SPC BENCHMARK 1™

FULL DISCLOSURE REPORT

HITACHI DATA SYSTEMS CORPORATION

HITACHI UNIFIED STORAGE VM

(WITH HITACHI ACCELERATED FLASH)

SPC-1 V1.14

Submitted for Review: June 17, 2014

Submission Identifier: A00145

First Edition – June 2014

Trademarks

Table of Contents

AUDIT CERTIFICATION

Storage Performance Council

Gradient SYSTEMS

James Byun
Hitachi Data Systems Corporation
2845 Lafayette Street, MS3275
Santa Clara, CA 95050

June 16, 2014

The SPC Benchmark 1™ Reported Data listed below for the Hitachi Unified Storage VM *(with Hitachi Accelerated Flash)*was produced in compliance with the SPC Benchmark 1™ v1.14 Onsite Audit requirements.

SPC Benchmark 1™ v1.14 Reported Data	
Tested Storage Product (TSP) Name: Hitachi Unified Storage VM *(with Hitachi Accelerated Flash)*	
Metric	**Reported Result**
SPC-1 IOPS™	304,127.12
SPC-1 Price-Performance	$1.18/SPC-1 IOPS™
Total ASU Capacity	9,851.581 GB
Data Protection Level	Protected 2 *(Mirroring)*
Total Price (including three-year maintenance)	$360,190.52
Currency Used	U.S. Dollars
Target Country for availability, sales and support	USA

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

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

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

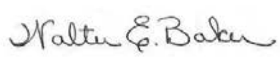
Hitachi Unified Storage VM *(with Hitachi Accelerated Flash)* Page 2
SPC-1 Audit Certification

- An appropriate diagram of the Benchmark Configuration (BC)/Tested Storage Configuration (TSC).
- Physical verification of the components to match the above diagram.
- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters that were changed from default values.
- SPC-1 Workload Generator commands and parameters used for the audited SPC Test Runs.
- The following Host System requirements were verified by physical inspection and information supplied by Hitachi Data Systems Corporation:
  - ✓ The type of Host System including the number of processors and main memory.
  - ✓ The presence and version number of the SPC-1 Workload Generator on the Host System.
  - ✓ The TSC boundary within the Host System.
- The execution of each Test, Test Phase, and Test Run was observed and found compliant with all of the requirements and constraints of Clauses 4, 5, and 11 of the SPC-1 Benchmark Specification.
- The Test Results Files and resultant Summary Results Files received from Hitachi Data Systems Corporation for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4 and 5 of the SPC-1 Benchmark Specification:
  - ✓ Data Persistence Test
  - ✓ Sustainability Test Phase
  - ✓ IOPS Test Phase
  - ✓ Response Time Ramp Test Phase
  - ✓ Repeatability Test
- The Priced Storage Configuration included a second 36-port FC switch as a spare to fulfill one of the requirements for a data protection level of **Protected 2**. If that second switch was added to the Tested Storage Configuration, there would be no impact on the measured SPC-1 performance.
- The submitted pricing information met all of the requirements and constraints of Clause 8 of the SPC-1 Benchmark Specification.
- The Full Disclosure Report (FDR) met all of the requirements in Clause 9 of the SPC-1 Benchmark Specification.
- This successfully audited SPC measurement is not subject to an SPC Confidential Review.

Audit Notes:

There were no audit notes or exceptions.

Respectfully,



Walter E. Baker
SPC Auditor

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LETTER OF GOOD FAITH

HITACHI
Inspire the Next

May 12, 2014

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

Subject: SPC-1 Letter of Good Faith for the Hitachi Unified Storage VM with Hitachi Accelerated Flash

Hitachi Data Systems is the SPC-1 Test Sponsor for the above listed product. To the best of our knowledge and belief, the required SPC-1 benchmark results and materials we have submitted for that product are complete, accurate, and in full compliance with Version 1.14 of the SPC-1 benchmark specification.

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

Regards,

Charles F Hart
VP Solutions Engineering/Technical Operations
Hitachi Data Systems

Hitachi Data Systems Corporation
610 Lincoln Street, Suite 300, Waltham, MA 02451 Tel: 781.810.6000 Fax: 781.810.6028

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EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact	Hitachi Data Systems Corporation –http://www.hds.com James Byun – james.byun@hds.com 2845 Lafayette Street, MS3275 Santa Clara, CA 95050 Phone: (408) 970-1391 FAX: (408) 327-3066
Test Sponsor Alternate Contact	Hitachi Data Systems Corporation –http://www.hds.com William Lundin – William.lundin@hds.com 2845 Lafayette Street, MS3275 Santa Clara, CA 95050 Phone: (408) 970-7534 FAX: (408) 327-3066
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	June 17, 2014
Date the FDR was submitted to the SPC	June 17, 2014
Date the Priced Storage Configuration is available for shipment to customers	currently available
Date the TSC completed audit certification	June 16, 2014

Tested Storage Product (TSP) Description

Hitachi Unified Storage VM eases the management of information. It manages all of your existing storage and consolidates all of your data in a single, virtualized platform. Hitachi Unified Storage VM is built with trusted Hitachi reliability for application availability, flash-accelerated performance and lower cost of ownership. Delivering enterprise storage virtualization in a unified platform lets you manage information more efficiently.

HUS VM places emphasis on high availability with non-disruptive microcode and hardware upgrades, automatic failover architecture with redundant, hot-swappable components, dual data paths and dual control paths and nonvolatile backup of cache using a combination of battery and flash disk drives. Universal data replication can be provided for local and remote data protection across multiple data centers.

Intelligent, controller-based storage virtualization provides a platform for aggregating all storage services for multivendor storage systems. Host-transparent movement, copy and migration of data between storage is enabled with reduced interruption of applications. Hitachi Command Suite provides the software management platform for advanced data and storage management that helps improve administration, operations, provisioning, performance and resilience.

Summary of Results

SPC-1 Reported Data	
Tested Storage Product (TSP) Name: Hitachi Unified Storage VM *(with Hitachi Accelerated Flash)*	
Metric	**Reported Result**
SPC-1 IOPS™	304,127.12
SPC-1 Price-Performance™	$1.18/SPC-1 IOPS™
Total ASU Capacity	9,851.581 GB
Data Protection Level	Protected 2 *(mirroring)*
Total Price	$360,190.52
Currency Used	U.S. Dollars
Target Country for availability, sales and support	USA

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

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

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

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

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

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

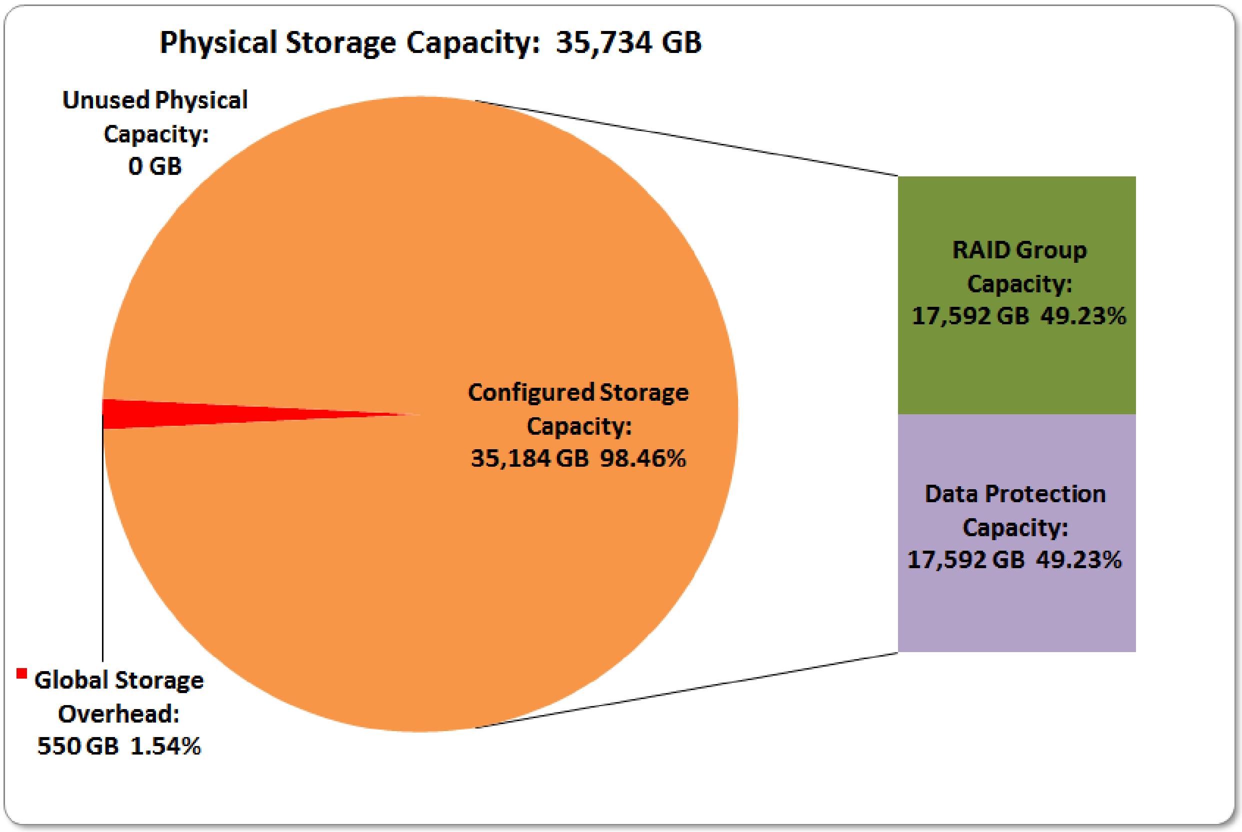
Currency Used is formal name for the currency used in calculating the **Total Price** and **SPC-1 Price-Performance™**. That currency may be the local currency of the **Target Country** or the currency of a difference country *(non-local currency)*.

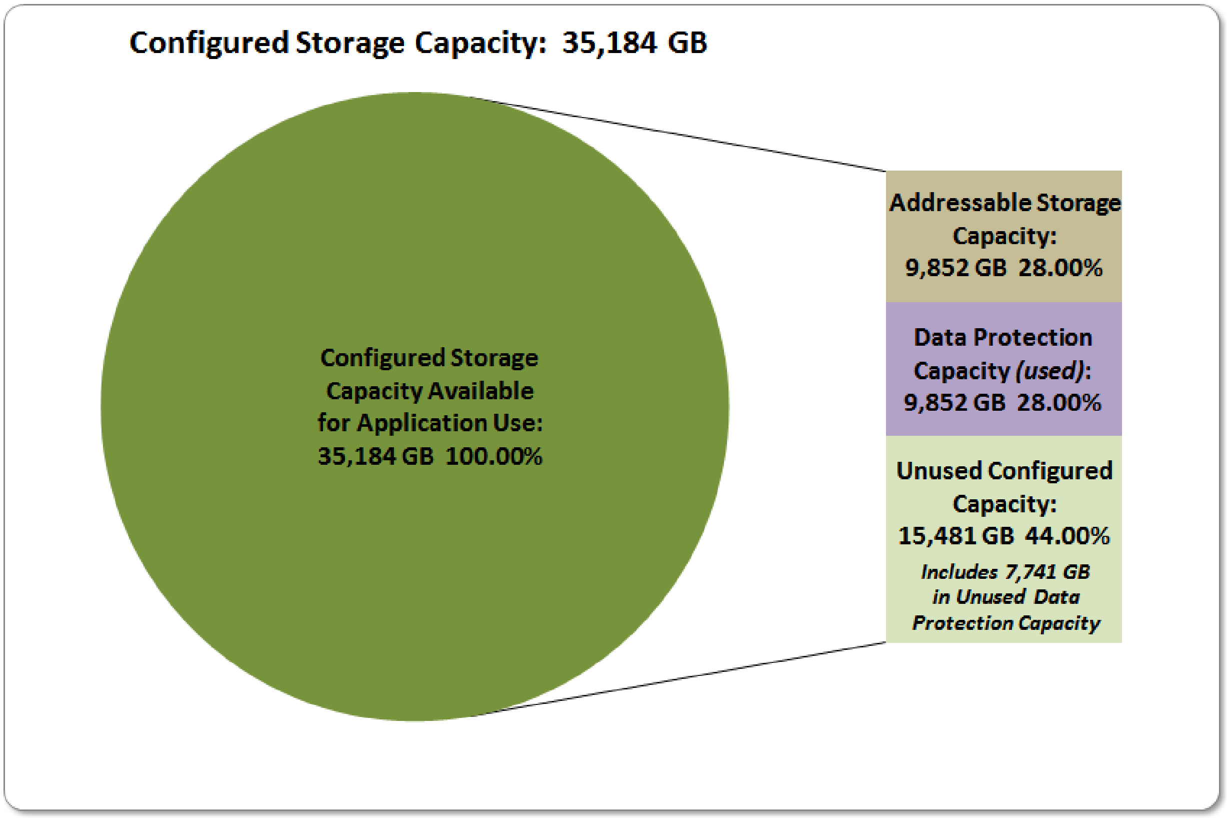
The **Target Country** is the country in which the Priced Storage Configuration is available for sale and in which the required hardware maintenance and software support is provided either directly from the Test Sponsor or indirectly via a third-party supplier.

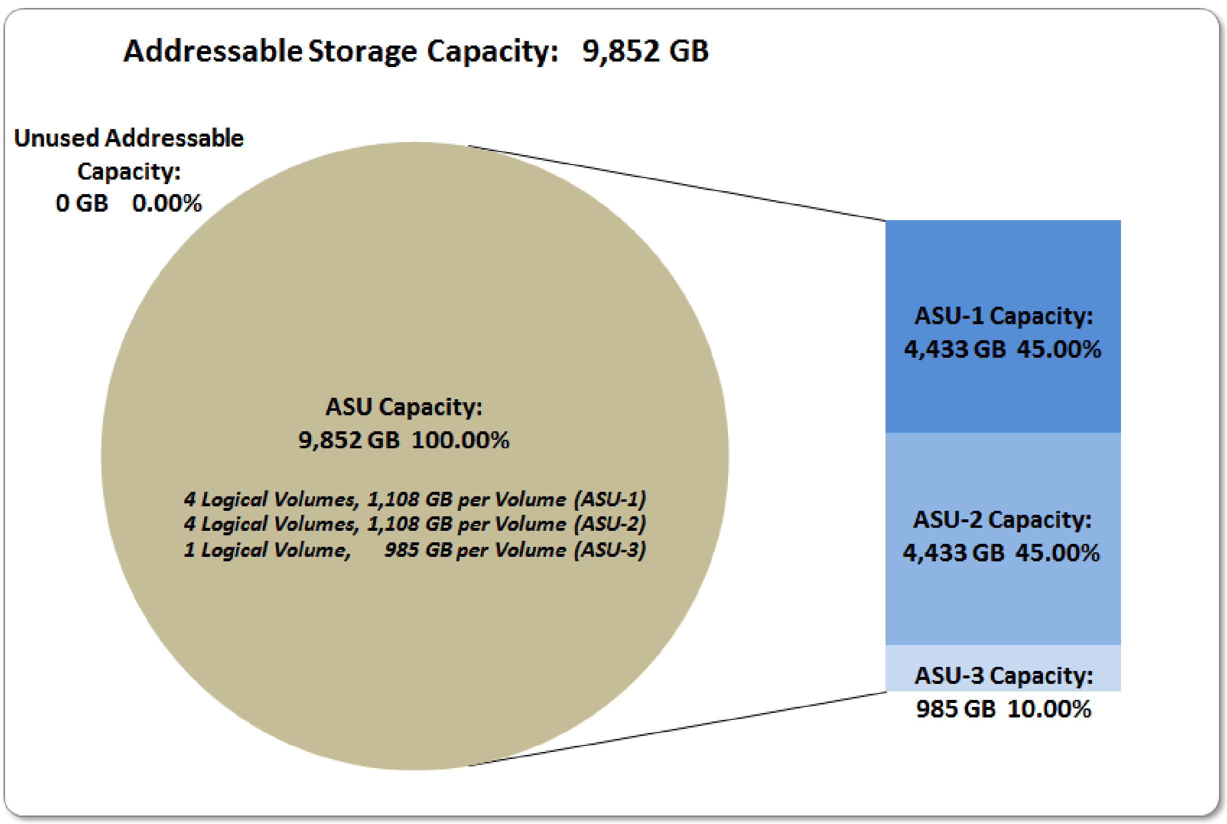
Storage Capacities, Relationships, and Utilization

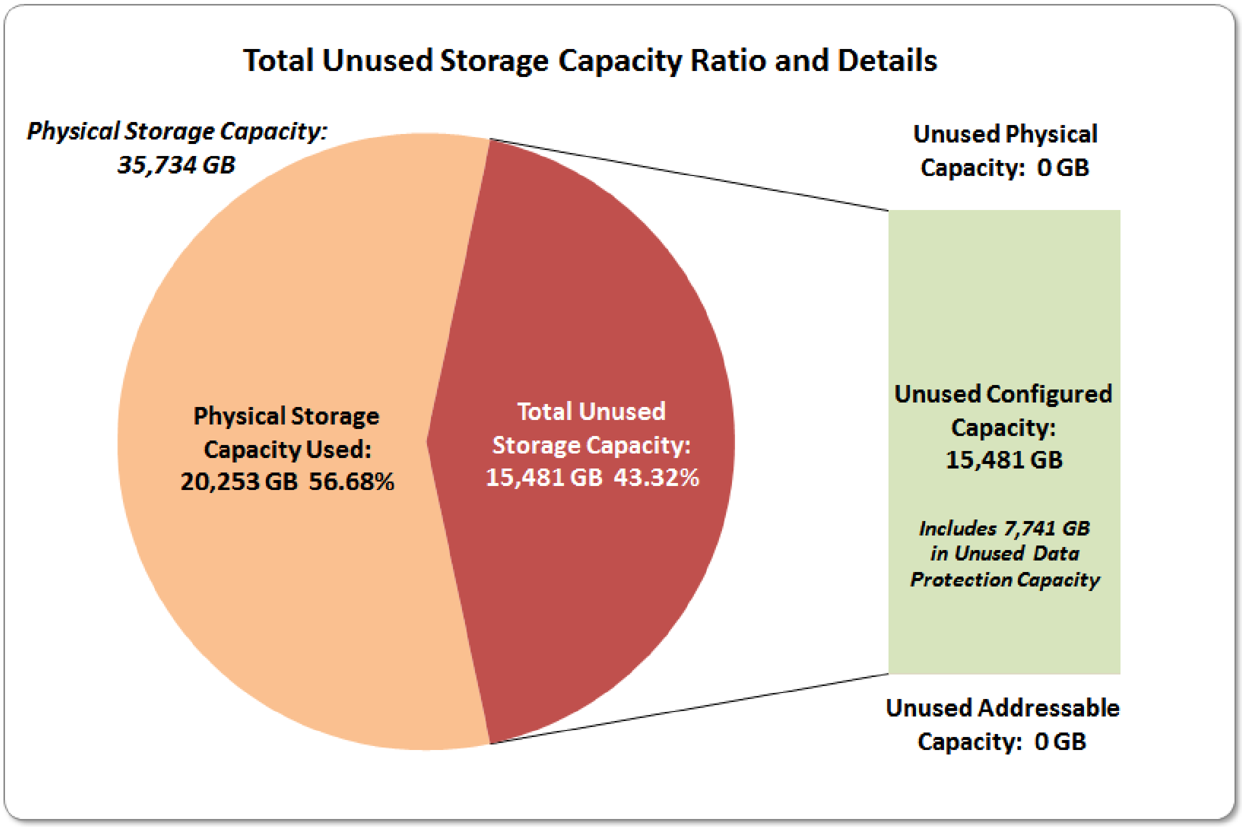
The following four charts and table document the various storage capacities, used in this benchmark, and their relationships, as well as the storage utilization values required to be reported.

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




Configured Storage Capacity: 35,184 GB
Configured Storage Capacity Available for Application Use: 35,184 GB 100.00%
Addressable Storage Capacity: 9,852 GB 28.00%
Data Protection Capacity (used): 9,852 GB 28.00%
Unused Configured Capacity: 15,481 GB 44.00%
Includes 7,741 GB in Unused Data Protection Capacity


Addressable Storage Capacity: 9,852 GB
Unused Addressable Capacity: 0 GB 0.00%
ASU Capacity: 9,852 GB 100.00%
4 Logical Volumes, 1,108 GB per Volume (ASU-1)
4 Logical Volumes, 1,108 GB per Volume (ASU-2)
1 Logical Volume, 985 GB per Volume (ASU-3)
ASU-1 Capacity: 4,433 GB 45.00%
ASU-2 Capacity: 4,433 GB 45.00%
ASU-3 Capacity: 985 GB 10.00%



SPC-1 Storage Capacity Utilization	
Application Utilization	27.57%
Protected Application Utilization	55.14%
Unused Storage Ratio	43.32%

Application Utilization: Total ASU Capacity *(9,851.581 GB)* divided by Physical Storage Capacity *(35,734.094 GB).*

Protected Application Utilization: (Total ASU Capacity *(9,851.581 GB)* plus total Data Protection Capacity *(17,592.167 GB)* minus unused Data Protection Capacity *(7,740.585 GB)*) divided by Physical Storage Capacity *(35,734.094 GB).*

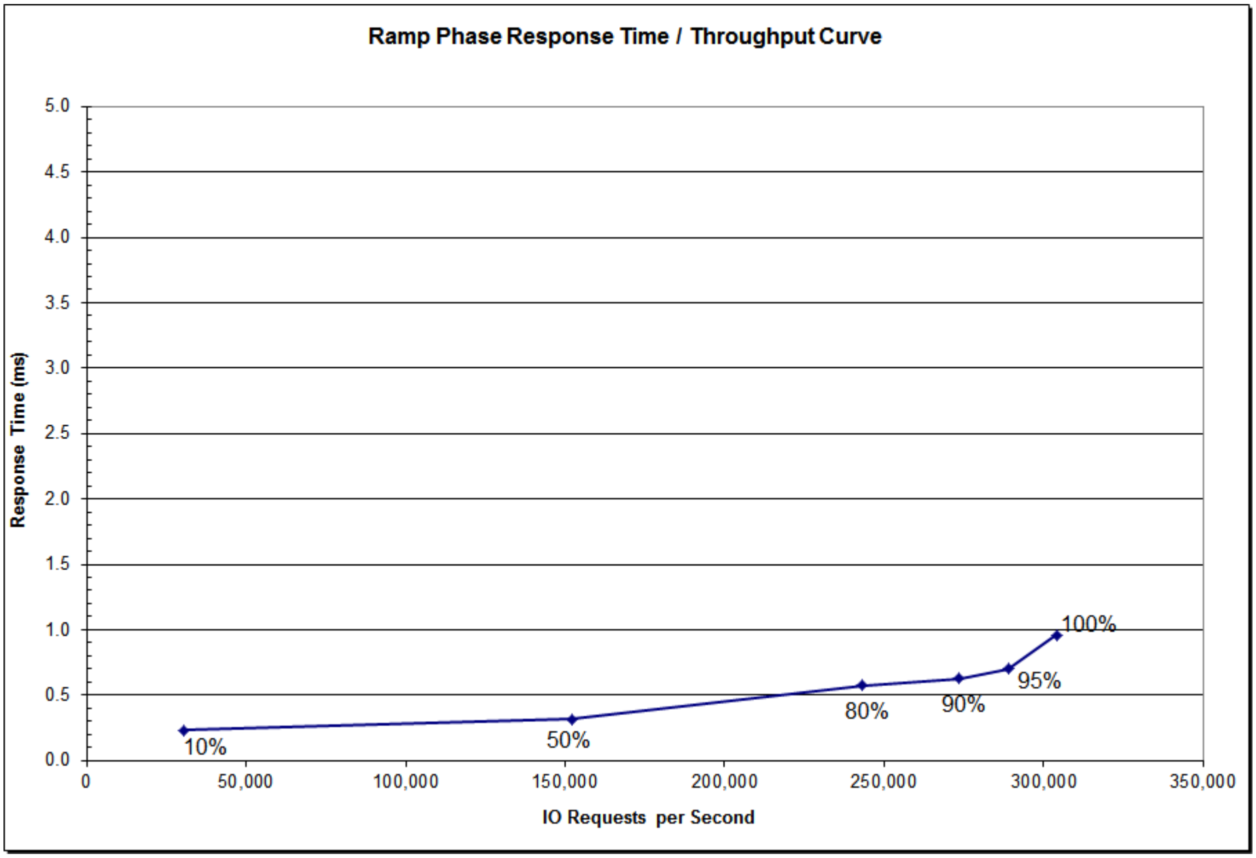
Unused Storage Ratio: Total Unused Capacity *(GB)* divided by Physical Storage Capacity *(35,734.094 GB)* and may not exceed 45%.

