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SPC BENCHMARK 1™
FULL DISCLOSURE REPORT

FUJITSU LIMITED
FUJITSU STORAGE SYSTEMS ETERNUS DX100 S3

SPC-1 V1.14

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AUDIT CERTIFICATION

C.A. (Sandy) Wilson
Fujitsu Limited
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P.O. Box 3470
Sunnyvale, CA 94088 3470

October 3, 2014

The SPC Benchmark 1™ Reported Data listed below for the Fujitsu Storage Systems ETERNUS DX100 S3 was produced in compliance with the SPC Benchmark 1™ v1.14 Remote Audit requirements.

SPC Benchmark 1™ v1.14 Reported Data	
Tested Storage Product (TSP) Name: Fujitsu Storage Systems ETERNUS DX100 S3	
Metric	**Reported Result**
SPC-1 IOPS™	55,235.28
SPC-1 Price-Performance	$0.99/SPC-1 IOPS™
Total ASU Capacity	1,120.000 GB
Data Protection Level	Protected 2 *(Mirroring)*
Total Price (including three-year maintenance)	$54,892.68
Currency Used	U.S. Dollars
Target Country for availability, sales and support	USA

The following SPC Benchmark 1™ Remote 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 information supplied by Fujitsu Limited:
  - ✓ 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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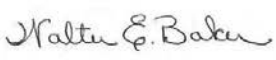
AUDIT CERTIFICATION *(CONT.)*

- An appropriate diagram of the Benchmark Configuration (BC)/Tested Storage Configuration (TSC).
- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters that were changed from default values.
- SPC-1 Workload Generator commands and parameters used for the audited SPC Test Runs.
- The following Host System requirements were verified by information supplied by Fujitsu Limited:
  - ✓ The type of Host Systems including the number of processors and main memory.
  - ✓ The presence and version number of the SPC-1 Workload Generator on each Host System.
  - ✓ The TSC boundary within each Host System.
- The execution of each Test, Test Phase, and Test Run was 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 Fujitsu Limited for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4 and 5 of the SPC-1 Benchmark Specification:
  - ✓ Data Persistence Test
  - ✓ Sustainability Test Phase
  - ✓ IOPS Test Phase
  - ✓ Response Time Ramp Test Phase
  - ✓ Repeatability Test
- There were no differences between the Tested Storage Configuration (TSC) and the 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:

There were no audit notes or exceptions.

Respectfully,



Walter E. Baker
SPC Auditor

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LETTER OF GOOD FAITH

FUJITSU

Kanagawa-ken,Kawasaki-shi,Nakahara-ku,Kamikodanaka,4-1-1,JAPAN211-8588
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July 3 , 2014
From: Shigeo Konno, Fujitsu Limited

To: Walter E. Baker, SPC Auditor
Gradient Systems, Inc.
643 Bair Island Road, Suite 103
Redwood City, CA 94063-2755. U.S.A.

Contact Information: Carrel A. (Sandy)Wilson
Fujitsu America, Inc.
1250 East Arques Ave. PO Box 3470
Sunnyvale, CA 94088, U.S.A.

Subject: SPC-1 Letter of Good Faith for the FUJITSU Storage ETERNUS DX100 S3

Fujitsu Limited 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 V2.3.0 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 disclosed by the SPC-1 benchmark specification.

Signed: Date:

Shigeo Konno
General Manager, Storage System Division

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
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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	October 6, 2014
Date the FDR was submitted to the SPC	October 6, 2014
Date the Priced Storage Configuration is available for shipment to customers	currently available
Date the TSC completed audit certification	October 3, 2014

Tested Storage Product (TSP) Description

The scalable and unified Fujitsu Storage ETERNUS DX100 S3 delivers enterprise-class functionality to small and medium-sized companies and subsidiaries with an excellent price/performance ratio. It is the perfect solution when consolidating data for server virtualization, e-mail, databases and business applications as well a centralized file services. Simple, intuitive system management, highly flexible network connectivity and the option of field upgrades to higher system classes significantly reduce operational and migration costs. The ETERNUS DX family architecture lets customers benefit from software options, such as thin provisioning, automatic storage tiering and quality of service management even as early as the entry-level class. This all contributes to better business support.

Summary of Results

SPC-1 Reported Data	
Tested Storage Product (TSP) Name: Fujitsu Storage Systems ETERNUS DX100 S3	
Metric	**Reported Result**
SPC-1 IOPS™	55,235.28
SPC-1 Price-Performance™	$0.99/SPC-1 IOPS™
Total ASU Capacity	1,120.000 GB
Data Protection Level	Protected 2 *(mirroring)*
Total Price	$54,892.68
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.*

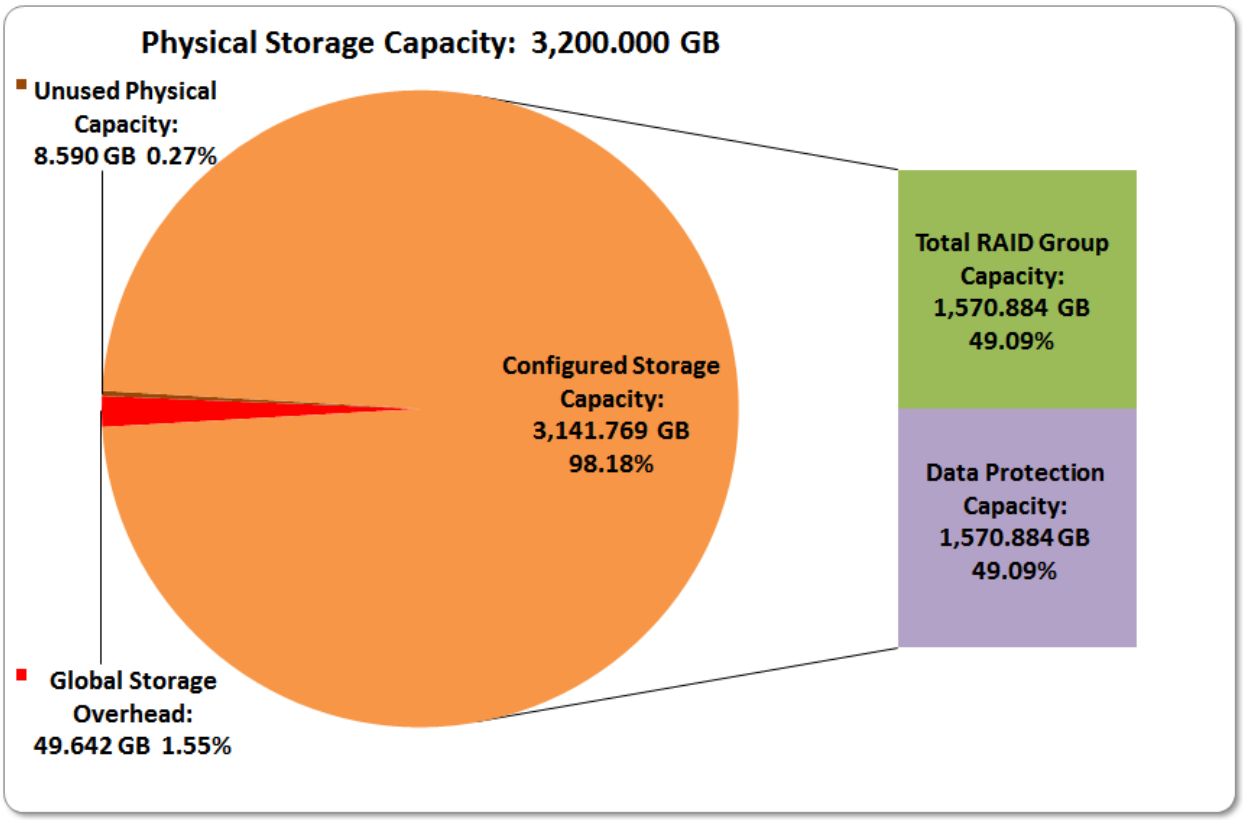
Total Price includes the cost of the Priced Storage Configuration plus three years of hardware maintenance and software support as detailed on page 17.

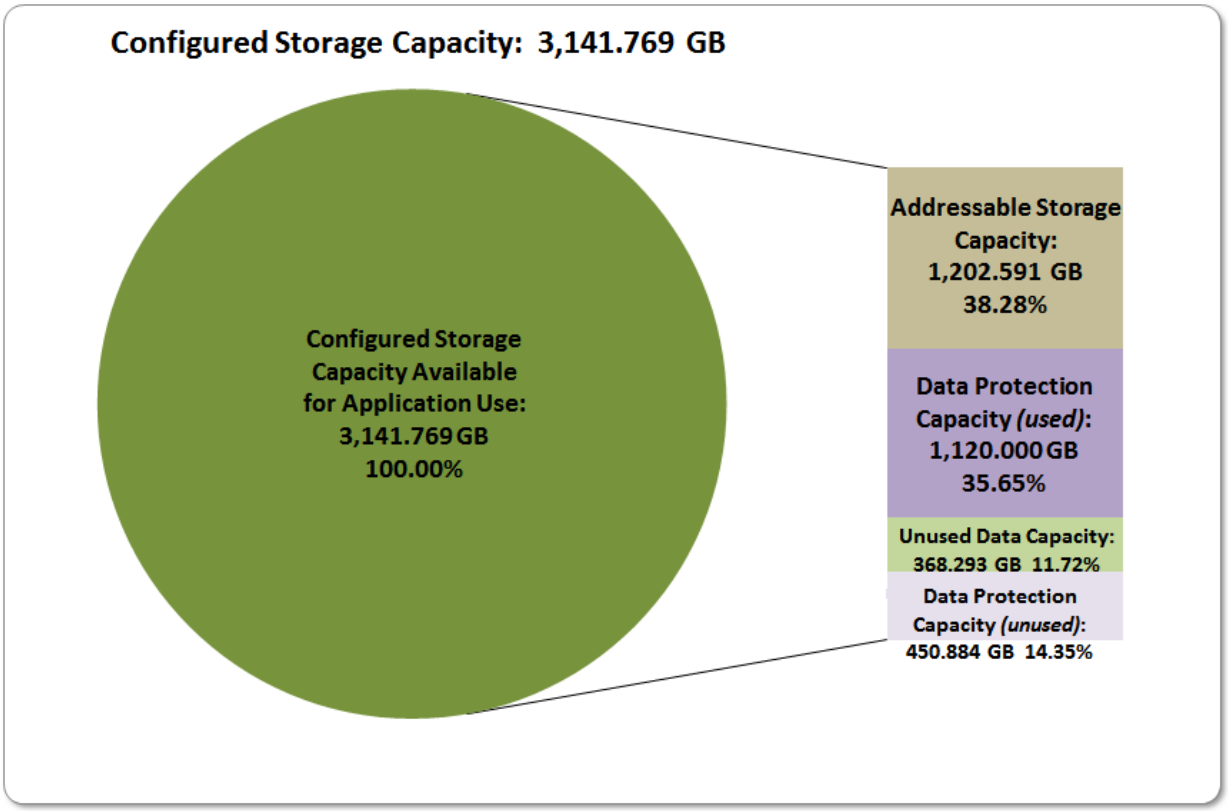
Currency Used is formal name for the currency used in calculating the **Total Price** and **SPC-1 Price-Performance™**. That currency may be the local currency of the **Target Country** or the currency of a difference country *(non-local currency)*.

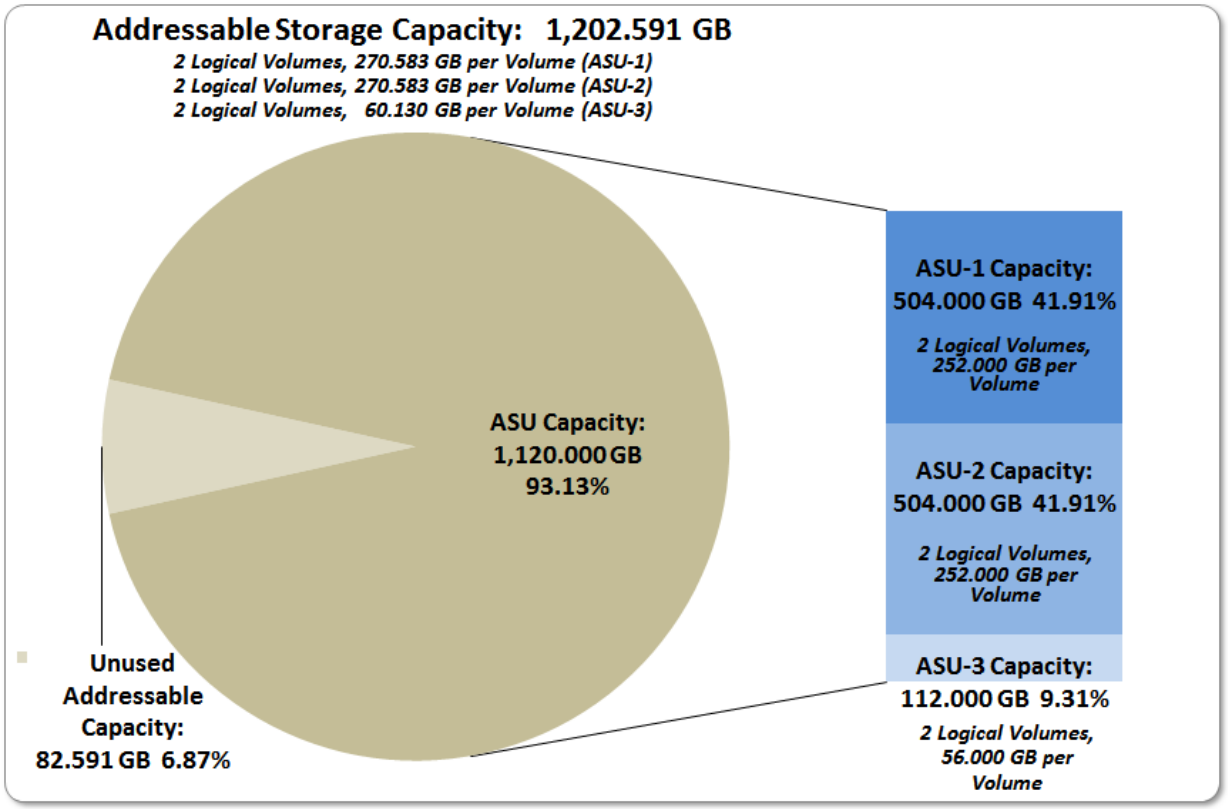
The **Target Country** is the country in which the Priced Storage Configuration is available for sale and in which the required hardware maintenance and software support is provided either directly from the Test Sponsor or indirectly via a third-party supplier.

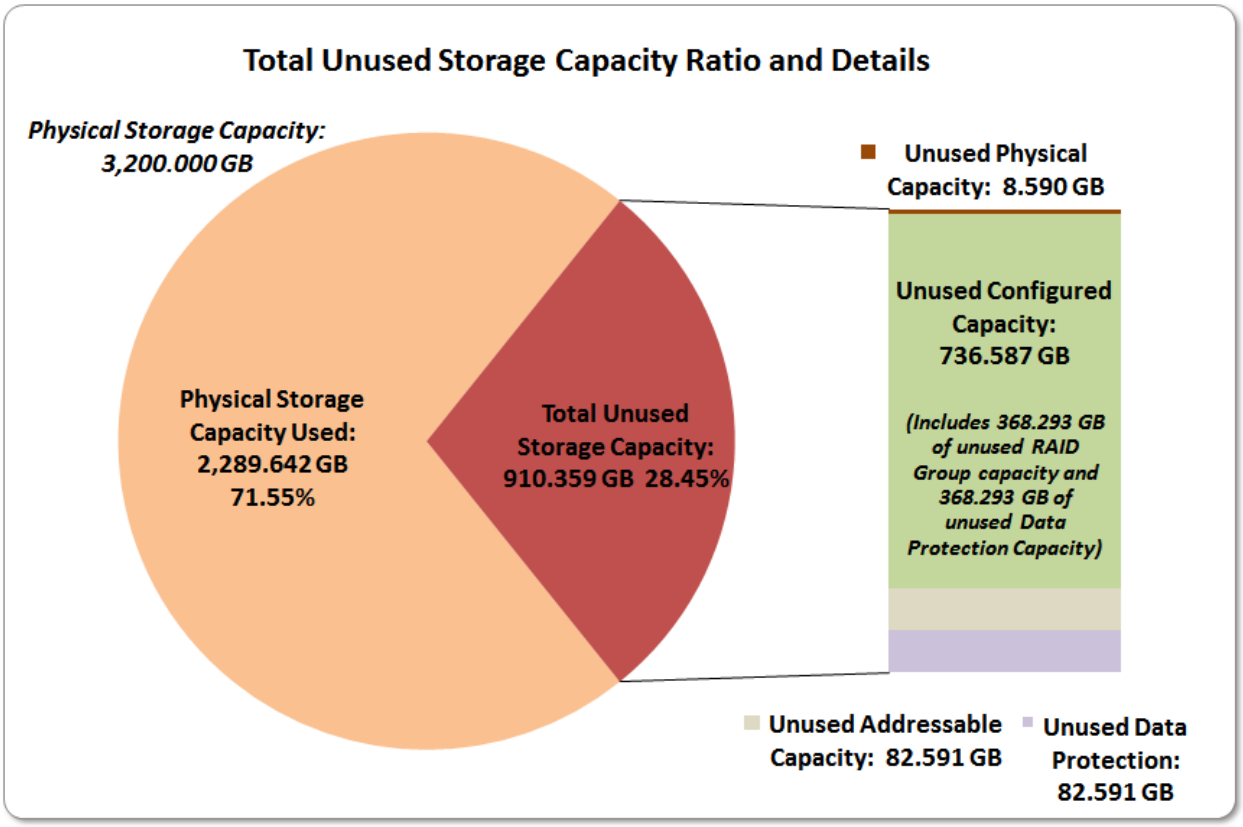
Storage Capacities, Relationships, and Utilization

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.




Configured Storage Capacity: 3,141.769 GB
Configured Storage Capacity Available for Application Use: 3,141.769 GB 100.00%
Addressable Storage Capacity: 1,202.591 GB 38.28%
Data Protection Capacity (used): 1,120.000 GB 35.65%
Unused Data Capacity: 368.293 GB 11.72%
Data Protection Capacity (unused): 450.884 GB 14.35%


Addressable Storage Capacity: 1,202.591 GB
2 Logical Volumes, 270.583 GB per Volume (ASU-1)
2 Logical Volumes, 270.583 GB per Volume (ASU-2)
2 Logical Volumes, 60.130 GB per Volume (ASU-3)
ASU Capacity: 1,120.000 GB 93.13%
Unused Addressable Capacity: 82.591 GB 6.87%
ASU-1 Capacity: 504.000 GB 41.91%
2 Logical Volumes, 252.000 GB per Volume
ASU-2 Capacity: 504.000 GB 41.91%
2 Logical Volumes, 252.000 GB per Volume
ASU-3 Capacity: 112.000 GB 9.31%
2 Logical Volumes, 56.000 GB per Volume



SPC-1 Storage Capacity Utilization	
Application Utilization	35.00%
Protected Application Utilization	70.00%
Unused Storage Ratio	28.45%

Application Utilization: Total ASU Capacity *(1,120.000 GB)* divided by Physical Storage Capacity *(3,200.000 GB)*.

Protected Application Utilization: (Total ASU Capacity *(1,120.000 GB)* plus total Data Protection Capacity *(1,570.884 GB)* minus unused Data Protection Capacity 450.884 *GB)*) divided by Physical Storage Capacity *(3,200.000 GB)*.

