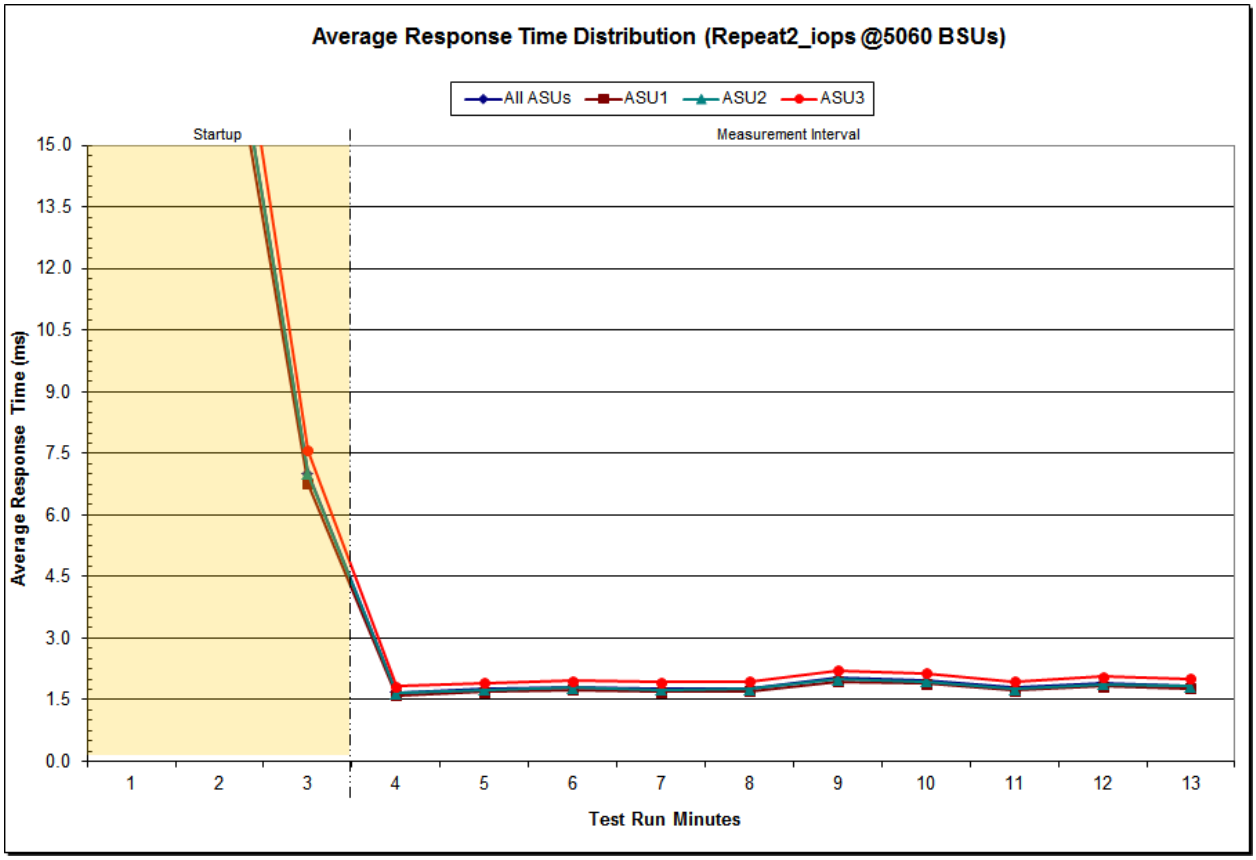
Repeatability 2 IOPS – I/O Request Throughput Distribution Graph



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

5,060 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:24:58	20:27:59	0-3	0:03:01
Measurement Interval	20:27:59	20:37:59	4-13	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	17.89	17.41	17.76	18.95
1	20.14	19.43	20.11	21.65
2	7.02	6.76	6.99	7.58
3	1.67	1.61	1.65	1.82
4	1.76	1.69	1.74	1.92
5	1.81	1.74	1.78	1.97
6	1.77	1.70	1.74	1.93
7	1.78	1.71	1.75	1.94
8	2.03	1.95	2.00	2.21
9	1.96	1.89	1.94	2.14
10	1.79	1.72	1.77	1.95
11	1.90	1.83	1.88	2.06
12	1.85	1.78	1.82	2.01
Average	***1.83***	***1.76***	***1.81***	***1.99***