Detailed information for the various storage capacities and utilizations is available on pages 27-28.

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	30,400.59	152,071.60	243,276.72	273,618.15	288,840.88	304,127.12
Average Response Time (ms):						
All ASUs	0.23	0.32	0.57	0.63	0.70	0.96
ASU-1	0.27	0.37	0.66	0.73	0.82	1.11
ASU-2	0.22	0.30	0.55	0.61	0.67	0.93
ASU-3	0.17	0.21	0.41	0.42	0.47	0.66
Reads	0.34	0.50	0.85	0.97	1.08	1.45
Writes	0.16	0.20	0.39	0.40	0.45	0.64

Priced Storage Configuration Pricing

Product Description	Qty	Unit List Price	Product List Price
Hitachi Unified Storage VM Microcode Kit	1	$0.00	$0.00
Hitachi Unified Storage VM Product Documentation Library	1	$0.00	$0.00
Dummy FMD	4	$0.00	$0.00
Universal rail kit	1	$239.00	$239.00
Minkels Universal Rack 600x1200x2010 mm (WxDxH) 42U	1	$4,474.00	$4,474.00
Left Corner Guide Rail 740 mm Depth	2	$21.00	$42.00
Right Corner Guide Rail 740 mm Depth	2	$21.00	$42.00
Side Panel 1200 mm Depth (qty 1)	2	$292.00	$584.00
4GB USB memory stick with lanyard	1	$102.00	$102.00
HUS VM 16GB Cache Module	16	$4,295.00	$68,720.00
HUS VM Cache Flash Memory Module (supports 256GB)	1	$19,776.00	$19,776.00
HUS VM B/E I/O Module	4	$1,393.00	$5,572.00
HUS VM Drive Box (Flash)	2	$16,056.00	$32,112.00
HUS VM Controller Chassis	1	$74,000.00	$74,000.00
HUS VM 1.6TB Flash Module Drive for Base	20	$28,427.00	$568,540.00
HUS VM 4x8Gbps FC Interface Adapter	8	$3,267.00	$26,136.00
LAN Cable 14ft	1	$0.00	$0.00
RJ-45 Modular In-Line Coupler 6 Conductor	1	$4.00	$4.00
PDU 0RU 10xC13 2xC19 1Phase 208V 30A NEMA L6-30P	4	$781.00	$3,124.00
Power Cable - 208/220V, 1m (3ft)	6	$9.00	$54.00
Brocade 6510 Switch, 36P, 8Gb SWL SFPs, Rack Kit	2	$30,903.90	$61,807.80
Hardware Components:		---	**$865,328.80**
HUS VM Hitachi Base Operating System 5TB Block License	1	$6,500.00	$6,500.00
HUS VM BOS flash optimization Base License (20TB)	1	$37,800.00	$37,800.00
Software Components:		---	**$44,300.00**
HUS VM Service Installation	1	$2,750.00	$2,750.00
HUS VM Hardware Maintenance Support - Includes 3 years of Standard Support (24 x 7 x 4 hour response)	1	$7,817.76	$7,817.76
HUS VM Storage Software Support - Includes 3 years of Standard Support	1	$19,935.00	$19,935.00
Brocade 6510 Service Installation	1	$250.00	$250.00
Brocade 6510 Hardware Maintenance Support - Includes 3 years of Standard Support	2	$3,150.00	$6,300.00
Installation and Support:		---	**$37,052.76**
Emulex LightPulse Dual Port Fibre Channel Host Bus Adapter LPE12002-M8	8	$550.00	$4,400.00
Fibre Channel Cables	32	$11.49	$367.68
Third Party Components:		---	**$4,767.68**

Hardware Components	**$865,328.80**	**65%**	**$302,865.08**
Software Components	**$44,300.00**	**65%**	**$15,505.00**
Installation & Support	**$37,052.76**	**0%**	**$37,052.76**
Third Party Components	**$4,767.68**	**0%**	**$4,767.68**
Total:			**$360,190.52**

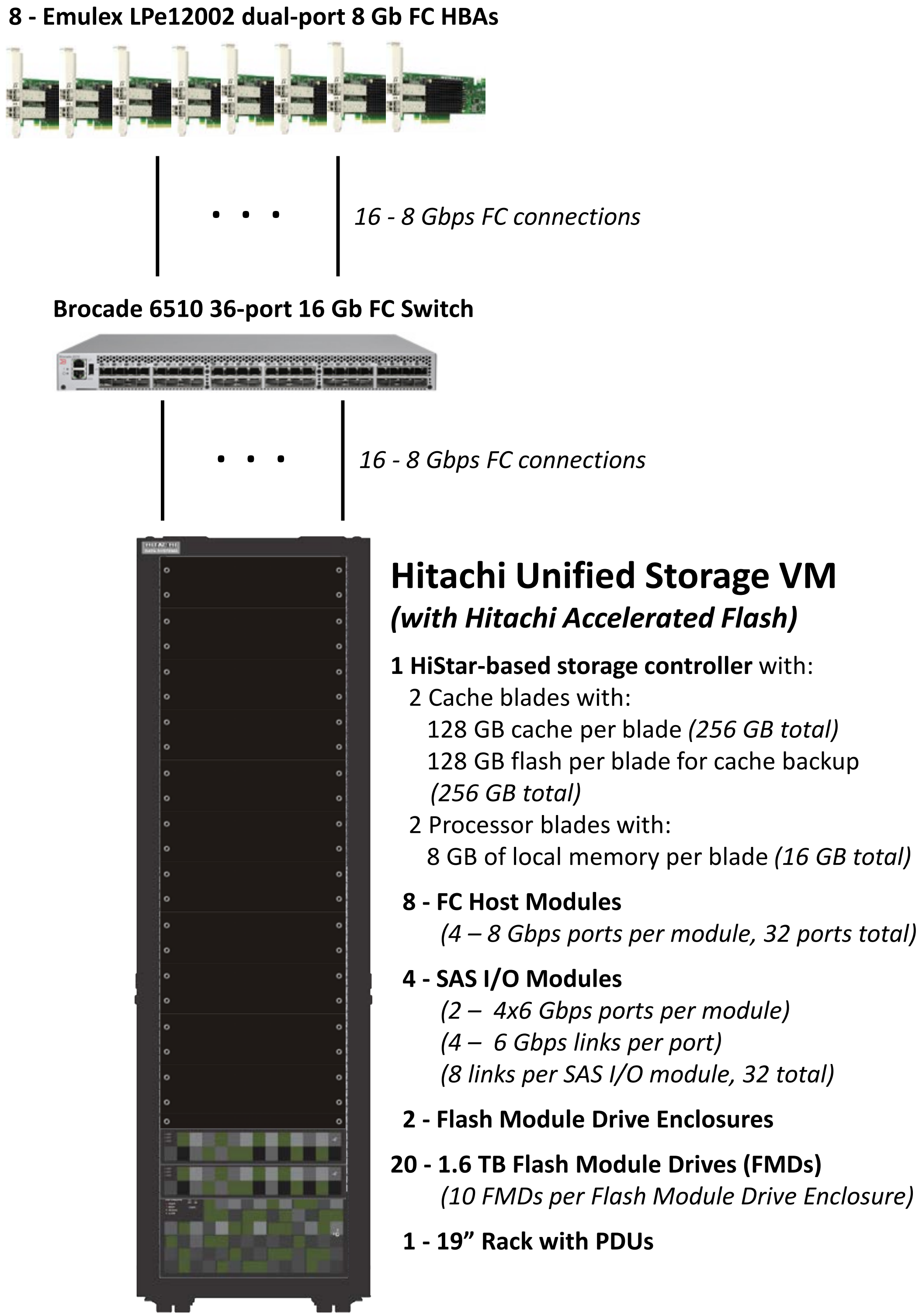
The above pricing includes hardware maintenance and software support for three years, 7 days per week, 24 hours per day. The hardware maintenance and software support provides the following:

- 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

A second 36-port FC switch was included in the Priced Storage Configuration as a spare to fulfill one of the requirements for a data protection level of **Protected 2**. If that second switch was added to the TSC, there would be no impact on the measured SPC-1 performance.

Priced Storage Configuration Diagram



Priced Storage Configuration Components

Priced Storage Configuration:
8 – Emulex LightPulse LPe12002-M8 8Gbps dual port FC HBAs
2 – Brocade 6510 FC switch, 32 active ports, 32 8Gb SFPs *(a second switch was included to serve as a spare)*
Hitachi Unified Storage VM *(with Hitachi Accelerated Flash)* 1 HiStar-based storage controller with: 2 Cache blades with: 128 GB cache per blade *(256 GB total)* 128 GB flash for cache backup per blade *(256 GB total)* 1 flash battery per blade *(2 total)* 2 Processor blades with 8 GB of local memory per blade *(16 GB total)* 8 – FC Host Modules *(4 – 8 Gbps ports per module)* *(16 ports per blade, 32 ports total)* *(8 ports used per blade, 16 total used)* 4 – SAS I/O Modules *(2 – 4x6Gbps ports per module)* *(4 – 1x6Gbps links per port)* *(8 links per module, 32 total links, 16 links used)*
2 – Flash Module Drive Enclosures
20 – 1.6 TB Flash Module Drives (FMDs) *(10 FMDs per Flash Module Drive Enclosure)*
1 – 19” rack with PDUs

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

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

Clause 9.4.3.4.3

The FDR will contain a table that lists the major components of each Host System and the Tested Storage Configuration (TSC).

The Host System(s) and TSC table of components may be found on page 24 (*Host System and Tested Storage Configuration Components*).

Storage Network Configuration

Clause 9.4.3.4.1

…

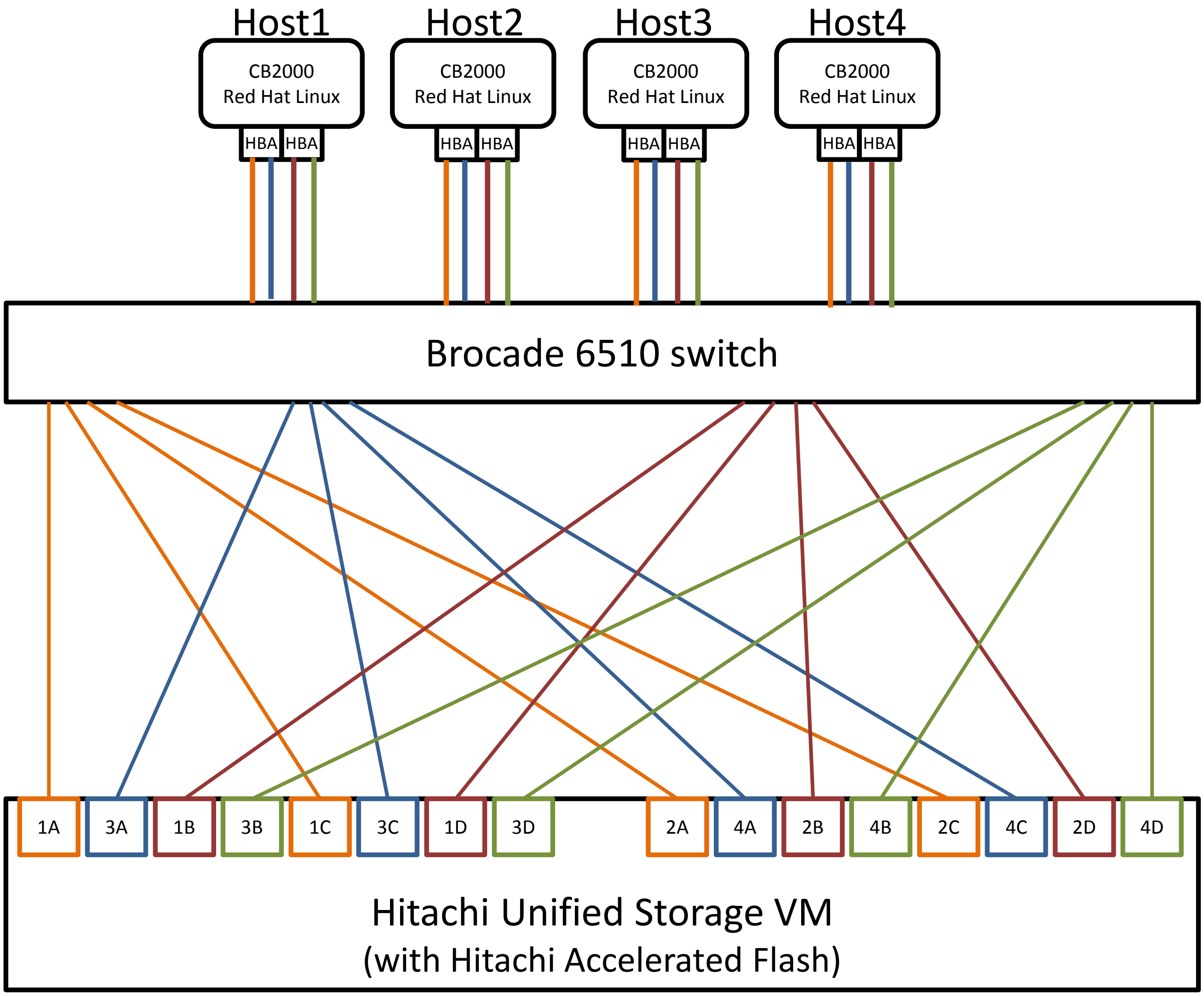
5. *If the TSC contains network storage, the diagram will include the network configuration. If a single diagram is not sufficient to illustrate both the Benchmark Configuration and network configuration in sufficient detail, the Benchmark Configuration diagram will include a high-level network illustration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

Clause 9.4.3.4.2

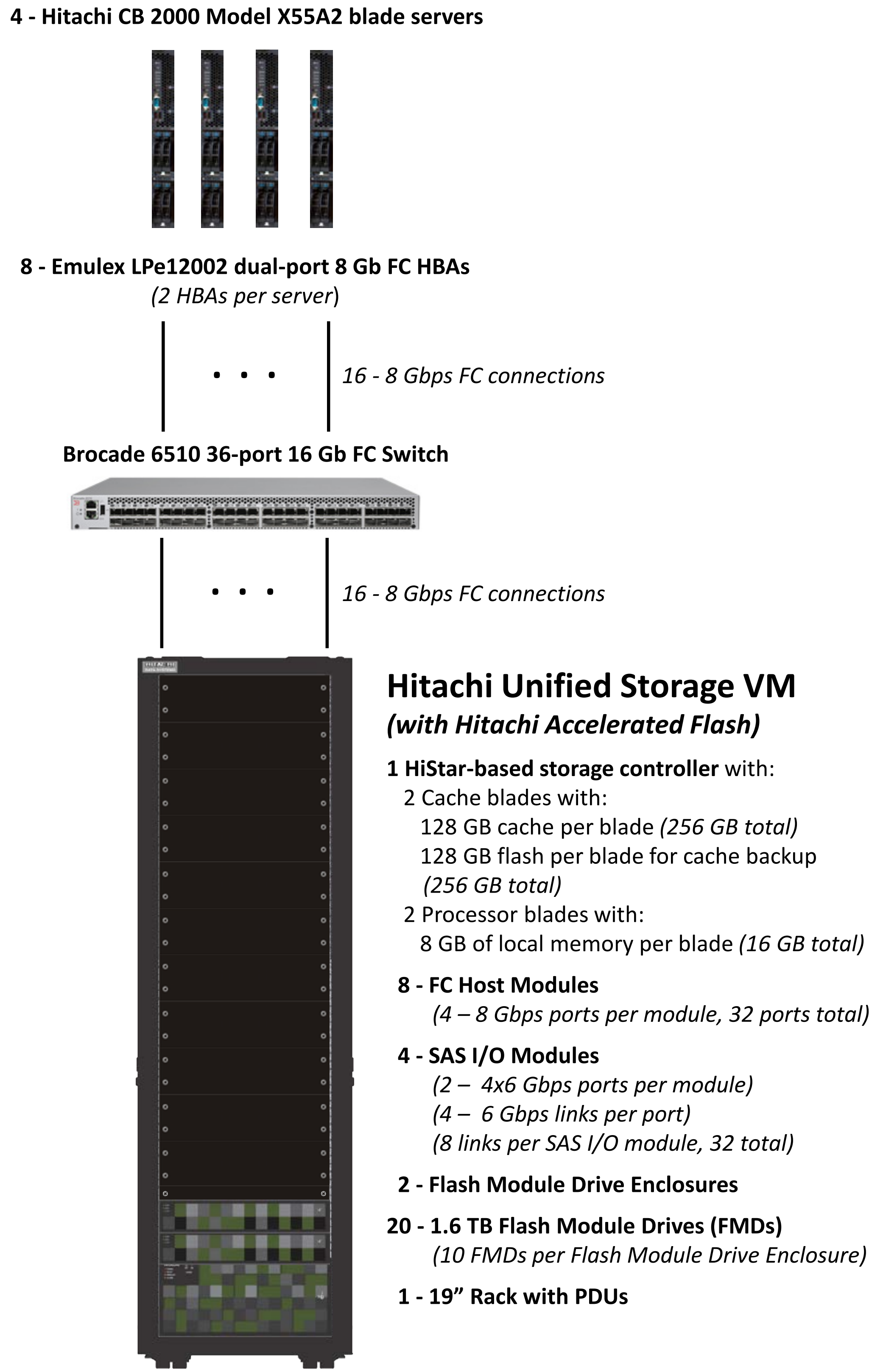
If a storage network was configured as a part of the Tested Storage Configuration and the Benchmark Configuration diagram described in Clause 9.4.3.4.1 contains a high-level illustration of the network configuration, the Executive Summary will contain a one page topology diagram of the storage network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

Each HBA port is zoned to 4 HUS VM ports so that each host system is connected to the same 16 HUS VM ports. Colors, in the diagram below, are used to differentiate between the four different zones and also to identify the members of each individual zone.

Storage Network Diagram



Benchmark Configuration/Tested Storage Configuration Diagram



Host System and Tested Storage Configuration Components

Host Systems
4 – Hitachi Compute Blade 2000 Model E55A2, each with: 2 – Intel® Xeon® 5690 six core 3.46 GHz processors 12 MB Intel® SmartCache per processor 64 GB main memory Red Hate Enterprise Linux 6.4 (x86_64) Linux Logical Volume Manager LVM version 2.02.98-9 PCIe
Tested Storage Configuration (TSC) Components
8 – Emulex LightPulse LPe12002-M8 8Gbps dual port FC HBAs *(2 HBAs per Host System)*
1 – Brocade 6510 FC switch, 32 active ports, 32 8Gb SFPs
Hitachi Unified Storage VM *(with Hitachi Accelerated Flash)* 1 HiStar-based storage controller with: 2 Cache blades with: 128 GB cache per blade *(256 GB total)* 128 GB flash for cache backup per blade *(256 GB total)* 1 flash battery per blade *(2 total)* 2 Processor blades with 8 GB of local memory per blade *(16 GB total)* 8 – FC Host Modules *(4 – 8 Gbps ports per modules)* *(16 ports per blade, 32 ports total)* *(8 ports used per blade, 16 total used)* 4 – SAS I/O Modules *(2 – 4x6Gbps ports per module)* *(4 – 1x6Gbps links per port)* *(8 links per module, 32 total links, 16 links used)*
2 – Flash Module Drive Enclosures
20 – 1.6 TB Flash Module Drives (FMDs) *(10 FMDs per Flash Module Enclosure)*
1 – 19" rack with PDUs

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 68 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 69 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 77.

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 77.

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 64 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 35,734.094 GB distributed over 20 solid state storage devices (SSDs) each with a formatted capacity of 1,786.705 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 549.761 GB (1.54%) of the Physical Storage Capacity. There was 15,481.171 GB (44.00%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 100% of the Addressable Storage Capacity resulting in 0.000 GB (0.00%) of Unused Storage within the Addressable Storage Capacity. The Data Protection *(Mirroring)* capacity was 17,592.167 GB of which 9,851.581 GB was utilized. The total Unused Storage capacity was 15,481.171 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.

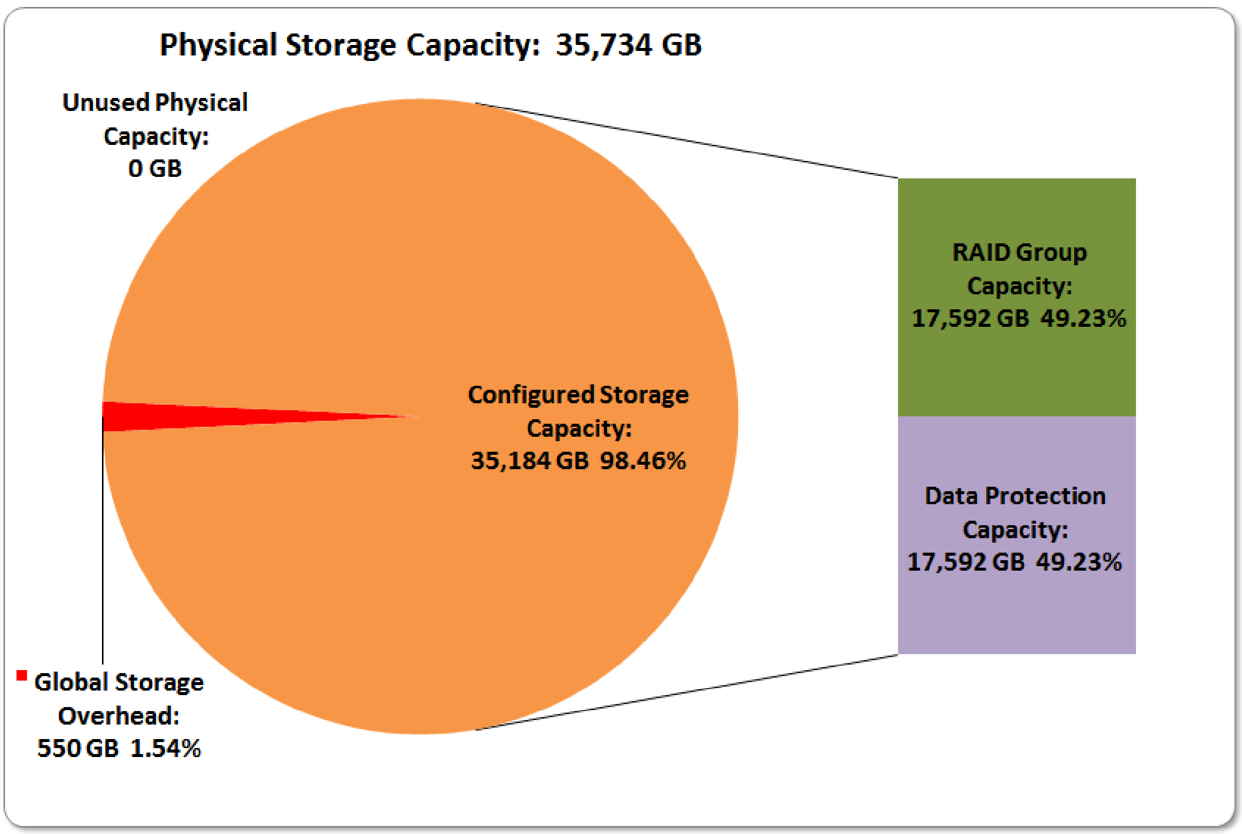
SPC-1 Storage Capacities

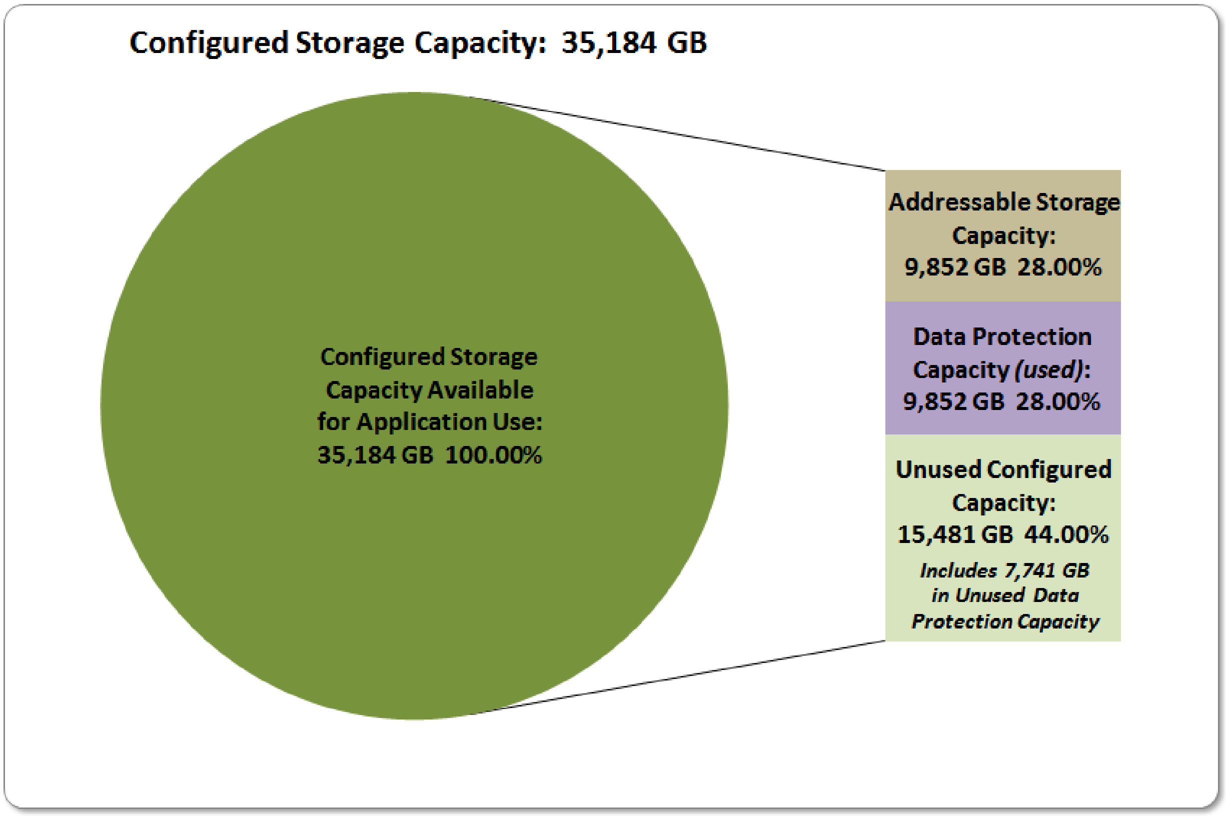
Storage Hierarchy Component	Units	Capacity
Total ASU Capacity	Gigabytes (GB)	9,851.581
Addressable Storage Capacity	Gigabytes (GB)	9,851.581
Configured Storage Capacity	Gigabytes (GB)	35,184.333
Physical Storage Capacity	Gigabytes (GB)	35,734.094
Data Protection *(Mirroring)*	Gigabytes (GB)	17,592.167
Required Storage *(metadata/overhead/spares)*	Gigabytes (GB)	0.000
Global Storage Overhead	Gigabytes (GB)	549.761
Total Unused Storage	Gigabytes (GB)	15,481.171