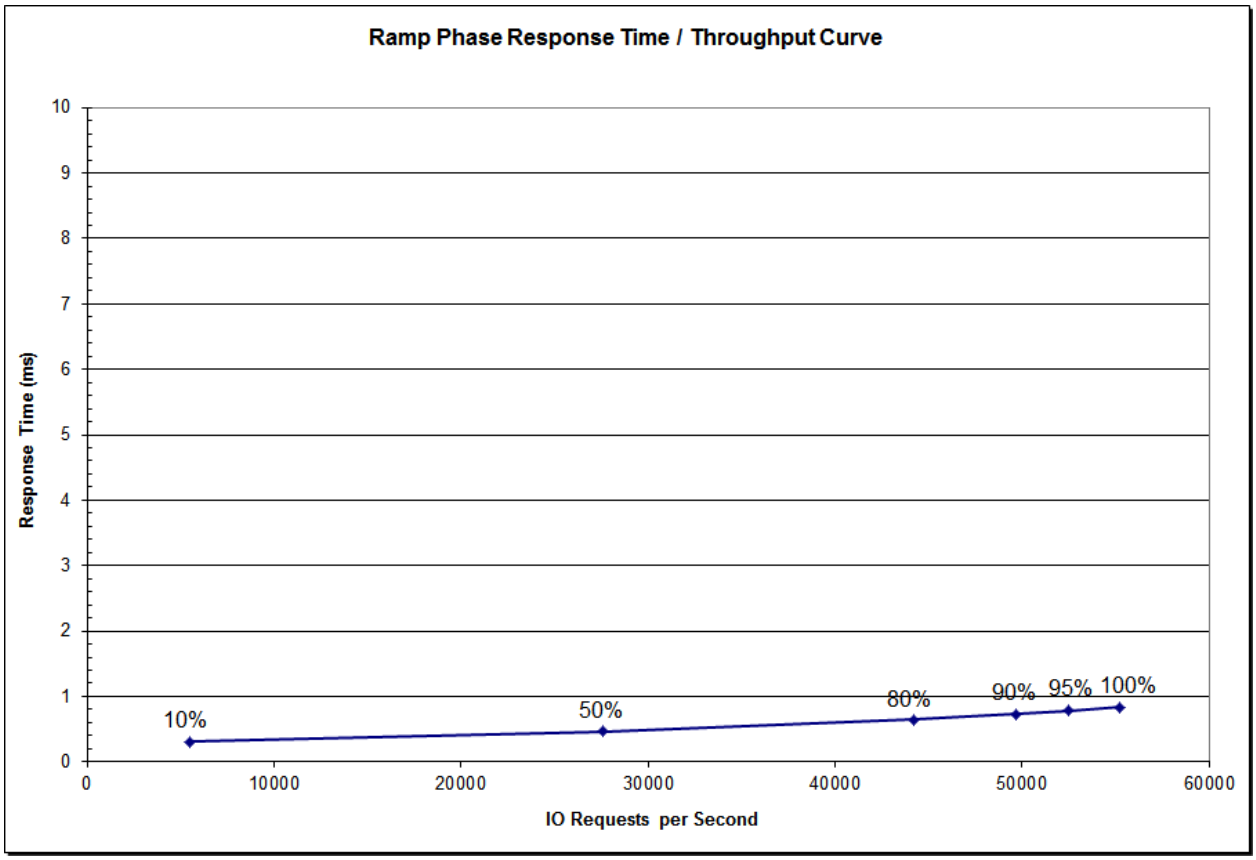
Unused Storage Ratio: Total Unused Capacity *(910.359 GB)* divided by Physical Storage Capacity *(3,200.000 GB)* and may not exceed 45%.

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	5,500.12	27,601.70	44,209.62	49,702.35	52,465.11	55,235.28
Average Response Time (ms):						
All ASUs	0.30	0.46	0.65	0.73	0.79	0.84
ASU-1	0.33	0.55	0.77	0.86	0.93	1.00
ASU-2	0.33	0.61	0.89	1.00	1.07	1.09
ASU-3	0.24	0.23	0.29	0.33	0.35	0.38
Reads	0.43	0.85	1.22	1.37	1.46	1.54
Writes	0.22	0.21	0.28	0.32	0.35	0.38

Priced Storage Configuration Pricing

Product ID	Product Name	Qty	Unit List Price	Extended LP	Discount %	Discounted Price
ET103AU_System	**ETERNUS DX100 S3 Storage Array**	**1**	**$56,381.00**	**$56,381.00**	**30%**	**$39,466.70**
ET103AU	DX100 S3 Base System Rackmount (AC200V, 2RU) (2.5" type)	1				
ETFM41U	Cache Memory - DX100 S3 4GB per CM	2				
ETFCH2E	FC Host Interface, 2 ports DX100 S3 CM & CA#0 (4/8/16Gbps, Host/Remote)	2				
ETFHH2	FC Host Interface, 2 ports DX100/200 S3 CA1 (4/8/16Gbps, Host/Remote)	2				
ETFSA4	MLC-SSD 400GB 2.5" x1 SAS for DX100/200 S3	8				
ETFKF30U	AC Power Cords (125V - NEMA 5-15, 3m)	1				
QLE2562	**QLogic 8Gbps Dual Port Fibre Channel Host Bus Adapter**	**4**	**$2,597.85**	**$10,391.40**	**30%**	**$7,273.98**
61-343827-003	**Fibre Channel Host IF Cable LC/LC - 3m**	**6**	**$132.00**	**$792.00**	**30%**	**$554.40**
	(Provide 24 hour per day / 7days per week 4 hour response maintenance for 36 months)					
ETD100-W025360-AJA	Warranty Service, 36 months Standard, 9x5 phone, NBD response	1	$0.00	$0.00		$0.00
ETD100-U004361-AJA	Warranty Uplift, 36 months Enhanced plus, 24x7 4hr Onsight	1	$9,497.00	$9,497.00	20%	$7,597.60
	SFPs are included.			**Total:**		**$54,892.68**

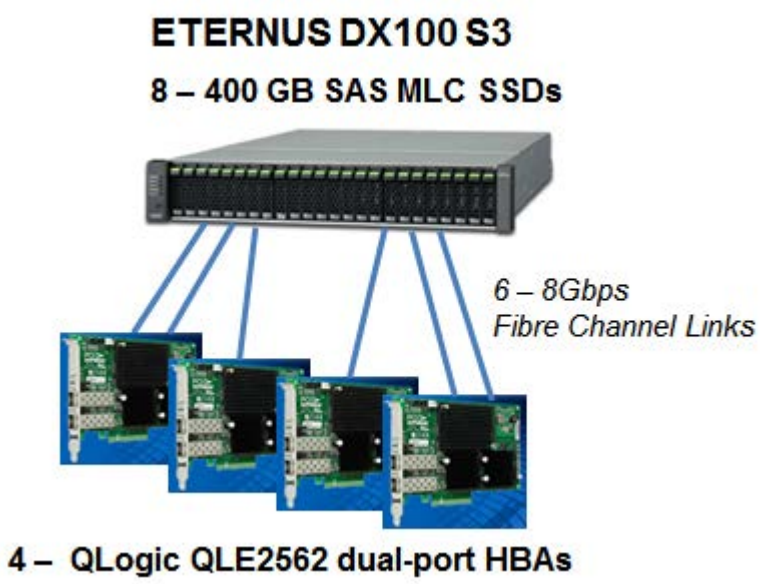
The above pricing includes hardware maintenance and software support for three years, 7 days per week, 24 hours per day. The hardware maintenance and software support provides the following:

- 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 Priced Storage Configuration.

Priced Storage Configuration Diagram



Priced Storage Configuration Components

Priced Storage Configuration
4 – QLogic QLE2562 dual-port HBAs
Fujitsu Storage Systems ETERNUS DX100 S3 1 – DX100 S3 Control Enclosure with 2 – Controllers (CMs) each with 4 GB cache (8 GB total) 2 – FC Channel Adapters (CAs) each with 2 – 16 Gbps FC host ports *(4 ports per CM, 8 ports total,* *3 ports used per CM, 6 ports total used)* 1 – SAS Expander Drive Interface with QSFP 12 Gbps SAS-3 *(1 – SAS-3 x4 link per interface,* *1 – SAS-3 x4 link used)* 8 – 400 GB SAS MLC 2.5” SSD storage devices

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)*.

Storage Network Configuration

Clause 9.4.3.4.1

…

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

Clause 9.4.3.4.2

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

The Benchmark Configuration (BC)/Tested Storage Configuration (TSC) utilized direct attached storage.

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

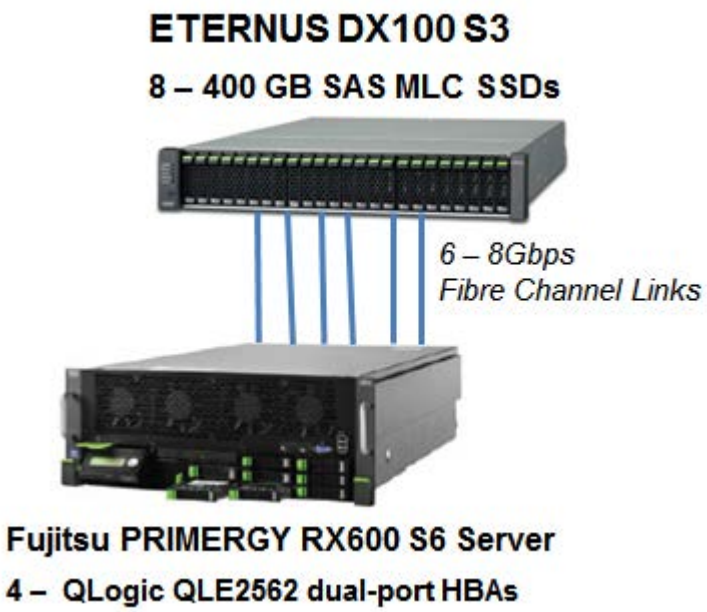
Clause 9.4.3.4.3

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*)*.

Benchmark Configuration/Tested Storage Configuration Diagram



Host System and Tested Storage Configuration Components

Host System
1 – Fujitsu PRIMERGY RX600 S6 Servers, each with: 4 – Intel Xeon 2.67 GHz processor E7-8837 each with 8 cores, 24 MB cache 64 GB main memory Red Hat Enterprise Linux Server release 6.2 PCI-Express 2.0
Priced Storage Configuration
4 – QLogic QLE2562 dual-port HBAs
Fujitsu Storage Systems ETERNUS DX100 S3 1 – DX100 S3 Control Enclosure with 2 – Controllers (CMs) each with 4 GB cache (8 GB total) 2 – FC Channel Adapters (CAs) each with 2 – 16 Gbps FC host ports *(4 ports per CM, 8 ports total, 3 ports used per CM)* 1 – SAS Expander Drive Interface with QSFP 12 Gbps SAS-3 *(1 – SAS-3 x4 link per interface, 1 – SAS-3 x4 link used)* 8 – 400 GB SAS MLC 2.5" SSD storage devices

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 64 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 65 contains the detailed information that describes how to create and configure the logical TSC.

SPC-1 Workload Generator Storage Configuration

Clause 9.4.3.5.3

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

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

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 69.

SPC-1 DATA REPOSITORY

This portion of the Full Disclosure Report presents the detailed information that fully documents the various SPC-1 storage capacities and mappings used in the Tested Storage Configuration. SPC-1 Data Repository Definitions on page 60 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 3,200.000 GB distributed over 12 solid state devices (SSDs) each with a formatted capacity of 400.000 GB. There was 8.590 GB (0.27%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 49.642 GB (1.55%) of the Physical Storage Capacity. There was 736.587 GB (23.44%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 93.13% of the Addressable Storage Capacity resulting in 82.591 GB (6.92%) of Unused Storage within the Addressable Storage Capacity. The Data Protection *(Mirroring)* capacity was 1,570.884 GB of which 1,120.000 GB was utilized. The total Unused Storage capacity was 910.359 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.

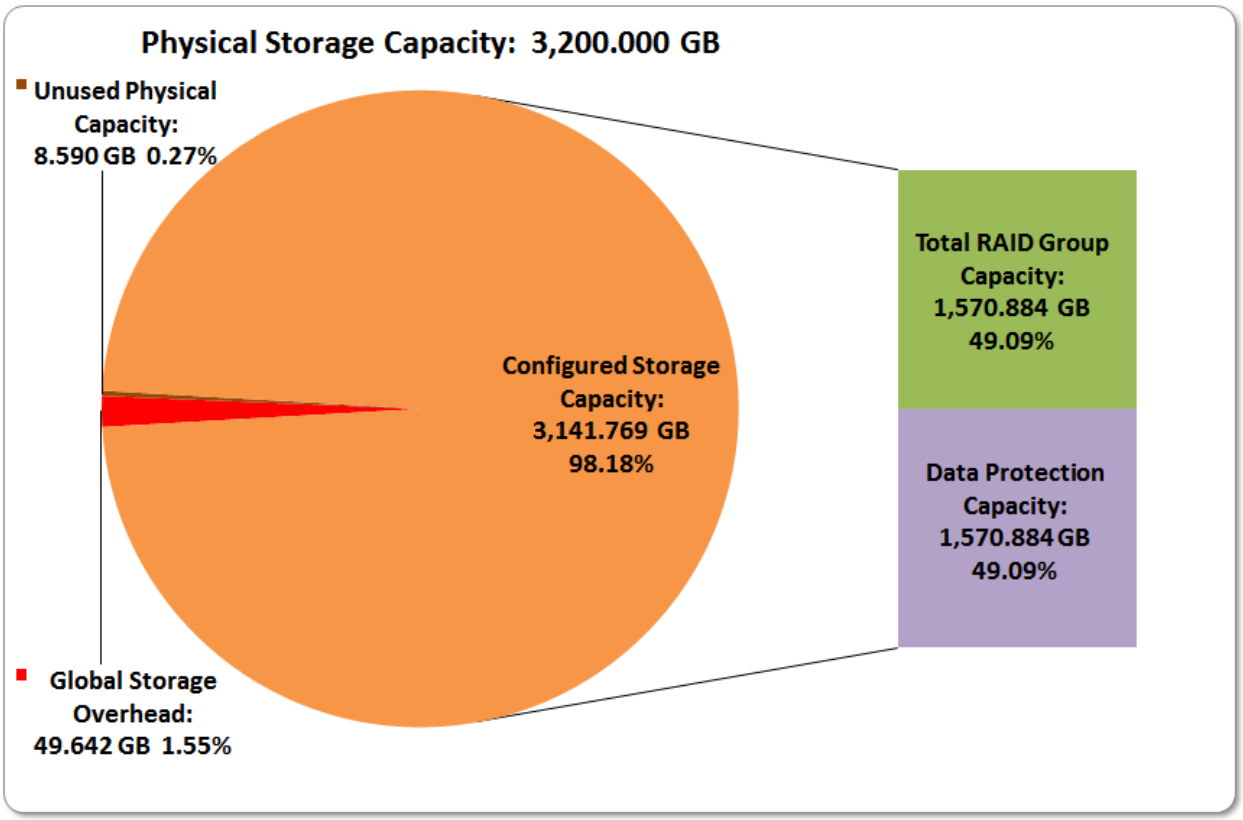
SPC-1 Storage Capacities

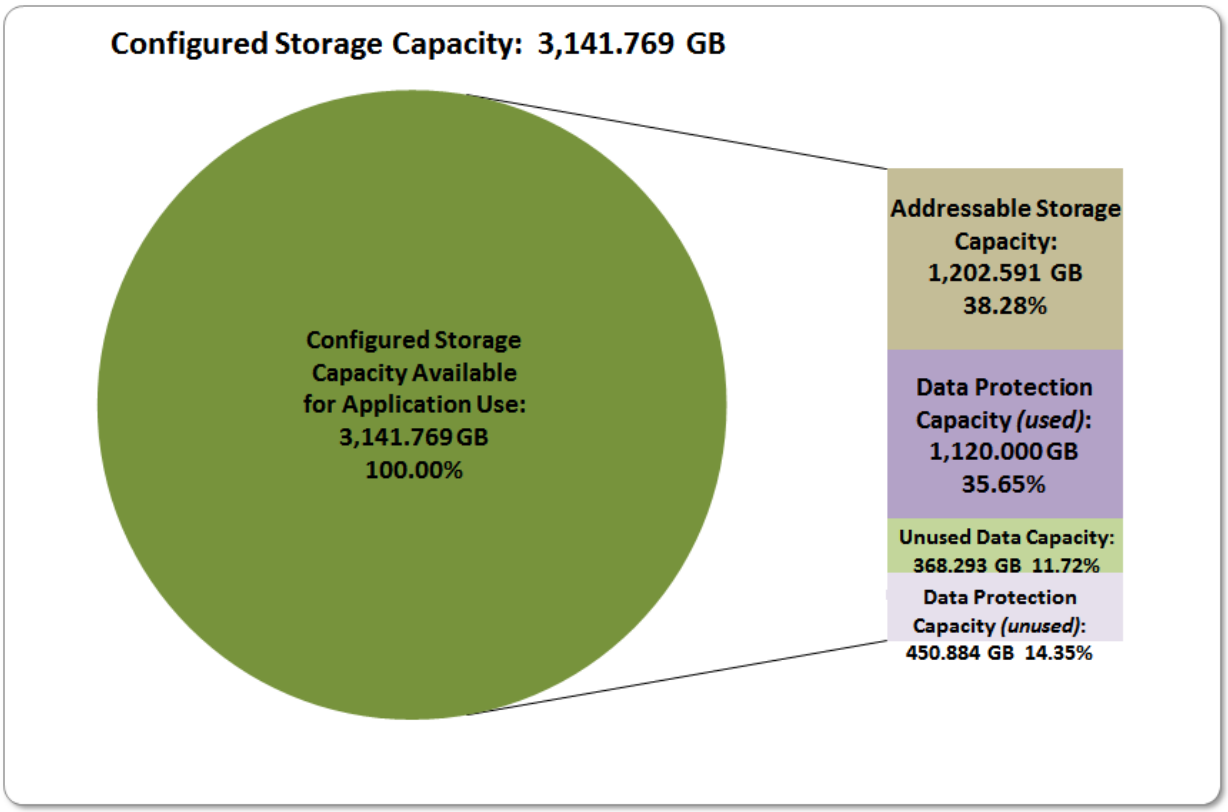
Storage Hierarchy Component	Units	Capacity
Total ASU Capacity	Gigabytes (GB)	1,120.000
Addressable Storage Capacity	Gigabytes (GB)	1,202.591
Configured Storage Capacity	Gigabytes (GB)	3,141.769
Physical Storage Capacity	Gigabytes (GB)	3,200.000
Data Protection *(Mirroring)*	Gigabytes (GB)	1,570.884
Required Storage *(sparing capacity)*	Gigabytes (GB)	0.000
Global Storage Overhead	Gigabytes (GB)	49.642
Total Unused Storage	Gigabytes (GB)	910.359