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.*

Clauses5.1.10 and 5.3.15.2

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 5.3.15.3

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	0.0699	0.0350	0.2809
COV	0.007	0.001	0.003	0.001	0.006	0.003	0.004	0.001

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.001	0.000	0.001	0.000	0.002	0.001	0.001	0.000

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0349	0.2811	0.0700	0.2100	0.0180	0.0699	0.0350	0.2811
COV	0.005	0.001	0,.003	0.001	0.008	0.003	0.003	0.001

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	0.2100	0.0180	0.0700	0.0350	0.2809
COV	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0,.000

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 (may be contained in an appendix).*

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 73.

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	817,734
Total Number of Logical Blocks Verified	703,529
Total Number of Logical Blocks that Failed Verification	0
Time Duration for Writing Test Logical Blocks	5 minutes
Size in bytes of each Logical Block	1,024
Number of Failed I/O Requests in the process of the Test	0

If approved by the SPC Auditor, the SPC-2 Persistence Test may be used to meet the SPC-1 persistence requirements. Both the SPC-1 and SPC-2 Persistence Tests provide the same level of functionality and verification of data integrity. The SPC-2 Persistence Test may be easily configured to address an SPC-1 storage configuration. The SPC-2 Persistence Test extends the size of storage configurations that may be tested and significantly reduces the test duration of such configurations.

The SPC-2 Persistence Test was approved for use in this set of audited measurements.

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 9.4.3.9

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 X-IO ISE 820 G3 All Flash Array 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 be found in the Priced Storage Configuration Pricing section on page 17.

TESTED STORAGE CONFIGURATION (TSC) AND PRICED STORAGE CONFIGURATION DIFFERENCES

Clause 9.4.3.3.8

The Executive Summary shall contain a list of all differences 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 17.

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.

The X-IO ISE 820 G3 All Flash Array SPC-1 audited measurements used the SPC-2 Persistence Test as an approved substitute for the SPC-1 Persistence Test. That substitution requires a minimum of 1 SPC-2 Stream to be specified for every 30 BSUs specified for the maximum SPC-1 load level.

The minimum number of SPC-2 Streams required for this use of the SPC-2 Persistence Test is 168. The SPC-2 Persistence Test used in these audited measurements specified 155 SPC-2 Streams. The difference of 13 Streams did not materially affect the results of the SPC-2 Persistence Test execution, which completed successfully.

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 1: The single point of failure of any ***storage device*** in the configuration will not result in permanent loss of access to or integrity of the SPC-1 Data Repository.

Protected 2: The single point of failure of any ***component*** in the configuration will not result in permanent loss of access to or integrity of the SPC-1 Data Repository.

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.

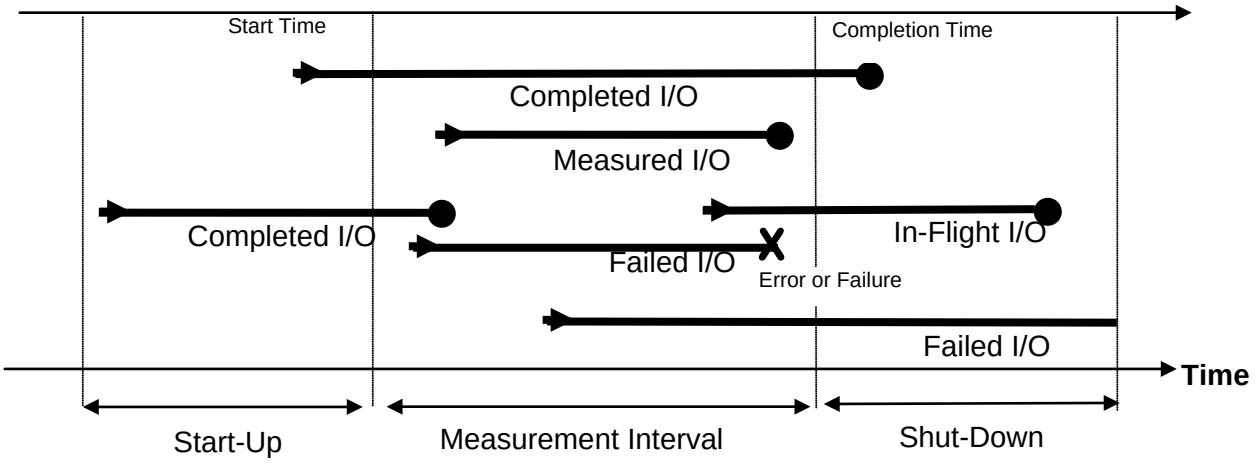
Steady State: The consistent and sustainable throughput of the TSC. During this period the load presented to the TSC by the Workload Generator is constant.