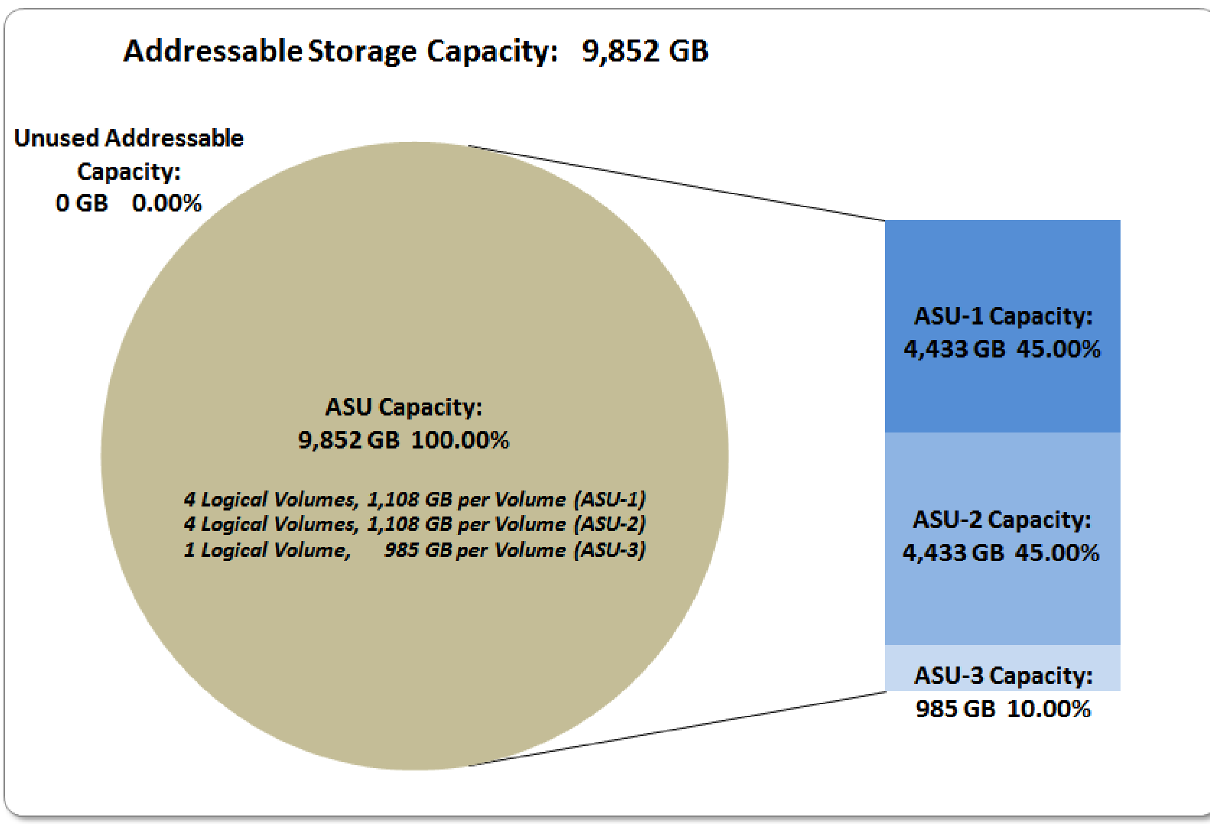
SPC-1 Storage Hierarchy Ratios

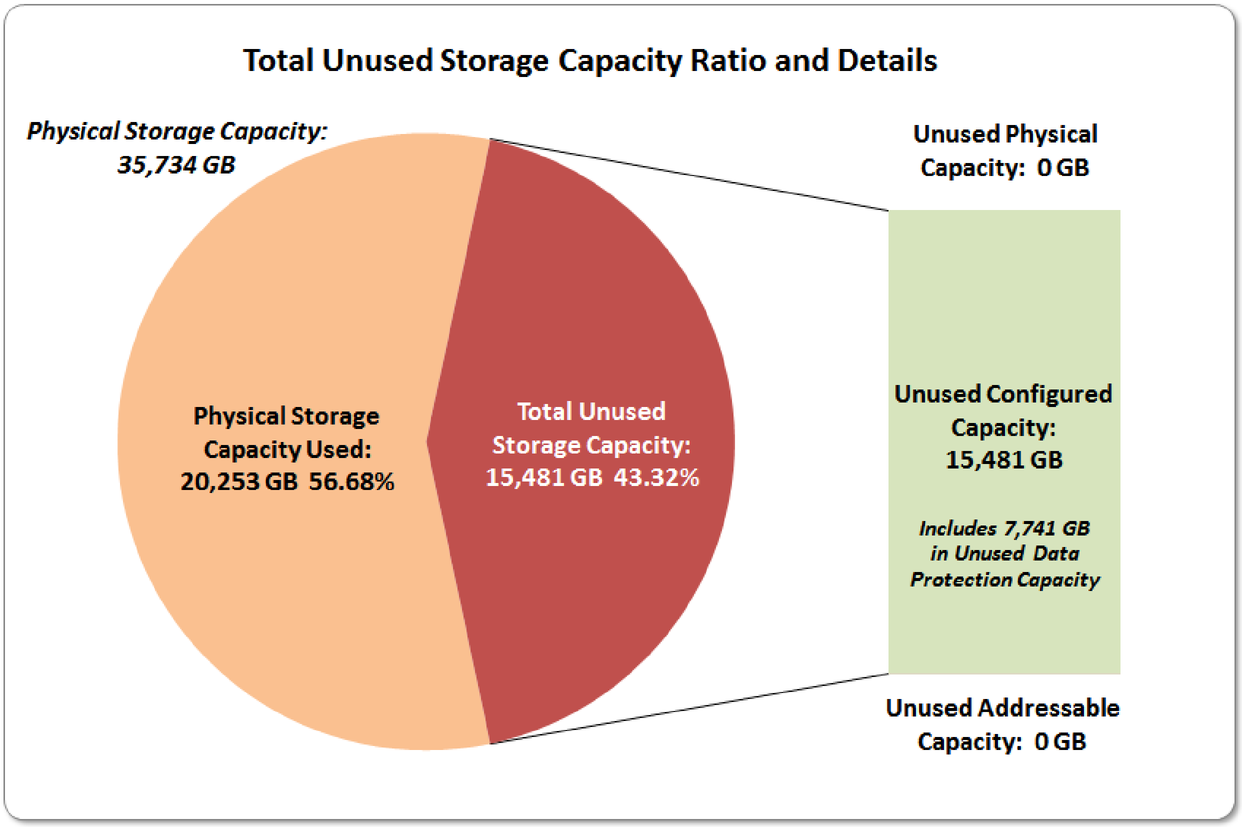
	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	28.00%	27.57%
Required for Data Protection *(Mirroring)*		50.00%	49.23%
Addressable Storage Capacity		28.00%	27.57%
Required Storage *(spares, overhead)*		0.00%	0.00%
Configured Storage Capacity			98.46%
Global Storage Overhead			1.54%
Unused Storage:			
Addressable	0.00%		
Configured		44.00%	
Physical			0.00%

SPC-1 Storage Capacity Charts




Configured Storage Capacity: 35,184 GB
Configured Storage Capacity Available for Application Use: 35,184 GB 100.00%
Addressable Storage Capacity: 9,852 GB 28.00%
Data Protection Capacity (used): 9,852 GB 28.00%
Unused Configured Capacity: 15,481 GB 44.00%
Includes 7,741 GB in Unused Data Protection Capacity


Addressable Storage Capacity: 9,852 GB
Unused Addressable Capacity: 0 GB 0.00%
ASU Capacity: 9,852 GB 100.00%
4 Logical Volumes, 1,108 GB per Volume (ASU-1)
4 Logical Volumes, 1,108 GB per Volume (ASU-2)
1 Logical Volume, 985 GB per Volume (ASU-3)
ASU-1 Capacity: 4,433 GB 45.00%
ASU-2 Capacity: 4,433 GB 45.00%
ASU-3 Capacity: 985 GB 10.00%



Storage Capacity Utilization

Clause 9.4.3.6.2

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

Clause 2.8.1

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

Clause 2.8.2

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

Clause 2.8.3

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

SPC-1 Storage Capacity Utilization	
Application Utilization	27.57%
Protected Application Utilization	55.14%
Unused Storage Ratio	43.32%

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 (4,433.212 GB)	**ASU-2 (4,433.212 GB)**	**ASU-3 (985.158 GB)**
4 Logical Volumes 1,108.303 GB per Logical Volume (1,108.303 GB used per Logical Volume)	4 Logical Volumes 1,108.303 GB per Logical Volume (1,108.303 GB used per Logical Volume)	1 Logical Volume 985.158 GB per Logical Volume (985.158 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 64 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

<u>Clause 5.3.13</u>

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.

<u>Clause 5.3.13.3</u>

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

<u>Clause 9.4.3.7.1</u>

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

<u>Clause 5.4.4.1.1</u>

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™).

<u>Clause 5.4.4.1.2</u>

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

<u>Clause 5.4.4.1.4</u>

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.

<u>Clause 9.4.3.7.2</u>

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 81.

Sustainability Test Results File

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

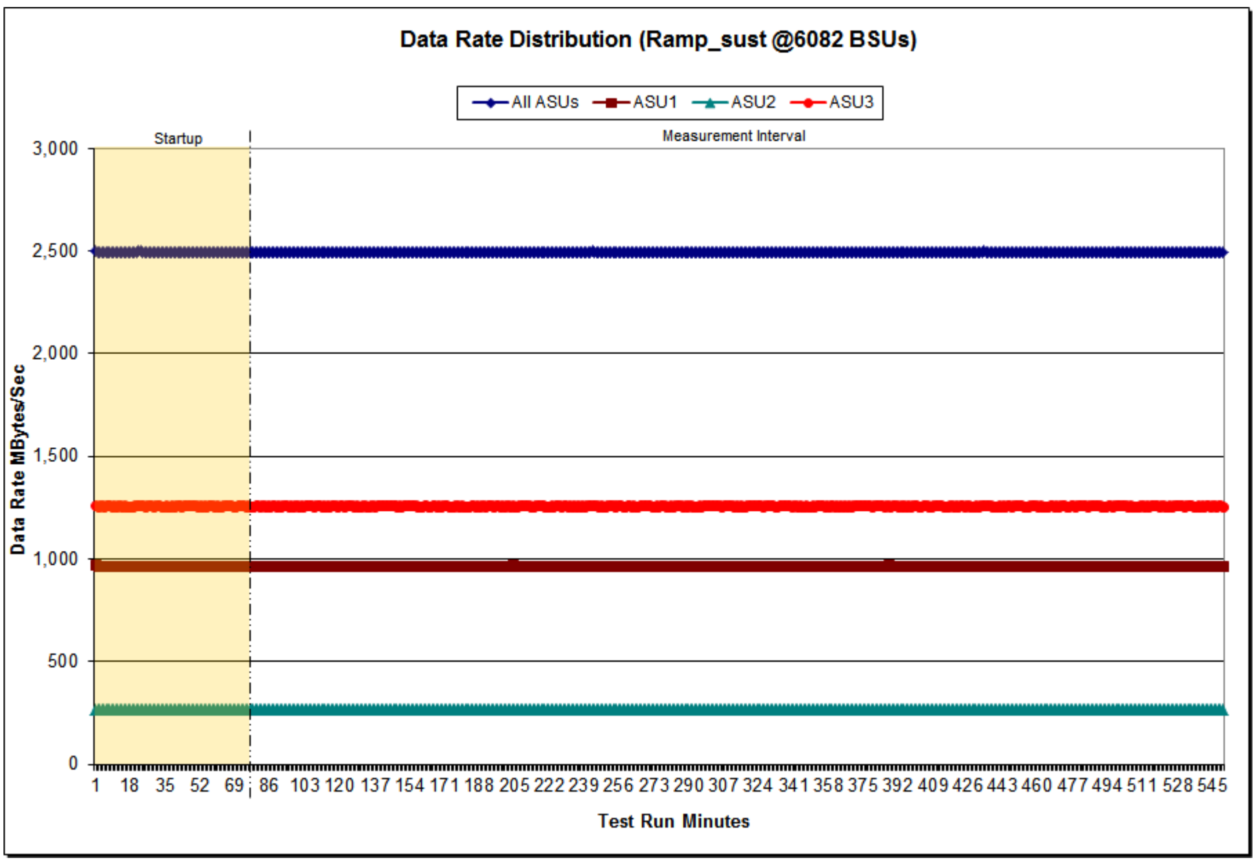
Sustainability Test Results File

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

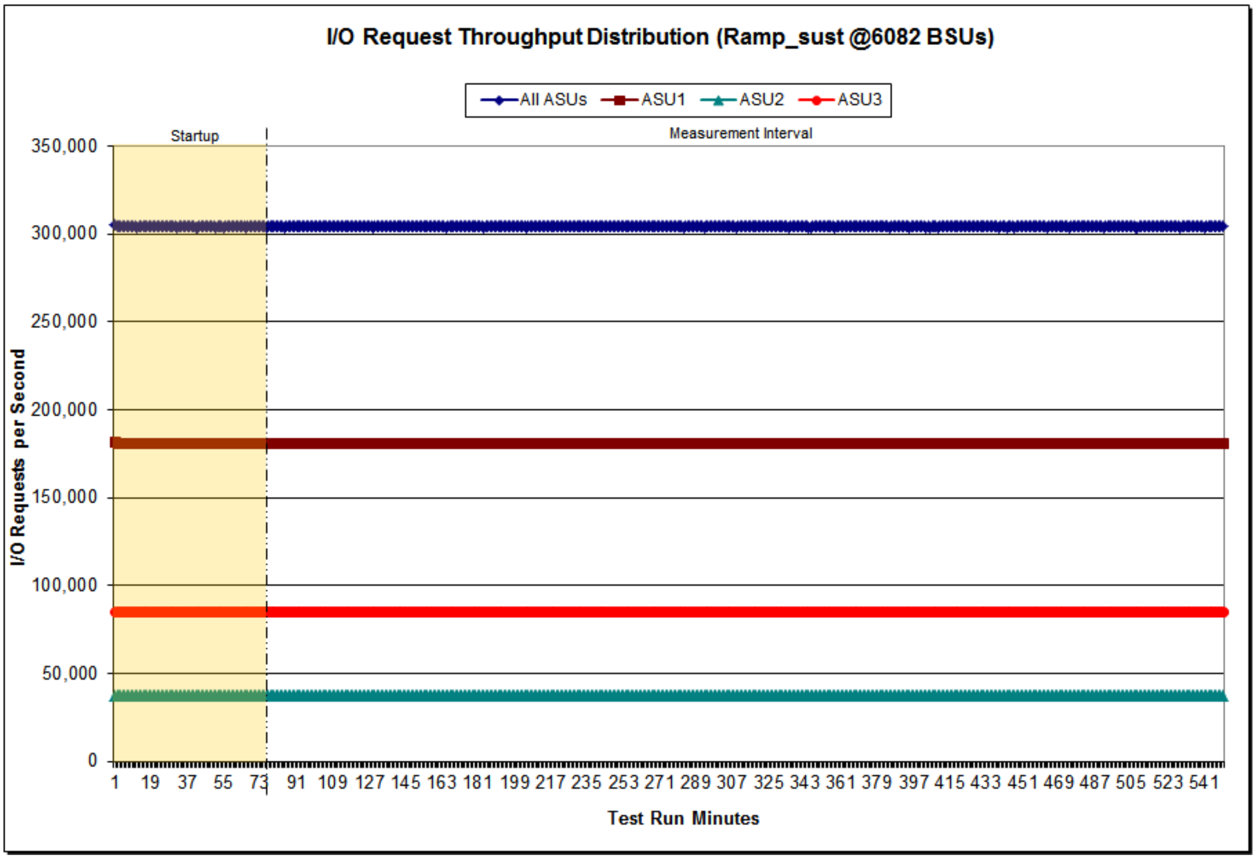


Sustainability – I/O Request Throughput Distribution Data

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

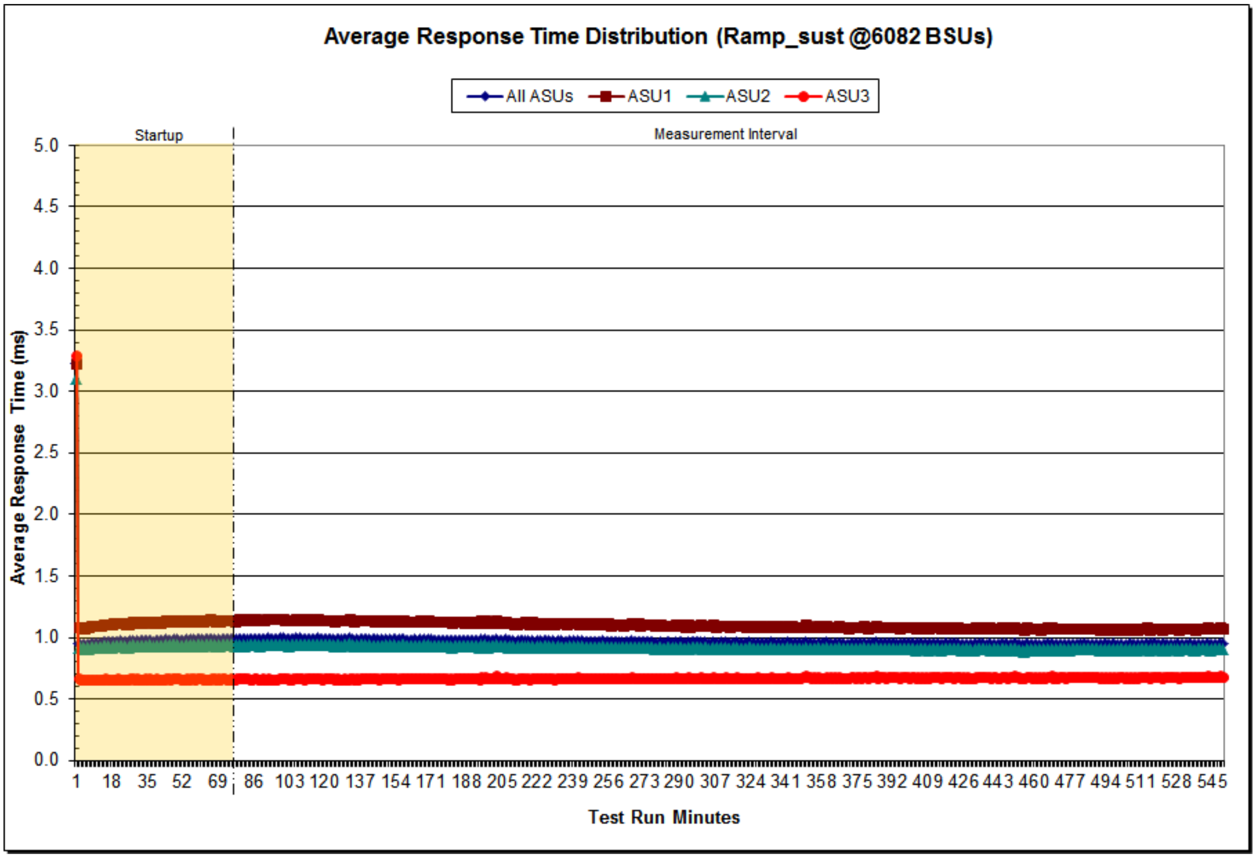


Sustainability – Average Response Time (ms) Distribution Data

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

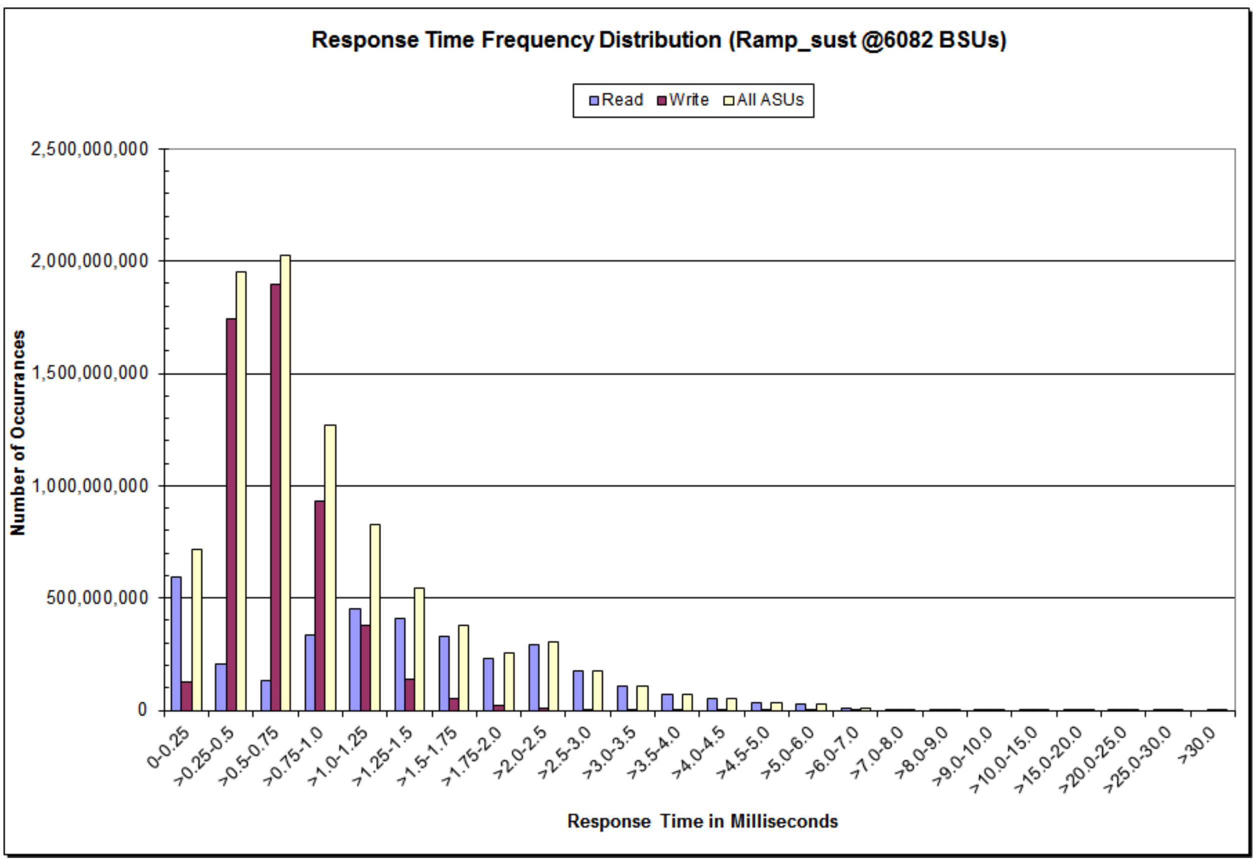
Sustainability – Average Response Time (ms) Distribution Graph



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	592,968,564	207,554,133	133,043,815	333,989,910	450,010,394	407,931,847	326,372,467	233,458,559
Write	125,991,008	1,746,134,202	1,894,802,925	933,871,681	376,269,955	135,804,655	49,975,118	19,735,303
All ASUs	718,959,572	1,953,688,335	2,027,846,740	1,267,861,591	826,280,349	543,736,502	376,347,585	253,193,862
ASU1	510,026,533	959,913,351	933,208,325	673,158,014	540,033,659	406,834,792	302,324,526	210,580,805
ASU2	160,093,368	235,832,377	210,872,521	133,824,392	94,559,987	66,615,530	47,541,140	32,112,730
ASU3	48,839,671	757,942,607	883,765,894	460,879,185	191,686,703	70,286,180	26,481,919	10,500,327
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	293,199,669	173,233,137	108,265,009	71,771,148	49,255,826	32,060,923	29,255,206	7,971,762
Write	11,472,501	3,066,074	1,407,621	893,927	697,659	554,954	842,903	646,442
All ASUs	304,672,170	176,299,211	109,672,630	72,665,075	49,953,485	32,615,877	30,098,109	8,618,204
ASU1	260,520,527	153,203,861	95,904,869	63,769,852	43,898,698	28,657,720	26,336,398	7,364,587
ASU2	38,209,718	21,588,115	13,105,582	8,485,032	5,737,025	3,704,171	3,374,665	954,754
ASU3	5,941,925	1,507,235	662,179	410,191	317,762	253,986	387,046	298,863
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	2,368,108	740,009	260,276	328,121	40,408	16,259	2,101	108
Write	466,206	363,648	257,103	585,869	103,375	19,092	3,088	1,353
All ASUs	2,834,314	1,103,657	517,379	913,990	143,783	35,351	5,189	1,461
ASU1	2,304,015	812,417	340,112	537,404	79,005	21,954	3,024	611
ASU2	314,082	120,964	56,295	97,432	14,447	3,716	538	143
ASU3	216,217	170,276	120,972	279,154	50,331	9,681	1,627	707

Sustainability – Response Time Frequency Distribution Graph



Sustainability – Measured Intensity Multiplier and Coefficient of Variation

<u>*Clause 3.4.3*</u>

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.*

<u>*Clauses 5.1.10 and 5.3.15.2*</u>

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%.*

<u>*Clause 5.3.15.3*</u>

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	0.0.350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.001	0.000	0.00-1	0.000	0.002	0.001	0.001	0.000

Primary Metrics Test – IOPS Test Phase

Clause 5.4.4.2

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

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

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

Clause 9.4.3.7.3

For the IOPS Test Phase the FDR shall contain:

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

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in Appendix E: SPC-1 Workload Generator Input Parameters on Page 81.