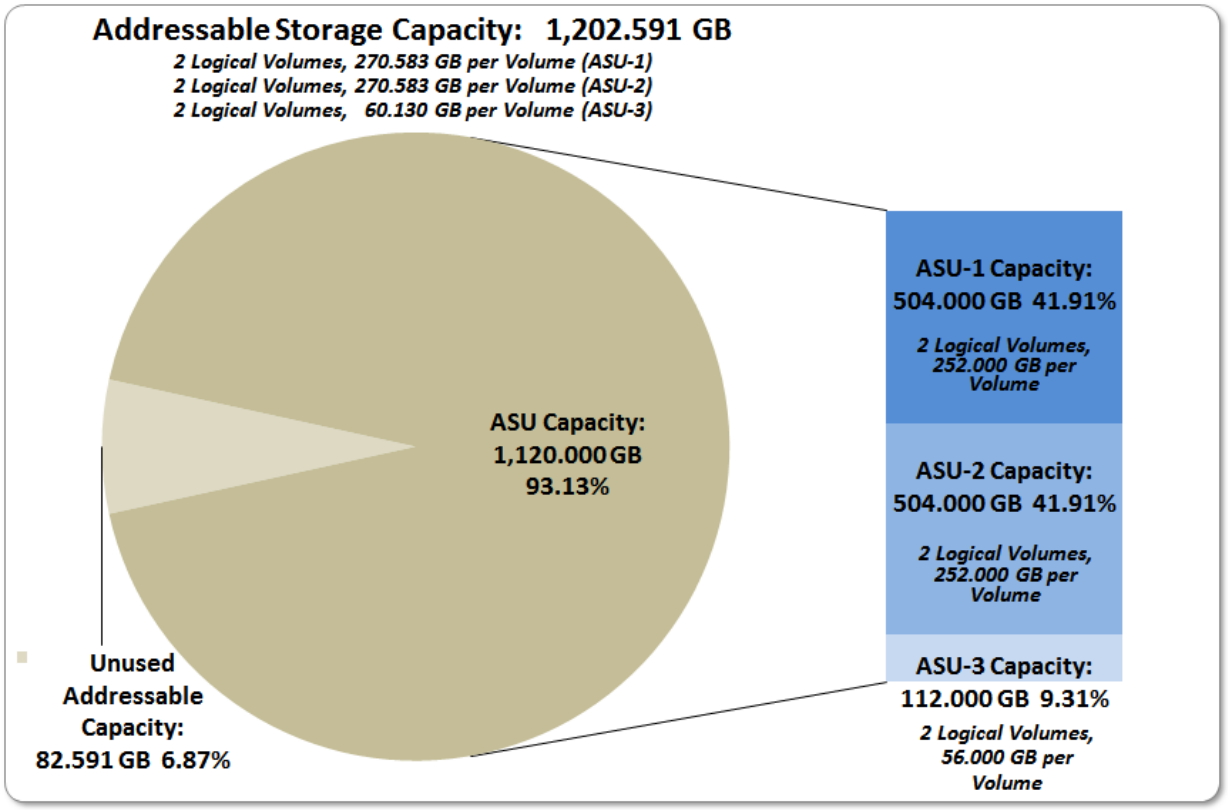
SPC-1 Storage Hierarchy Ratios

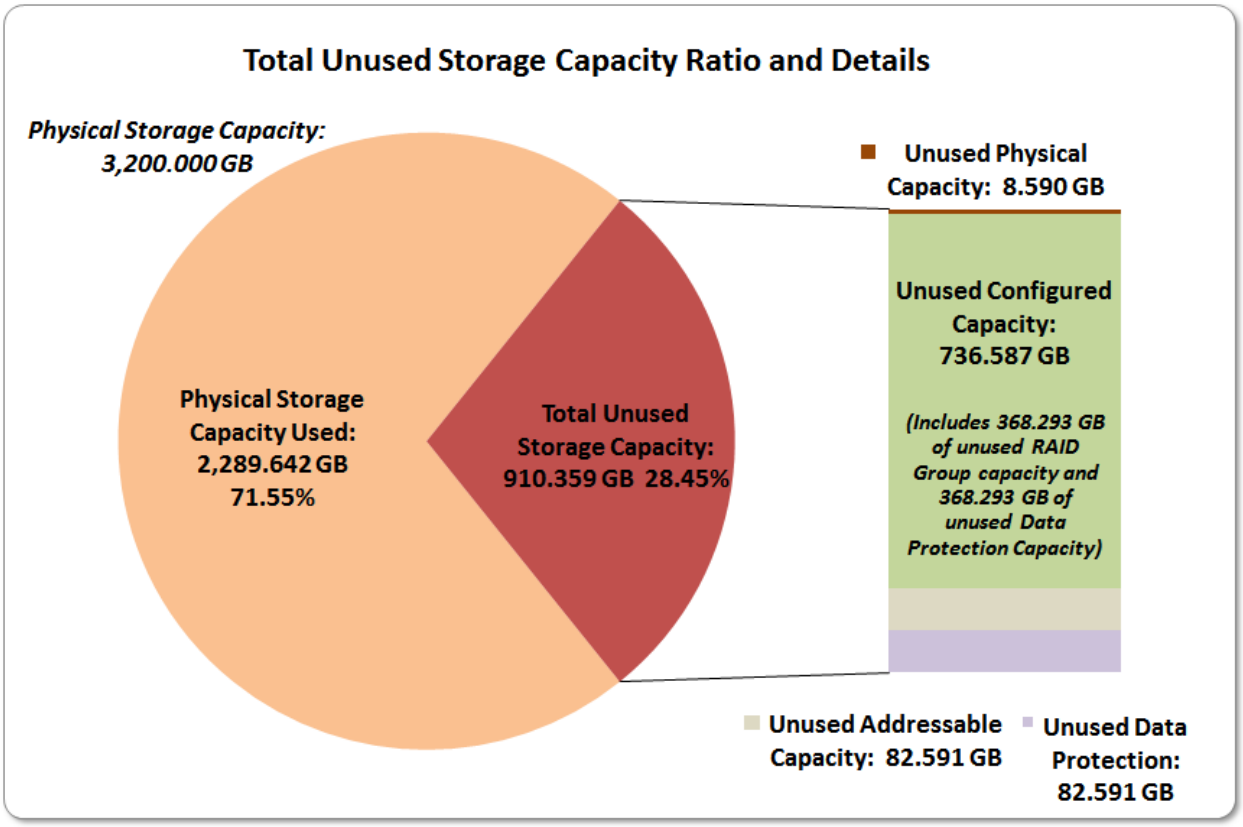
	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	93.13%	35.65%	35.00%
Required for Data Protection *(Mirroring)*		50.00%	49.09%
Addressable Storage Capacity		38.28%	37.58%
Required Storage *(sparing capacity)*		0.00%	0.00%
Configured Storage Capacity			98.18%
Global Storage Overhead			1.55%
Unused Storage:			
Addressable	6.87%		
Configured		23.44%	
Physical			0.27%

SPC-1 Storage Capacity Charts




Configured Storage Capacity: 3,141.769 GB
Configured Storage Capacity Available for Application Use: 3,141.769 GB 100.00%
Addressable Storage Capacity: 1,202.591 GB 38.28%
Data Protection Capacity (used): 1,120.000 GB 35.65%
Unused Data Capacity: 368.293 GB 11.72%
Data Protection Capacity (unused): 450.884 GB 14.35%


Addressable Storage Capacity: 1,202.591 GB
2 Logical Volumes, 270.583 GB per Volume (ASU-1)
2 Logical Volumes, 270.583 GB per Volume (ASU-2)
2 Logical Volumes, 60.130 GB per Volume (ASU-3)
ASU Capacity: 1,120.000 GB 93.13%
Unused Addressable Capacity: 82.591 GB 6.87%
ASU-1 Capacity: 504.000 GB 41.91%
2 Logical Volumes, 252.000 GB per Volume
ASU-2 Capacity: 504.000 GB 41.91%
2 Logical Volumes, 252.000 GB per Volume
ASU-3 Capacity: 112.000 GB 9.31%
2 Logical Volumes, 56.000 GB per Volume



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	35.00%
Protected Application Utilization	70.00%
Unused Storage Ratio	28.45%

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 (504.000 GB)	**ASU-2 (504.000 GB)**	**ASU-3 (112.000 GB)**
2 Logical Volumes 270.583 GB per Logical Volume (252.000 GB used per Logical Volume)	2 Logical Volumes 270.583 GB per Logical Volume (252.000 GB used per Logical Volume)	2 Logical Volumes 60.130 GB per Logical Volume (56.000 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 60 contains definitions of terms specific to the SPC-1 Tests, Test Phases, and Test Runs.

Clause 5.4.3

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

SPC-1 Tests, Test Phases, and Test Runs

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

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

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

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

"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 72.

Sustainability Test Results File

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

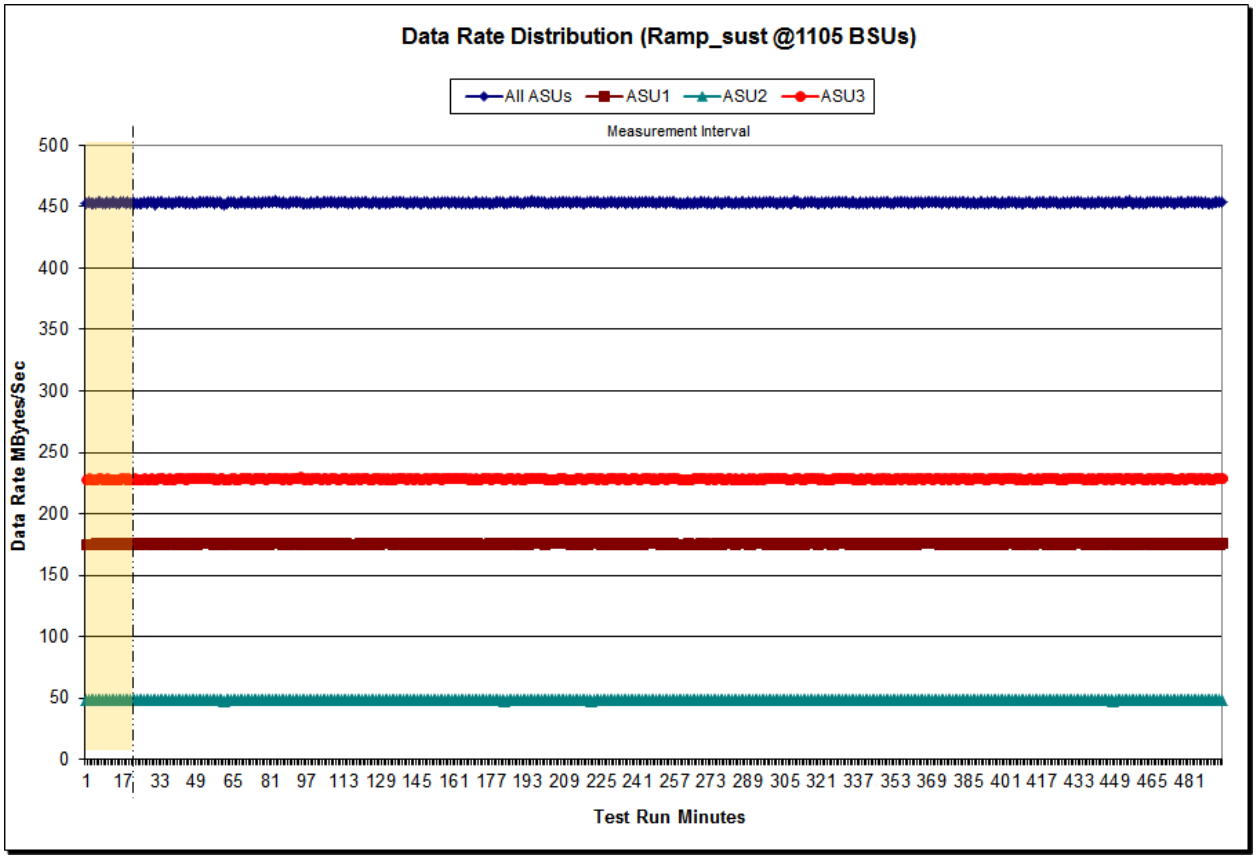
Sustainability Test Results File

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

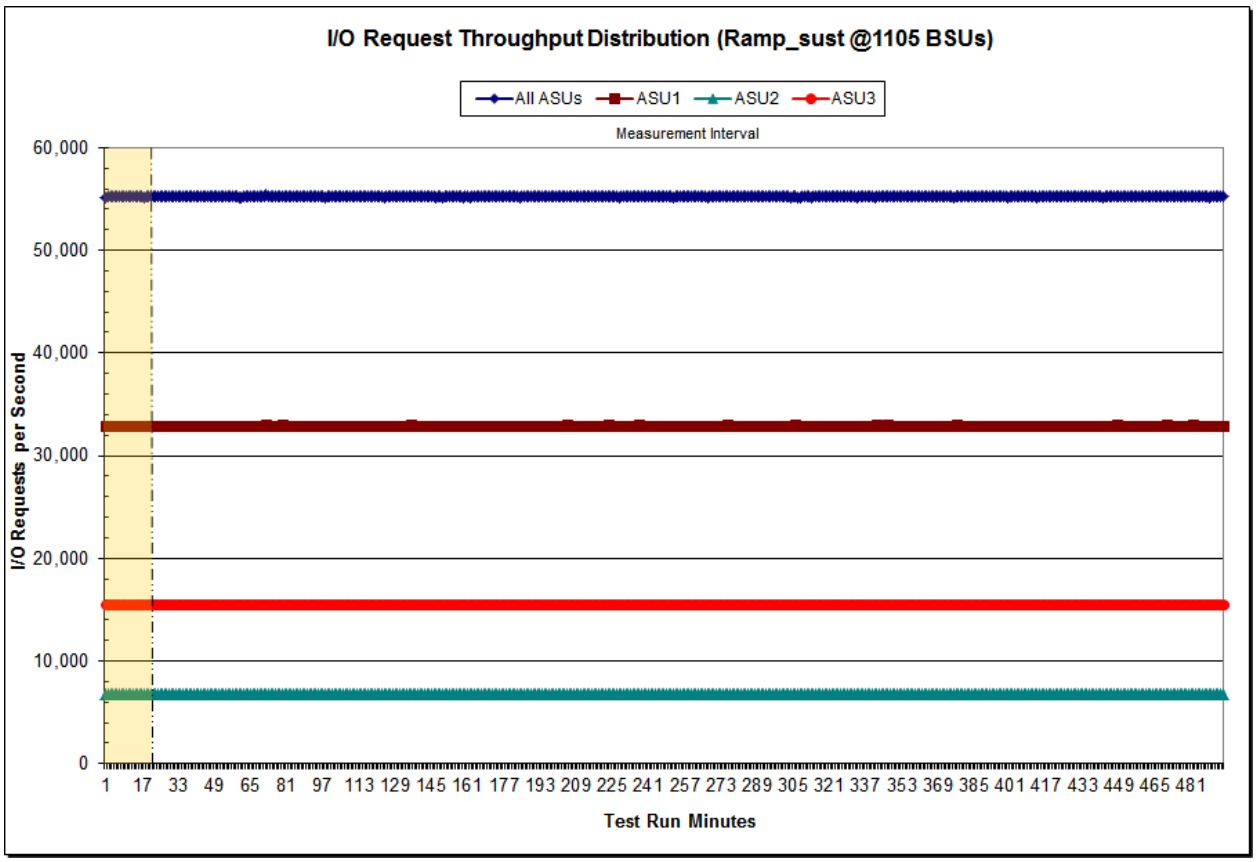


Sustainability – I/O Request Throughput Distribution Data

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

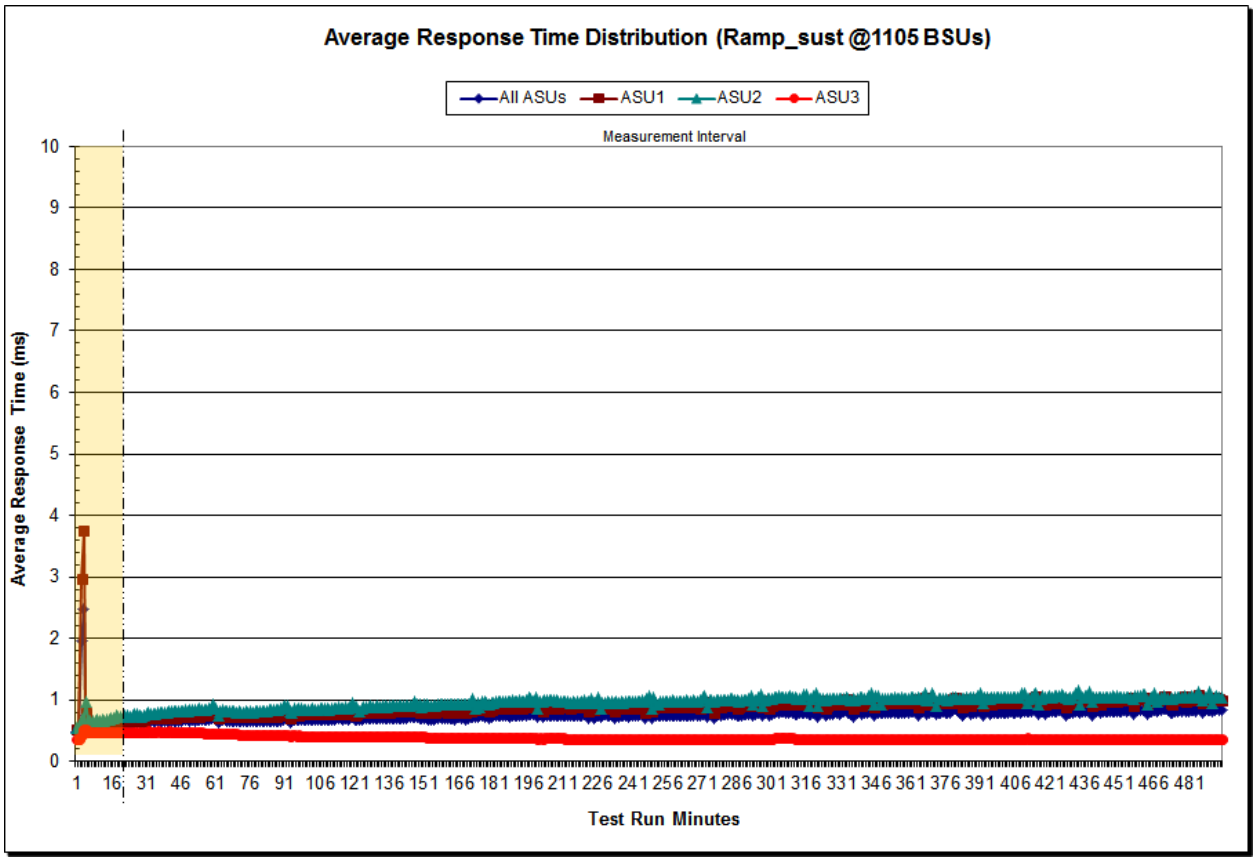


Sustainability – Average Response Time (ms) Distribution Data

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



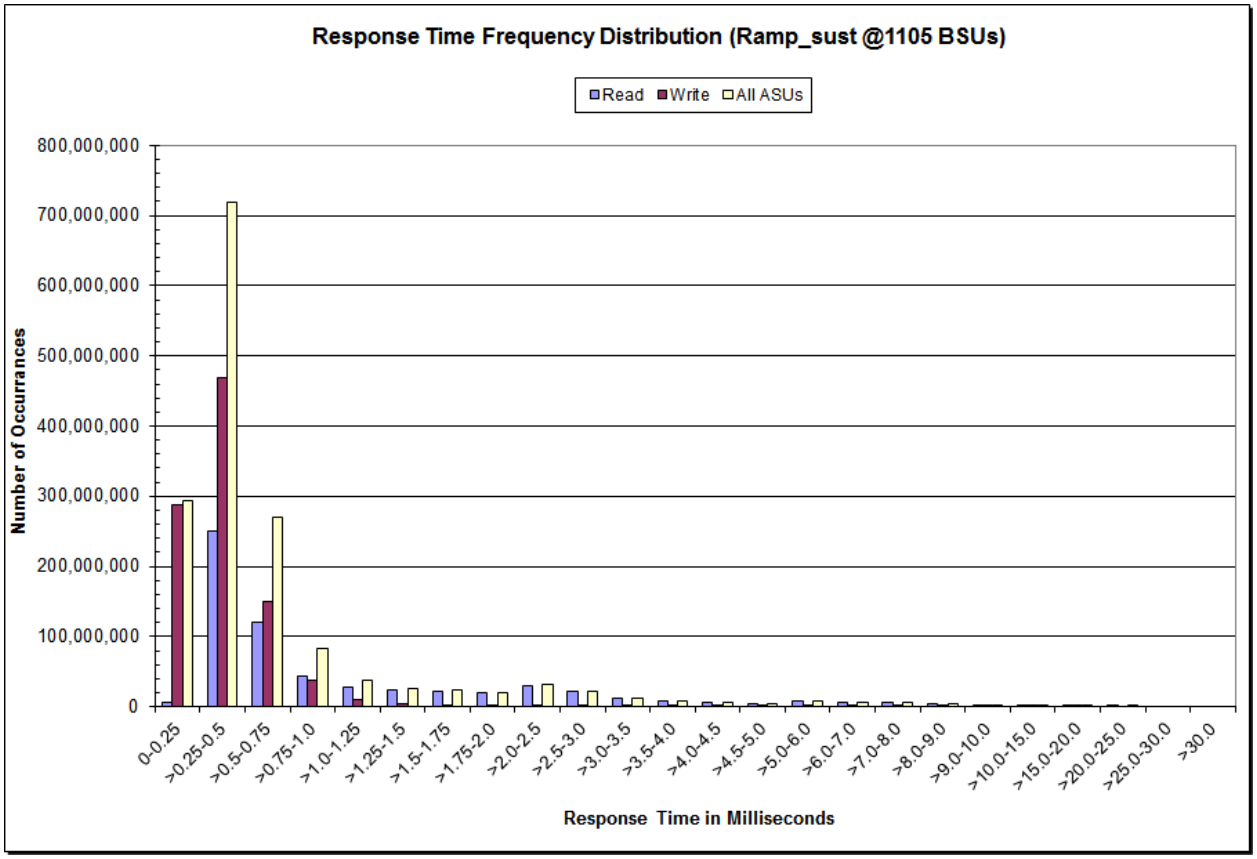
Sustainability – Response Time Frequency Distribution Data

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	6,294,111	249,632,339	120,874,247	44,531,020	27,759,517	23,384,230	21,642,592	19,347,823
Write	287,481,180	469,759,976	149,879,609	37,787,638	9,777,055	3,349,590	1,626,524	1,002,166
All ASUs	293,775,291	719,392,315	270,753,856	82,318,658	37,536,572	26,733,820	23,269,116	20,349,989
ASU1	139,470,172	416,359,754	163,645,683	51,682,214	26,948,351	20,977,835	18,874,280	16,663,085
ASU2	32,878,097	77,440,932	33,107,576	11,691,302	5,838,474	4,340,768	3,882,155	3,473,546
ASU3	121,427,022	225,591,629	74,000,597	18,945,142	4,749,747	1,415,217	512,681	213,358

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	30,749,502	21,789,297	11,644,210	8,054,662	6,156,398	5,025,597	8,106,939	6,253,816
Write	1,199,448	722,582	445,945	258,527	147,030	76,003	59,442	17,136
All ASUs	31,948,950	22,511,879	12,090,155	8,313,189	6,303,428	5,101,600	8,166,381	6,270,952
ASU1	26,066,976	17,954,956	9,536,020	6,599,900	5,031,353	4,090,588	6,536,915	5,005,230
ASU2	5,735,518	4,505,420	2,529,465	1,700,131	1,264,462	1,007,472	1,626,621	1,265,101
ASU3	146,456	51,503	24,670	13,158	7,613	3,540	2,845	621

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	5,373,599	4,636,644	3,171,965	3,106,696	9,855	246	44	29
Write	5,741	2,491	1,404	1,376	285	39	-	1
All ASUs	5,379,340	4,639,135	3,173,369	3,108,072	10,140	285	44	30
ASU1	4,290,176	3,677,337	2,498,474	2,413,093	8,557	265	42	23
ASU2	1,089,002	961,688	674,788	694,867	1,580	19	2	6
ASU3	162	110	107	112	3	1	-	1

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	0.003	0.001	0.002	0.001	0.004	0.002	0.003	0.001

Primary Metrics Test – IOPS Test Phase

Clause 5.4.4.2

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

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

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

Clause 9.4.3.7.3

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 72.