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

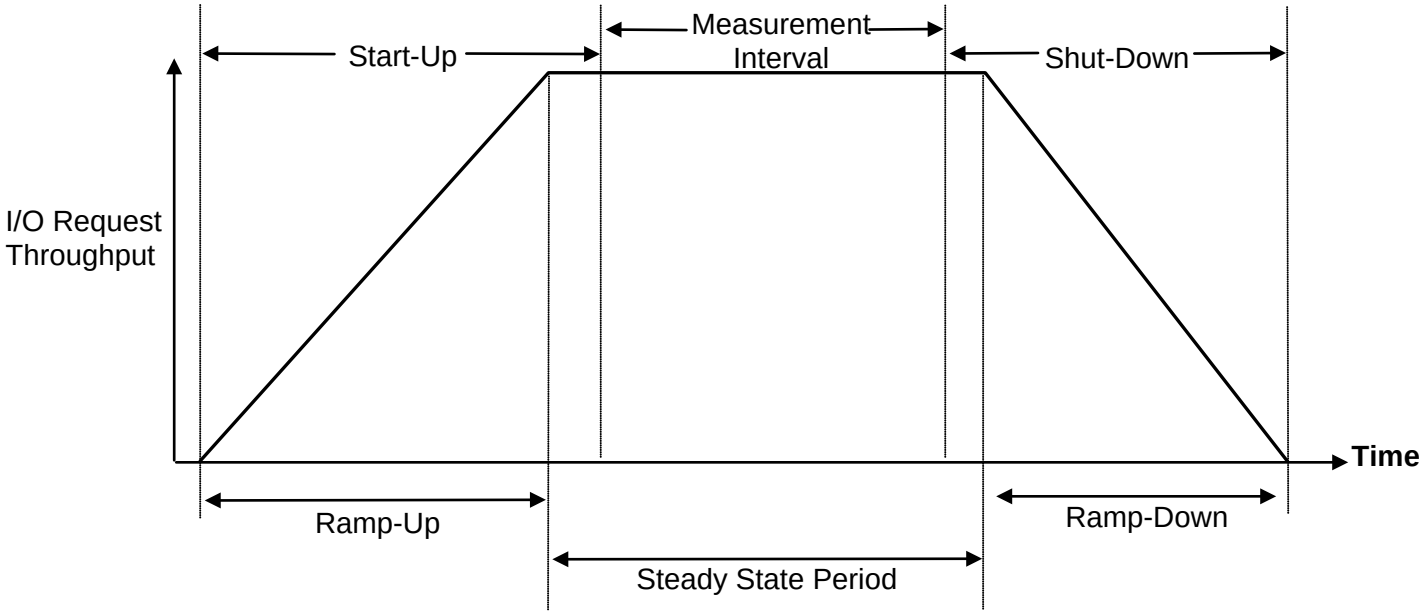
Test Run: The execution of SPC-1 for the purpose of producing or supporting an SPC-1 test result. SPC-1 Test Runs may have a finite and measured Ramp-Up period, Start-Up period, Shut-Down period, and Ramp-Down period as illustrated in the "SPC-1 Test Run Components" below. All SPC-1 Test Runs shall have 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

The execution throttle parameter was changed for each QLogic HBA to specify a maximum number of outstanding I/O requests (queue depth) of 8192. The parameter is changed by using the Windows QLogic CLI utility **QConvergeConsole CLI**.