IOPS Test Results File

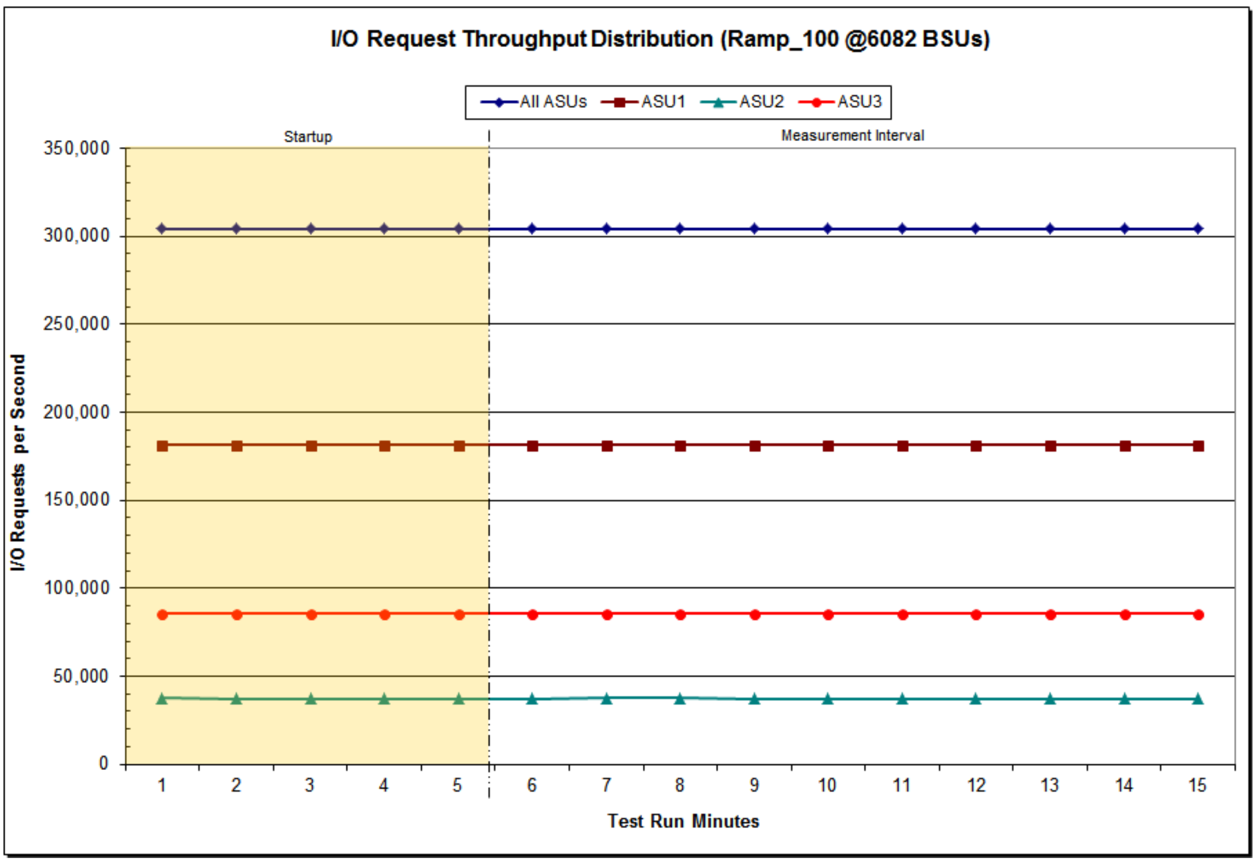
A link to the test results file generated from the IOPS Test Run is listed below.

IOPS Test Results File

IOPS Test Run – I/O Request Throughput Distribution Data

6,082 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:25:27	21:30:28	0-4	0:05:01
Measurement Interval	21:30:28	21:40:28	5-15	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	304,015.58	181,150.20	37,427.80	85,437.58
1	304,053.95	181,217.50	37,375.90	85,460.55
2	304,119.42	181,250.00	37,405.35	85,464.07
3	304,102.87	181,251.58	37,411.88	85,439.40
4	304,074.75	181,257.47	37,404.48	85,412.80
5	304,058.40	181,221.33	37,386.50	85,450.57
6	304,140.78	181,221.45	37,432.02	85,487.32
7	304,268.55	181,380.40	37,425.62	85,462.53
8	304,114.90	181,285.12	37,378.40	85,451.38
9	304,167.87	181,309.95	37,415.28	85,442.63
10	304,107.12	181,284.02	37,374.60	85,448.50
11	304,159.92	181,285.40	37,396.58	85,477.93
12	304,107.07	181,196.88	37,420.93	85,489.25
13	304,070.15	181,210.15	37,403.43	85,456.57
14	304,076.48	181,236.33	37,402.20	85,437.95
Average	***304,127.12***	***181,263.10***	***37,403.56***	***85,460.46***

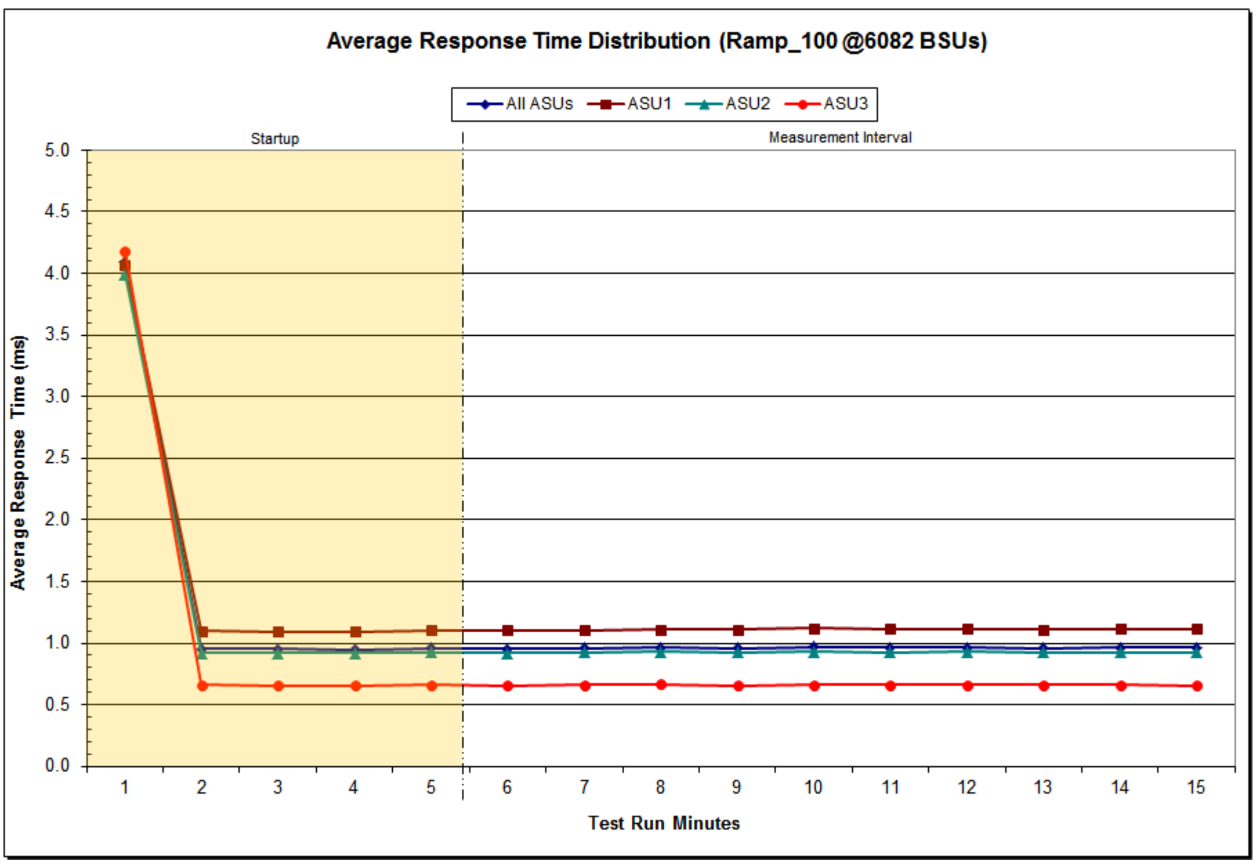
IOPS Test Run – I/O Request Throughput Distribution Graph



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

6,082 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:25:27	21:30:28	0-4	0:05:01
Measurement Interval	21:30:28	21:40:28	5-15	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	4.09	4.06	3.99	4.19
1	0.95	1.10	0.92	0.66
2	0.95	1.09	0.92	0.66
3	0.95	1.10	0.92	0.66
4	0.96	1.10	0.92	0.66
5	0.95	1.10	0.92	0.66
6	0.96	1.11	0.92	0.66
7	0.96	1.11	0.93	0.66
8	0.96	1.11	0.92	0.66
9	0.97	1.12	0.93	0.66
10	0.96	1.11	0.93	0.66
11	0.97	1.12	0.93	0.66
12	0.96	1.11	0.92	0.66
13	0.96	1.12	0.93	0.66
14	0.96	1.11	0.92	0.66
Average	***0.96***	***1.11***	***0.93***	***0.66***

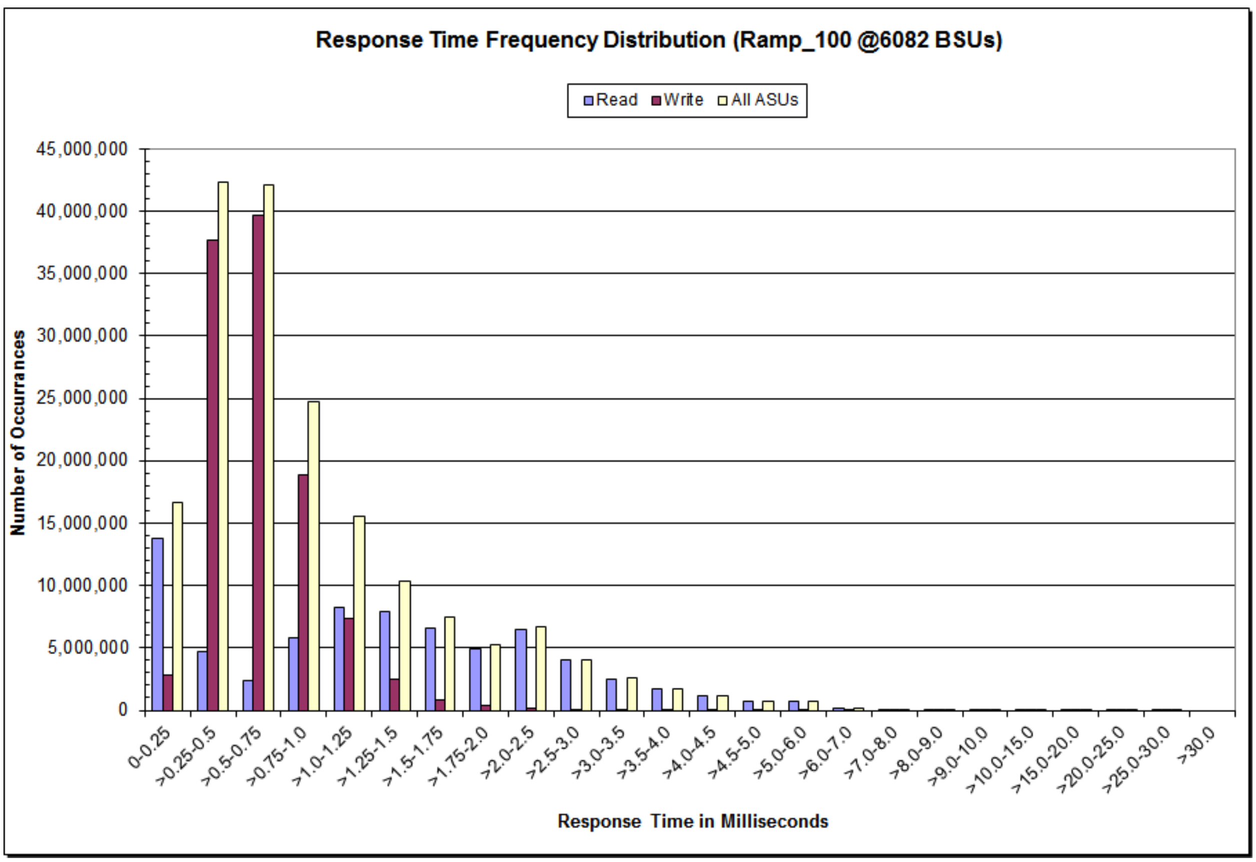
IOPS Test Run – Average Response Time (ms) Distribution Graph



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	13,807,094	4,716,282	2,433,215	5,809,991	8,251,229	7,873,907	6,585,403	4,891,346
Write	2,835,182	37,649,448	39,692,448	18,906,909	7,307,858	2,509,103	883,307	335,284
All ASUs	16,642,276	42,365,730	42,125,663	24,716,900	15,559,087	10,383,010	7,468,710	5,226,630
ASU1	12,106,501	21,008,396	19,215,473	12,710,598	9,979,119	7,749,244	6,013,194	4,358,220
ASU2	3,435,823	5,021,259	4,353,901	2,627,563	1,832,660	1,322,709	981,246	687,880
ASU3	1,099,952	16,336,075	18,556,289	9,378,739	3,747,308	1,311,057	474,270	180,530
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	6,456,692	3,994,595	2,533,664	1,686,539	1,154,179	755,946	716,106	205,678
Write	194,218	54,794	27,763	18,752	14,763	11,463	17,463	12,950
All ASUs	6,650,910	4,049,389	2,561,427	1,705,291	1,168,942	767,409	733,569	218,628
ASU1	5,695,978	3,524,878	2,245,784	1,501,792	1,032,338	678,311	646,976	189,625
ASU2	854,055	498,012	302,536	194,939	129,917	83,850	78,617	23,091
ASU3	100,877	26,499	13,107	8,560	6,687	5,248	7,976	5,912
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	61,636	19,349	6,596	7,184	777	336	42	1
Write	9,852	7,491	5,495	12,389	1,118	119	12	-
All ASUs	71,488	26,840	12,091	19,573	1,895	455	54	1
ASU1	59,372	20,549	8,230	11,532	1,156	343	39	1
ASU2	7,543	2,835	1,281	2,143	185	50	8	-
ASU3	4,573	3,456	2,580	5,898	554	62	7	-

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
182,475,968	182,475,967	1

IOPS Test Run – Measured Intensity Multiplier and Coefficient of Variation

<u>*Clause 3.4.3*</u>

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.*

<u>*Clauses 5.1.10 and 5.3.15.2*</u>

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%.*

<u>*Clause 5.3.15.3*</u>

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	0.2101	0.0180	0.0700	0.0350	0.2810
COV	0.001	0.000	0.001	0.000	0.002	0.001	0.001	0.000

Primary Metrics Test – 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 81.

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: 6,082 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:25:27	21:30:28	0-4	0:05:01
Measurement Interval	21:30:28	21:40:28	5-14	0:10:00
(60 second intervals)	**All ASUs**	**ASU-1**	**ASU-2**	**ASU-3**
0	304,015.58	181,150.20	37,427.80	85,437.58
1	304,053.95	181,217.50	37,375.90	85,460.55
2	304,119.42	181,250.00	37,405.35	85,464.07
3	304,102.87	181,251.58	37,411.88	85,439.40
4	304,074.75	181,257.47	37,404.48	85,412.80
5	304,058.40	181,221.33	37,386.50	85,450.57
6	304,140.78	181,221.45	37,432.02	85,487.32
7	304,268.55	181,380.40	37,425.62	85,462.53
8	304,114.90	181,285.12	37,378.40	85,451.38
9	304,167.87	181,309.95	37,415.28	85,442.63
10	304,107.12	181,284.02	37,374.60	85,448.50
11	304,159.92	181,285.40	37,396.58	85,477.93
12	304,107.07	181,196.88	37,420.93	85,489.25
13	304,070.15	181,210.15	37,403.43	85,456.57
14	304,076.48	181,236.33	37,402.20	85,437.95
Average	***304,127.12***	***181,263.10***	***37,403.56***	***85,460.46***

95% Load Level: 5,777 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:40:46	21:45:47	0-4	0:05:01
Measurement Interval	21:45:47	21:55:47	5-14	0:10:00
(60 second intervals)	**All ASUs**	**ASU-1**	**ASU-2**	**ASU-3**
0	288,966.58	172,223.32	35,554.58	81,188.68
1	288,868.77	172,208.27	35,533.93	81,126.57
2	288,856.92	172,194.18	35,569.78	81,092.95
3	288,804.37	172,116.03	35,523.70	81,164.63
4	288,822.97	172,168.73	35,538.72	81,115.52
5	288,725.68	172,171.47	35,478.95	81,075.27
6	288,851.77	172,193.40	35,503.05	81,155.32
7	288,857.45	172,162.32	35,516.73	81,178.40
8	288,871.27	172,114.58	35,553.70	81,202.98
9	288,823.43	172,101.53	35,537.05	81,184.85
10	288,753.50	172,124.73	35,486.63	81,142.13
11	288,886.85	172,178.65	35,531.50	81,176.70
12	288,841.98	172,131.83	35,514.65	81,195.50
13	288,801.47	172,121.10	35,505.67	81,174.70
14	288,995.38	172,278.17	35,523.75	81,193.47
Average	***288,840.88***	***172,157.78***	***35,515.17***	***81,167.93***

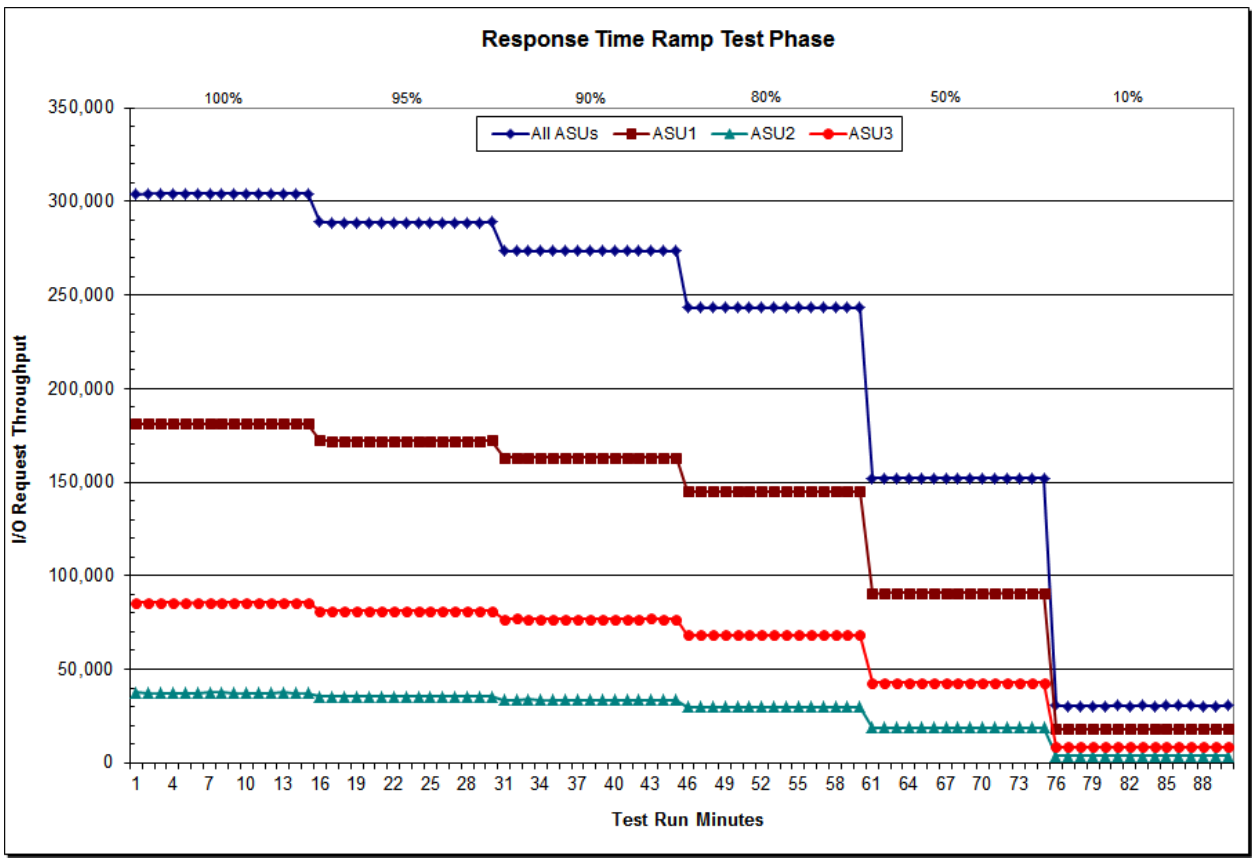
90% Load Level: 5,473 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:56:04	22:01:05	0-4	0:05:01
Measurement Interval	22:01:05	22:11:05	5-14	0:10:00
(60 second intervals)	**All ASUs**	**ASU-1**	**ASU-2**	**ASU-3**
0	273,761.58	163,163.67	33,679.57	76,918.35
1	273,657.23	163,050.13	33,665.35	76,941.75
2	273,680.65	163,043.98	33,725.90	76,910.77
3	273,641.53	163,055.78	33,653.65	76,932.10
4	273,655.67	163,104.47	33,680.92	76,870.28
5	273,568.87	163,041.90	33,658.88	76,868.08
6	273,640.67	163,058.82	33,664.95	76,916.90
7	273,610.60	163,109.78	33,597.78	76,903.03
8	273,716.97	163,217.17	33,664.03	76,835.77
9	273,570.25	163,062.52	33,651.15	76,856.58
10	273,713.73	163,142.40	33,701.00	76,870.33
11	273,593.50	163,115.42	33,609.93	76,868.15
12	273,683.02	163,066.73	33,660.52	76,955.77
13	273,546.75	163,070.02	33,656.97	76,819.77
14	273,537.18	163,017.22	33,625.10	76,894.87
Average	***273,618.15***	***163,090.20***	***33,649.03***	***76,878.93***