IOPS Test Results File

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

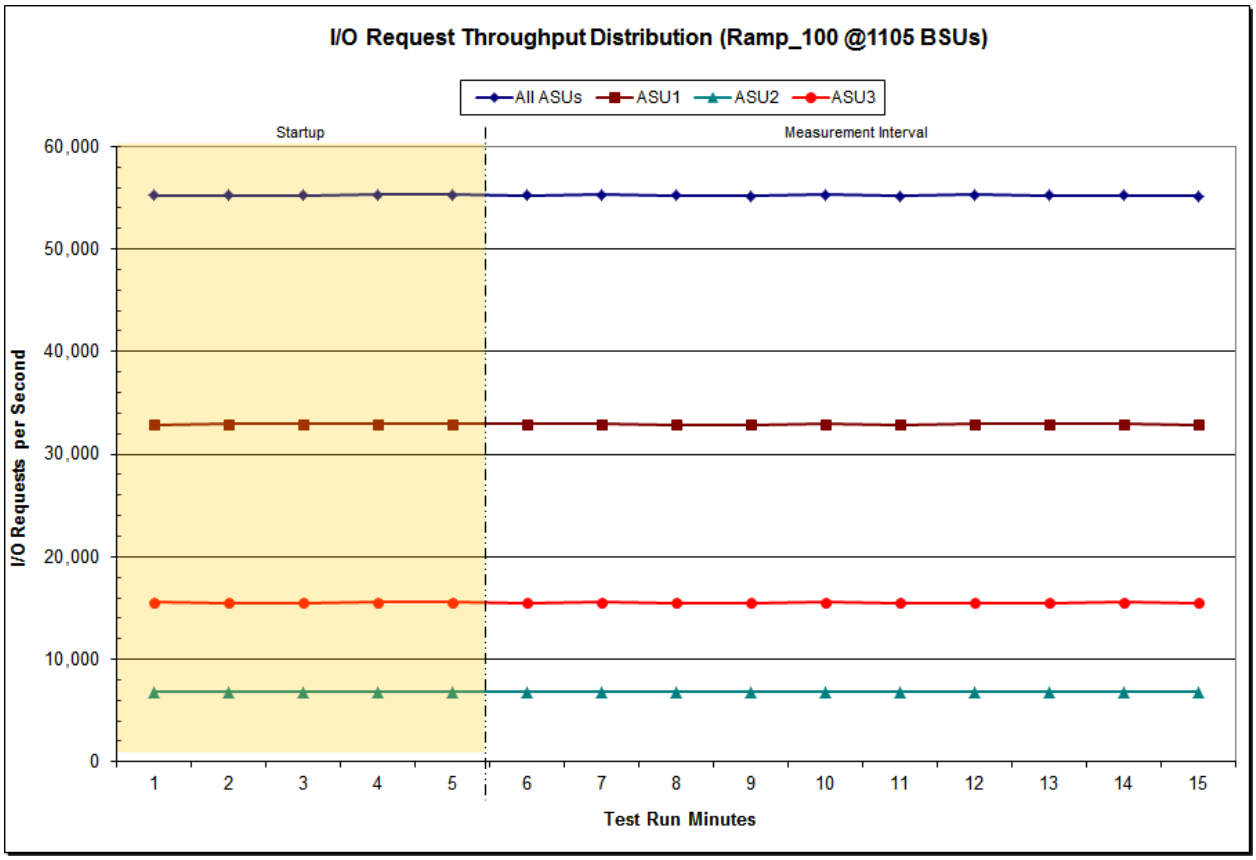
IOPS Test Results File

IOPS Test Run – I/O Request Throughput Distribution Data

1,105 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	15:45:57	15:50:58	0-4	0:05:01
Measurement Interval	15:50:58	16:00:58	5-14	0:10:00

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	55,227.60	32,882.43	6,802.48	15,542.68
1	55,251.45	32,916.70	6,808.93	15,525.82
2	55,225.83	32,918.07	6,795.18	15,512.58
3	55,303.40	32,932.28	6,813.63	15,557.48
4	55,264.75	32,939.00	6,785.53	15,540.22
5	55,249.20	32,932.35	6,794.20	15,522.65
6	55,297.90	32,950.35	6,813.07	15,534.48
7	55,209.43	32,902.73	6,802.75	15,503.95
8	55,187.35	32,867.63	6,799.58	15,520.13
9	55,269.77	32,940.40	6,795.85	15,533.52
10	55,170.20	32,890.47	6,786.10	15,493.63
11	55,287.42	32,961.17	6,802.60	15,523.65
12	55,246.73	32,934.50	6,796.60	15,515.63
13	55,257.92	32,933.35	6,788.28	15,536.28
14	55,176.92	32,899.45	6,791.37	15,486.10
Average	***55,235.28***	***32,921.24***	***6,797.04***	***15,517.00***

IOPS Test Run – I/O Request Throughput Distribution Graph

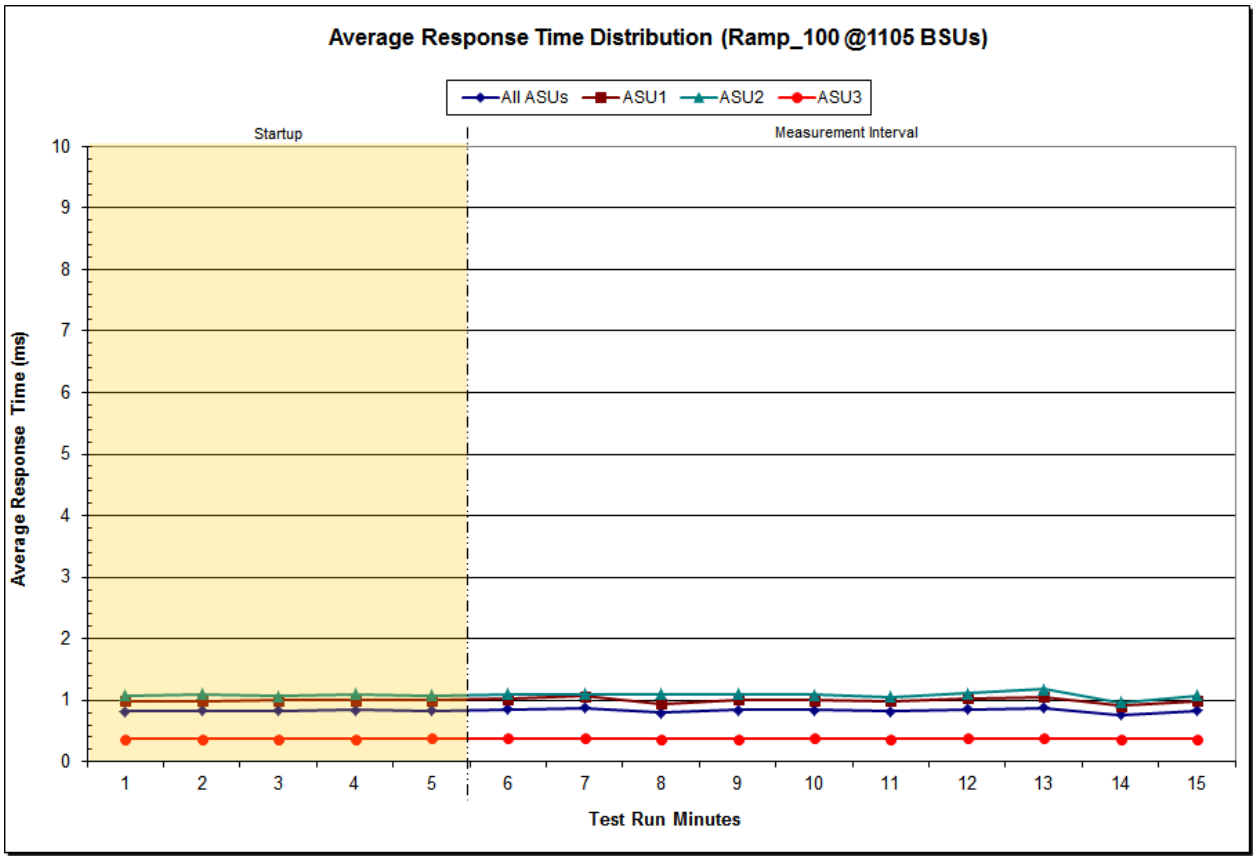


IOPS Test Run – Average Response Time (ms) Distribution Data

1,105 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	15:45:57	15:50:58	0-4	0:05:01
Measurement Interval	15:50:58	16:00:58	5-14	0:10:00

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	0.83	0.99	1.08	0.37
1	0.83	0.99	1.10	0.37
2	0.83	1.00	1.07	0.38
3	0.84	1.00	1.10	0.38
4	0.84	1.00	1.08	0.38
5	0.85	1.02	1.10	0.38
6	0.88	1.07	1.10	0.38
7	0.80	0.94	1.11	0.37
8	0.84	1.01	1.10	0.38
9	0.84	1.00	1.09	0.38
10	0.83	0.99	1.06	0.38
11	0.86	1.03	1.12	0.38
12	0.88	1.05	1.18	0.38
13	0.77	0.91	0.97	0.37
14	0.83	0.99	1.08	0.38
Average	***0.84***	***1.00***	***1.09***	***0.38***

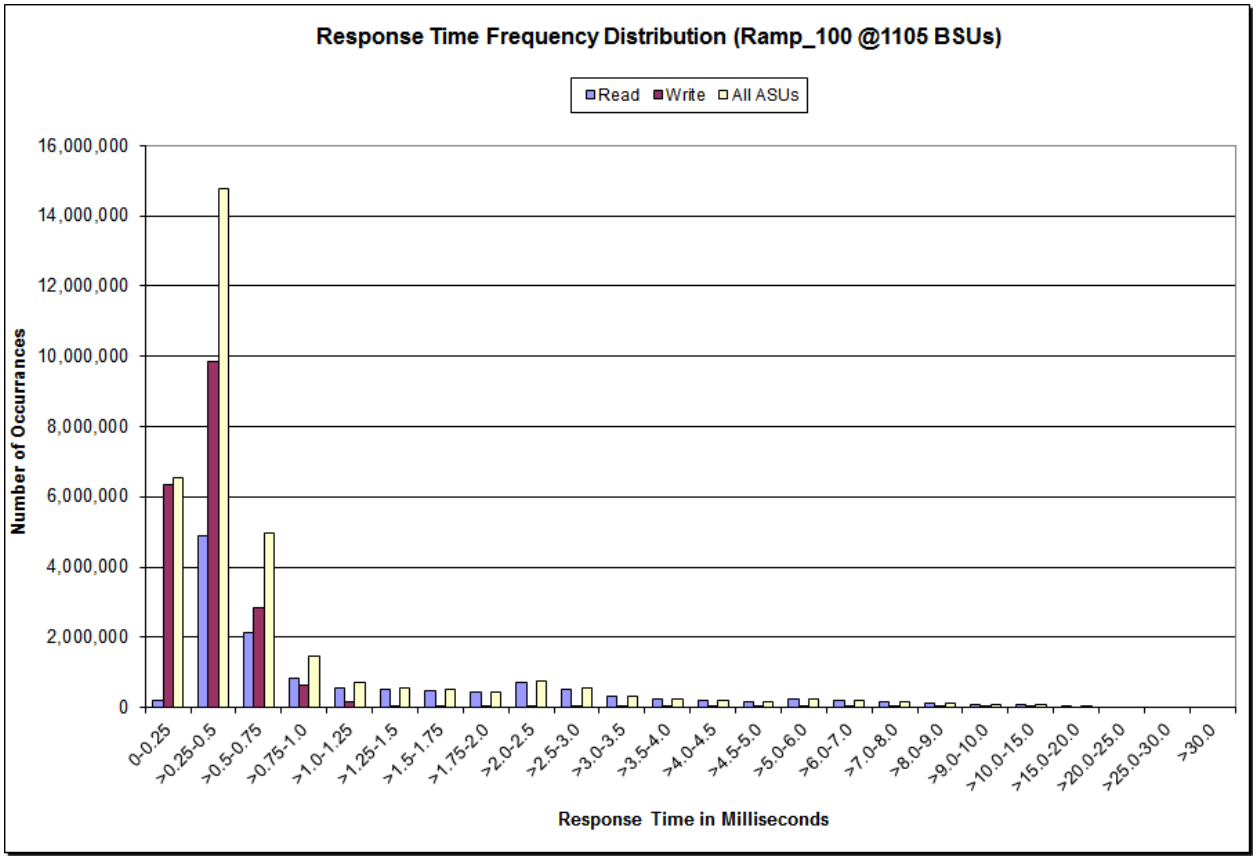
IOPS Test Run – Average Response Time (ms) Distribution Graph



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	194,530	4,887,879	2,137,431	834,225	572,707	502,277	471,425	428,300
Write	6,335,852	9,867,154	2,842,250	638,799	159,644	62,789	37,807	27,396
All ASUs	6,530,382	14,755,033	4,979,681	1,473,024	732,351	565,066	509,232	455,696
ASU1	3,157,926	8,399,506	2,936,541	939,374	544,809	452,936	416,684	374,331
ASU2	748,745	1,559,174	590,523	205,674	114,582	91,466	84,972	78,128
ASU3	2,623,711	4,796,353	1,452,617	327,976	72,960	20,664	7,576	3,237
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	704,828	531,925	315,903	234,432	186,124	153,029	246,043	185,451
Write	37,616	24,459	15,536	9,360	5,657	2,773	2,029	470
All ASUs	742,444	556,384	331,439	243,792	191,781	155,802	248,072	185,921
ASU1	605,820	446,454	264,365	195,623	154,378	126,043	200,639	150,162
ASU2	134,251	108,798	66,393	47,748	37,137	29,639	47,358	35,733
ASU3	2,373	1,132	681	421	266	120	75	26
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	158,168	136,024	94,180	96,075	327	1	-	-
Write	162	65	17	13	-	-	-	-
All ASUs	158,330	136,089	94,197	96,088	327	1	-	-
ASU1	127,769	108,807	74,790	75,487	274	1	-	-
ASU2	30,558	27,280	19,407	20,598	53	-	-	-
ASU3	3	2	-	3	-	-	-	-

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
33,141,132	33,141,132	0

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	0.2811	0.0701	0.2099	0.0180	0.0700	0.0350	0.2809
COV	0.003	0.001	0.002	0.001	0.004	0.002	0.003	0.001

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 72.

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: 1,105 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	15:45:57	15:50:58	0-4	0:05:01
Measurement Interval	15:50:58	16:00:58	5-14	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	55,227.60	32,882.43	6,802.48	15,542.68
1	55,251.45	32,916.70	6,808.93	15,525.82
2	55,225.83	32,918.07	6,795.18	15,512.58
3	55,303.40	32,932.28	6,813.63	15,557.48
4	55,264.75	32,939.00	6,785.53	15,540.22
5	55,249.20	32,932.35	6,794.20	15,522.65
6	55,297.90	32,950.35	6,813.07	15,534.48
7	55,209.43	32,902.73	6,802.75	15,503.95
8	55,187.35	32,867.63	6,799.58	15,520.13
9	55,269.77	32,940.40	6,795.85	15,533.52
10	55,170.20	32,890.47	6,786.10	15,493.63
11	55,287.42	32,961.17	6,802.60	15,523.65
12	55,246.73	32,934.50	6,796.60	15,515.63
13	55,257.92	32,933.35	6,788.28	15,536.28
14	55,176.92	32,899.45	6,791.37	15,486.10
Average	***55,235.28***	***32,921.24***	***6,797.04***	***15,517.00***

95% Load Level: 1,049 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	16:01:00	16:06:01	0-4	0:05:01
Measurement Interval	16:06:01	16:16:01	5-14	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	52,464.85	31,289.68	6,447.82	14,727.35
1	52,387.58	31,236.57	6,448.40	14,702.62
2	52,454.88	31,243.08	6,454.58	14,757.22
3	52,474.12	31,267.45	6,466.25	14,740.42
4	52,490.73	31,277.25	6,465.75	14,747.73
5	52,476.07	31,272.38	6,455.33	14,748.35
6	52,444.18	31,251.85	6,455.00	14,737.33
7	52,497.23	31,304.93	6,458.02	14,734.28
8	52,455.57	31,266.02	6,454.07	14,735.48
9	52,498.60	31,258.07	6,457.07	14,783.47
10	52,455.30	31,263.47	6,457.58	14,734.25
11	52,486.98	31,260.73	6,465.22	14,761.03
12	52,463.83	31,263.72	6,460.15	14,739.97
13	52,455.62	31,266.90	6,451.90	14,736.82
14	52,417.75	31,228.72	6,446.75	14,742.28
Average	***52,465.11***	***31,263.68***	***6,456.11***	***14,745.33***

90% Load Level: 994 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	16:16:03	16:21:04	0-4	0:05:01
Measurement Interval	16:21:04	16:31:04	5-14	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	49,734.52	29,639.50	6,097.28	13,997.73
1	49,744.97	29,639.32	6,120.37	13,985.28
2	49,670.43	29,612.43	6,086.08	13,971.92
3	49,687.58	29,623.47	6,105.18	13,958.93
4	49,717.82	29,640.45	6,109.78	13,967.58
5	49,646.25	29,573.35	6,119.88	13,953.02
6	49,744.78	29,647.07	6,131.50	13,966.22
7	49,665.45	29,593.18	6,117.82	13,954.45
8	49,710.05	29,621.93	6,117.12	13,971.00
9	49,738.47	29,631.43	6,121.72	13,985.32
10	49,700.77	29,625.75	6,111.30	13,963.72
11	49,670.22	29,598.13	6,111.47	13,960.62
12	49,735.28	29,644.77	6,114.93	13,975.58
13	49,673.95	29,636.18	6,092.20	13,945.57
14	49,738.32	29,634.70	6,124.23	13,979.38
Average	***49,702.35***	***29,620.65***	***6,116.22***	***13,965.49***