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

All referenced scripts will appear at the end of this appendix in the Referenced Scripts section.

Configure Sparing Capacity and Storage Pool

The ISE 820 automatically reserves 20% of the total available capacity for sparing and creates a storage pool with the remaining available capacity for use in a RAID-0, RAID-1 or RAID-5 configuration as selected by the end-user.

Create ISE LUNs

The **create-r1.sh** script was executed from the Master Host System in a CLI window to create eight ISE LUNs and present those LUNs to the two Host Systems.

Create SPC-1 Logical Volumes

The **create_lun.txt** script was executed on the Master Host System, using the Windows **Diskpart** utility, to create the three SPC-1 Logical Volumes from the eight ISE LUNs

Import Disk Group

The **import_lun.txt** script was executed on the Slave Host System, using the Windows **Diskpart** utility, to import the disk group created on the Master Host System.

Referenced Scripts

create-r1.sh

```
#
#    Initialize ISE
#
/bin/nseash -c "initialize"
/bin/nseash -c "configure --upsmode=enable"
#
#    Create Raid-1 volumes for SPC-1 testing on 600 GB DataPacs at 99.8% utilization
#
/bin/nseash -c "create --volume=d1 --size=340 --raid1"
/bin/nseash -c "create --volume=d2 --size=340 --raid1"
/bin/nseash -c "create --volume=d3 --size=340 --raid1"
/bin/nseash -c "create --volume=d4 --size=340 --raid1"
/bin/nseash -c "create --volume=d5 --size=340 --raid1"
/bin/nseash -c "create --volume=d6 --size=340 --raid1"
/bin/nseash -c "create --volume=d7 --size=340 --raid1"
/bin/nseash -c "create --volume=d8 --size=340 --raid1"
sleep 10
#
#    Create the host QLogic HBAs
#
/bin/nseash -c "create --host=g4proto-1 21000024FF699E34, 21000024FF699E35,
21000024FF699E36, 21000024FF699E37"
/bin/nseash -c "create --host=g4proto-2 21000024FF698F2C, 21000024FF698F2D,
21000024FF698F2E, 21000024FF698F2F"
```

```
#
#    Present the SPC-1 LUNs to the hosts
#
/bin/nseash -c "present --host=g4proto-1 --all"
/bin/nseash -c "present --host=g4proto-2 --all"
```

create_lun.txt

```
REM
REM Create three ASU LUNs for SPC-1 testing on ISE 820
REM
REM Execute by "diskpart /s create_lun.txt"
REM
SELECT DISK 1
ATTRIBUTE DISK CLEAR READONLY
ONLINE DISK NOERR
CONVERT DYNAMIC NOERR
SELECT DISK 2
ATTRIBUTE DISK CLEAR READONLY
ONLINE DISK NOERR
CONVERT DYNAMIC NOERR
SELECT DISK 3
ATTRIBUTE DISK CLEAR READONLY
ONLINE DISK NOERR
CONVERT DYNAMIC NOERR
SELECT DISK 4
ATTRIBUTE DISK CLEAR READONLY
ONLINE DISK NOERR
CONVERT DYNAMIC NOERR
SELECT DISK 5
ATTRIBUTE DISK CLEAR READONLY
ONLINE DISK NOERR
CONVERT DYNAMIC NOERR
SELECT DISK 6
ATTRIBUTE DISK CLEAR READONLY
ONLINE DISK NOERR
CONVERT DYNAMIC NOERR
SELECT DISK 7
ATTRIBUTE DISK CLEAR READONLY
ONLINE DISK NOERR
CONVERT DYNAMIC NOERR
SELECT DISK 8
ATTRIBUTE DISK CLEAR READONLY
ONLINE DISK NOERR
CONVERT DYNAMIC NOERR
REM Luns for all-flash ISE (ISE LUN = 340 GB x 8)
CREATE VOLUME STRIPE SIZE=153000 DISK=1,2,3,4,5,6,7,8
ASSIGN LETTER=E NOERR
CREATE VOLUME STRIPE SIZE=153000 DISK=1,2,3,4,5,6,7,8
ASSIGN LETTER=F NOERR
CREATE VOLUME STRIPE SIZE=34000 DISK=1,2,3,4,5,6,7,8
ASSIGN LETTER=G NOERR
```

import_lun.txt

```
REM
REM Import the disk group created on the other host
REM
REM Execute by "diskpart /s import_lun.txt"
REM
SELECT DISK 1
IMPORT NOERR
```