80% Load Level: 4,865 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	22:11:22	22:16:23	0-4	0:05:01
Measurement Interval	22:16:23	22:26:23	5-14	0:10:00
(60 second intervals)	**All ASUs**	**ASU-1**	**ASU-2**	**ASU-3**
0	243,294.03	144,988.18	29,921.63	68,384.22
1	243,195.42	144,970.93	29,884.70	68,339.78
2	243,318.87	144,973.12	29,927.92	68,417.83
3	243,261.88	144,978.42	29,900.00	68,383.47
4	243,271.62	144,995.18	29,945.82	68,330.62
5	243,247.42	144,906.48	29,935.22	68,405.72
6	243,396.53	145,046.88	29,940.53	68,409.12
7	243,409.32	145,030.82	29,947.82	68,430.68
8	243,348.55	144,968.77	29,954.33	68,425.45
9	243,287.00	144,951.37	29,927.92	68,407.72
10	243,232.98	144,910.73	29,919.73	68,402.52
11	243,262.48	144,956.98	29,932.25	68,373.25
12	243,172.82	144,958.05	29,858.48	68,356.28
13	243,179.62	144,924.25	29,907.17	68,348.20
14	243,230.47	144,942.28	29,932.67	68,355.52
Average	***243,276.72***	***144,959.66***	***29,925.61***	***68,391.45***

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

50% Load Level: 3,041 BSUs	Start	Stop	Interval	Duration	10% Load Level: 608 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	22:26:37	22:31:38	0-4	0:05:01	Start-Up/Ramp-Up	22:41:49	22:46:50	0-4	0:05:01
Measurement Interval	22:31:38	22:41:38	5-14	0:10:00	Measurement Interval	22:46:50	22:56:50	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	151,955.35	90,555.72	18,691.57	42,708.07	0	30,408.42	18,123.17	3,741.53	8,543.72
1	152,094.93	90,626.37	18,717.07	42,751.50	1	30,380.48	18,120.25	3,738.12	8,522.12
2	152,104.58	90,624.45	18,701.88	42,778.25	2	30,376.22	18,120.00	3,732.63	8,523.58
3	152,057.17	90,639.68	18,703.87	42,713.62	3	30,337.20	18,065.67	3,751.73	8,519.80
4	152,007.57	90,616.97	18,694.33	42,696.27	4	30,350.40	18,112.35	3,724.85	8,513.20
5	152,112.57	90,665.98	18,721.18	42,725.40	5	30,412.77	18,117.87	3,753.62	8,541.28
6	152,072.17	90,651.55	18,699.33	42,721.28	6	30,387.73	18,114.80	3,735.82	8,537.12
7	152,025.95	90,604.53	18,705.53	42,715.88	7	30,402.90	18,132.97	3,737.18	8,532.75
8	152,126.83	90,658.82	18,702.73	42,765.28	8	30,384.42	18,095.92	3,736.83	8,551.67
9	152,047.58	90,598.35	18,701.82	42,747.42	9	30,414.85	18,119.37	3,740.75	8,554.73
10	152,027.17	90,594.75	18,700.93	42,731.48	10	30,408.83	18,118.58	3,755.30	8,534.95
11	152,035.53	90,617.42	18,708.30	42,709.82	11	30,413.48	18,146.35	3,726.07	8,541.07
12	152,148.50	90,634.13	18,738.08	42,776.28	12	30,385.08	18,110.63	3,739.85	8,534.60
13	152,064.13	90,646.07	18,687.12	42,730.95	13	30,379.45	18,099.18	3,735.82	8,544.45
14	152,055.55	90,615.25	18,704.33	42,735.97	14	30,416.37	18,137.43	3,732.88	8,546.05
Average	***152,071.60***	***90,628.69***	***18,706.94***	***42,735.98***	***Average***	***30,400.59***	***18,119.31***	***3,739.41***	***8,541.87***

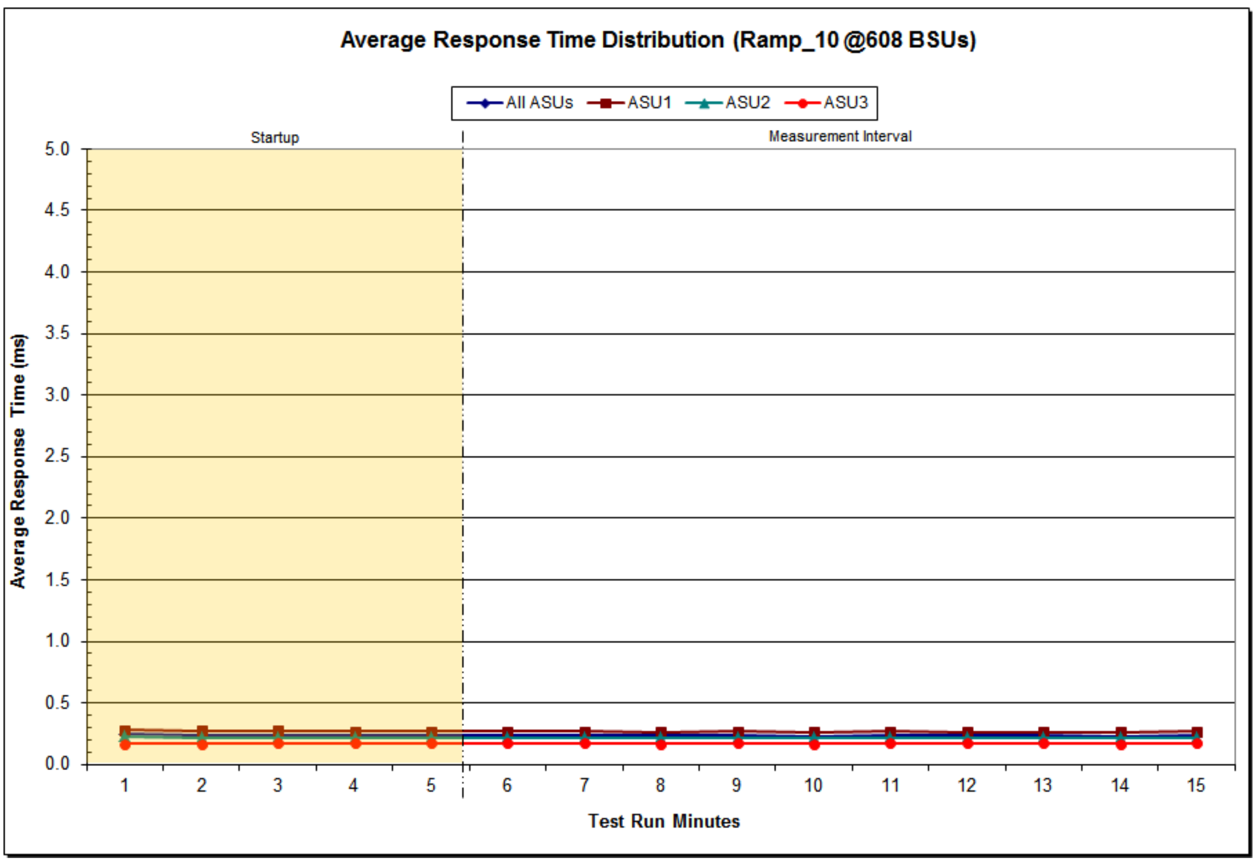
Response Time Ramp Distribution (IOPS) Graph



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

608 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	22:41:49	22:46:50	0-4	0:05:01
Measurement Interval	22:46:50	22:56:50	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.24	0.28	0.23	0.17
1	0.24	0.27	0.22	0.17
2	0.24	0.27	0.22	0.17
3	0.23	0.27	0.22	0.17
4	0.24	0.27	0.22	0.17
5	0.23	0.27	0.22	0.17
6	0.23	0.27	0.22	0.17
7	0.23	0.26	0.22	0.17
8	0.23	0.27	0.22	0.17
9	0.23	0.26	0.22	0.17
10	0.23	0.27	0.22	0.17
11	0.23	0.26	0.22	0.17
12	0.23	0.27	0.22	0.17
13	0.23	0.26	0.22	0.17
14	0.23	0.27	0.22	0.17
Average	***0.23***	***0.27***	***0.22***	***0.17***

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



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

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.15.2

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

Clause 5.3.15.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2812	0.0700	0.2098	0.0180	0.0700	0.0350	0.2810
COV	0.004	0.001	0.003	0.002	0.005	0.003	0.004	0.001

Repeatability Test

Clause 5.4.5

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

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

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

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

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

Clause 9.4.3.7.5

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

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

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in Appendix E: SPC-1 Workload Generator Input Parameters on Page 81.

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	***304,127.12***
Repeatability Test Phase 1	304,130.32
Repeatability Test Phase 2	304,145.31

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	***0.23 ms***
Repeatability Test Phase 1	0.23 ms
Repeatability Test Phase 2	0.23 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).

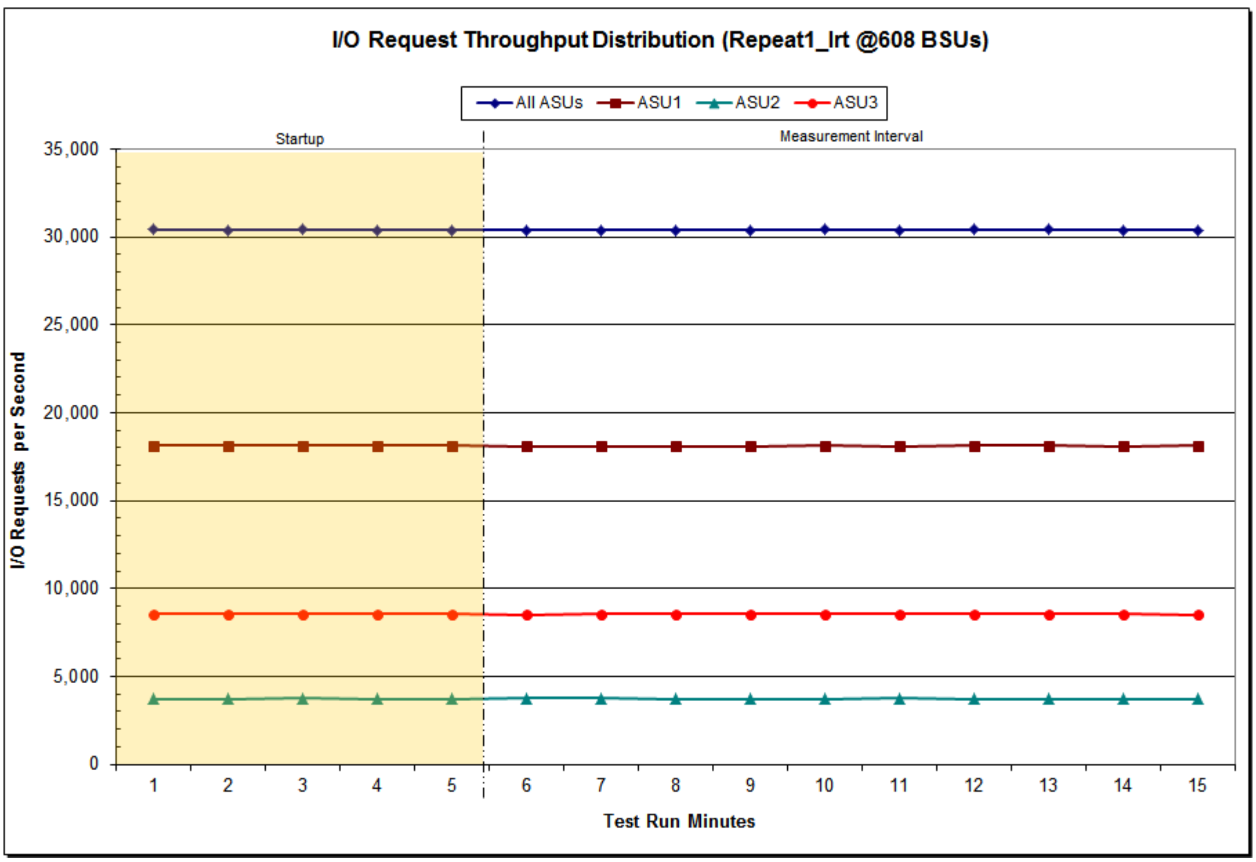
A link to the test result file generated from each Repeatability Test Run is listed below.

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

608 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	22:58:36	23:03:36	0-4	0:05:00
Measurement Interval	23:03:36	23:13:36	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	30,400.55	18,125.02	3,727.75	8,547.78
1	30,393.60	18,118.02	3,730.47	8,545.12
2	30,405.02	18,121.77	3,744.98	8,538.27
3	30,389.03	18,112.03	3,742.00	8,535.00
4	30,385.73	18,124.82	3,728.25	8,532.67
5	30,377.93	18,104.92	3,751.38	8,521.63
6	30,362.90	18,078.07	3,747.40	8,537.43
7	30,377.35	18,110.55	3,729.45	8,537.35
8	30,380.03	18,092.68	3,742.05	8,545.30
9	30,407.70	18,124.22	3,738.30	8,545.18
10	30,397.40	18,094.38	3,747.93	8,555.08
11	30,407.87	18,126.20	3,740.43	8,541.23
12	30,426.37	18,135.90	3,740.52	8,549.95
13	30,397.13	18,110.70	3,733.60	8,552.83
14	30,384.13	18,117.45	3,736.72	8,529.97
Average	***30,391.88***	***18,109.51***	***3,740.78***	***8,541.60***

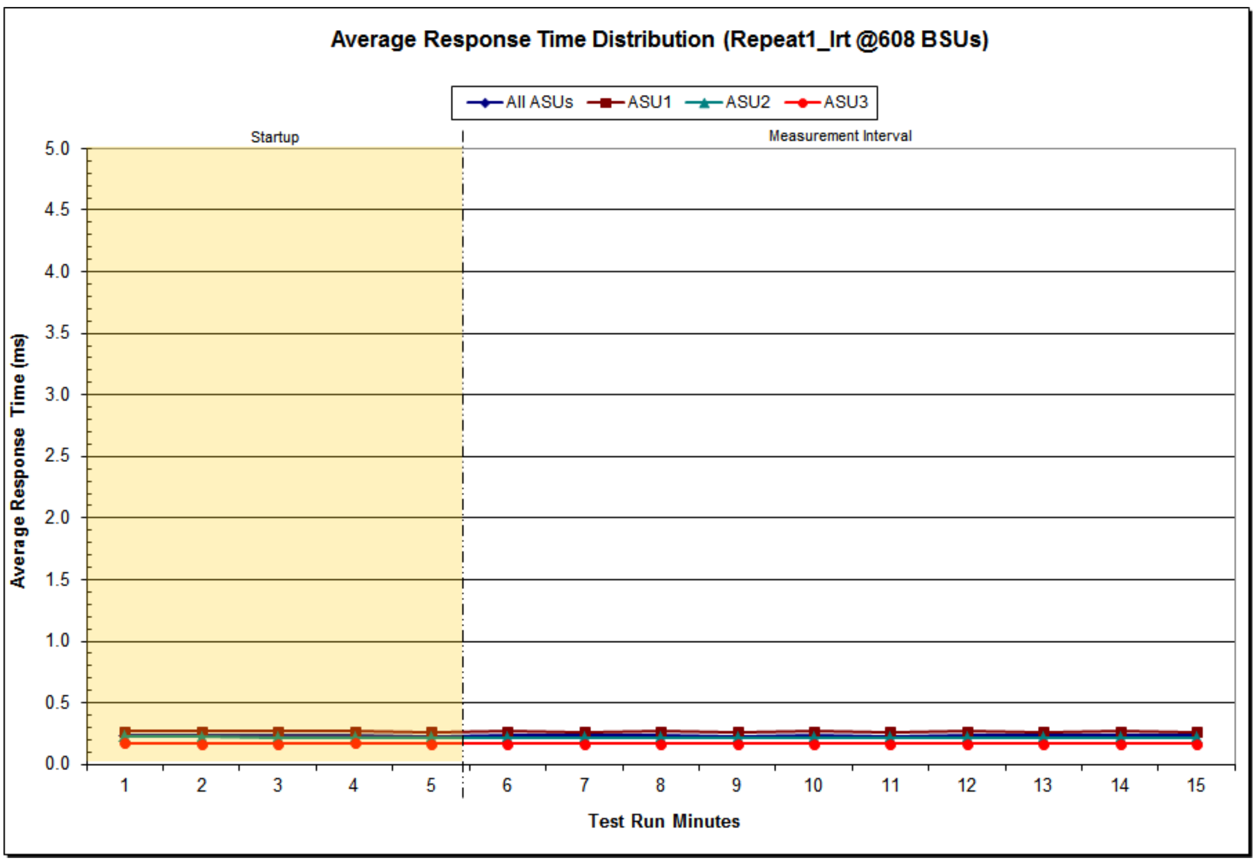
Repeatability 1 LRT – I/O Request Throughput Distribution Graph



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

608 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	22:58:36	23:03:36	0-4	0:05:00
Measurement Interval	23:03:36	23:13:36	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.24	0.27	0.23	0.17
1	0.23	0.27	0.22	0.17
2	0.23	0.27	0.22	0.17
3	0.23	0.27	0.22	0.17
4	0.23	0.26	0.22	0.17
5	0.23	0.27	0.22	0.17
6	0.23	0.27	0.22	0.17
7	0.23	0.27	0.22	0.17
8	0.23	0.26	0.22	0.17
9	0.23	0.27	0.22	0.17
10	0.23	0.26	0.22	0.17
11	0.23	0.27	0.22	0.17
12	0.23	0.26	0.22	0.17
13	0.23	0.27	0.22	0.17
14	0.23	0.26	0.22	0.17
Average	***0.23***	***0.27***	***0.22***	***0.17***

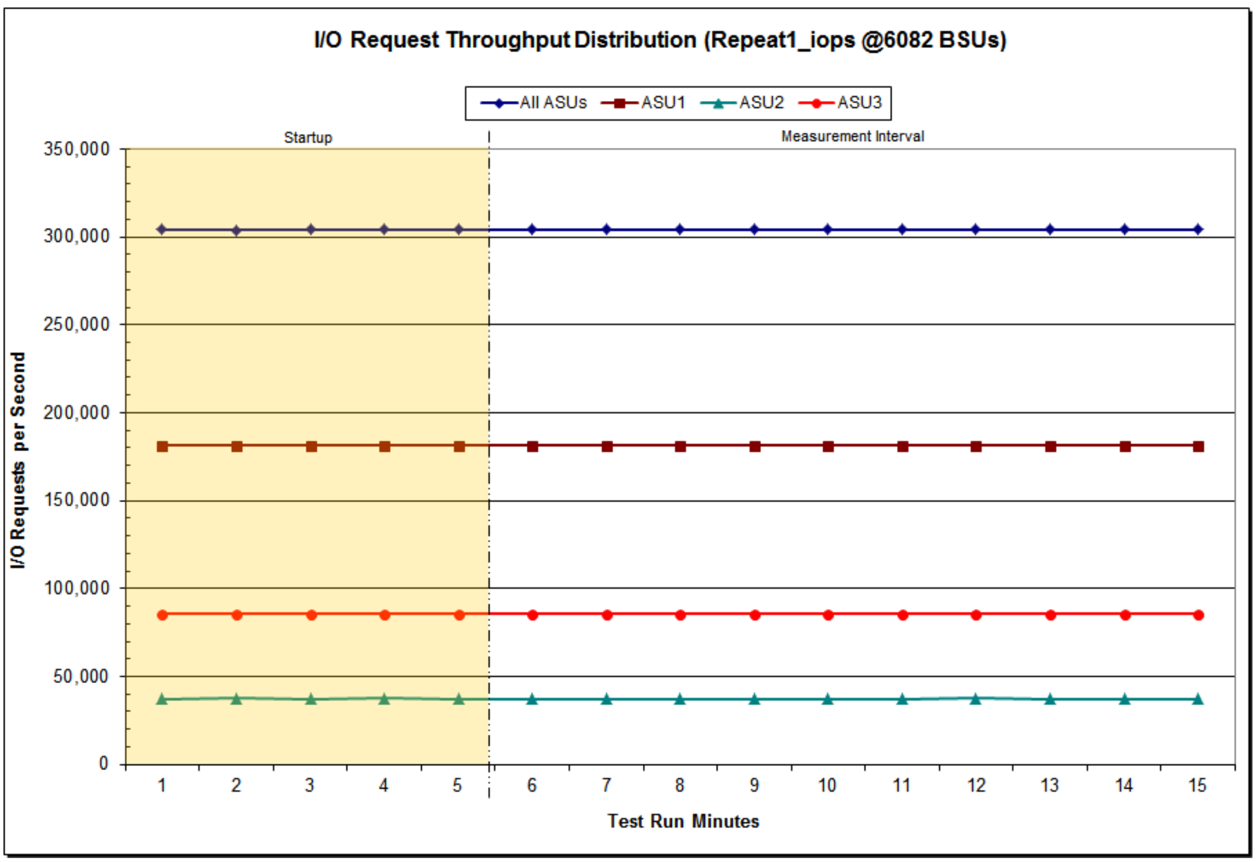
Repeatability 1 LRT –Average Response Time (ms) Distribution Graph



Repeatability 1 IOPS – I/O Request Throughput Distribution Data

6,082 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	23:14:02	23:19:03	0-4	0:05:01
Measurement Interval	23:19:03	23:29:03	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	304,159.03	181,275.95	37,397.10	85,485.98
1	303,969.38	181,152.48	37,425.93	85,390.97
2	304,165.97	181,292.58	37,413.37	85,460.02
3	304,122.53	181,257.28	37,432.28	85,432.97
4	304,083.88	181,238.38	37,423.47	85,422.03
5	304,082.63	181,268.18	37,373.77	85,440.68
6	304,276.18	181,342.90	37,397.37	85,535.92
7	304,172.38	181,298.48	37,422.80	85,451.10
8	304,084.70	181,156.80	37,412.02	85,515.88
9	304,107.10	181,247.97	37,368.88	85,490.25
10	304,060.70	181,280.18	37,343.65	85,436.87
11	304,133.42	181,246.48	37,445.93	85,441.00
12	304,087.48	181,243.30	37,405.80	85,438.38
13	304,191.50	181,276.98	37,421.05	85,493.47
14	304,107.10	181,214.58	37,416.75	85,475.77
Average	***304,130.32***	***181,257.59***	***37,400.80***	***85,471.93***

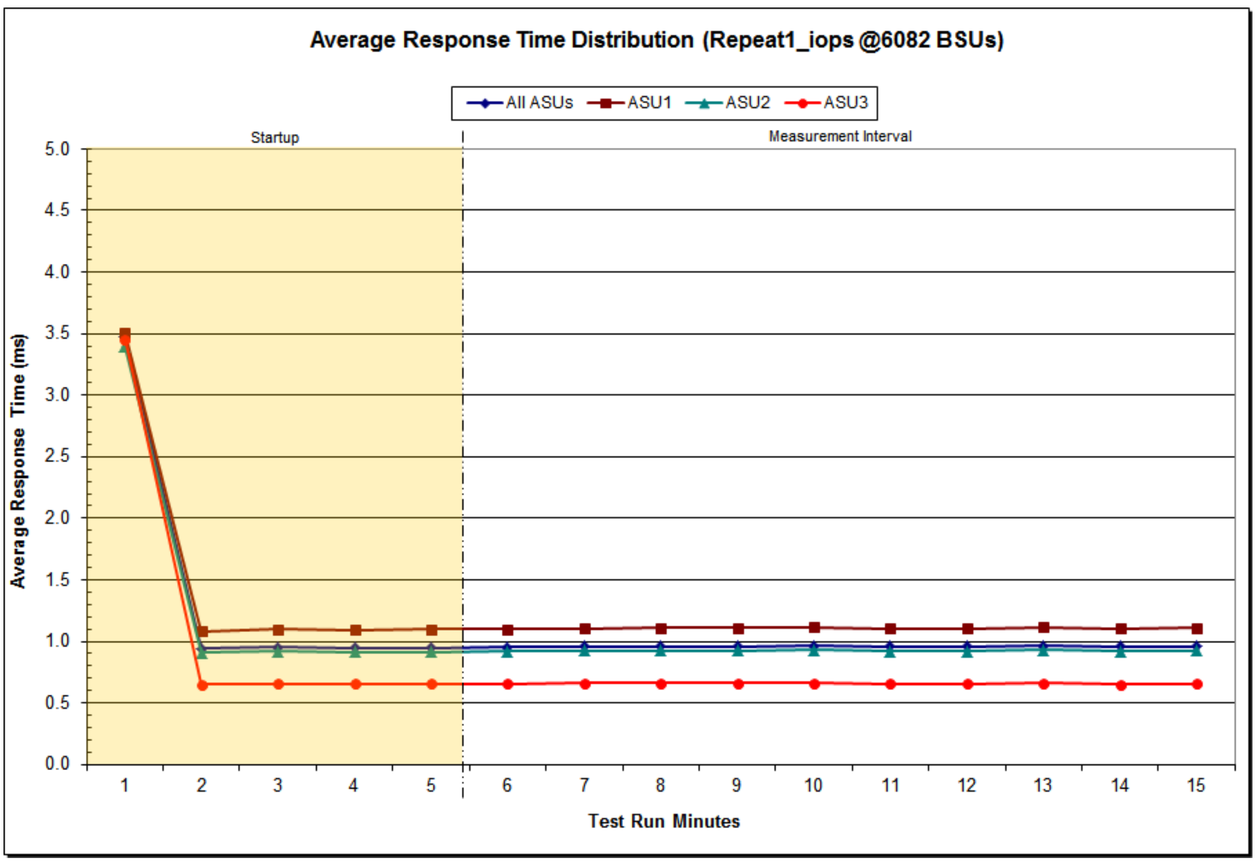
Repeatability 1 IOPS – I/O Request Throughput Distribution Graph