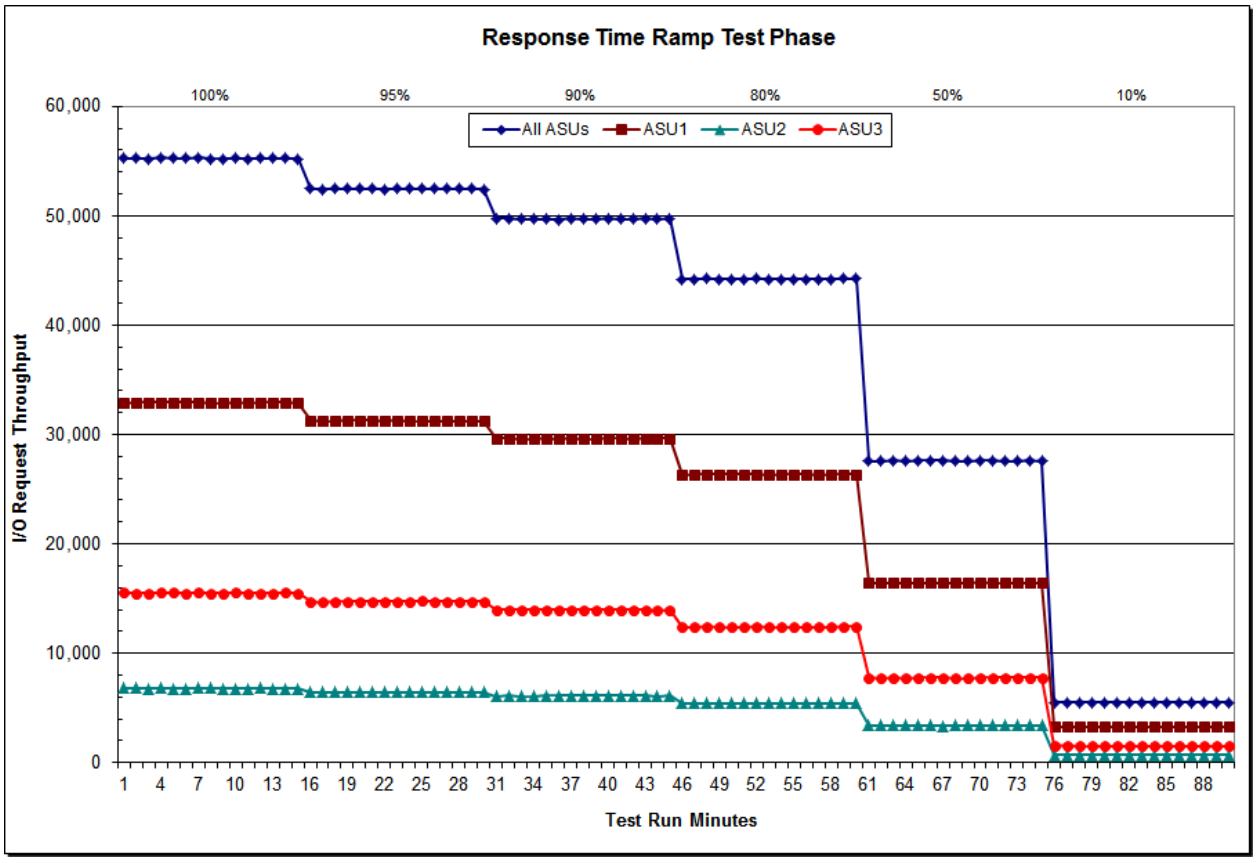
80% Load Level: 884 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	16:31:06	16:36:07	0-4	0:05:01
Measurement Interval	16:36:07	16:46:07	5-14	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	44,167.15	26,307.07	5,434.95	12,425.13
1	44,179.77	26,348.02	5,432.72	12,399.03
2	44,227.68	26,360.27	5,428.32	12,439.10
3	44,187.60	26,353.05	5,422.17	12,412.38
4	44,223.83	26,362.52	5,442.32	12,419.00
5	44,222.53	26,360.97	5,448.25	12,413.32
6	44,235.63	26,346.95	5,449.23	12,439.45
7	44,163.92	26,294.83	5,446.10	12,422.98
8	44,214.73	26,344.65	5,454.07	12,416.02
9	44,205.38	26,374.72	5,443.98	12,386.68
10	44,198.38	26,341.88	5,440.18	12,416.32
11	44,174.02	26,312.58	5,457.72	12,403.72
12	44,195.30	26,349.75	5,440.15	12,405.40
13	44,230.42	26,351.68	5,441.32	12,437.42
14	44,255.92	26,391.25	5,434.22	12,430.45
Average	***44,209.62***	***26,346.93***	***5,445.52***	***12,417.18***

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

50% Load Level: 552 BSUs	Start	Stop	Interval	Duration	10% Load Level: 110 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	16:46:09	16:51:10	0-4	0:05:01	Start-Up/Ramp-Up	17:01:12	17:06:13	0-4	0:05:01
Measurement Interval	16:51:10	17:01:10	5-14	0:10:00	Measurement Interval	17:06:13	17:16:13	5-14	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	27,588.73	16,424.75	3,396.38	7,767.60	0	5,503.77	3,283.87	678.95	1,540.95
1	27,576.97	16,437.78	3,401.58	7,737.60	1	5,510.75	3,282.52	670.73	1,557.50
2	27,640.00	16,474.23	3,397.07	7,768.70	2	5,511.95	3,277.70	682.73	1,551.52
3	27,583.22	16,426.52	3,407.70	7,749.00	3	5,488.70	3,274.27	674.20	1,540.23
4	27,615.25	16,459.17	3,398.65	7,757.43	4	5,504.07	3,282.00	676.90	1,545.17
5	27,611.72	16,448.97	3,396.63	7,766.12	5	5,502.35	3,278.67	675.25	1,548.43
6	27,602.83	16,464.35	3,385.97	7,752.52	6	5,501.17	3,274.05	685.30	1,541.82
7	27,591.18	16,436.17	3,404.67	7,750.35	7	5,501.67	3,283.22	682.22	1,536.23
8	27,590.68	16,439.67	3,408.52	7,742.50	8	5,490.40	3,272.70	676.20	1,541.50
9	27,662.38	16,479.60	3,398.85	7,783.93	9	5,496.52	3,267.45	677.65	1,551.42
10	27,608.47	16,461.40	3,393.15	7,753.92	10	5,495.98	3,275.08	673.38	1,547.52
11	27,571.73	16,418.83	3,396.32	7,756.58	11	5,495.00	3,276.15	673.42	1,545.43
12	27,585.13	16,432.28	3,390.63	7,762.22	12	5,500.48	3,277.65	674.83	1,548.00
13	27,608.75	16,440.95	3,398.32	7,769.48	13	5,516.22	3,286.58	679.52	1,550.12
14	27,584.07	16,428.07	3,397.12	7,758.88	14	5,501.38	3,274.15	674.22	1,553.02
Average	***27,601.70***	***16,445.03***	***3,397.02***	***7,759.65***	***Average***	***5,500.12***	***3,276.57***	***677.20***	***1,546.35***

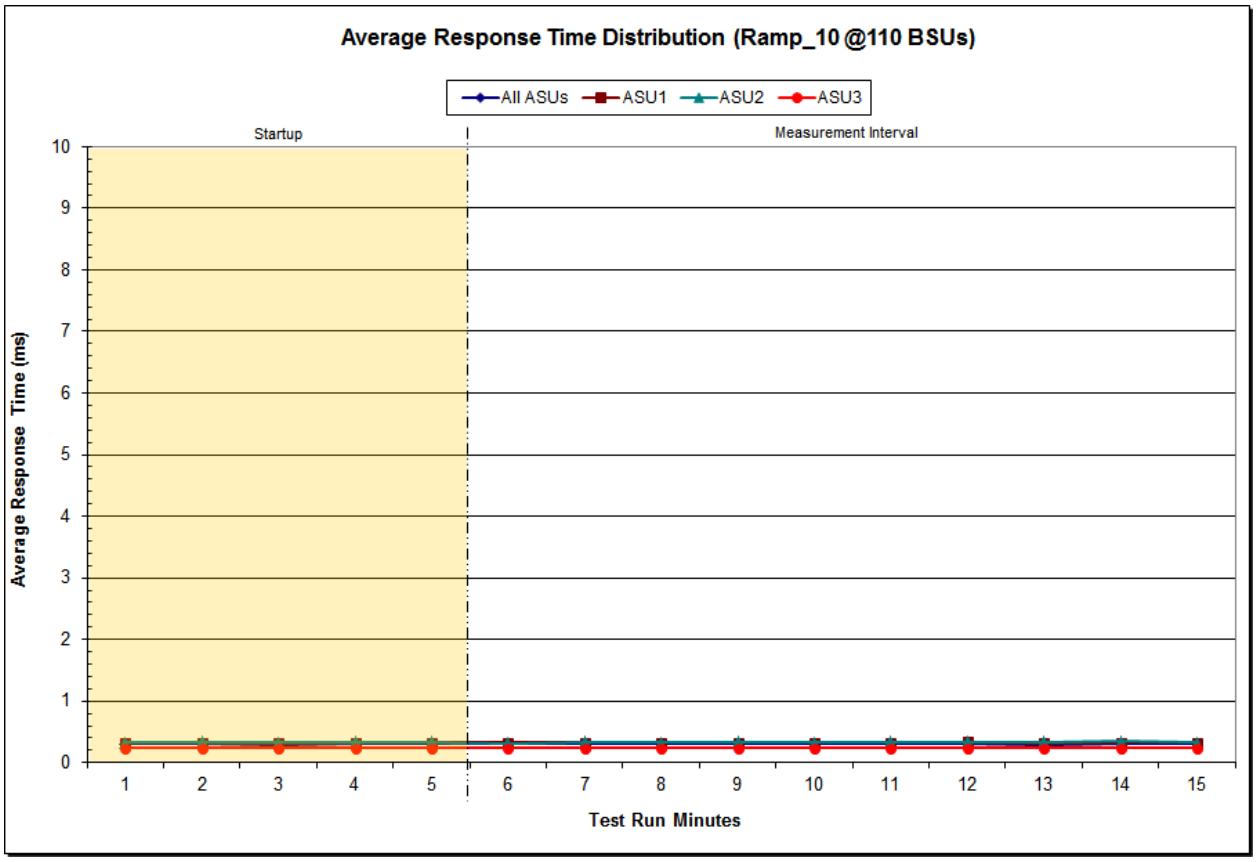
Response Time Ramp Distribution (IOPS) Graph



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

110 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:01:12	17:06:13	0-4	0:05:01
Measurement Interval	17:06:13	17:16:13	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.30	0.33	0.33	0.24
1	0.30	0.33	0.34	0.24
2	0.30	0.32	0.33	0.24
3	0.30	0.33	0.34	0.24
4	0.30	0.33	0.33	0.24
5	0.30	0.33	0.32	0.24
6	0.30	0.32	0.34	0.24
7	0.30	0.32	0.33	0.24
8	0.31	0.33	0.34	0.24
9	0.30	0.33	0.33	0.24
10	0.30	0.33	0.33	0.24
11	0.31	0.33	0.34	0.24
12	0.30	0.32	0.34	0.24
13	0.31	0.33	0.34	0.24
14	0.30	0.32	0.33	0.24
Average	***0.30***	***0.33***	***0.33***	***0.24***

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	0.2809	0.0700	0.2098	0.0181	0.0701	0.0349	0.2811
COV	0.009	0.003	0.006	0.004	0.015	0.008	0.013	0.003

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 72.

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	***55,235.28***
Repeatability Test Phase 1	55,258.88
Repeatability Test Phase 2	55,263.91

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	***0.30 ms***
Repeatability Test Phase 1	0.30 ms
Repeatability Test Phase 2	0.30 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).

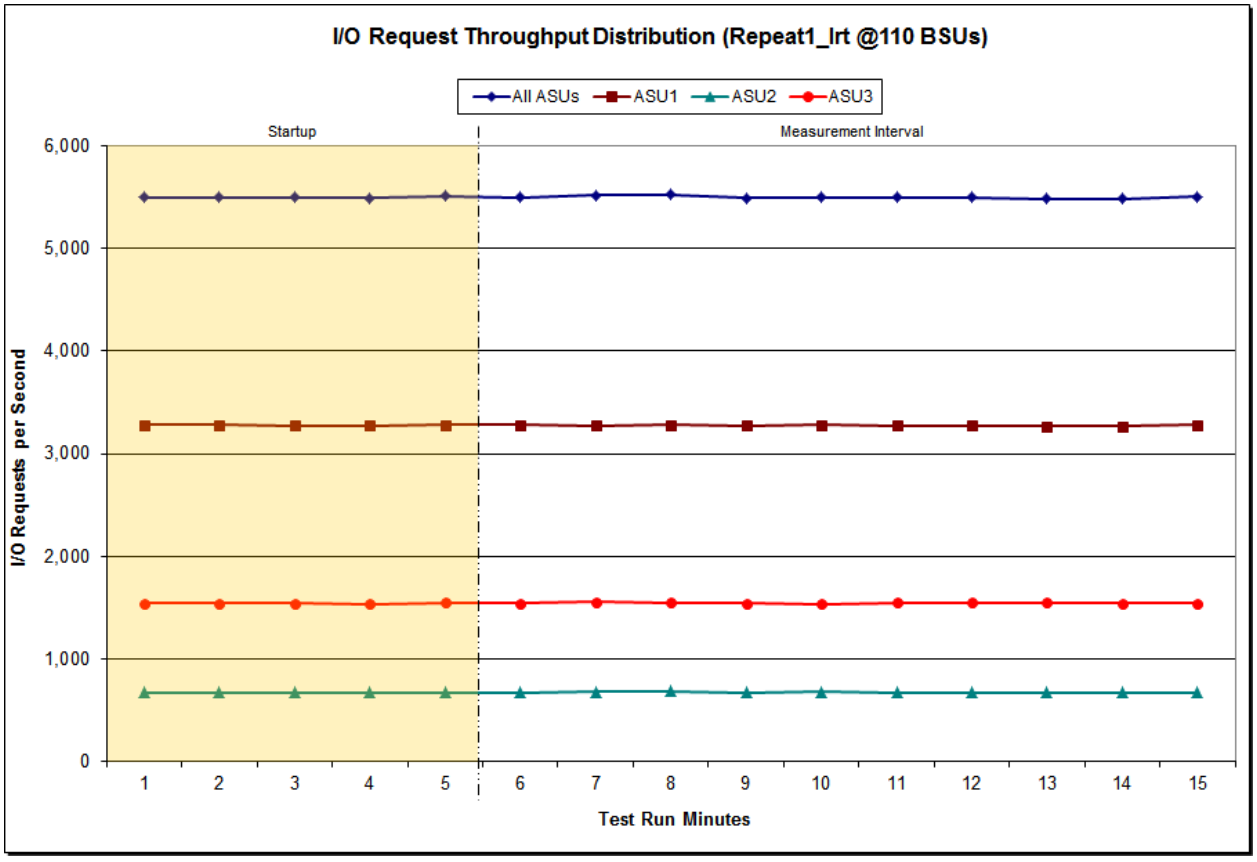
A link to the test result file generated from each Repeatability Test Run is listed below.

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

110 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:16:46	17:21:46	0-4	0:05:00
Measurement Interval	17:21:46	17:31:46	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	5,497.95	3,279.75	673.40	1,544.80
1	5,495.22	3,280.68	674.52	1,540.02
2	5,494.12	3,275.47	677.27	1,541.38
3	5,488.82	3,273.32	676.18	1,539.32
4	5,511.33	3,283.28	677.42	1,550.63
5	5,497.88	3,278.52	676.03	1,543.33
6	5,513.53	3,276.42	681.07	1,556.05
7	5,520.98	3,283.53	684.52	1,552.93
8	5,490.65	3,273.18	676.62	1,540.85
9	5,495.50	3,277.60	678.47	1,539.43
10	5,498.62	3,272.57	674.40	1,551.65
11	5,495.47	3,271.07	672.58	1,551.82
12	5,484.87	3,263.77	673.77	1,547.33
13	5,485.60	3,269.52	676.22	1,539.87
14	5,499.63	3,280.83	676.73	1,542.07
Average	***5,498.27***	***3,274.70***	***677.04***	***1,546.53***

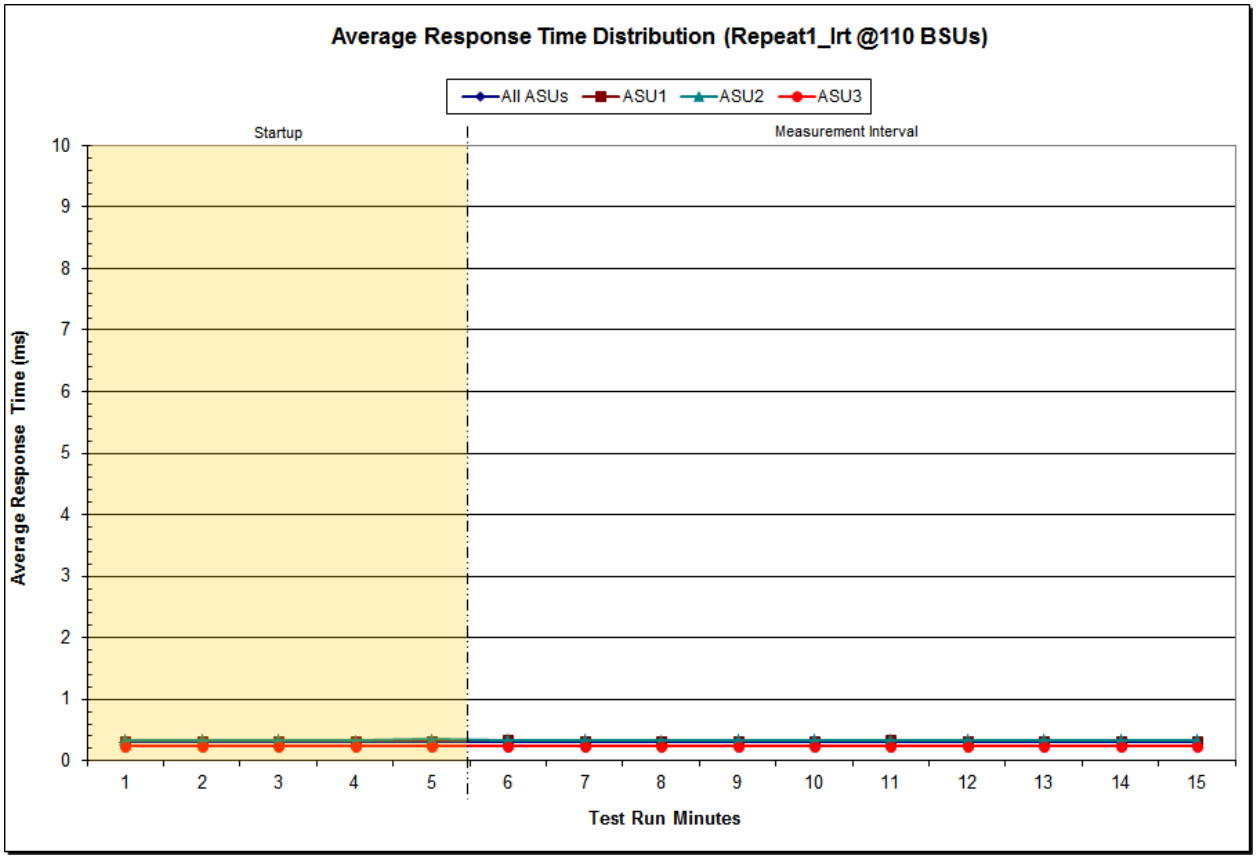
Repeatability 1 LRT – I/O Request Throughput Distribution Graph



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

110 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:16:46	17:21:46	0-4	0:05:00
Measurement Interval	17:21:46	17:31:46	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.30	0.32	0.34	0.24
1	0.30	0.33	0.34	0.24
2	0.30	0.33	0.34	0.24
3	0.30	0.32	0.33	0.24
4	0.30	0.32	0.35	0.24
5	0.31	0.34	0.34	0.24
6	0.30	0.32	0.34	0.24
7	0.31	0.33	0.33	0.24
8	0.30	0.32	0.34	0.24
9	0.30	0.32	0.34	0.24
10	0.31	0.33	0.34	0.24
11	0.30	0.33	0.34	0.24
12	0.30	0.33	0.34	0.24
13	0.31	0.33	0.34	0.24
14	0.30	0.33	0.34	0.24
Average	***0.30***	***0.33***	***0.34***	***0.24***