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

ASU Pre-Fill

The content of command and parameter file, used in this benchmark to execute the required ASU pre-fill, is listed below.

```
*
* This will produce a random data pattern of the entire LBA range using LSFR 32bit
*
* Execute as: vdbench -f prefill.parm -o prefill-out
*
compratio=1
*
* All SPC AUS LUNs (note that all sd's must be defined prior to the wd's)
*
sd=sd1,lun=\\.\E:,threads=32
sd=sd2,lun=\\.\F:,threads=32
sd=sd3,lun=\\.\G:,threads=32
*
* The applied prefill workload
*
wd=wd1,sd=sd1,rdpct=0,seekpct=-1,xfersize=128K
wd=wd2,sd=sd2,rdpct=0,seekpct=-1,xfersize=128K
wd=wd3,sd=sd3,rdpct=0,seekpct=-1,xfersize=128K
*
rd=asu_prefill,wd=wd*,iorate=max,elapsed=360000,interval=10
```

Primary Metrics and Repeatability Tests

The content of SPC-1 Workload Generator command and parameter file used in this benchmark to execute the Primary Metrics *(Sustainability Test Phase, IOPS Test Phase, and Response Time Ramp Test Phase)* and Repeatability *(Repeatability Test Phase 1 and Repeatability Test Phase 2)* Tests is listed below.

```
host=master
slaves=(s0,s1,s2,s3,s4,s5,s6,s7,s8,s9,s10,s11,s12,s13,s14,s15,s16,s17,s18,s19,s20,s2
1,s22,s23,s24,s25,s0r1,s1r1,s2r1,s3r1,s4r1,s5r1,s6r1,s7r1,s8r1,s9r1,s10r1,s11r1,s12r
1,s13r1,s14r1,s15r1,s16r1,s17r1,s18r1,s19r1,s20r1,s21r1,s22r1,s23r1,s24r1,s25r1)
sd=asu1_1,lun=\\.\E:
sd=asu2_1,lun=\\.\F:
sd=asu3_1,lun=\\.\G:
```

SPC-1 Persistence Test Run 1

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

```
sd=asu1_1,lun=\\.\E:
sd=asu2_1,lun=\\.\F:
sd=asu3_1,lun=\\.\G:
```

Slave JVMs

Each Slave JVM was invoked with a command and parameter file similar to the example listed below. The only difference in each file was **host** parameter value, which was unique to each Slave JVM, e.g. ***s0…s25r1***.

```
javaparms="-Xmx1024m"
master=localhost
host=s0
sd=asu1_1,lun=\\.\E:
sd=asu2_1,lun=\\.\F:
sd=asu3_1,lun=\\.\G:
```

SPC-2 Persistence Test

If approved by the SPC Auditor, the SPC-2 Persistence Test may be used to meet the SPC-1 persistence requirements. Both the SPC-1 and SPC-2 Persistence Tests provide the same level of functionality and verification of data integrity.

SPC-2 Persistence Test Run 1 *(write phase)*

```
host=localhost,jvms=2,maxstreams=200

sd=asu1_1,host=localhost,lun=\\.\E:,size=1283457024000
sd=asu2_1,host=localhost,lun=\\.\F:,size=1283457024000
sd=asu3_1,host=localhost,lun=\\.\G:,size=285212672000

maxlatestart=1
reportinginterval=5
segmentlength=512m

rd=default,rampup=180,periods=90,measurement=300,runout=0,rampdown=0,buffers=1

rd=default,rdpct=0,xfersize=1024k
rd=TR1-155s_SPC-2-persist-w,streams=155
```