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

6,082 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	23:14:02	23:19:03	0-4	0:05:01
Measurement Interval	23:19:03	23:29:03	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	3.48	3.50	3.39	3.45
1	0.94	1.08	0.91	0.65
2	0.95	1.10	0.92	0.66
3	0.95	1.09	0.92	0.65
4	0.95	1.10	0.92	0.65
5	0.95	1.10	0.92	0.65
6	0.96	1.11	0.92	0.66
7	0.96	1.11	0.92	0.66
8	0.96	1.11	0.92	0.66
9	0.96	1.11	0.93	0.66
10	0.96	1.11	0.92	0.65
11	0.96	1.11	0.92	0.66
12	0.97	1.12	0.93	0.66
13	0.96	1.11	0.92	0.65
14	0.96	1.11	0.92	0.66
Average	***0.96***	***1.11***	***0.92***	***0.66***

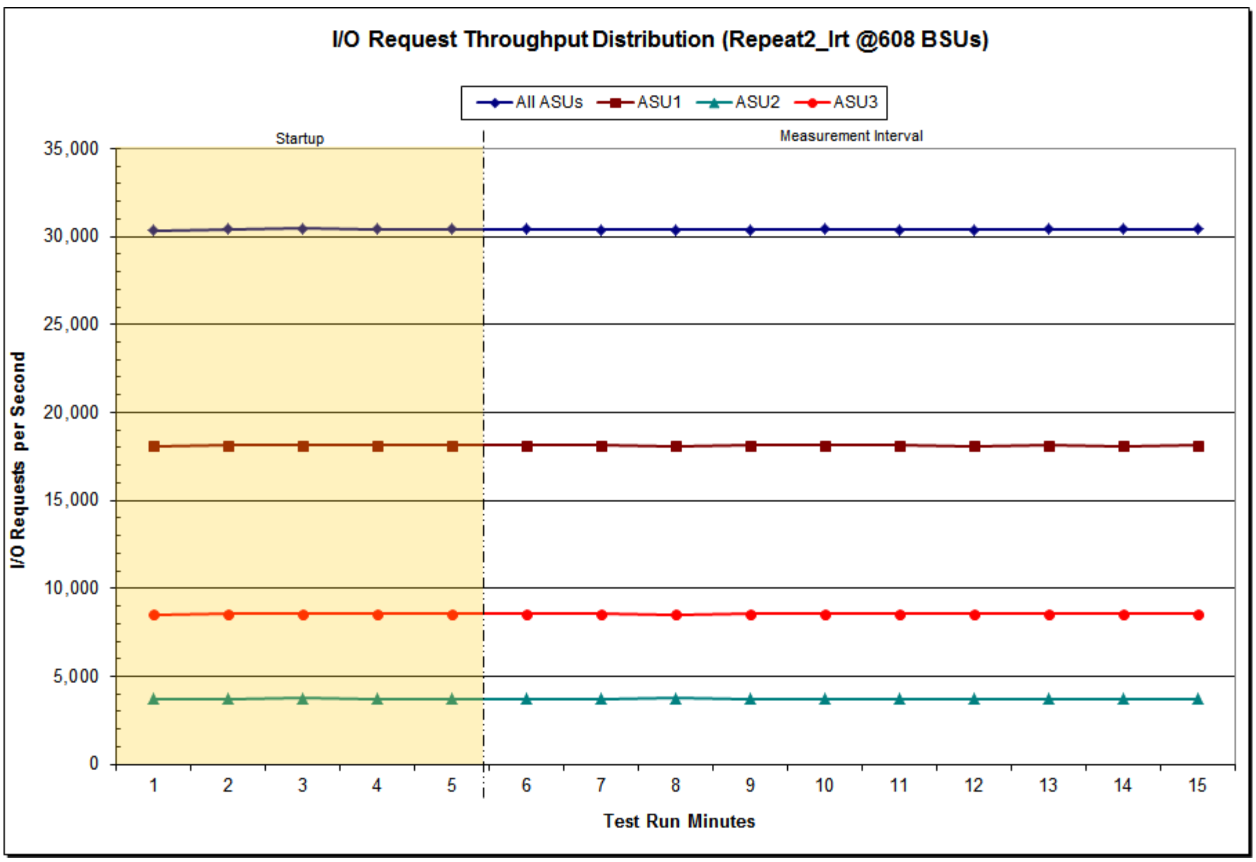
Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph



Repeatability 2 LRT – I/O Request Throughput Distribution Data

608 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	23:30:49	23:35:49	0-4	0:05:00
Measurement Interval	23:35:49	23:45:49	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	30,346.18	18,086.70	3,728.87	8,530.62
1	30,415.98	18,133.80	3,735.70	8,546.48
2	30,451.10	18,144.37	3,752.50	8,554.23
3	30,432.45	18,142.77	3,738.38	8,551.30
4	30,400.02	18,124.92	3,739.48	8,535.62
5	30,407.58	18,113.53	3,737.92	8,556.13
6	30,394.52	18,115.47	3,733.33	8,545.72
7	30,380.15	18,105.83	3,745.78	8,528.53
8	30,398.40	18,132.42	3,732.53	8,533.45
9	30,405.72	18,117.87	3,739.02	8,548.83
10	30,390.05	18,125.63	3,722.97	8,541.45
11	30,389.15	18,106.25	3,731.72	8,551.18
12	30,423.45	18,139.38	3,739.97	8,544.10
13	30,409.38	18,109.55	3,742.13	8,557.70
14	30,418.35	18,134.52	3,737.83	8,546.00
Average	***30,401.68***	***18,120.05***	***3,736.32***	***8,545.31***

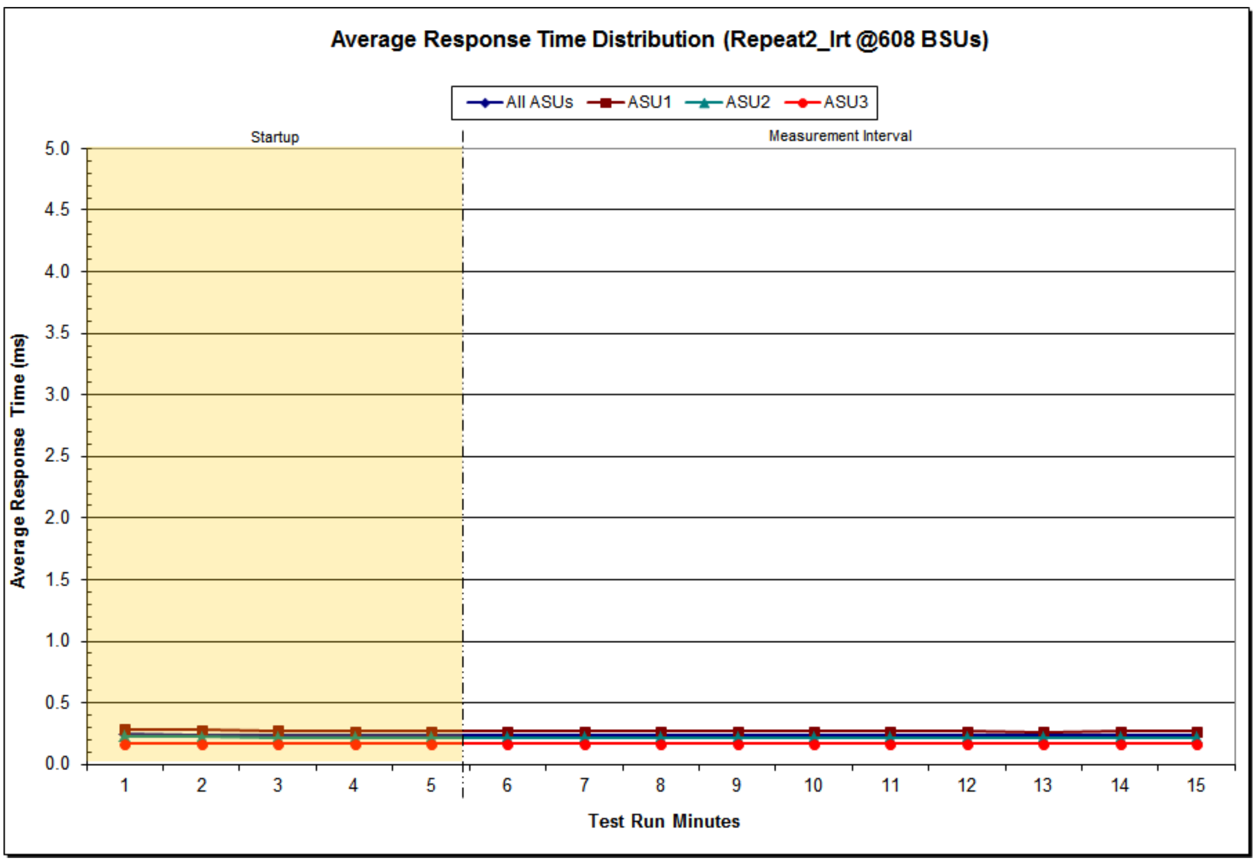
Repeatability 2 LRT – I/O Request Throughput Distribution Graph



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

608 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	23:30:49	23:35:49	0-4	0:05:00
Measurement Interval	23:35:49	23:45:49	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.24	0.28	0.23	0.17
1	0.24	0.28	0.22	0.17
2	0.24	0.27	0.22	0.17
3	0.24	0.27	0.22	0.17
4	0.24	0.27	0.22	0.17
5	0.23	0.27	0.22	0.17
6	0.23	0.27	0.22	0.17
7	0.23	0.27	0.22	0.17
8	0.23	0.27	0.22	0.17
9	0.23	0.27	0.22	0.17
10	0.23	0.27	0.22	0.17
11	0.23	0.27	0.22	0.17
12	0.23	0.27	0.22	0.17
13	0.23	0.27	0.22	0.17
14	0.23	0.27	0.22	0.17
Average	***0.23***	***0.27***	***0.22***	***0.17***

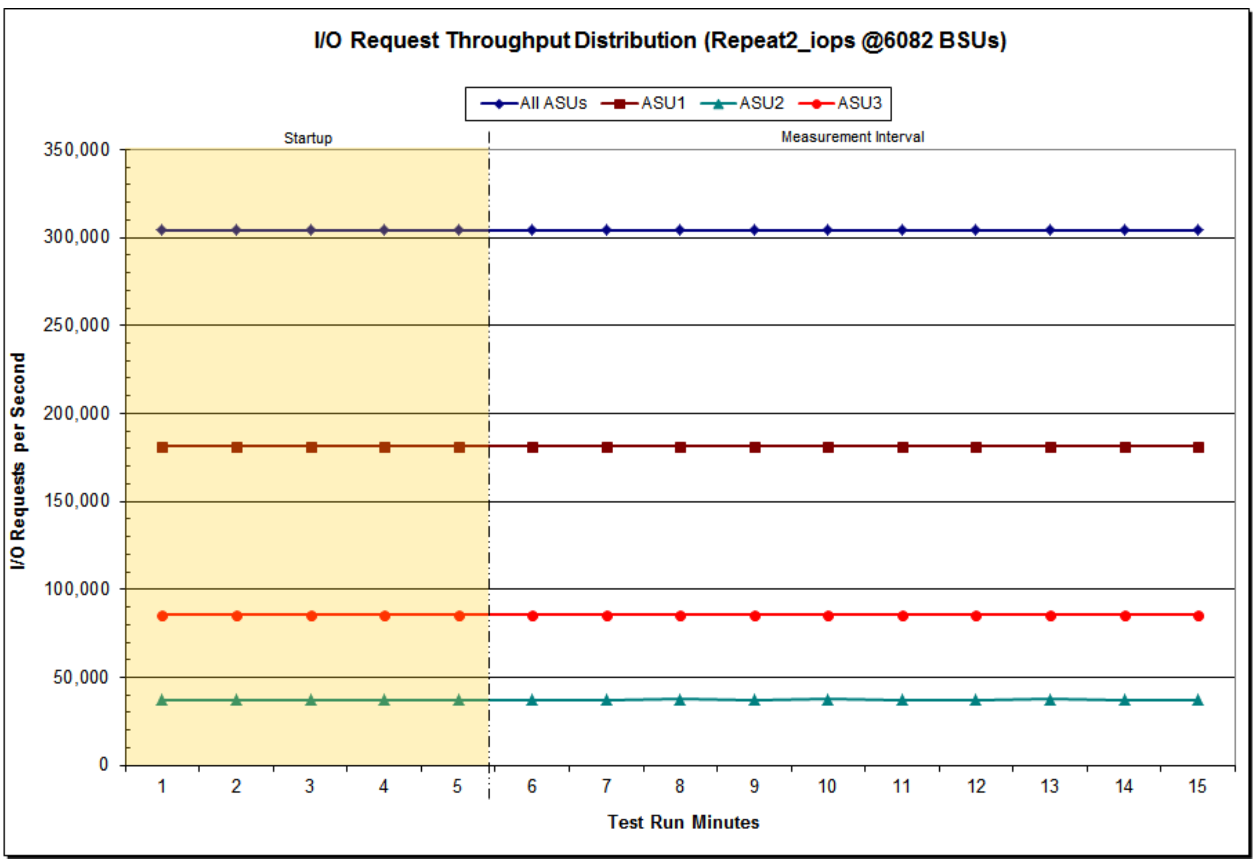
Repeatability 2 LRT –Average Response Time (ms) Distribution Graph



Repeatability 2 IOPS – I/O Request Throughput Distribution Data

6,082 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	23:46:15	23:51:16	0-4	0:05:01
Measurement Interval	23:51:16	0:01:16	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	304,082.37	181,215.02	37,413.32	85,454.03
1	304,020.78	181,165.10	37,425.05	85,430.63
2	304,015.18	181,157.77	37,400.40	85,457.02
3	304,082.85	181,231.77	37,400.00	85,451.08
4	304,116.93	181,239.17	37,416.28	85,461.48
5	304,092.95	181,248.58	37,401.10	85,443.27
6	304,177.53	181,337.17	37,387.45	85,452.92
7	304,246.70	181,330.80	37,443.50	85,472.40
8	304,178.82	181,263.33	37,382.77	85,532.72
9	304,206.93	181,309.18	37,435.57	85,462.18
10	304,028.72	181,225.08	37,385.23	85,418.40
11	304,119.50	181,255.58	37,416.15	85,447.77
12	304,085.85	181,178.27	37,443.58	85,464.00
13	304,156.25	181,230.38	37,412.53	85,513.33
14	304,159.82	181,250.18	37,401.58	85,508.05
Average	***304,145.31***	***181,262.86***	***37,410.95***	***85,471.50***

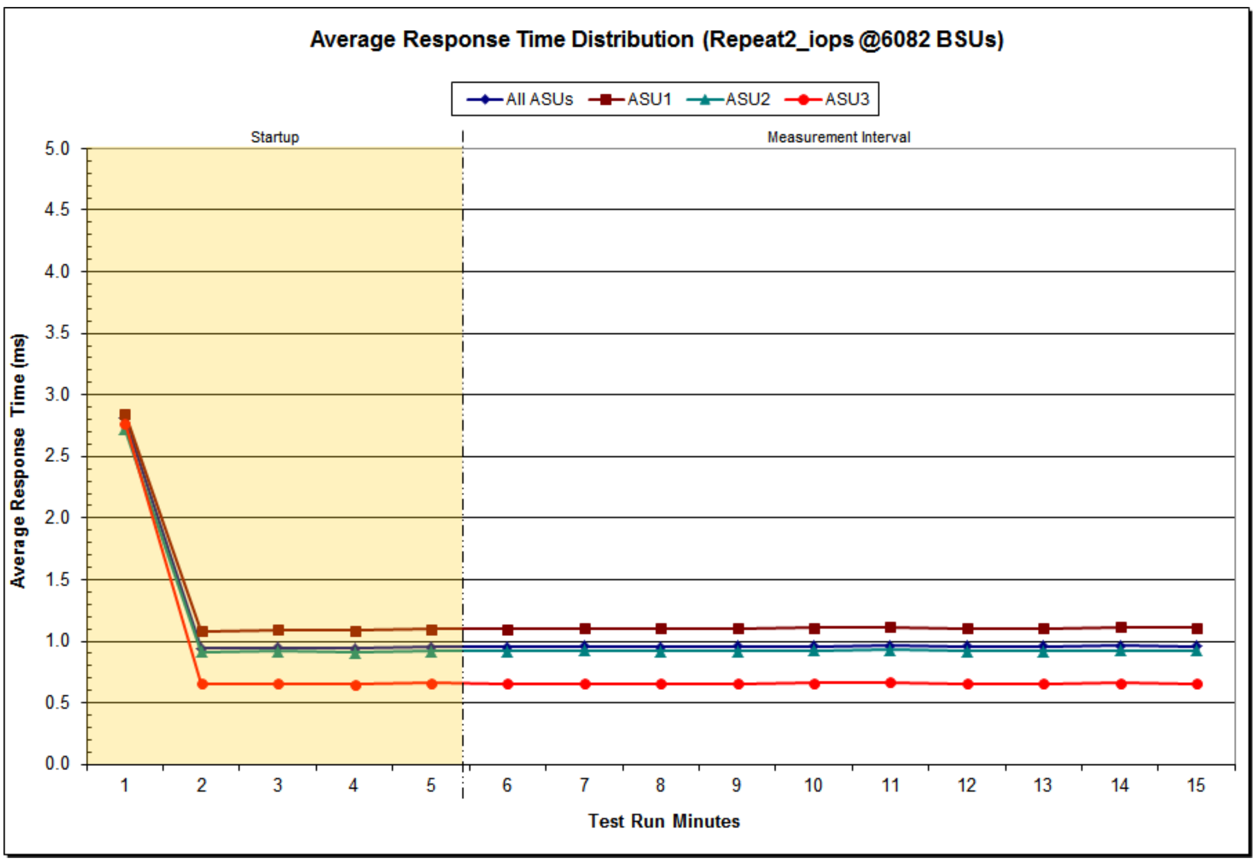
Repeatability 2 IOPS – I/O Request Throughput Distribution Graph



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

6,082 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	23:46:15	23:51:16	0-4	0:05:01
Measurement Interval	23:51:16	0:01:16	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	2.81	2.85	2.72	2.77
1	0.94	1.08	0.91	0.65
2	0.95	1.09	0.92	0.66
3	0.94	1.09	0.91	0.65
4	0.95	1.10	0.92	0.66
5	0.95	1.10	0.92	0.65
6	0.96	1.11	0.92	0.66
7	0.95	1.10	0.92	0.66
8	0.96	1.10	0.92	0.66
9	0.96	1.11	0.93	0.66
10	0.97	1.11	0.93	0.66
11	0.96	1.11	0.92	0.66
12	0.96	1.10	0.92	0.66
13	0.96	1.11	0.93	0.66
14	0.96	1.11	0.92	0.66
Average	***0.96***	***1.11***	***0.92***	***0.66***

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



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

Clause 3.4.3

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

Clauses5.1.10 and 5.3.15.2

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

Clause 5.3.15.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2810	0.0700	0.2099	0.0180	0.0700	0.0350	0.2810
COV	0.005	0.001	0.003	0.001	0.006	0.003	0.005	0.001

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2810	0.0700	0.2099	0.0180	0.0700	0.0350	0.2810
COV	0.001	0.000	0.001	0.000	0.001	0.001	0.001	0.000

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0351	0.2809	0.0699	0.2101	0.0180	0.0699	0.0350	0.2811
COV	0.004	0.001	0.003	0.001	0.006	0.002	0.003	0.001

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

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

Data Persistence Test

Clause 6

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

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

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

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

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

Clause 9.4.3.8

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

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

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in Appendix E: SPC-1 Workload Generator Input Parameters on Page 81.

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	697,268
Total Number of Logical Blocks Verified	671,579
Total Number of Logical Blocks that Failed Verification	0
Time Duration for Writing Test Logical Blocks	5 minutes
Size in bytes of each Logical Block	1,024
Number of Failed I/O Requests in the process of the Test	0

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

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

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

PRICED STORAGE CONFIGURATION AVAILABILITY DATE

Clause 9.4.3.9

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

The Hitachi Unified Storage VM 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 Onsite Audit of the Hitachi Unified Storage VM.

APPENDIX A: SPC-1 GLOSSARY

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

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

A kilobyte (KB) is equal to 1,000 (10^3) bytes.

A megabyte (MB) is equal to 1,000,000 (10^6) bytes.

A gigabyte (GB) is equal to 1,000,000,000 (10^9) bytes.

A terabyte (TB) is equal to 1,000,000,000,000 (10^{12}) bytes.

A petabyte (PB) is equal to 1,000,000,000,000,000 (10^{15}) bytes

An exabyte (EB) is equal to 1,000,000,000,000,000,000 (10^{18}) bytes

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

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

A kibibyte (KiB) is equal to 1,024 (2^{10}) bytes.

A mebibyte (MiB) is equal to 1,048,576 (2^{20}) bytes.

A gigibyte (GiB) is equal to 1,073,741,824 (2^{30}) bytes.

A tebibyte (TiB) is equal to 1,099,511,627,776 (2^{40}) bytes.

A pebibyte (PiB) is equal to 1,125,899,906,842,624 (2^{50}) bytes.

An exbibyte (EiB) is equal to 1,152,921,504,606,846,967 (2^{60}) bytes.

SPC-1 Data Repository Definitions

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

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

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

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

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

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

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

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

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

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

SPC-1 Data Protection Levels

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

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

SPC-1 Test Execution Definitions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

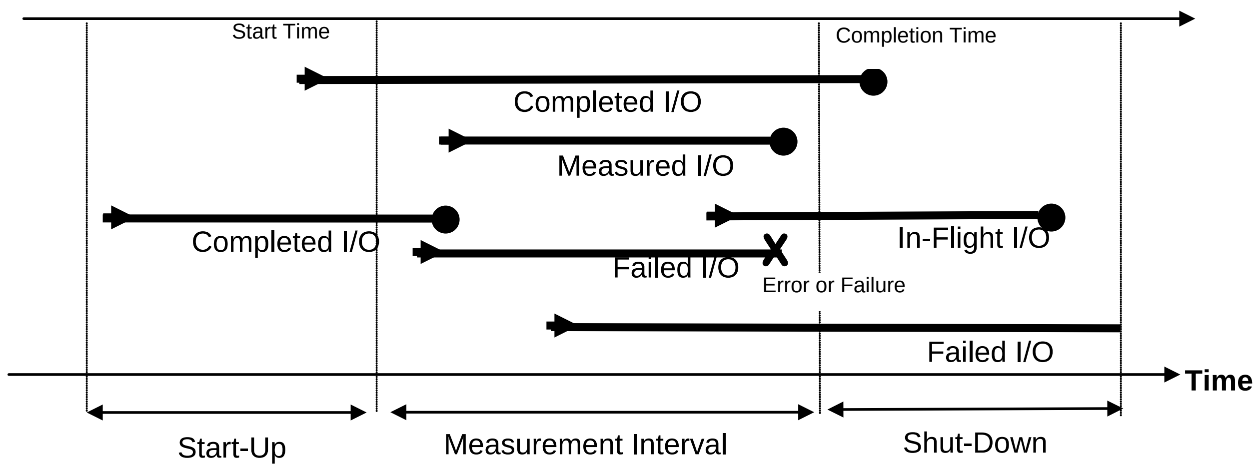
Steady State: The consistent and sustainable throughput of the TSC. During this period the load presented to the TSC by the Workload Generator is constant.