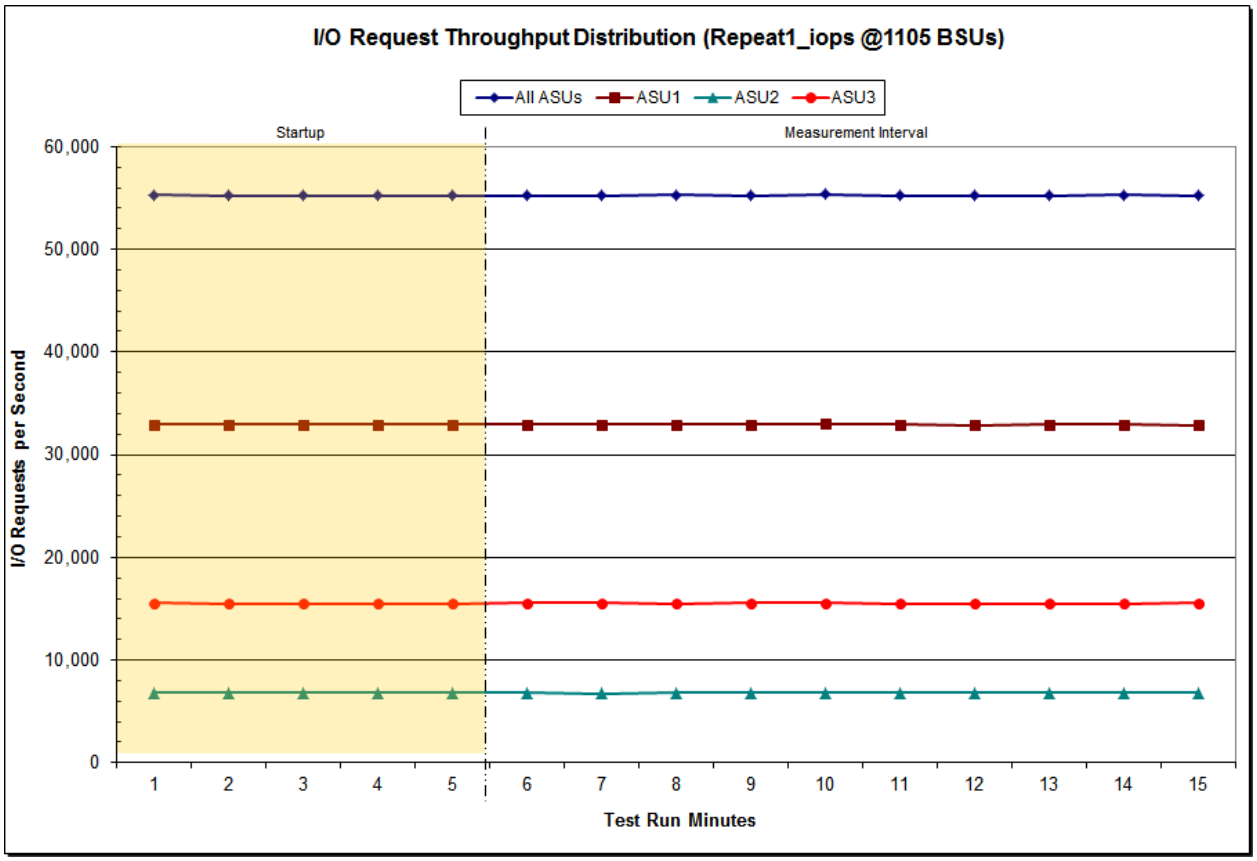
Repeatability 1 LRT –Average Response Time (ms) Distribution Graph



Repeatability 1 IOPS – I/O Request Throughput Distribution Data

1,105 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:31:49	17:36:50	0-4	0:05:01
Measurement Interval	17:36:50	17:46:50	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	55,282.53	32,939.08	6,805.23	15,538.22
1	55,236.07	32,917.85	6,805.15	15,513.07
2	55,230.77	32,928.50	6,782.62	15,519.65
3	55,234.87	32,925.75	6,790.28	15,518.83
4	55,245.67	32,934.52	6,790.50	15,520.65
5	55,250.65	32,911.00	6,799.95	15,539.70
6	55,250.88	32,948.05	6,768.02	15,534.82
7	55,264.03	32,938.50	6,801.20	15,524.33
8	55,255.78	32,915.23	6,803.95	15,536.60
9	55,335.62	32,995.30	6,801.12	15,539.20
10	55,260.30	32,921.90	6,826.43	15,511.97
11	55,200.07	32,902.70	6,784.62	15,512.75
12	55,241.35	32,921.07	6,803.13	15,517.15
13	55,292.72	32,967.75	6,800.47	15,524.50
14	55,237.40	32,899.52	6,799.80	15,538.08
Average	***55,258.88***	***32,932.10***	***6,798.87***	***15,527.91***

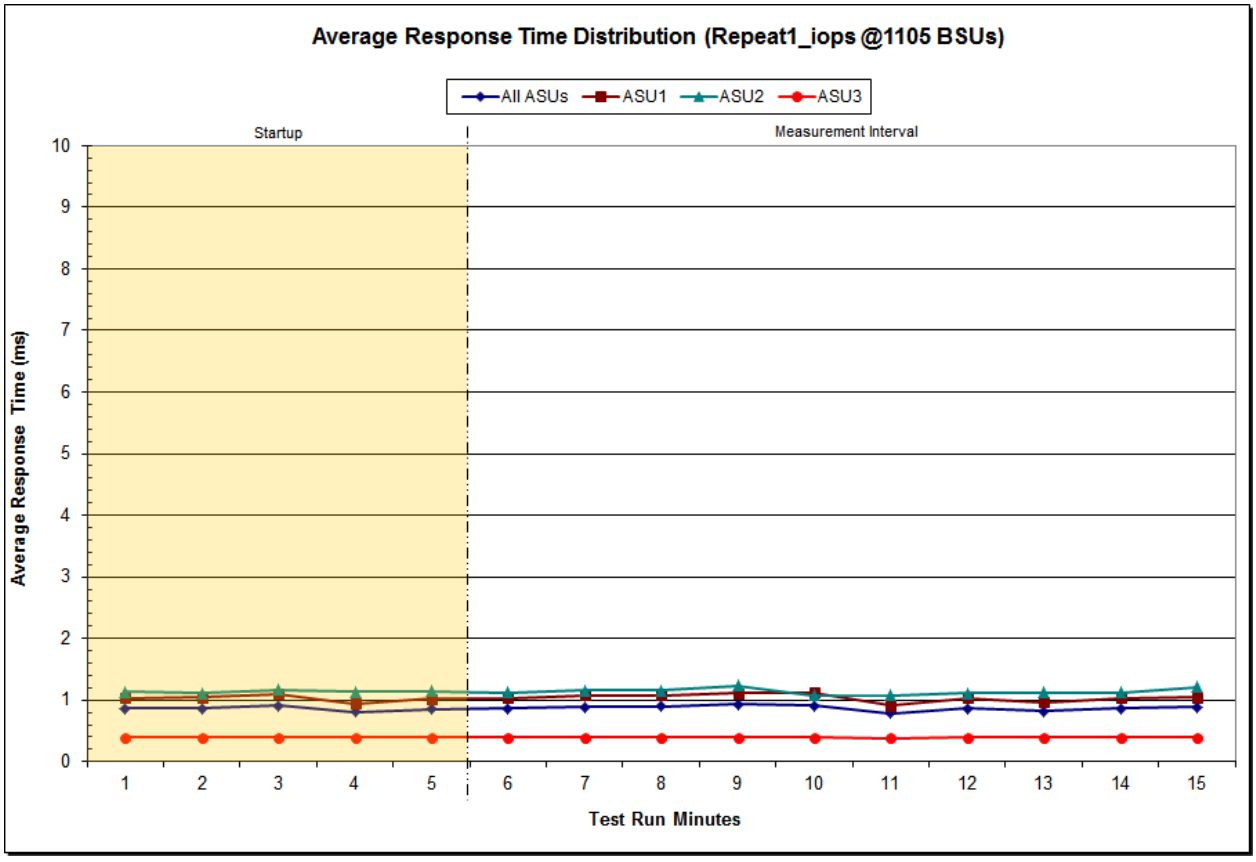
Repeatability 1 IOPS – I/O Request Throughput Distribution Graph



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

1,105 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:31:49	17:36:50	0-4	0:05:01
Measurement Interval	17:36:50	17:46:50	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.86	1.03	1.13	0.39
1	0.87	1.04	1.12	0.39
2	0.91	1.10	1.17	0.39
3	0.81	0.95	1.13	0.39
4	0.86	1.02	1.14	0.39
5	0.87	1.03	1.13	0.39
6	0.89	1.07	1.16	0.39
7	0.90	1.08	1.16	0.39
8	0.93	1.12	1.23	0.40
9	0.92	1.13	1.08	0.40
10	0.78	0.91	1.08	0.39
11	0.86	1.04	1.11	0.39
12	0.82	0.96	1.12	0.39
13	0.87	1.04	1.13	0.39
14	0.88	1.05	1.21	0.39
Average	***0.87***	***1.04***	***1.14***	***0.39***

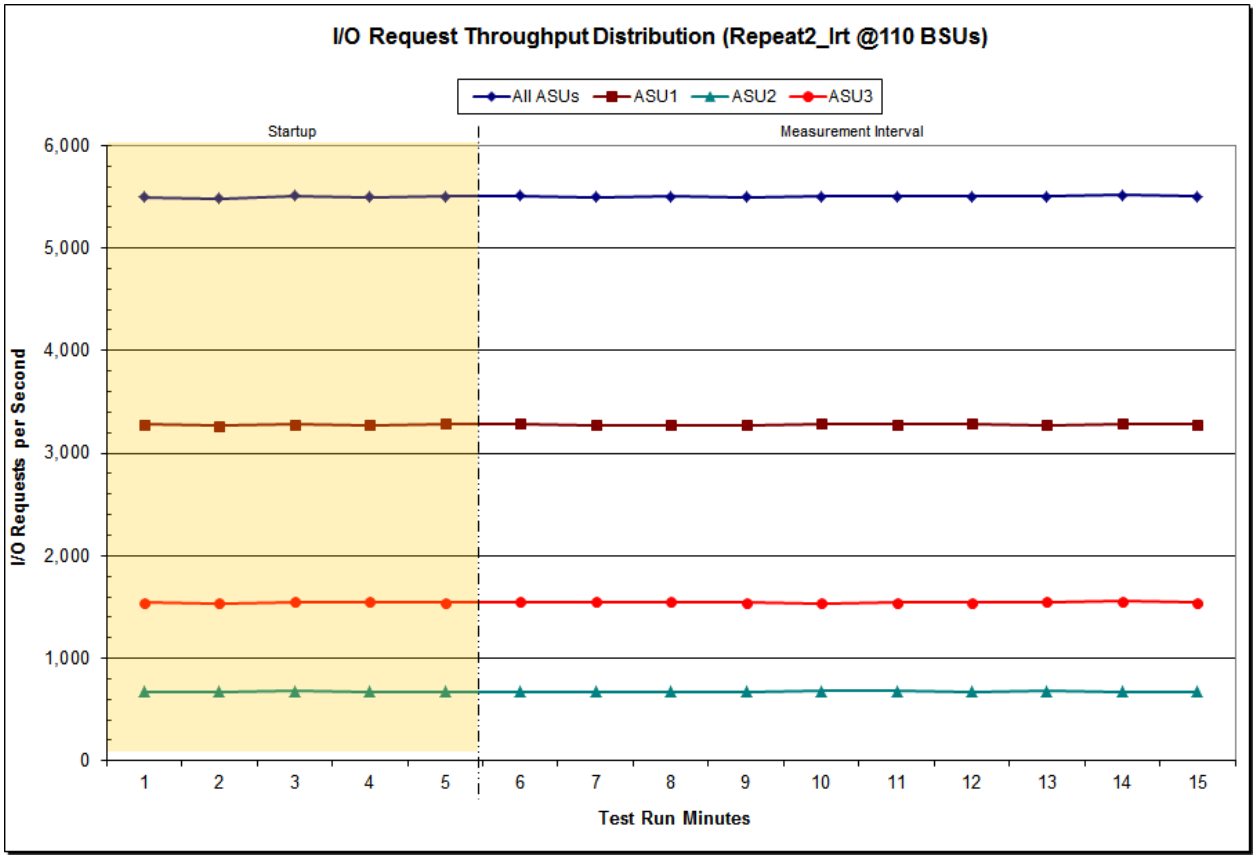
Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph



Repeatability 2 LRT – I/O Request Throughput Distribution Data

110 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:47:23	17:52:23	0-4	0:05:00
Measurement Interval	17:52:23	18:02:23	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	5,498.00	3,278.72	676.88	1,542.40
1	5,481.52	3,269.75	672.28	1,539.48
2	5,512.08	3,282.42	679.70	1,549.97
3	5,497.00	3,275.10	675.43	1,546.47
4	5,499.77	3,284.85	671.10	1,543.82
5	5,512.73	3,288.70	677.03	1,547.00
6	5,498.70	3,274.30	677.08	1,547.32
7	5,500.20	3,275.92	671.43	1,552.85
8	5,492.83	3,275.07	675.10	1,542.67
9	5,503.10	3,288.43	679.38	1,535.28
10	5,503.62	3,280.78	678.48	1,544.35
11	5,505.73	3,284.30	676.68	1,544.75
12	5,500.92	3,273.17	679.78	1,547.97
13	5,514.88	3,287.63	673.15	1,554.10
14	5,500.90	3,279.53	677.22	1,544.15
Average	***5,503.36***	***3,280.78***	***676.54***	***1,546.04***

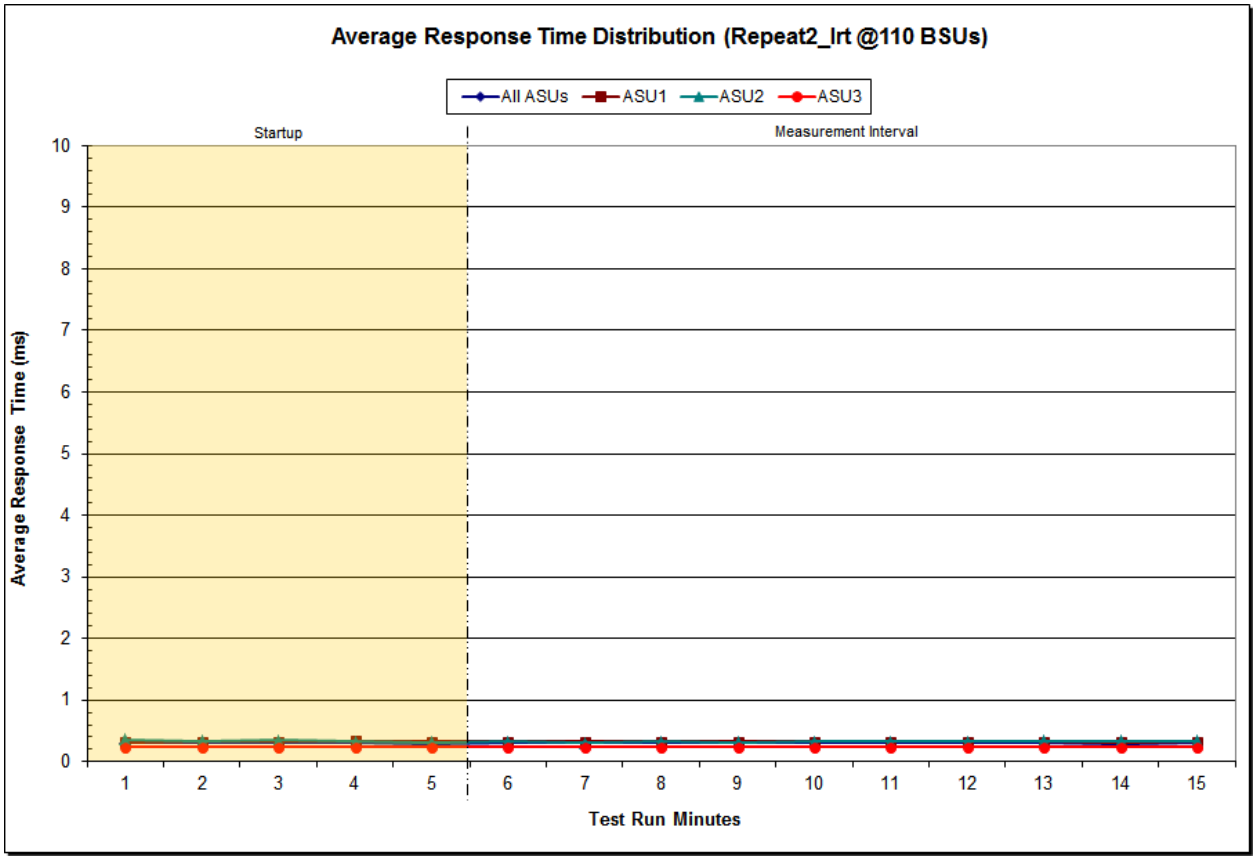
Repeatability 2 LRT – I/O Request Throughput Distribution Graph



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

110 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:47:23	17:52:23	0-4	0:05:00
Measurement Interval	17:52:23	18:02:23	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.30	0.32	0.36	0.24
1	0.30	0.33	0.33	0.24
2	0.30	0.32	0.35	0.24
3	0.31	0.33	0.33	0.24
4	0.30	0.32	0.31	0.24
5	0.30	0.33	0.33	0.24
6	0.30	0.33	0.31	0.24
7	0.30	0.33	0.33	0.24
8	0.30	0.33	0.31	0.24
9	0.30	0.32	0.33	0.24
10	0.30	0.33	0.32	0.24
11	0.30	0.33	0.33	0.24
12	0.31	0.33	0.33	0.24
13	0.30	0.32	0.34	0.24
14	0.30	0.32	0.34	0.24
Average	***0.30***	***0.33***	***0.33***	***0.24***

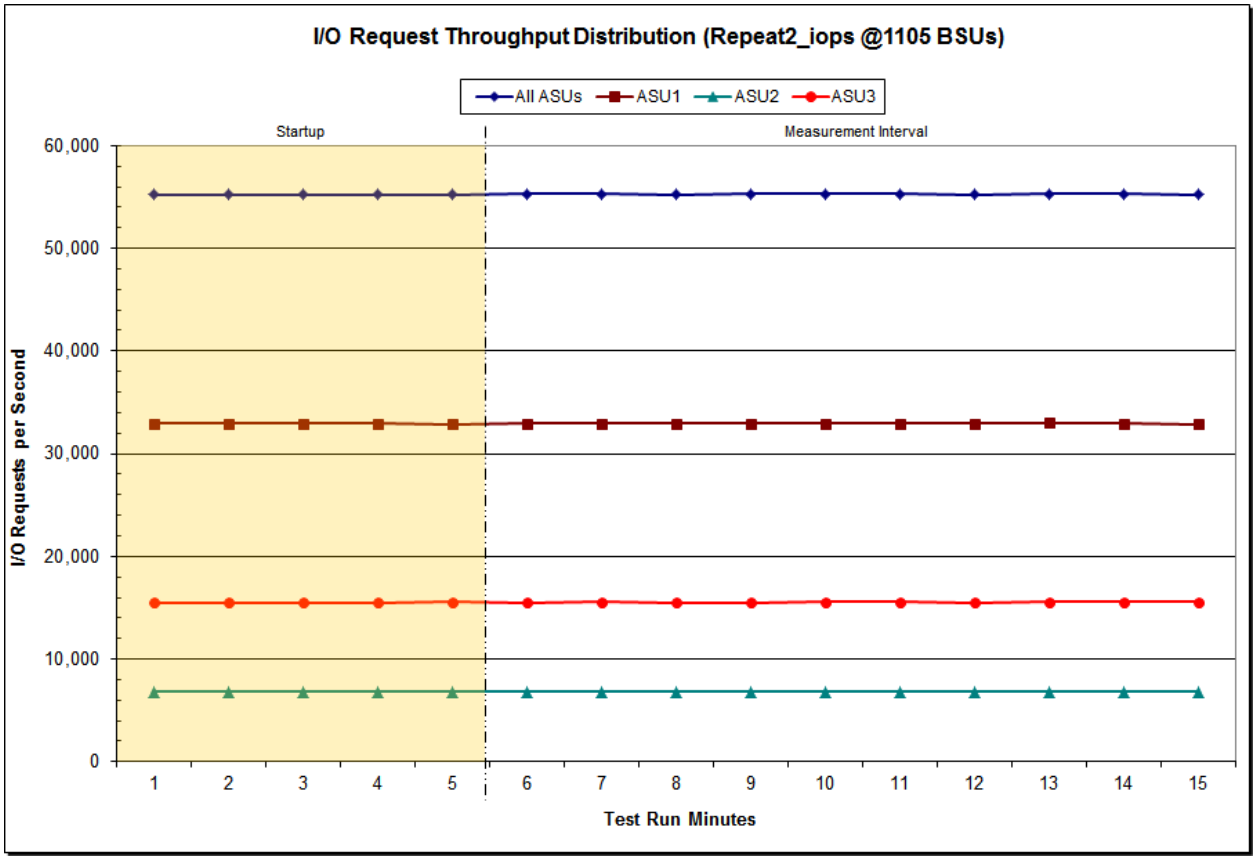
Repeatability 2 LRT –Average Response Time (ms) Distribution Graph