SPC-2 Persistence Test Run 2 *(read phase)*

```
host=localhost,jvms=1,maxstreams=200

sd=asu1_1,host=localhost,lun=\\.\E:,size=1283457024000
sd=asu2_1,host=localhost,lun=\\.\F:,size=1283457024000
sd=asu3_1,host=localhost,lun=\\.\G:,size=285212672000

maxlatestart=1
reportinginterval=5
segmentlength=512m
maxpersistenceerrors=5

rd=default,buffers=1,rdpct=100,xfersize=1024k
rd=TR1-155s_SPC-2-persist-r
```

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

The following script, **run_spc1_part1.bat**, calls the standard **vdbench** script to execute the required ASU pre-fill and upon completion of that first step, invokes **start_local.bat** to start the Slave JVMs on the Master Host System. The 'master' script pauses until the **start_remote.bat** script is executed manually to start the Slave JVMs on the Slave Host System. The 'master' script will then resume upon Test Sponsor response to the ***pause*** command and then invoke the commands to execute the Primary Metrics Test *(Sustainability Test Phase, IOPS Test Phase, and Response Time Ramp Test Phase)*, the Repeatability Test *(Repeatability Test Phase 1 and Repeatability Test Phase 2)*, a reduced level SPC-1 Persistence Test Run 1 *(write phase)* and SPC-2 Persistence Test Run 1 *(write phase)* in an uninterrupted sequence.

run_spc1_part1.bat

```
set /a BSU=5060

rem Prefill the ASUs using the previously created prefill.parm configuration file
call vdbench -f prefill.parm -o prefill-out

rem Start up the slaves on the master host
call start_local.bat luns.cfg 26 26

rem echo Start up the slaves on the remote host by entering "start_remote luns.cfg
g4proto-2 1 26"
rem pause

rem Start the SPC-1 metrics
java -Xms8192m -Xmx8192m metrics -b %BSU% -t 28800 -r 600 -s 600

rem Start the SPC-1 repeatability test
java -Xms8192m -Xmx8192m repeat1 -b %BSU%  -s 180
java -Xms8192m -Xmx8192m repeat2 -b %BSU%  -s 180

rem Reduced level SPC-1 Persistence Test Run 1 (write phase)
set /a P-BSU=BSU*.1
java -Xms2048m -Xmx2048m persist1 –b %P-BSU%

rem SPC-2 "init" and Persistence Test Run 1 (write phase)
cd c:\spc\spc2
java -Xmx1536m -Xms1536m -cp c:\spc\spc2 vdbench -w SPC2 -f
c:\spc1\spc2_persist1.cfg -o c:\spc1\init_spc2 -init
java -Xmx1536m -Xms1536m -cp c:\spc\spc2 vdbench -w SPC2 -f
c:\spc1\spc2_persist1.cfg -o c:\spc1\persist1_spc2

echo Power cycle the ISE, then enter "run_spec_part2.bat"
```

start_local.bat

This script was invoked from **run_spc1_part1.bat** to start the Slave JVMs on the Master Host System.

```
@echo off

REM
REM    Check parameters, offer help
REM
if not -%1-==-- goto SkipHelp
  echo Create the multi-host spc1.cfg file on the master host, then start
  echo the requested number of java processes
  echo   parameter 1 - base .cfg file
  echo   parameter 2 - number of local java processes (0 is ok)
  echo   parameter 3 - number of remote java processes for remote host index 1
  echo   parameter 4 - number of remote java processes for remote host index 2
  echo   parameter 5 - number of remote java processes for remote host index 3
  echo   etc...
  exit /b

:SkipHelp

REM
REM    Check cfg file
REM
set cfgfile=%1
if exist %cfgfile% goto CfgFileThere
  echo Could not find file %cfgfile%
  exit /b
:CfgFileThere
echo CFG file: %cfgfile%
shift

REM
REM     Create and start the localhost java processes
REM
set /a lclcnt=%1
set SlaveStr=
set /a cnt=0
:LclStrLoop
if %cnt%==%lclcnt% goto LclDone
  if defined SlaveStr (
    set SlaveStr=%SlaveStr%,s%cnt%
  ) else (
    set SlaveStr=s%cnt%
  )
  echo javaparms="-Xmx1024m" > s%cnt%.txt
  echo master=localhost >> s%cnt%.txt
  echo host=s%cnt% >> s%cnt%.txt
  more %cfgfile% >> s%cnt%.txt
  start /min java spc1 -f s%cnt%.txt -o s%cnt%
  set /a cnt+=1
  goto LclStrLoop
:LclDone

REM
REM    Configure the slaves= string with the remote hosts
REM
set /a rmthost=0
:NextRemoteArg
```

```
shift
if -%1-==-- goto RemoteArgsDone
set /a rmthost+=1
set /a rmtcnt=%1
set /a cnt=0

:RmtStrLoop
if %cnt%==%rmtcnt% goto NextRemoteArg
  if defined SlaveStr (
    set SlaveStr=%SlaveStr%,s%cnt%r%rmthost%
  ) else (
    set Slavestr=s%cnt%r%rmthost%
  )
  set /a cnt+=1
  goto RmtStrLoop
:RemoteArgsDone

echo %SlaveStr%

REM
REM     Create spc1.cfg
REM
echo host=master > spc1.cfg
echo slaves=(%SlaveStr%) >> spc1.cfg
more %cfgfile% >> spc1.cfg
echo spc1.cfg created

echo %lclcnt% java processes started

exit /b
```