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

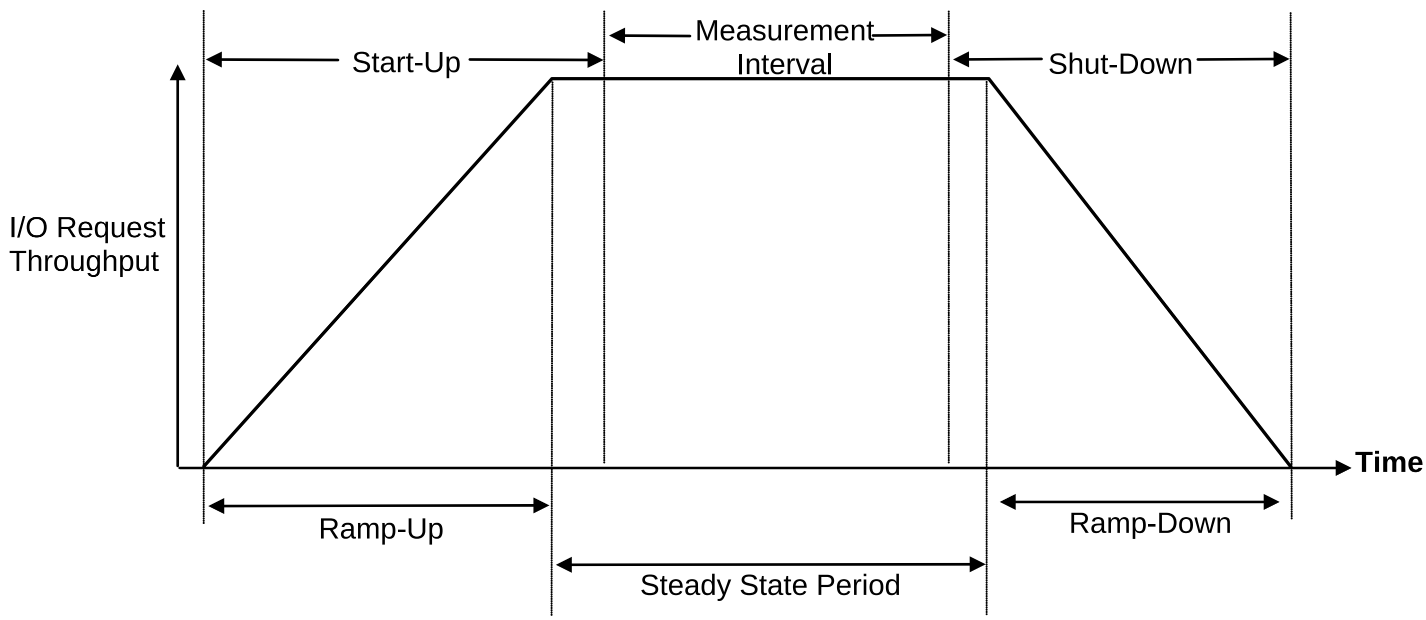
Test Run: The execution of SPC-1 for the purpose of producing or supporting an SPC-1 test result. SPC-1 Test Runs may have a finite and measured Ramp-Up period, Start-Up period, Shut-Down period, and Ramp-Down period as illustrated in the "SPC-1 Test Run Components" below. All SPC-1 Test Runs shall have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

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

I/O Completion Types



SPC-1 Test Run Components



APPENDIX B: CUSTOMER TUNABLE PARAMETERS AND OPTIONS

The following customer tunable parameters/options were changed from their default values for the submitted SPC-1 measurements as documented in Appendix C: Tested Storage Configuration (TSC) Creation on page 70.

Parameter/Option	Default Value	New Value
Linux I/O Scheduler *The default "Completely Fair Queueing" (CFQ) scheduler attempts to balance fairness, performance, and timely servicing of I/O requests. The noop scheduler inserts all incoming I/O requests into a simple FIFO queue and implements request merging.*	**cfq**	**noop**
HBA LUN queue depth on each Host System ***(lpfc_lun_queue_depth)***	**32**	**128**

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

All referenced scripts will appear at the end of this appendix in the TSC Creation/Configuration Scripts section.

1. Initial Installation and Configuration - Customer Support Engineer

The initial installation and configuration of the **Hitachi Unified Storage VM *(with Hitachi Accelerated Flash)*** is typically done by a customer support engineer. That initial installation and configuration was completed according to the following diagram:

Tray-01	PG 1-1		PG 1-2		PG 1-3		PG 1-4		PG 1-5			
Tray-00												
	00	01	02	03	04	05	06	07	08	09	10	11

Each set of four disks represents a physical RAID-10 *(2D+2D)* Parity Group.

2. Create Logical Devices

Mount the **"Hitachi Command Control Interface Software"** CD-ROM on one of the Host Systems. As the root user, unpack the contents of the RMHORC archive, where **/media/HS042_52** is the mount point for the CD-ROM, as follows:

cd /HORCM

./horcminstall.sh

Edit the **/etc/horcm.conf** file, replacing the sample contents with the following, where 192.168.100.100 is the IP address of the storage array's service processor:

```
HORCM_MON
localhost    11099    1000    3000
HORCM_CMD
\\.\IPCMD-192.168.100.100-31001
```

Start the Hitachi RAID Manager CLI by executing the following command:

/usr/bin/horcmstart.sh

Execute the **ldevcreate.sh** RAID Manager CLI script to create 80 Logical Devices.

3. Format Logical Devices

Format the Logical Devices by executing the **ldevformat.sh** RAID Manager CLI script.

4. Map Logical Devices to Host Ports

After the formatting of the Logical Devices is finished, map them to host ports by executing the **lunmap.sh** RAID Manager CLI script.

5. Modify RHEL I/O Scheduler

Change the I/O scheduler from the default of ***cfq*** to ***noop*** on each Host System, which will result in all incoming I/O requests inserted into a simple, unordered FIFO queue. This was done by adding the following parameter in **/boot/grub/grub.conf** at the end of the kernel line on each Host System.

elevator=noop

6. Change Emulex HBA Queue Depth

Change the Emulex driver queue depth from a default of 32 to 128 on all HBA ports by executing the following CLI commands on each Host System:

hbacmd setdriverparam <WWPN> l p lun-queue-depth 128

The values for ***<WWPN>*** are available from the output of the following command:

hbacmd listhbas local m=lpe12002* | grep ‘Port WWN’

7. Reboot Host Systems

In order to make the changes in steps #5 and #6 effective, the Host Systems must be rebooted.

8. Initialize LVM Physical Volumes

Verify that the **lsscsi** package is installed and that the ***lsscsi*** command is available. Execute the **pvcreate.sh** script on one of the Host Systems to initialize all LUNs and make them visible to LVM as Physical Volumes. The other Host Systems will automatically detect the configuration changes.

If the **lsscsi** package is not installed, the package can be found on the **RHEL Server 6.4 x86_64** installation media at **/Packages/lsscsi-0.23-2.el6.x86_64.rpm** and installed using the ***rpm -i*** command.

9. Create LVM Volume Group

Execute the **vgcreate.sh** script on one of the Host Systems to create a single Volume Group for all three ASUs.

The script first generates a sorted LUN mapping table that lists the storage array **CU:LDEV** identifier **(LDEV ID)** along with the Linux device name. It then creates the Volume Group using the Linux device names taken from the LUN mapping table. The default Physical Extent (PE) size of 4 MiB is used.

This script only needs to be run on one of the Host Systems as the LVM software on the other Host System will automatically detect the configuration changes.

10. Create LVM Logical Volumes

Execute the **lvcreate.sh** script, on one of the Host Systems, to create a total of 9 Logical Volumes according to the following:

- 4 Logical Volumes for **ASU-1**, each using the parameters:
  - ***-l 264240*** *(number of logical extents)*
  - ***-i 80*** *(number of stripes)*
  - ***-I 4M*** *(stripe size in MiB)*
  - ***-n*** *(name of the Logical Volume)*
- 4 Logical Volumes for **ASU-2**, each using the parameters:
  - ***-l 264240*** *(number of logical extents)*
  - ***-i 80*** *(number of stripes)*
  - ***-I 4M*** *(stripe size in MiB)*
  - ***-n*** *(name of the Logical Volume)*
- 4 Logical Volumes for **ASU-3**, each using the parameters:
  - ***-l 234880*** *(number of logical extents)*
  - ***-i 80*** *(number of stripes)*
  - ***-I 4M*** *(stripe size in MiB)*
  - ***-n*** *(name of the Logical Volume)*

The LVM software on the other Host Systems will automatically detect the configuration changes.

11. Verify LVM Logical Volume Availability

On each Host System, verify that the LVM Logical Volumes are available by executing the following CLI command:

lvs | grep lvasu

The expected output is shown below.

```
lvasu11 vgasu -wi-a----   1.01t
lvasu12 vgasu -wi-a----   1.01t
lvasu13 vgasu -wi-a----   1.01t
lvasu14 vgasu -wi-a----   1.01t
lvasu21 vgasu -wi-a----   1.01t
lvasu22 vgasu -wi-a----   1.01t
lvasu23 vgasu -wi-a----   1.01t
lvasu24 vgasu -wi-a----   1.01t
lvasu31 vgasu -wi-a---- 917.50g
```

If any Logical Volumes are missing the **"a"** attribute and, as a result not available, issue the following command for each of those Logical Volumes:

lvchange -ay /dev/<VGNAME>/<LVNAME>

The value for ***<VGNAME>*** is the name of the Volume Group in column #2 of the ***lvs*** command output. The value for ***<LVNAME>*** is the name of the Logical Volume in column #1 of the ***lvs*** command output.

TSC Creation/Configuration Scripts

ldevcreate.sh

```
raidcom add ldev -parity_grp_id 1-1 -ldev_id 00:00 -capacity 429494272
raidcom add ldev -parity_grp_id 1-2 -ldev_id 00:01 -capacity 429494272
raidcom add ldev -parity_grp_id 1-3 -ldev_id 00:02 -capacity 429494272
raidcom add ldev -parity_grp_id 1-4 -ldev_id 00:03 -capacity 429494272
raidcom add ldev -parity_grp_id 1-5 -ldev_id 00:04 -capacity 429494272
raidcom add ldev -parity_grp_id 1-1 -ldev_id 00:05 -capacity 429494272
raidcom add ldev -parity_grp_id 1-2 -ldev_id 00:06 -capacity 429494272
raidcom add ldev -parity_grp_id 1-3 -ldev_id 00:07 -capacity 429494272
raidcom add ldev -parity_grp_id 1-4 -ldev_id 00:08 -capacity 429494272
raidcom add ldev -parity_grp_id 1-5 -ldev_id 00:09 -capacity 429494272
raidcom add ldev -parity_grp_id 1-1 -ldev_id 00:0A -capacity 429494272
raidcom add ldev -parity_grp_id 1-2 -ldev_id 00:0B -capacity 429494272
raidcom add ldev -parity_grp_id 1-3 -ldev_id 00:0C -capacity 429494272
raidcom add ldev -parity_grp_id 1-4 -ldev_id 00:0D -capacity 429494272
raidcom add ldev -parity_grp_id 1-5 -ldev_id 00:0E -capacity 429494272
raidcom add ldev -parity_grp_id 1-1 -ldev_id 00:0F -capacity 429494272
raidcom add ldev -parity_grp_id 1-2 -ldev_id 00:10 -capacity 429494272
raidcom add ldev -parity_grp_id 1-3 -ldev_id 00:11 -capacity 429494272
raidcom add ldev -parity_grp_id 1-4 -ldev_id 00:12 -capacity 429494272
raidcom add ldev -parity_grp_id 1-5 -ldev_id 00:13 -capacity 429494272
raidcom add ldev -parity_grp_id 1-1 -ldev_id 00:14 -capacity 429494272
raidcom add ldev -parity_grp_id 1-2 -ldev_id 00:15 -capacity 429494272
raidcom add ldev -parity_grp_id 1-3 -ldev_id 00:16 -capacity 429494272
raidcom add ldev -parity_grp_id 1-4 -ldev_id 00:17 -capacity 429494272
raidcom add ldev -parity_grp_id 1-5 -ldev_id 00:18 -capacity 429494272
raidcom add ldev -parity_grp_id 1-1 -ldev_id 00:19 -capacity 429494272
raidcom add ldev -parity_grp_id 1-2 -ldev_id 00:1A -capacity 429494272
raidcom add ldev -parity_grp_id 1-3 -ldev_id 00:1B -capacity 429494272
raidcom add ldev -parity_grp_id 1-4 -ldev_id 00:1C -capacity 429494272
raidcom add ldev -parity_grp_id 1-5 -ldev_id 00:1D -capacity 429494272
raidcom add ldev -parity_grp_id 1-1 -ldev_id 00:1E -capacity 429494272
raidcom add ldev -parity_grp_id 1-2 -ldev_id 00:1F -capacity 429494272
raidcom add ldev -parity_grp_id 1-3 -ldev_id 00:20 -capacity 429494272
raidcom add ldev -parity_grp_id 1-4 -ldev_id 00:21 -capacity 429494272
raidcom add ldev -parity_grp_id 1-5 -ldev_id 00:22 -capacity 429494272
raidcom add ldev -parity_grp_id 1-1 -ldev_id 00:23 -capacity 429494272
raidcom add ldev -parity_grp_id 1-2 -ldev_id 00:24 -capacity 429494272
raidcom add ldev -parity_grp_id 1-3 -ldev_id 00:25 -capacity 429494272
raidcom add ldev -parity_grp_id 1-4 -ldev_id 00:26 -capacity 429494272
raidcom add ldev -parity_grp_id 1-5 -ldev_id 00:27 -capacity 429494272
raidcom add ldev -parity_grp_id 1-1 -ldev_id 00:28 -capacity 429494272
raidcom add ldev -parity_grp_id 1-2 -ldev_id 00:29 -capacity 429494272
raidcom add ldev -parity_grp_id 1-3 -ldev_id 00:2A -capacity 429494272
raidcom add ldev -parity_grp_id 1-4 -ldev_id 00:2B -capacity 429494272
raidcom add ldev -parity_grp_id 1-5 -ldev_id 00:2C -capacity 429494272
raidcom add ldev -parity_grp_id 1-1 -ldev_id 00:2D -capacity 429494272
raidcom add ldev -parity_grp_id 1-2 -ldev_id 00:2E -capacity 429494272
raidcom add ldev -parity_grp_id 1-3 -ldev_id 00:2F -capacity 429494272
raidcom add ldev -parity_grp_id 1-4 -ldev_id 00:30 -capacity 429494272
raidcom add ldev -parity_grp_id 1-5 -ldev_id 00:31 -capacity 429494272
raidcom add ldev -parity_grp_id 1-1 -ldev_id 00:32 -capacity 429494272
raidcom add ldev -parity_grp_id 1-2 -ldev_id 00:33 -capacity 429494272
raidcom add ldev -parity_grp_id 1-3 -ldev_id 00:34 -capacity 429494272
raidcom add ldev -parity_grp_id 1-4 -ldev_id 00:35 -capacity 429494272
raidcom add ldev -parity_grp_id 1-5 -ldev_id 00:36 -capacity 429494272
raidcom add ldev -parity_grp_id 1-1 -ldev_id 00:37 -capacity 429494272
raidcom add ldev -parity_grp_id 1-2 -ldev_id 00:38 -capacity 429494272
```

```
raidcom add ldev -parity_grp_id 1-3 -ldev_id 00:39 -capacity 429494272
raidcom add ldev -parity_grp_id 1-4 -ldev_id 00:3A -capacity 429494272
raidcom add ldev -parity_grp_id 1-5 -ldev_id 00:3B -capacity 429494272
raidcom add ldev -parity_grp_id 1-1 -ldev_id 00:3C -capacity 429494272
raidcom add ldev -parity_grp_id 1-2 -ldev_id 00:3D -capacity 429494272
raidcom add ldev -parity_grp_id 1-3 -ldev_id 00:3E -capacity 429494272
raidcom add ldev -parity_grp_id 1-4 -ldev_id 00:3F -capacity 429494272
raidcom add ldev -parity_grp_id 1-5 -ldev_id 00:40 -capacity 429494272
raidcom add ldev -parity_grp_id 1-1 -ldev_id 00:41 -capacity 429494272
raidcom add ldev -parity_grp_id 1-2 -ldev_id 00:42 -capacity 429494272
raidcom add ldev -parity_grp_id 1-3 -ldev_id 00:43 -capacity 429494272
raidcom add ldev -parity_grp_id 1-4 -ldev_id 00:44 -capacity 429494272
raidcom add ldev -parity_grp_id 1-5 -ldev_id 00:45 -capacity 429494272
raidcom add ldev -parity_grp_id 1-1 -ldev_id 00:46 -capacity 429494272
raidcom add ldev -parity_grp_id 1-2 -ldev_id 00:47 -capacity 429494272
raidcom add ldev -parity_grp_id 1-3 -ldev_id 00:48 -capacity 429494272
raidcom add ldev -parity_grp_id 1-4 -ldev_id 00:49 -capacity 429494272
raidcom add ldev -parity_grp_id 1-5 -ldev_id 00:4A -capacity 429494272
raidcom add ldev -parity_grp_id 1-1 -ldev_id 00:4B -capacity 429494272
raidcom add ldev -parity_grp_id 1-2 -ldev_id 00:4C -capacity 429494272
raidcom add ldev -parity_grp_id 1-3 -ldev_id 00:4D -capacity 429494272
raidcom add ldev -parity_grp_id 1-4 -ldev_id 00:4E -capacity 429494272
raidcom add ldev -parity_grp_id 1-5 -ldev_id 00:4F -capacity 429494272
```

ldevformat.sh

```
raidcom initialize ldev -ldev_id 00:00 -operation fmt
raidcom initialize ldev -ldev_id 00:01 -operation fmt
raidcom initialize ldev -ldev_id 00:02 -operation fmt
raidcom initialize ldev -ldev_id 00:03 -operation fmt
raidcom initialize ldev -ldev_id 00:04 -operation fmt
raidcom initialize ldev -ldev_id 00:05 -operation fmt
raidcom initialize ldev -ldev_id 00:06 -operation fmt
raidcom initialize ldev -ldev_id 00:07 -operation fmt
raidcom initialize ldev -ldev_id 00:08 -operation fmt
raidcom initialize ldev -ldev_id 00:09 -operation fmt
raidcom initialize ldev -ldev_id 00:0A -operation fmt
raidcom initialize ldev -ldev_id 00:0B -operation fmt
raidcom initialize ldev -ldev_id 00:0C -operation fmt
raidcom initialize ldev -ldev_id 00:0D -operation fmt
raidcom initialize ldev -ldev_id 00:0E -operation fmt
raidcom initialize ldev -ldev_id 00:0F -operation fmt
raidcom initialize ldev -ldev_id 00:10 -operation fmt
raidcom initialize ldev -ldev_id 00:11 -operation fmt
raidcom initialize ldev -ldev_id 00:12 -operation fmt
raidcom initialize ldev -ldev_id 00:13 -operation fmt
raidcom initialize ldev -ldev_id 00:14 -operation fmt
raidcom initialize ldev -ldev_id 00:15 -operation fmt
raidcom initialize ldev -ldev_id 00:16 -operation fmt
raidcom initialize ldev -ldev_id 00:17 -operation fmt
raidcom initialize ldev -ldev_id 00:18 -operation fmt
raidcom initialize ldev -ldev_id 00:19 -operation fmt
raidcom initialize ldev -ldev_id 00:1A -operation fmt
raidcom initialize ldev -ldev_id 00:1B -operation fmt
raidcom initialize ldev -ldev_id 00:1C -operation fmt
raidcom initialize ldev -ldev_id 00:1D -operation fmt
raidcom initialize ldev -ldev_id 00:1E -operation fmt
raidcom initialize ldev -ldev_id 00:1F -operation fmt
raidcom initialize ldev -ldev_id 00:20 -operation fmt
raidcom initialize ldev -ldev_id 00:21 -operation fmt
raidcom initialize ldev -ldev_id 00:22 -operation fmt
raidcom initialize ldev -ldev_id 00:23 -operation fmt
```

```
raidcom initialize ldev -ldev_id 00:24 -operation fmt
raidcom initialize ldev -ldev_id 00:25 -operation fmt
raidcom initialize ldev -ldev_id 00:26 -operation fmt
raidcom initialize ldev -ldev_id 00:27 -operation fmt
raidcom initialize ldev -ldev_id 00:28 -operation fmt
raidcom initialize ldev -ldev_id 00:29 -operation fmt
raidcom initialize ldev -ldev_id 00:2A -operation fmt
raidcom initialize ldev -ldev_id 00:2B -operation fmt
raidcom initialize ldev -ldev_id 00:2C -operation fmt
raidcom initialize ldev -ldev_id 00:2D -operation fmt
raidcom initialize ldev -ldev_id 00:2E -operation fmt
raidcom initialize ldev -ldev_id 00:2F -operation fmt
raidcom initialize ldev -ldev_id 00:30 -operation fmt
raidcom initialize ldev -ldev_id 00:31 -operation fmt
raidcom initialize ldev -ldev_id 00:32 -operation fmt
raidcom initialize ldev -ldev_id 00:33 -operation fmt
raidcom initialize ldev -ldev_id 00:34 -operation fmt
raidcom initialize ldev -ldev_id 00:35 -operation fmt
raidcom initialize ldev -ldev_id 00:36 -operation fmt
raidcom initialize ldev -ldev_id 00:37 -operation fmt
raidcom initialize ldev -ldev_id 00:38 -operation fmt
raidcom initialize ldev -ldev_id 00:39 -operation fmt
raidcom initialize ldev -ldev_id 00:3A -operation fmt
raidcom initialize ldev -ldev_id 00:3B -operation fmt
raidcom initialize ldev -ldev_id 00:3C -operation fmt
raidcom initialize ldev -ldev_id 00:3D -operation fmt
raidcom initialize ldev -ldev_id 00:3E -operation fmt
raidcom initialize ldev -ldev_id 00:3F -operation fmt
raidcom initialize ldev -ldev_id 00:40 -operation fmt
raidcom initialize ldev -ldev_id 00:41 -operation fmt
raidcom initialize ldev -ldev_id 00:42 -operation fmt
raidcom initialize ldev -ldev_id 00:43 -operation fmt
raidcom initialize ldev -ldev_id 00:44 -operation fmt
raidcom initialize ldev -ldev_id 00:45 -operation fmt
raidcom initialize ldev -ldev_id 00:46 -operation fmt
raidcom initialize ldev -ldev_id 00:47 -operation fmt
raidcom initialize ldev -ldev_id 00:48 -operation fmt
raidcom initialize ldev -ldev_id 00:49 -operation fmt
raidcom initialize ldev -ldev_id 00:4A -operation fmt
raidcom initialize ldev -ldev_id 00:4B -operation fmt
raidcom initialize ldev -ldev_id 00:4C -operation fmt
raidcom initialize ldev -ldev_id 00:4D -operation fmt
raidcom initialize ldev -ldev_id 00:4E -operation fmt
raidcom initialize ldev -ldev_id 00:4F -operation fmt
```