Repeatability 2 IOPS – I/O Request Throughput Distribution Data

1,105 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:02:27	18:07:28	0-4	0:05:01
Measurement Interval	18:07:28	18:17:28	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	55,217.67	32,916.67	6,795.12	15,505.88
1	55,228.80	32,926.72	6,786.30	15,515.78
2	55,254.95	32,934.73	6,802.88	15,517.33
3	55,257.73	32,955.85	6,786.98	15,514.90
4	55,236.48	32,893.63	6,806.88	15,535.97
5	55,265.47	32,943.97	6,792.77	15,528.73
6	55,276.92	32,964.10	6,782.50	15,530.32
7	55,258.20	32,944.50	6,792.52	15,521.18
8	55,269.03	32,938.60	6,814.48	15,515.95
9	55,266.90	32,944.13	6,790.55	15,532.22
10	55,286.47	32,955.55	6,795.07	15,535.85
11	55,198.90	32,929.05	6,792.83	15,477.02
12	55,307.15	32,977.53	6,792.08	15,537.53
13	55,288.88	32,952.57	6,782.08	15,554.23
14	55,221.22	32,891.10	6,796.55	15,533.57
Average	***55,263.91***	***32,944.11***	***6,793.14***	***15,526.66***

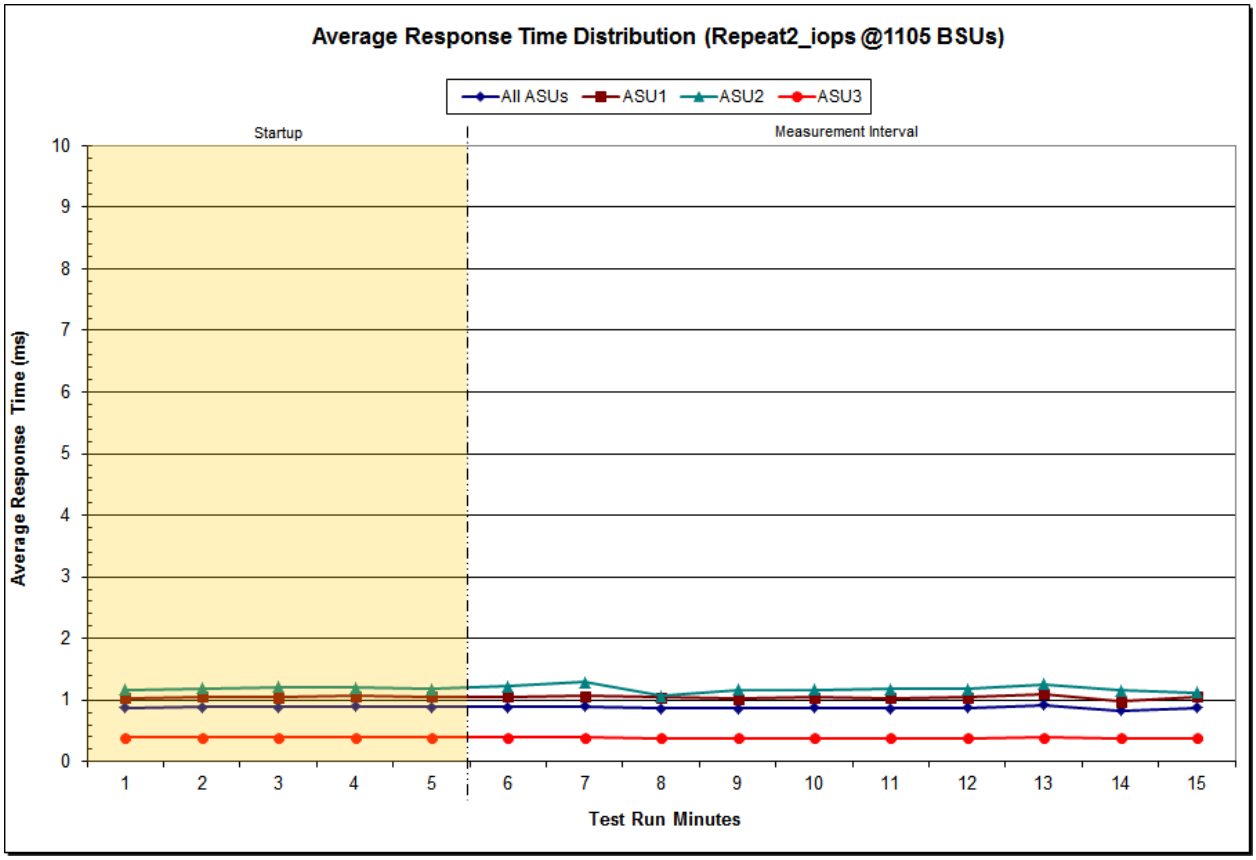
Repeatability 2 IOPS – I/O Request Throughput Distribution Graph



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

1,105 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:02:27	18:07:28	0-4	0:05:01
Measurement Interval	18:07:28	18:17:28	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.87	1.04	1.17	0.39
1	0.88	1.05	1.19	0.39
2	0.89	1.05	1.21	0.40
3	0.90	1.07	1.20	0.40
4	0.89	1.06	1.19	0.40
5	0.89	1.05	1.23	0.40
6	0.90	1.06	1.29	0.40
7	0.86	1.04	1.06	0.39
8	0.86	1.02	1.17	0.39
9	0.88	1.04	1.17	0.39
10	0.87	1.03	1.18	0.39
11	0.87	1.04	1.18	0.39
12	0.92	1.11	1.25	0.39
13	0.83	0.98	1.16	0.38
14	0.88	1.06	1.13	0.39
Average	***0.88***	***1.04***	***1.18***	***0.39***

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	0.0351	0.2805	0.0700	0.2100	0.0179	0.0702	0.0350	0.2813
COV	0.009	0.003	0.008	0.004	0.013	0.006	0.009	0.003

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

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

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2810	0.0700	0.2101	0.0181	0.0698	0.0351	0.2809
COV	0.008	0.002	0.003	0.003	0.017	0.005	0.009	0.003

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2811	0.0701	0.2100	0.0180	0.0699	0.0350	0.2810
COV	0.002	0.001	0.002	0.001	0.004	0.001	0.003	0.001

Data Persistence Test

Clause 6

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

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

The SPC-1 Workload Generator will write 16 block I/O requests at random over the total Addressable Storage Capacity of the TSC for ten (10) minutes at a minimum of 25% of the load used to generate the SPC-1 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 72.

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	132,430,192
Total Number of Logical Blocks Verified	84,508,624
Total Number of Logical Blocks that Failed Verification	0
Time Duration for Writing Test Logical Blocks	10 minutes
Size in bytes of each Logical Block	512
Number of Failed I/O Requests in the process of the Test	0

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

PRICED STORAGE CONFIGURATION AVAILABILITY DATE

Clause 9.4.3.9

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 Fujitsu Storage Systems ETERNUS DX100 S3 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.

There were no anomalies or irregularities encountered during the SPC-1 Remote Audit of the Fujitsu Storage Systems ETERNUS DX100 S3.

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.

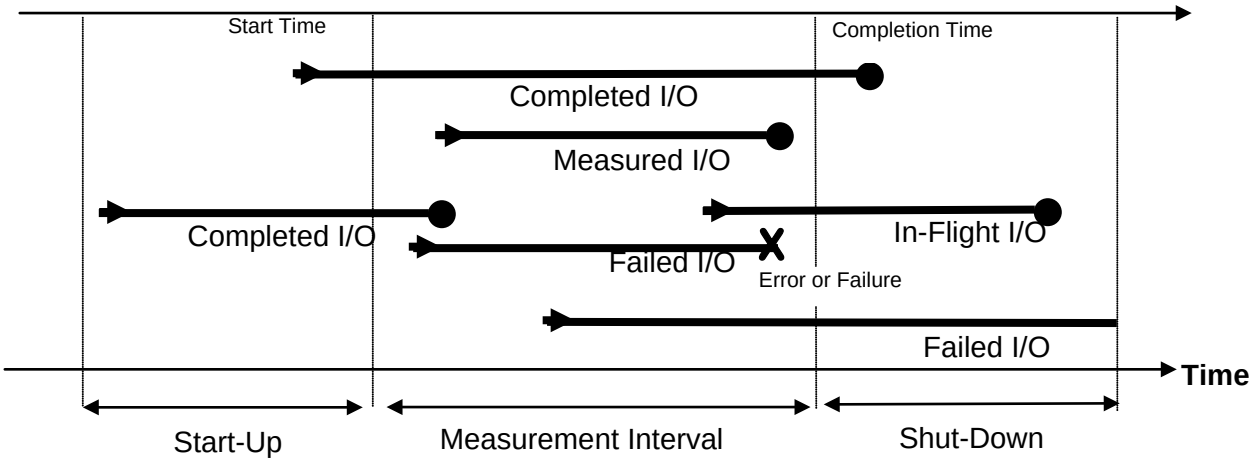
Steady State: The consistent and sustainable throughput of the TSC. During this period the load presented to the TSC by the Workload Generator is constant.

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

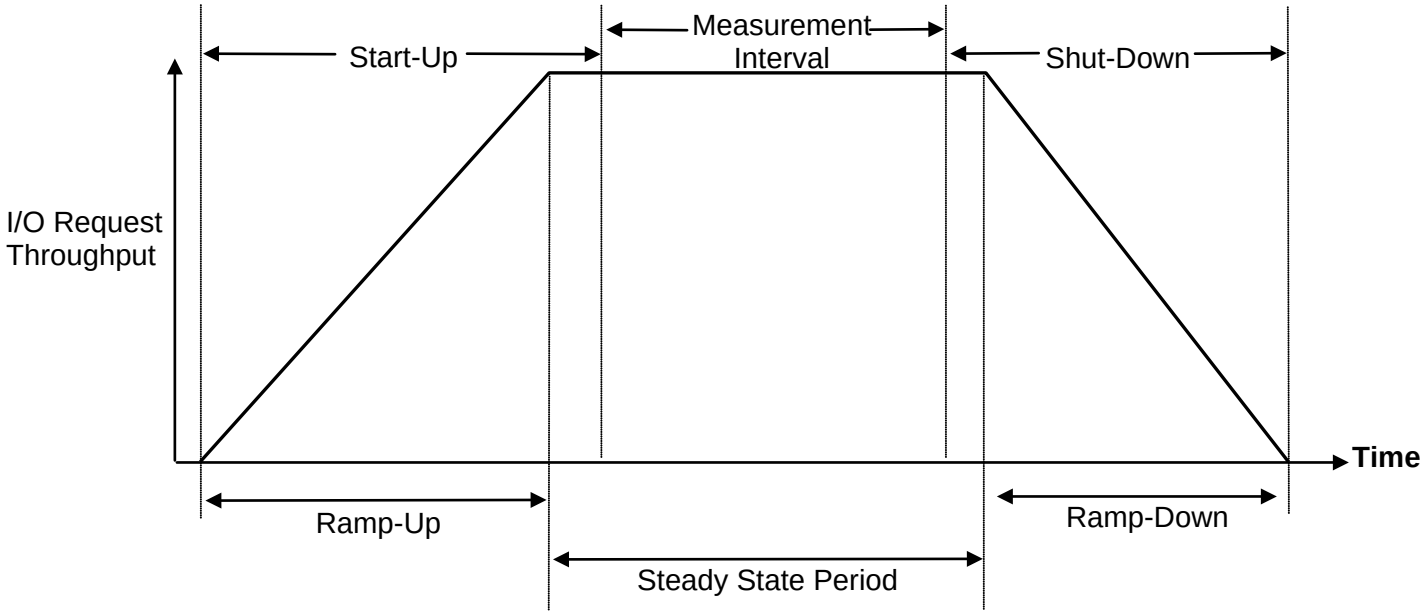
Test Run: The execution of SPC-1 for the purpose of producing or supporting an SPC-1 test result. SPC-1 Test Runs may have a finite and measured Ramp-Up period, Start-Up period, Shut-Down period, and Ramp-Down period as illustrated in the "SPC-1 Test Run Components" below. All SPC-1 Test Runs shall have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

QLogic HBA Driver

The following parameter was set in the QLogic HBA driver configuration file, **qla2xxx.conf**, to set the maximum queue depth to 128 from the default of 32:

options qla2xxx ql2xmaxqdepth=128

The file was copied to the **/etc/modprobe.d/** directory in the Host System and the system was rebooted to set the queue depth in all of the installed HBAs.

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

The standard Fujitsu Command Line tool (CLI) was used to create the ETERNUS DX600 S3 SPC-1 configuration.

The 'master' script, **doFDRcfg.sh**, was executed, which in turn, invoked the script, **DX100S3_20140618.exp**. The 'master' script included shell commands to monitor the progress as the physical formatting proceeded, which used the **expect** script **showFormatStatus.exp** to pick up the status information from the array.

The **DX100S3_20140618.exp** script completed steps 1-3, described below for the 6 host port configuration.

Each **expect** script included the **docli** procedure, which was used to issue the CLI commands to the array. That procedure used **ssh** for communication with the array. A second procedure in the script, **doexit**, was used to conclude the execution sequence at the end of the script.

Step 1 – Creation of RAID Groups

A total of 4 RAID Groups were created, according to the configuration plan, **DX100-200 S3 Design Views - SPC-1_Option_R1x4_SSD.xlsx**, which is typically prepared in concert with a Fujitsu SE. Each RAID Group was made up of 2 disk drives in a RAID1(1+1) configuration and assigned to a specific CM for operational control. The RAID Groups were named RG00 through RG03.

Step 2 – Creation of the Logical Volumes

Wide striped logical volumes were created across 2 sets of RAID Groups (each with 2 RAID Groups). Three volumes were created on each of the RAID Groups, one for each of the three ASUs, for a total of 6 logical volumes. The sizes of two volumes created on the 2 sets for ASU-1 and ASU-2 were set to 258,048 MiB (270,582 MB) each. The size of the volumes on the 2 sets for ASU-3 was set to 57,344 MiB (60,130 MB) each.

Step 3 – Assignment of LUN Mapping to the Linux Host Systems

The **DX100S3_20140618.exp** script provided mapping to 6 host ports.

Port LUN mapping was assigned for each of the Logical Volumes using three ports on each of the two Controller Modules (CM). Each of the volumes, which were defined on RAID Groups, owned by CM-0, were assigned LUN numbers on the active ports (2 on one Channel Adapter (CA), and 1 on the other CA) on CM-0. Each of the volumes, which were defined on RAID Groups, owned by CM-1, were assigned LUN numbers on the active ports (2 on one CA and 1 on the other CA) on CM-1.

Referenced Scripts

doFDRcfg.sh

```
#!/bin/bash
#
# Do the configuration steps required for the SPC1 benchmark
#
# create tmp directory for spc1 if it does not exist
if [ ! -d /tmp/spc1 ]; then
mkdir /tmp/spc1
fi
ROOT=/home/spc1/fdr/fdrwork
SCRIPTS=${ROOT}/7_Execution
CONFIGURE=${ROOT}/5_Creation
PollingInterval=1200           # wait 20 minutes to check format status

#
# confID uniquely identifies the configuration of the array
#
confID=DX100S3_20140618

#
# obtain cjobID based on the timestamp
# cjobID uniquely identifies the configuration job
cjobID=C`date +%y%m%d%H%M%S`

echo job start time `date` | tee -a /tmp/spc1/${cjobID}_message.txt
echo This is an array configuration job | tee -a /tmp/spc1/${cjobID}_message.txt
echo job confID=$confID | tee -a /tmp/spc1/${cjobID}_message.txt
echo job cjobID=$cjobID | tee -a /tmp/spc1/${cjobID}_message.txt
echo "Starting Configuration Job=${cjobID}" | tee -a ${cjobID}_message.txt

#
# Configure Array using the Expect script to issue CLI commands
#
echo "Starting Eternus CLI script for configuration Job=${cjobID}" | tee -a
${cjobID}_message.txt
${CONFIGURE}/${confID}.exp
echo "Completed Eternus CLI script for configuration Job=${cjobID}" | tee -a
${cjobID}_message.txt

#
# Wait for physical format to complete
#
echo "Waiting for physical format to complete Job=${cjobID}" | tee -a
${cjobID}_message.txt

${CONFIGURE}/showFormatStatus.exp dx100s3 root /tmp/spc1/fmt_${cjobID}.txt

LUNS=`grep Available /tmp/spc1/fmt_${cjobID}.txt|wc|awk '{print $1}'`
while [ $LUNS -gt 0 ]; do
 echo "-------------------------------------------"  >>
/tmp/spc1/${cjobID}_message.txt
 cat  /tmp/spc1/fmt_${cjobID}.txt >> /tmp/spc1/${cjobID}_message.txt
 echo "Currently formatting $LUNS LUNS Job=${cjobID}" ${cjobID}_message.txt
 sleep $PollingInterval
 ${CONFIGURE}/showFormatStatus.exp dx100s3 root /tmp/spc1/fmt_${cjobID}.txt
 LUNS=`grep Available /tmp/spc1/fmt_${cjobID}.txt |wc |awk '{print $1}'`
done
echo "Physical format complete please proceed. Job=${cjobID}" | tee -a
${cjobID}_message.txt
```

DX100S3_20140618.exp

```
#!/usr/bin/expect
# script to setup initial configuration for dx100s3
# for SPC-1 benchmark
# Requirment: ssh public key for this server  registered to the array
set timeout 600
set user root
spawn ssh dx100s3 -l $user
expect "root@dx100s3's password: "
send "root\r"
set timeout 200
expect "CLI>"
# procedure to execute dx100s3 cli command
proc docli { cmd args} {
send "$cmd $args\r"
expect "CLI>"
}
# procedure to exit
proc doexit {} {
send "exit\r"
}

#DX100S3 Configuration

## Create RAID ##
docli create raid-group -name RG00 -disks 0000,0001 -level 1 -assigned-cm 0
docli create raid-group -name RG01 -disks 0002,0003 -level 1 -assigned-cm 1
docli create raid-group -name RG02 -disks 0004,0005 -level 1 -assigned-cm 0
docli create raid-group -name RG03 -disks 0006,0007 -level 1 -assigned-cm 1

## Create Volume ##
docli create volume -name ASU1-1 -count 1 -rg-name RG00,RG02 -type wsv -size
258048mb
docli create volume -name ASU3-1 -count 1 -rg-name RG00,RG02 -type wsv -size 57344mb
docli create volume -name ASU2-1 -count 1 -rg-name RG00,RG02 -type wsv -size
258048mb
docli create volume -name ASU1-2 -count 1 -rg-name RG01,RG03 -type wsv -size
258048mb
docli create volume -name ASU3-2 -count 1 -rg-name RG01,RG03 -type wsv -size 57344mb
docli create volume -name ASU2-2 -count 1 -rg-name RG01,RG03 -type wsv -size
258048mb

## Set LUN Mapping ##
docli set mapping -port 000 -volume-number 0 -lun 0
docli set mapping -port 001 -volume-number 1 -lun 1
docli set mapping -port 010 -volume-number 2 -lun 2
docli set mapping -port 100 -volume-number 3 -lun 3
docli set mapping -port 101 -volume-number 4 -lun 4
docli set mapping -port 110 -volume-number 5 -lun 5

## Logout ##
doexit
```

showFormatStatus.exp

Invoked from **doFDRcfg.sh**.

```
#!/usr/bin/expect -f
# Create volumes from the array
# getFormatStatus  <array> <arrayid> <file>
# assumption: array's ssh port has ssh-key-pre-registered no no password is required
# please register ssh-keys
# procedure to execute commands
proc docli {cmd args} {
send "$cmd $args\r"
expect "CLI>"
}
# procedure to exit
proc doexit {} {
send "exit \r"
}
set array [lindex $argv 0]
set arrayid [lindex $argv 1]
set file [lindex $argv 2]
#set file /tmp/formatstatus.txt
# login
spawn ssh $arrayid@$array
expect "root@dx100s3's password: "
send "root\r"
set timeout 40
expect "CLI>"
if [catch {open $file "w" } output] {
  puts "$output"
  exit
}
send "show volume-progress\r"
expect "CLI>"
puts $output "Output = $expect_out(buffer)"
close $output
doexit
close
```