start_remote.bat

This script was invoked manually to start the Slave JVMs on the Slave Host System.

```
@echo off

REM
REM    Check parameters, offer help
REM
if not -%1-==-- goto SkipHelp
  echo Start the java processes for the SPC1 test on one of the remote hosts
  echo  parameter 1 - base .cfg file
  echo  parameter 2 - master host's IP or name
  echo  parameter 3 - this host's index (1 is the first host, not 0)
  echo  parameter 4 - number of remote java processes for this host
  echo                (should be greater or = to the number specified in
  echo                the start_local run for this host's index)
  exit /b

:SkipHelp

REM
REM    Check cfg file
REM
set cfgfile=%1
if exist %cfgfile% goto CfgFileThere
  echo Could not find file %cfgfile%
  exit /b
:CfgFileThere
echo CFG file: %cfgfile%
shift

REM
REM     Check the IP
REM
set hostIP=%1
ping -n 1 %hostIP% | find "TTL=" >nul
if errorlevel 0 goto HostIpOK
  echo Can not reach %hostIP%
  exit /b
:HostIpOK
echo Pinged host %hostIP% OK
shift

REM
REM     Get the host index
REM
set /a hostidx=%1
if %hostidx% neq 0 goto HostIndexOK
  echo  Zero is an illegal host index, start at 1
  exit /b
:HostIndexOK
shift

REM
REM     Create and start the java processes
REM
set /a lclcnt=%1
set /a cnt=0
:loop
if %cnt%==%lclcnt% goto LclDone
```

```
    echo javaparms="-Xmx1024m" > s%cnt%.txt
    echo master=%hostIP% >> s%cnt%.txt
    echo host=s%cnt%r%hostidx% >> s%cnt%.txt
    more %cfgfile% >> s%cnt%.txt
    start /min java spc1 -f s%cnt%.txt -o s%cnt%
    set /a cnt+=1
    goto loop
  :LclDone
  echo %lclcnt% java processes started

  exit /b
```

SPC-2 Persistence Test Run 2

The following script is executed to invoke the SPC-2 Persistence Test Run 2 *(read phase)* after completion of the required TSC power off/power on cycle.

run_spc1_part2.bat

```
rem X-io SPC-1 ISE 820 audit script part 2

set /a BSU=5060

diskpart -s import_lun.txt

rem Start the SPC-1 repeatability test part 2 (normal)
rem java -Xms8192m -Xmx8192m repeat2 -b %BSU%  -s 180

rem Start the SPC-1 persistence test part 2 (using SPC-2)
java -Xmx1536m -Xms1536m -cp c:\spc\spc2 vdbench -w SPC2 -f
c:\spc1\spc2_persist2.cfg -o c:\spc1\persist2_spc2
```

APPENDIX F: THIRD-PARTY QUOTATIONS

Q-Logic QLE2564 HBAs