lunmap.sh

```
raidcom add lun -port CL1-A -ldev_id 00:00
raidcom add lun -port CL1-B -ldev_id 00:01
raidcom add lun -port CL1-C -ldev_id 00:02
raidcom add lun -port CL1-D -ldev_id 00:03
raidcom add lun -port CL2-A -ldev_id 00:04
raidcom add lun -port CL2-B -ldev_id 00:05
raidcom add lun -port CL2-C -ldev_id 00:06
raidcom add lun -port CL2-D -ldev_id 00:07
raidcom add lun -port CL3-A -ldev_id 00:08
raidcom add lun -port CL3-B -ldev_id 00:09
raidcom add lun -port CL3-C -ldev_id 00:0A
raidcom add lun -port CL3-D -ldev_id 00:0B
raidcom add lun -port CL4-A -ldev_id 00:0C
raidcom add lun -port CL4-B -ldev_id 00:0D
raidcom add lun -port CL4-C -ldev_id 00:0E
```

```
raidcom add lun -port CL4-D -ldev_id 00:0F
raidcom add lun -port CL1-A -ldev_id 00:10
raidcom add lun -port CL1-B -ldev_id 00:11
raidcom add lun -port CL1-C -ldev_id 00:12
raidcom add lun -port CL1-D -ldev_id 00:13
raidcom add lun -port CL2-A -ldev_id 00:14
raidcom add lun -port CL2-B -ldev_id 00:15
raidcom add lun -port CL2-C -ldev_id 00:16
raidcom add lun -port CL2-D -ldev_id 00:17
raidcom add lun -port CL3-A -ldev_id 00:18
raidcom add lun -port CL3-B -ldev_id 00:19
raidcom add lun -port CL3-C -ldev_id 00:1A
raidcom add lun -port CL3-D -ldev_id 00:1B
raidcom add lun -port CL4-A -ldev_id 00:1C
raidcom add lun -port CL4-B -ldev_id 00:1D
raidcom add lun -port CL4-C -ldev_id 00:1E
raidcom add lun -port CL4-D -ldev_id 00:1F
raidcom add lun -port CL1-A -ldev_id 00:20
raidcom add lun -port CL1-B -ldev_id 00:21
raidcom add lun -port CL1-C -ldev_id 00:22
raidcom add lun -port CL1-D -ldev_id 00:23
raidcom add lun -port CL2-A -ldev_id 00:24
raidcom add lun -port CL2-B -ldev_id 00:25
raidcom add lun -port CL2-C -ldev_id 00:26
raidcom add lun -port CL2-D -ldev_id 00:27
raidcom add lun -port CL3-A -ldev_id 00:28
raidcom add lun -port CL3-B -ldev_id 00:29
raidcom add lun -port CL3-C -ldev_id 00:2A
raidcom add lun -port CL3-D -ldev_id 00:2B
raidcom add lun -port CL4-A -ldev_id 00:2C
raidcom add lun -port CL4-B -ldev_id 00:2D
raidcom add lun -port CL4-C -ldev_id 00:2E
raidcom add lun -port CL4-D -ldev_id 00:2F
raidcom add lun -port CL1-A -ldev_id 00:30
raidcom add lun -port CL1-B -ldev_id 00:31
raidcom add lun -port CL1-C -ldev_id 00:32
raidcom add lun -port CL1-D -ldev_id 00:33
raidcom add lun -port CL2-A -ldev_id 00:34
raidcom add lun -port CL2-B -ldev_id 00:35
raidcom add lun -port CL2-C -ldev_id 00:36
raidcom add lun -port CL2-D -ldev_id 00:37
raidcom add lun -port CL3-A -ldev_id 00:38
raidcom add lun -port CL3-B -ldev_id 00:39
raidcom add lun -port CL3-C -ldev_id 00:3A
raidcom add lun -port CL3-D -ldev_id 00:3B
raidcom add lun -port CL4-A -ldev_id 00:3C
raidcom add lun -port CL4-B -ldev_id 00:3D
raidcom add lun -port CL4-C -ldev_id 00:3E
raidcom add lun -port CL4-D -ldev_id 00:3F
raidcom add lun -port CL1-A -ldev_id 00:40
raidcom add lun -port CL1-B -ldev_id 00:41
raidcom add lun -port CL1-C -ldev_id 00:42
raidcom add lun -port CL1-D -ldev_id 00:43
raidcom add lun -port CL2-A -ldev_id 00:44
raidcom add lun -port CL2-B -ldev_id 00:45
raidcom add lun -port CL2-C -ldev_id 00:46
raidcom add lun -port CL2-D -ldev_id 00:47
raidcom add lun -port CL3-A -ldev_id 00:48
raidcom add lun -port CL3-B -ldev_id 00:49
raidcom add lun -port CL3-C -ldev_id 00:4A
raidcom add lun -port CL3-D -ldev_id 00:4B
raidcom add lun -port CL4-A -ldev_id 00:4C
raidcom add lun -port CL4-B -ldev_id 00:4D
```

```
raidcom add lun -port CL4-C -ldev_id 00:4E
raidcom add lun -port CL4-D -ldev_id 00:4F
```

pvcreate.sh

```
#!/bin/bash

for disk in `lsscsi | grep HITACHI | awk '{ print $6 }'`
do
   pvcreate $disk
done
```

vgcreate.sh

```
#!/bin/bash

lunmap=lunmap.txt

# Generate a mapping of the Storage Array LDEV ID to Linux SCSI Device name
cat /dev/null > $lunmap
for disk in `lsscsi | grep HITACHI | awk '{ print $6 }'`
do
   lun=`scsi_id --page=0x83 --whitelisted --device=$disk | tail -c 5`
   cu=`echo $lun | cut -c 1-2`
   ldev=`echo $lun | cut -c 3-4`
   echo -e $cu":"$ldev"\t"$disk >> $lunmap
done
sort -o $lunmap $lunmap

# Build the list of PVs for the Volume Group
pvs=`cat $lunmap | awk '{ print $2 }'`

# Create the LVM Volume Group
vgcreate vgasu $pvs
```

lvcreate.sh

```
#!/bin/bash

lvcreate -l 264240 -i 80 -I 4M -n lvasu11 vgasu
lvcreate -l 264240 -i 80 -I 4M -n lvasu12 vgasu
lvcreate -l 264240 -i 80 -I 4M -n lvasu13 vgasu
lvcreate -l 264240 -i 80 -I 4M -n lvasu14 vgasu
lvcreate -l 264240 -i 80 -I 4M -n lvasu21 vgasu
lvcreate -l 264240 -i 80 -I 4M -n lvasu22 vgasu
lvcreate -l 264240 -i 80 -I 4M -n lvasu23 vgasu
lvcreate -l 264240 -i 80 -I 4M -n lvasu24 vgasu
lvcreate -l 234880 -i 80 -I 4M -n lvasu31 vgasu
```

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.
compratio=1

```
sd=sd1,lun=/dev/vgasu/lvasu11,size=1108302888960,threads=8,openflags=o_direct
sd=sd2,lun=/dev/vgasu/lvasu12,size=1108302888960,threads=8,openflags=o_direct
sd=sd3,lun=/dev/vgasu/lvasu13,size=1108302888960,threads=8,openflags=o_direct
sd=sd4,lun=/dev/vgasu/lvasu14,size=1108302888960,threads=8,openflags=o_direct
sd=sd5,lun=/dev/vgasu/lvasu21,size=1108302888960,threads=8,openflags=o_direct
sd=sd6,lun=/dev/vgasu/lvasu22,size=1108302888960,threads=8,openflags=o_direct
sd=sd7,lun=/dev/vgasu/lvasu23,size=1108302888960,threads=8,openflags=o_direct
sd=sd8,lun=/dev/vgasu/lvasu24,size=1108302888960,threads=8,openflags=o_direct
sd=sd9,lun=/dev/vgasu/lvasu31,size=985158123520,threads=8,openflags=o_direct

wd=wd1,sd=sd1,rdpct=0,seek=-1,xfersize=512k
wd=wd2,sd=sd2,rdpct=0,seek=-1,xfersize=512k
wd=wd3,sd=sd3,rdpct=0,seek=-1,xfersize=512k
wd=wd4,sd=sd4,rdpct=0,seek=-1,xfersize=512k
wd=wd5,sd=sd5,rdpct=0,seek=-1,xfersize=512k
wd=wd6,sd=sd6,rdpct=0,seek=-1,xfersize=512k
wd=wd7,sd=sd7,rdpct=0,seek=-1,xfersize=512k
wd=wd8,sd=sd8,rdpct=0,seek=-1,xfersize=512k
wd=wd9,sd=sd9,rdpct=0,seek=-1,xfersize=512k

rd=asu_prefill,wd=wd*,iorate=max,elapsed=100h,interval=10
```

Primary Metrics and Repeatability Tests

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

```
host=master
slaves=(cb22_1,cb22_2,cb22_3,cb22_4,cb22_5,cb22_6,cb22_7,cb22_8,cb22_9,cb22_10,cb22_
11,cb22_12,cb22_13,cb22_14,cb22_15,cb22_16,cb23_1,cb23_2,cb23_3,cb23_4,cb23_5,cb23_6
,cb23_7,cb23_8,cb23_9,cb23_10,cb23_11,cb23_12,cb23_13,cb23_14,cb23_15,cb23_16,cb24_1
,cb24_2,cb24_3,cb24_4,cb24_5,cb24_6,cb24_7,cb24_8,cb24_9,cb24_10,cb24_11,cb24_12,cb2
4_13,cb24_14,cb24_15,cb24_16,cb25_1,cb25_2,cb25_3,cb25_4,cb25_5,cb25_6,cb25_7,cb25_8
,cb25_9,cb25_10,cb25_11,cb25_12,cb25_13,cb25_14,cb25_15,cb25_16)

javaparms="-Xms1536m -Xmx2048m -Xss256k"

sd=asu1_1,lun=/dev/vgasu/lvasu11,size=1108302888960
sd=asu1_2,lun=/dev/vgasu/lvasu12,size=1108302888960
sd=asu1_3,lun=/dev/vgasu/lvasu13,size=1108302888960
sd=asu1_4,lun=/dev/vgasu/lvasu14,size=1108302888960

sd=asu2_1,lun=/dev/vgasu/lvasu21,size=1108302888960
sd=asu2_2,lun=/dev/vgasu/lvasu22,size=1108302888960
sd=asu2_3,lun=/dev/vgasu/lvasu23,size=1108302888960
sd=asu2_4,lun=/dev/vgasu/lvasu24,size=1108302888960

sd=asu3_1,lun=/dev/vgasu/lvasu31,size=985158123520
```

SPC-1 Persistence Test Run 1

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

```
javaparms="-Xms1536m -Xmx2048m -Xss256k"

sd=asu1_1,lun=/dev/vgasu/lvasu11,size=1108302888960
sd=asu1_2,lun=/dev/vgasu/lvasu12,size=1108302888960
sd=asu1_3,lun=/dev/vgasu/lvasu13,size=1108302888960
sd=asu1_4,lun=/dev/vgasu/lvasu14,size=1108302888960

sd=asu2_1,lun=/dev/vgasu/lvasu21,size=1108302888960
sd=asu2_2,lun=/dev/vgasu/lvasu22,size=1108302888960
sd=asu2_3,lun=/dev/vgasu/lvasu23,size=1108302888960
sd=asu2_4,lun=/dev/vgasu/lvasu24,size=1108302888960

sd=asu3_1,lun=/dev/vgasu/lvasu31,size=985158123520
```

SPC-2 Persistence Test

The content of SPC-2 Workload Generator command and parameter files, used in this benchmark to execute the SPC-2 Persistence Test, are listed below.

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

```
host=localhost,jvms=8,maxstreams=203
sd=asu1_1,lun=/dev/vgasu/lvasu11,size=1108302888960
sd=asu1_2,lun=/dev/vgasu/lvasu12,size=1108302888960
sd=asu1_3,lun=/dev/vgasu/lvasu13,size=1108302888960
sd=asu1_4,lun=/dev/vgasu/lvasu14,size=1108302888960
sd=asu2_1,lun=/dev/vgasu/lvasu21,size=1108302888960
sd=asu2_2,lun=/dev/vgasu/lvasu22,size=1108302888960
sd=asu2_3,lun=/dev/vgasu/lvasu23,size=1108302888960
sd=asu2_4,lun=/dev/vgasu/lvasu24,size=1108302888960
sd=asu3_1,lun=/dev/vgasu/lvasu31,size=985158123520

maxlatestart=1
reportinginterval=5
segmentlength=512m

rd=default,rampup=180,periods=90,measurement=300,runout=0,rampdown=0,buffers=1
rd=default,rdpct=0,xfersize=1024k
rd=TR1_SPC-2-persist-w,streams=203
```

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

```
host=localhost,jvms=8,maxstreams=203
sd=asu1_1,lun=/dev/vgasu/lvasu11,size=1108302888960
sd=asu1_2,lun=/dev/vgasu/lvasu12,size=1108302888960
sd=asu1_3,lun=/dev/vgasu/lvasu13,size=1108302888960
sd=asu1_4,lun=/dev/vgasu/lvasu14,size=1108302888960
sd=asu2_1,lun=/dev/vgasu/lvasu21,size=1108302888960
sd=asu2_2,lun=/dev/vgasu/lvasu22,size=1108302888960
sd=asu2_3,lun=/dev/vgasu/lvasu23,size=1108302888960
sd=asu2_4,lun=/dev/vgasu/lvasu24,size=1108302888960
sd=asu3_1,lun=/dev/vgasu/lvasu31,size=985158123520

maxlatestart=1
reportinginterval=5
segmentlength=512m
maxpersistenceerrors=10

rd=default,buffers=1,rdpct=100,xfersize=1024k
rd=TR1_SPC-2-persist-r
```

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. ***cb22_1…cb25_16***, and the **master** parameter value, which was ***cb22, cb23, cb24*** or ***cb25*** dependent upon which Host System the Slave JVMs were being invoked on.

```
host=cb22_1
master=cb22

javaparms="-Xms1536m -Xmx2048m -Xss256k"

sd=asu1_1,lun=/dev/vgasu/lvasu11,size=1108302888960
sd=asu1_2,lun=/dev/vgasu/lvasu12,size=1108302888960
sd=asu1_3,lun=/dev/vgasu/lvasu13,size=1108302888960
sd=asu1_4,lun=/dev/vgasu/lvasu14,size=1108302888960

sd=asu2_1,lun=/dev/vgasu/lvasu21,size=1108302888960
sd=asu2_2,lun=/dev/vgasu/lvasu22,size=1108302888960
sd=asu2_3,lun=/dev/vgasu/lvasu23,size=1108302888960
sd=asu2_4,lun=/dev/vgasu/lvasu24,size=1108302888960

sd=asu3_1,lun=/dev/vgasu/lvasu31,size=985158123520
```

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

The following script, **audit1.sh**, calls the standard **vdbench** script to execute the required ASU pre-fill and upon completion of that first step, invokes the commands to execute the Primary Metrics Test *(Sustainability Test Phase, IOPS Test Phase, and Response Time Ramp Test Phase)*, the Repeatability Test *(Repeatability Test Phase 1 and Repeatability Test Phase 2)*, a reduced level SPC-1 Persistence Test Run 1 *(write phase)* and SPC-2 Persistence Test Run 1 *(write phase)* in an uninterrupted sequence.

audit1.sh

```
#!/bin/bash

# Environment Variables
export LD_LIBRARY_PATH=/spc/spc1
export LIBPATH=/spc/spc1
export CLASSPATH=/spc/spc1
export PATH=/usr/java64/jre1.7.0_51/bin:$PATH

# Java Settings
XMS=1536m
XMX=2048m
XSS=256k

# SPC-1 Run Settings
BSU=6082
RUN=28800
RAMP=300
RAMPM="4200:300"

# Run ASU Prefill using Vdbench 5.03
cd /spc/vdbench503
vdbench -f prefill.parm -o prefill-out

# Run SPC-1 Metrics Test (8 Hours)
cd /spc/spc1
cp -p spc1.metrics.cfg spc1.cfg
/spc/spc1/startallslaves.sh
java -Xms$XMS -Xmx$XMX -Xss$XSS metrics -b $BSU -t $RUN -s $RAMPM
/spc/spc1/stopallslaves.sh

# Run SPC-1 Repeatability Test 1
/spc/spc1/startallslaves.sh
java -Xms$XMS -Xmx$XMX -Xss$XSS repeat1 -b $BSU -s $RAMP
/spc/spc1/stopallslaves.sh

# Run SPC-1 Repeatability Test 2
/spc/spc1/startallslaves.sh
java -Xms$XMS -Xmx$XMX -Xss$XSS repeat2 -b $BSU -s $RAMP
/spc/spc1/stopallslaves.sh

# Run SPC-1 Persistence Test 1 with Reduced BSU Count
printf -v BSU "%0.f" `echo "$BSU * 0.1" | bc`
cp -p spc1.persist.cfg spc1.cfg
java -Xms$XMS -Xmx$XMX -Xss$XSS persist1 -b $BSU

# Run SPC-2 Persistence Test 1
export LD_LIBRARY_PATH=/spc/spc2
export LIBPATH=/spc/spc2
export CLASSPATH=/spc/spc2
```

```
/spc/spc2/spc2 -f spc2.persist1.cfg -init -o persist-init-spc2
/spc/spc2/spc2 -f spc2.persist1.cfg -o persist1-spc2
```

The **startallslaves.sh** and **stopallslaves.sh** scripts were invoked by **audit1.sh** to start and stop the Slave JVMs. The **slavestart.sh** script was invoked by **startallslaves.sh** to actually start each Slave JVM on the appropriate Host System.

startallslaves.sh

```
#!/bin/bash

ssh cb22 '/spc/spc1/slavestart.sh' &
sleep 10
ssh cb23 '/spc/spc1/slavestart.sh' &
sleep 10
ssh cb24 '/spc/spc1/slavestart.sh' &
sleep 10
ssh cb25 '/spc/spc1/slavestart.sh' &
sleep 10
```

slavestart.sh

```
#!/bin/bash

# Environment Settings
export LD_LIBRARY_PATH=/spc/spc1
export LIBPATH=/spc/spc1
export CLASSPATH=/spc/spc1
export PATH=/usr/java64/jre1.7.0_51/bin:$PATH

DATE=`date +%Y%m%d-%H%M`
SPCDIR=/spc/spc1
OUTDIR=$SPCDIR/slave.`hostname -s`.$DATE

# Java Settings
XMS=1536m
XMX=2048m
XSS=256k

# Create Output Directory
mkdir -p $OUTDIR

# Start Java Slave Processes
cd $SPCDIR
nohup java -Xms$XMS -Xmx$XMX -Xss$XSS spc1 -f slave01.cfg -o $OUTDIR/slave01
1>/dev/null 2>&1 &
sleep 1
nohup java -Xms$XMS -Xmx$XMX -Xss$XSS spc1 -f slave02.cfg -o $OUTDIR/slave02
1>/dev/null 2>&1 &
sleep 1
nohup java -Xms$XMS -Xmx$XMX -Xss$XSS spc1 -f slave03.cfg -o $OUTDIR/slave03
1>/dev/null 2>&1 &
sleep 1
nohup java -Xms$XMS -Xmx$XMX -Xss$XSS spc1 -f slave04.cfg -o $OUTDIR/slave04
1>/dev/null 2>&1 &
sleep 1
nohup java -Xms$XMS -Xmx$XMX -Xss$XSS spc1 -f slave05.cfg -o $OUTDIR/slave05
1>/dev/null 2>&1 &
sleep 1
nohup java -Xms$XMS -Xmx$XMX -Xss$XSS spc1 -f slave06.cfg -o $OUTDIR/slave06
1>/dev/null 2>&1 &
```

```
sleep 1
nohup java -Xms$XMS -Xmx$XMX -Xss$XSS spc1 -f slave07.cfg -o $OUTDIR/slave07
1>/dev/null 2>&1 &
sleep 1
nohup java -Xms$XMS -Xmx$XMX -Xss$XSS spc1 -f slave08.cfg -o $OUTDIR/slave08
1>/dev/null 2>&1 &
sleep 1
nohup java -Xms$XMS -Xmx$XMX -Xss$XSS spc1 -f slave09.cfg -o $OUTDIR/slave09
1>/dev/null 2>&1 &
sleep 1
nohup java -Xms$XMS -Xmx$XMX -Xss$XSS spc1 -f slave10.cfg -o $OUTDIR/slave10
1>/dev/null 2>&1 &
sleep 1
nohup java -Xms$XMS -Xmx$XMX -Xss$XSS spc1 -f slave11.cfg -o $OUTDIR/slave11
1>/dev/null 2>&1 &
sleep 1
nohup java -Xms$XMS -Xmx$XMX -Xss$XSS spc1 -f slave12.cfg -o $OUTDIR/slave12
1>/dev/null 2>&1 &
sleep 1
nohup java -Xms$XMS -Xmx$XMX -Xss$XSS spc1 -f slave13.cfg -o $OUTDIR/slave13
1>/dev/null 2>&1 &
sleep 1
nohup java -Xms$XMS -Xmx$XMX -Xss$XSS spc1 -f slave14.cfg -o $OUTDIR/slave14
1>/dev/null 2>&1 &
sleep 1
nohup java -Xms$XMS -Xmx$XMX -Xss$XSS spc1 -f slave15.cfg -o $OUTDIR/slave15
1>/dev/null 2>&1 &
sleep 1
nohup java -Xms$XMS -Xmx$XMX -Xss$XSS spc1 -f slave16.cfg -o $OUTDIR/slave16
1>/dev/null 2>&1 &
sleep 1
```

stopallslaves.sh

```
#!/bin/bash

ssh cb22 'pkill java'
sleep 10
ssh cb23 'pkill java'
sleep 10
ssh cb24 'pkill java'
sleep 10
ssh cb25 'pkill java'
sleep 10
```

SPC-1 Persistence Test Run 2

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

audit2.sh

```
#!/bin/bash

# Environment Variables
export LD_LIBRARY_PATH=/spc/spc2
export LIBPATH=/spc/spc2
export CLASSPATH=/spc/spc2
export PATH=/usr/java64/jre1.7.0_51/bin:$PATH

# Run SPC-2 Persistence Test 2
cd /spc/spc1
/spc/spc2/spc2 -f spc2.persist2.cfg -o persist2-spc2
```

APPENDIX F: THIRD-PARTY QUOTATIONS

LPE12002-M8 Emulex LightPulse 2x LC PCI Express 2.0 8Gbps HBAs

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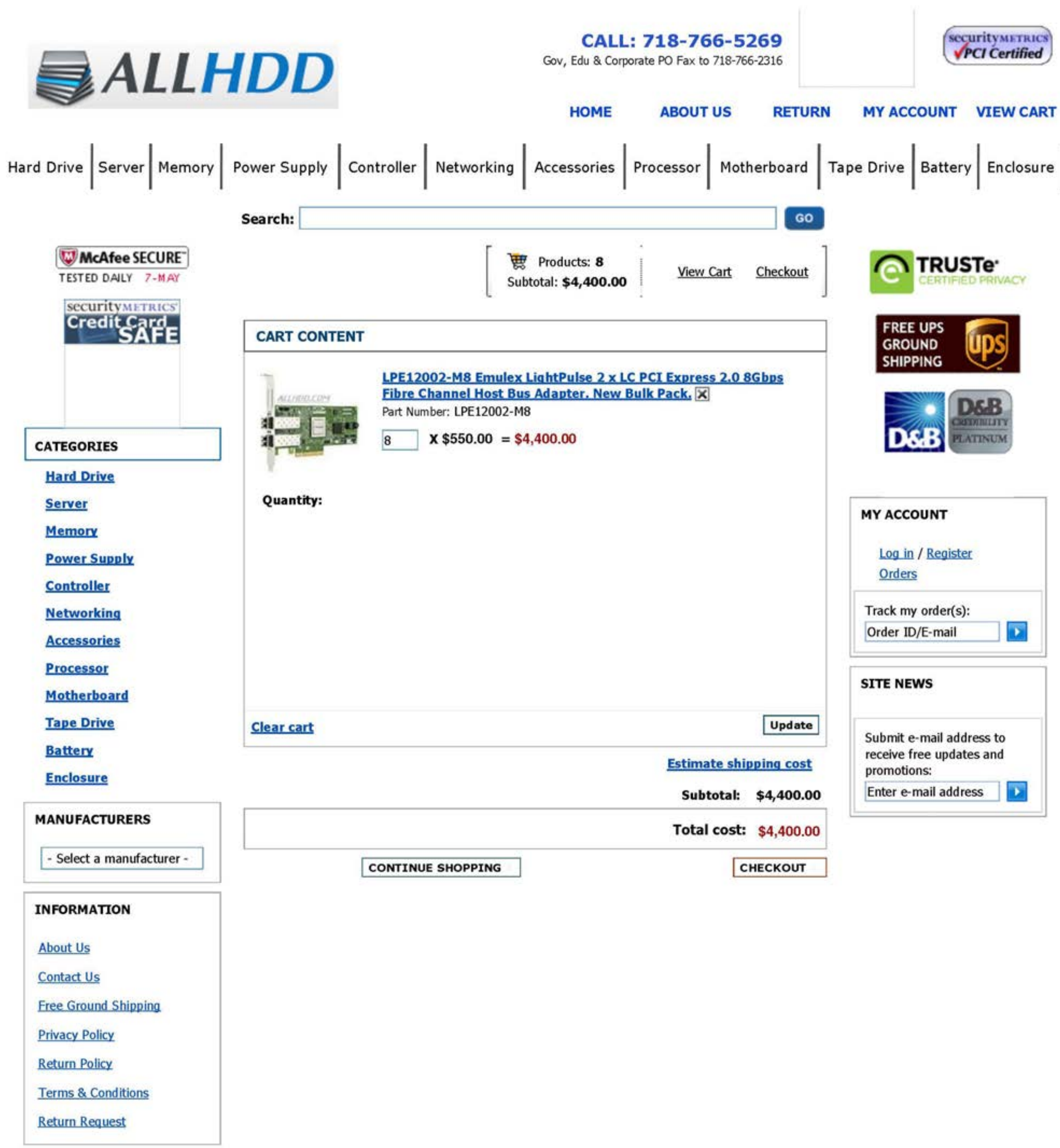

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