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.

```
*
* Prefill vdbench parameter file for SPC1 DX100S3 2014/06/18
*
* This will produce a random data pattern of the entire LBA range using LSFR
* 32 bit
*
compratio=1
*
*
*  openflags=directio is specified for linux since vdbench requires this when /dev
is used
*  size parameter is also specified because linux version of vdbench requires it
sd=asu1_1,lun=/dev/disk/by-id/scsi-
3600000e00d28000000028112200030000,size=252g,threads=32,openflags=directio
sd=asu1_2,lun=/dev/disk/by-id/scsi-
3600000e00d28000000028112200000000,size=252g,threads=32,openflags=directio
sd=asu2_1,lun=/dev/disk/by-id/scsi-
3600000e00d28000000028112200020000,size=252g,threads=32,openflags=directio
sd=asu2_2,lun=/dev/disk/by-id/scsi-
3600000e00d28000000028112200050000,size=252g,threads=32,openflags=directio
sd=asu3_1,lun=/dev/disk/by-id/scsi-
3600000e00d28000000028112200010000,size=56g,threads=32,openflags=directio
sd=asu3_2,lun=/dev/disk/by-id/scsi-
3600000e00d28000000028112200040000,size=56g,threads=32,openflags=directio
*
wd=wd1,sd=asu1_1,rdpct=0,seek=-1,xfersize=128K
wd=wd2,sd=asu3_1,rdpct=0,seek=-1,xfersize=128K
wd=wd3,sd=asu2_1,rdpct=0,seek=-1,xfersize=128K
wd=wd4,sd=asu1_2,rdpct=0,seek=-1,xfersize=128K
wd=wd5,sd=asu3_2,rdpct=0,seek=-1,xfersize=128K
wd=wd6,sd=asu2_2,rdpct=0,seek=-1,xfersize=128K
*
*==================================
* Use 10 hours as a maximum elapsed time,
* which should ensure the entire LBA range
* will be written before the time elapses
*==================================
rd=asu_prefill,wd=wd*,iorate=max,elapsed=36000,interval=10
* The above "elapsed=36000" may have to be increased to ensure that the utility will
reach
* the end of the LUN ("seek=-1") prior to the end of the specified elapsed time
```

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=(slave1,slave2,slave3,slave4,slave5,slave6,slave7,slave8,slave9,slave10,slave
11,slave12,slave13,slave14,slave15,slave16,slave17,slave18,slave19,slave20,slave21,s
lave22,slave23,slave24,slave25)
javaparms="-Xmx3072m -Xms3072m -Xss512k"
sd=asu1_1,lun=/dev/disk/by-id/scsi-3600000e00d28000000028112200030000,size=252g
sd=asu1_2,lun=/dev/disk/by-id/scsi-3600000e00d28000000028112200000000,size=252g
sd=asu2_1,lun=/dev/disk/by-id/scsi-3600000e00d28000000028112200020000,size=252g
sd=asu2_2,lun=/dev/disk/by-id/scsi-3600000e00d28000000028112200050000,size=252g
sd=asu3_1,lun=/dev/disk/by-id/scsi-3600000e00d28000000028112200010000,size=56g
sd=asu3_2,lun=/dev/disk/by-id/scsi-3600000e00d28000000028112200040000,size=56g
```

SPC-1 Persistence Test

The content of SPC-1 Workload Generator command and parameter file used in this benchmark to execute the SPC-1 Persistence Test *(write and read phases)* is listed below.

```
javaparms="-Xmx3072m -Xms3072m -Xss512k"
sd=asu1_1,lun=/dev/disk/by-id/scsi-3600000e00d28000000028112200030000,size=252g
sd=asu1_2,lun=/dev/disk/by-id/scsi-3600000e00d28000000028112200000000,size=252g
sd=asu2_1,lun=/dev/disk/by-id/scsi-3600000e00d28000000028112200020000,size=252g
sd=asu2_2,lun=/dev/disk/by-id/scsi-3600000e00d28000000028112200050000,size=252g
sd=asu3_1,lun=/dev/disk/by-id/scsi-3600000e00d28000000028112200010000,size=56g
sd=asu3_2,lun=/dev/disk/by-id/scsi-3600000e00d28000000028112200040000,size=56g
```

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. **slave1**…**slave25**.

```
master=masterh
host=slave1
javaparms="-Xmx3072m -Xms3072m -Xss512k"
sd=asu1_1,lun=/dev/disk/by-id/scsi-3600000e00d280000002811220003000,size=252g
sd=asu1_2,lun=/dev/disk/by-id/scsi-3600000e00d280000002811220000000,size=252g
sd=asu2_1,lun=/dev/disk/by-id/scsi-3600000e00d280000002811220002000,size=252g
sd=asu2_2,lun=/dev/disk/by-id/scsi-3600000e00d280000002811220005000,size=252g
sd=asu3_1,lun=/dev/disk/by-id/scsi-3600000e00d280000002811220001000,size=56g
sd=asu3_2,lun=/dev/disk/by-id/scsi-3600000e00d280000002811220004000,size=56g
```

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

'Master' Execution Script

The 'master' script, **doFDRall_1H.sh**, was used to execute the required ASU pre-fill, Primary Metrics Test *(Sustainability Test Phase, IOPS Test Phase, and Response Time Ramp Test Phase)*, Repeatability Test *(Repeatability Test Phase 1 and Repeatability Test Phase 2)* and SPC-1 Persistence Test Run 1 *(write phase)* in an uninterrupted sequence.

After the above test sequence completed, the required TSC power off/power was performed. That step was followed by execution of the **doFDRall_2H.sh** script, which was used to perform SPC-1 Persistence Test Run 2 *(read phase)*.

The **doFDRall_1H.sh** and **doFDRall_2H.sh** scripts invoked various other scripts which appear below in the **Referenced Scripts and Files** section with a brief description of each referenced script.

doFDRall_1H.sh

```
#!/bin/bash -x
#
# Script consists of Part 1 of the FDR job
#  - Prefill
#  - Save "Before FDR" logs
#  - Metricss
#  - Repeatability1/2
#  - Persistence1
#
#

#
# Configure Variable
#

if [ $# -ne 2 ]
then
     BSU=1105
else
     BSU=$1
fi

ROOT=/home/spc1/fdr/fdrwork;export ROOT            # Absolute path of Work
Directories
PREFILL=${ROOT}/prefill;export PREFILL       # directory for prefill step
SCRIPTS=${ROOT}/7_Execution;export SCRIPTS   # main script directory
NSLAVES=25;export NSLAVES                    # Total Number of Slave
METRICSRUNTIME=28800                         # Metrics running time (sec)
METRICSRAMPUPTIME="900:300"                  # Metrics ramp up time (sec)
RAMPUPTIME=300                               # ramp up time (sec)

# benchmark commands
JAVA=java;export JAVA
VDBENCH=/home/spc1/vdbench/vdbench;export VDBENCH
EXPORTLOG=exportLog.exp;export EXPORTLOG
JAVAPARMS="-Xmx3072m -Xms3072m -Xss512k";export JAVAPARMS # Java Parameter
BMTPATH=/usr/local/share3/StoragePerformance/SPC1_Benchmark/DX100S3/;export BMTPATH
     # Repository Info
BMTHOST=fjuser@129.212.198.24;export BMTHOST
```

```
# create tmp directory for spc1 if it does not exist
SPCTMP=/tmp/spc1;export SPCTMP
if [ ! -d ${SPCTMP} ]; then
     mkdir ${SPCTMP}
fi

#
# Create confID
#
confID=DX100S3_20140618;export confID

# obtain jobID based on the timestamp
# jobID uniquely identifies the benchmark run
jobID=JH`date +%y%m%d%H%M%S`;export jobID
WORKDIR=${ROOT}/${jobID};export WORKDIR            # WORK Directory

#
# save Variables Part 2 use
#
echo $confID > ${SPCTMP}/lastconfID
echo $jobID > ${SPCTMP}/lastjobID
echo $BMTPATH > ${SPCTMP}/BMTPATH
echo $BMTHOST > ${SPCTMP}/BMTHOST
echo $WORKDIR > ${SPCTMP}/WORKDIR
echo $JAVAPARMS > ${SPCTMP}/JAVAPARMS
echo $NSLAVES > ${SPCTMP}/NSLAVES
echo $EXPORTLOG > ${SPCTMP}/EXPORTLOG
echo $VDBENCH > ${SPCTMP}/VDBENCH
echo $JAVA > ${SPCTMP}/JAVA
echo $ROOT > ${SPCTMP}/ROOT
echo $SCRIPTS > ${SPCTMP}/SCRIPTS
echo $PREFILL > ${SPCTMP}/PREFILL
echo $BMTPATH > ${SPCTMP}/BMTPATH
echo $BMTHOST > ${SPCTMP}/BMTHOST

#
# setup the unique execution context(directory) for SPC1 job
#

# For Master host
cd ${ROOT}
mkdir ${jobID}
cd ${jobID}

echo -e DX100S3 "\n"  start time `date` "\n" | tee -a ${SPCTMP}/${jobID}_message.txt
echo -e  confID=$confID "\n" | tee -a ${SPCTMP}/${jobID}_message.txt
echo -e  jobID=$jobID "\n" | tee -a ${SPCTMP}/${jobID}_message.txt
echo "Starting DX100S3 FDR Job=${jobID}" | tee -a ${SPCTMP}/${jobID}_message.txt

#
# Start Sequence of SPC1 benchmark jobs
#

#
# Setup the Java environment variables for SPC1
#

CLASSPATH=/usr/local/spc/spc1;export CLASSPATH
LD_LIBRARY_PATH=/usr/local/spc/spc1;export LD_LIBRARY_PATH

#
# setup for Prefill task by copying the prefill parameters file
#
```

```
echo "Starting DX100S3 Prefill test for Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt
mkdir Prefill
cd Prefill
cp ${SCRIPTS}/${confID}_prefill.txt .
${VDBENCH} -f ${confID}_prefill.txt
cd ..

#
# Report Prefill Complete
#
echo "Completed DX100S3 Prefill test for Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt

#
# Collect Logs after the prefill job
#
echo "Starting  DX100S3 BeforeF log save Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt
${SCRIPTS}/${EXPORTLOG} ${jobID}_BeforeF
cp /tmp/*${jobID}_BeforeF* .
echo "Completed DX100S3 BeforeF log save Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt


#
# Setup headers for highlevel parameter files and the slave files
#
${SCRIPTS}/Setup2FDRH.sh ${BSU}
echo "Starting DX100S3 Metrics test step for Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt

#
# Start Metrics
#
cp ${SCRIPTS}/spc1.cfg .
${SCRIPTS}/setup_slave_dirsH.sh ${jobID} metrics
${SCRIPTS}/start_slavesH.sh metrics
${JAVA} $JAVAPARMS metrics -b ${BSU} -t ${METRICSRUNTIME} -s ${METRICSRAMPUPTIME}
${SCRIPTS}/stop_slaves.sh
echo "Completed DX100S3 Metrics test step for Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt

#
#Start Repeat-1
#
echo "Starting DX100S3 Repeatablity test 1 step for Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt
${SCRIPTS}/setup_slave_dirsH.sh ${jobID}  repeatability1
${SCRIPTS}/start_slavesH.sh repeatability1
${JAVA} $JAVAPARMS repeat1 -b ${BSU} -s ${RAMPUPTIME}
${SCRIPTS}/stop_slaves.sh
echo "Completed DX100S3 Repeatablity test 1 step for Job=${jobID} at `date`" | tee -
a ${SPCTMP}/${jobID}_message.txt

#
# Start Repeat-2
#
echo "Starting DX100S3 Repeatablity test 2 step for Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt
${SCRIPTS}/setup_slave_dirsH.sh ${jobID}  repeatability2
${SCRIPTS}/start_slavesH.sh repeatability2
${JAVA} $JAVAPARMS repeat2 -b ${BSU} -s ${RAMPUPTIME}
```

```
${SCRIPTS}/stop_slaves.sh
echo "Completed DX100S3 Repeatablity test 2 step for Job=${jobID} at `date`" | tee -
a ${SPCTMP}/${jobID}_message.txt

#
# Change Multihost spc1.cfg to Singlehost one
#
mv spc1.cfg multispc1.cfg
cp ${SCRIPTS}/persspc1.cfg spc1.cfg

#
# Start Persist-1
#
echo "Starting DX100S3 Persistence test 1 step for Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt
${JAVA} $JAVAPARMS persist1 -b ${BSU}
echo "Completed DX100S3 Persistence test 1 step for Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt

#
# Perform Power cycle
#
echo "Array is Ready for manual Power cycle Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt
```

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

The following script is executed to invoke the SPC-1 Persistence Test Run 2 *(read phase)* after completion of the required TSC power off/power on cycle.

doFDRall_2H.sh

```
#!/bin/bash -x
#
# Do 2nd steps required for the FDR run
#
# obtain jobID and confID saved from part 1
#
# check to see if previous context exists
# create tmp directory for spc1 if it does not exist
SPCTMP=/tmp/spc1
if [ ! -d ${SPCTMP} ]; then
     echo Error!
     exit
else
     confID=`cat ${SPCTMP}/lastconfID`
     jobID=`cat ${SPCTMP}/lastjobID`
     BMTPATH=`cat ${SPCTMP}/BMTPATH`
     BMTHOST=`cat ${SPCTMP}/BMTHOST`
     WORKDIR=`cat ${SPCTMP}/WORKDIR`
     JAVAPARMS=`cat ${SPCTMP}/JAVAPARMS`
     NSLAVES=`cat ${SPCTMP}/NSLAVES`
     EXPORTLOG=`cat ${SPCTMP}/EXPORTLOG`
     VDBENCH=`cat ${SPCTMP}/VDBENCH`
     JAVA=`cat ${SPCTMP}/JAVA`
     ROOT=`cat ${SPCTMP}/ROOT`
     SCRIPTS=`cat ${SPCTMP}/SCRIPTS`
     PREFILL=`cat ${SPCTMP}/PREFILL`
fi
```

```
export SPCTMP
export confID
export jobID
export BMTPATH
export BMTHOST
export WORKDIR
export JAVAPARMS
export NSLAVES
export EXPORTLOG
export VDBENCH
export JAVA
export ROOT
export SCRIPTS
export PREFILL

cd ${ROOT}/${jobID}

#
# Start Persist-2
#
echo "Starting DX100S3 Persistence test 2 step for Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt
${JAVA} $JAVAPARMS persist2
echo "Completed DX100S3 Persistence test 2 step for Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt

#
# Save after log
#
echo "Starting DX100S3 AfterJ log save Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt
${SCRIPTS}/exportLog.exp ${jobID}_AfterJ
cp /tmp/*${jobID}_AfterJ* .
echo "Completed DX100S3 AfterJ log save Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt

#
# Save after log 2
#
echo "Starting DX100S3 AfterJ2 log save Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt
${SCRIPTS}/exportLog.exp ${jobID}_AfterJ2
cp /tmp/*${jobID}_AfterJ2* .
echo "Completed DX100S3 AfterJ2 log save Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt
cp ${SCRIPTS}/nohup.out nohup_${jobID}.out
echo "current time = `date`."

echo "Completed DX100S3 FDR job All steps for Job=${jobID} at `date`" | tee -a
${SPCTMP}/${jobID}_message.txt
echo "Run /home/spc1/fdr/zipup.sh, Collect All FDR data and send it in ${BMTHOST} at
`date`" | tee -a ${SPCTMP}/${jobID}_message.txt
```

Referenced Scripts and Files

Setup2FDRH.sh

Invoked from **doFDRall_1H.sh**. This script will create the following files using the manually created file, **spc1-device.cfg**, as input:

- **slave_header.txt:** The header text for each of the Slave JVM configuration files.
- **spc1_master_header.txt:** The header text for the SPC-1 Workload Generator command and parameter file (spc1.cfg).
- **spc1.cfg:** The SPC-1 Workload Generator command and parameter file used for the Primary Metrics and Repeatability Tests.
- **persspec1.cfg:** The SPC-1 Workload Generator command and parameter file used for the reduced level SPC-1 Persistence Test Run 1.

```
#!/bin/bash
#
# Setup2FDRH.sh  <BSU>
# Setup the parameter files for FDR run
# Called by doFDRall_1H.sh
# Parameter  BSU - BSU used for FDR run
# Input files (generated manually)
#    spc1-device.cfg
#
# Output files:
#    slave_header.txt
#    spc1_master_header.txt
#    spc1.cfg
#    persspc1.cfg
#
# Enviroment Variables
#  SCRIPTS
#  JAVAPARMS
#  NSLAVES
#
if [ $# != 1 ]
 then
   echo "$0 <Bsu>"
   exit
fi
MASTERIP=masterh
BSU=$1
SCRIPTS=/home/spc1/fdr/fdrwork/7_Execution
cd $SCRIPTS
#Create header for slave configuration file
cat >slave_header.txt <<HERE
master=$MASTERIP
host=#slave1#
javaparms="$JAVAPARMS"
HERE
SLAVELIST=""
#Create header for master configuration file
for (( i=1; i<=NSLAVES; i++ ))
do
SLAVELIST=${SLAVELIST}slave${i}
if [ $i != $NSLAVES ]
 then
   SLAVELIST="${SLAVELIST},"
fi
done
cat > spc1_master_header.txt <<HERE
host=master
slaves=($SLAVELIST)
javaparms="$JAVAPARMS"
HERE
cat spc1_master_header.txt spc1-device.cfg > spc1.cfg
```

```
cat - spc1-device.cfg > persspc1.cfg <<HERE
javaparms="$JAVAPARMS"
HERE
```

spc1-device.cfg

Created manually and used by **Setup2FDRH.sh** and **setup_slave_dirsH.sh** to create various configuration files.

```
sd=asu1_1,lun=/dev/disk/by-id/scsi-3600000e00d2800000028112200030000,size=252g
sd=asu1_2,lun=/dev/disk/by-id/scsi-3600000e00d2800000028112200000000,size=252g
sd=asu2_1,lun=/dev/disk/by-id/scsi-3600000e00d2800000028112200020000,size=252g
sd=asu2_2,lun=/dev/disk/by-id/scsi-3600000e00d2800000028112200050000,size=252g
sd=asu3_1,lun=/dev/disk/by-id/scsi-3600000e00d2800000028112200010000,size=56g
sd=asu3_2,lun=/dev/disk/by-id/scsi-3600000e00d2800000028112200040000,size=56g
```

spc1_master_header.txt

Created by **Setup2FDRH.sh**.

```
host=master
slaves=(slave1,slave2,slave3,slave4,slave5,slave6,slave7,slave8,slave9,slave10,slave
11,slave12,slave13,slave14,slave15,slave16,slave17,slave18,slave19,slave20,slave21,s
lave22,slave23,slave24,slave25)
javaparms="-Xmx3072m -Xms3072m -Xss512k"
```

setup_slave_dirsH.sh

Invoked from **doFDRall_1H.sh**. This script uses **slave_header.txt**, which was created by **Setup2FDRH.sh**, and **spc1-device.cfg** as input to create each Slave JVM configuration file and a directory for each Slave JVM's execution output.

```
#!/bin/bash
# setup_slave_dirsH <jobID> <STEP>
# Create the work directory and slave sub directory for each steop
# environment
#    ${ROOT}
#    ${WORKDIR}
#    ${SCRIPTS}
#    ${NSLAVES}
# parameter jobID STEP
jobID=$1
STEP=$2
cd ${WORKDIR}
mkdir ${STEP}
cd ${STEP}
# create separate directory and  slave cfg files under each slave<n>/slave<n>.txt
for (( i=1; i<=NSLAVES ; i++ ))
do
 mkdir slave${i}
 cat ${SCRIPTS}/slave_header.txt ${SCRIPTS}/spc1-device.cfg  |sed
s/#slave1#/slave${i}/ > slave${i}/slave${i}.txt
done
```

slave_header.txt

Created by **Setup2FDRH.sh** and used by **setup_slave_dirsH.sh**.

```
master=masterh
host=#slave1#
javaparms="-Xmx3072m -Xms3072m -Xss512k"
```

start_slavesH.sh

Invoked from **doFDRall_1H.sh** to start all Slave JVMs prior to each SPC-1 Test or Test Phase execution.

```
#!/bin/bash -x

STEP=$1
cd $WORKDIR
cd $STEP

#
# Create Config file of slave
#
for (( i=1; i<=$(($NSLAVES)); i++ ))
do
     (cd slave${i};java ${JAVAPARMS} spc1 -f slave${i}.txt &>
slave${i}_console_out.txt) &
     sleep 1
done
```

stop_slaves.sh

Invoked from **doFDRall_1H.sh** to stop all Slave JVMs after each SPC-1 Test or Test Phase terminates.

```
ssh slaveh1 'pkill java'
```