SPC BENCHMARK 1™
FULL DISCLOSURE REPORT

HITACHI DATA SYSTEMS CORPORATION
HITACHI VIRTUAL STORAGE PLATFORM
(WITH HITACHI ACCELERATED FLASH)

SPC-1 V1.14

Submitted for Review: July 30, 2013
Submission Identifier: A00136
Revised: March 20, 2014

First Edition – July 2013

THE INFORMATION CONTAINED IN THIS DOCUMENT IS DISTRIBUTED ON AN AS IS BASIS WITHOUT ANY WARRANTY EITHER EXPRESS OR IMPLIED. The use of this information or the implementation of any of these techniques is the customer's responsibility and depends on the customer's ability to evaluate and integrate them into the customer's operational environment. While each item has been reviewed by Hitachi Data Systems Corporation for accuracy in a specific situation, there is no guarantee that the same or similar results will be obtained elsewhere. Customers attempting to adapt these techniques to their own environment do so at their own risk.

This publication was produced in the United States. Hitachi Data Systems Corporation may not offer the products, services, or features discussed in this document in other countries, and the information is subject to change with notice. Consult your local Hitachi Data Systems Corporation representative for information on products and services available in your area.

© Copyright Hitachi Data Systems Corporation 2013. All rights reserved.

Permission is hereby granted to reproduce this document in whole or in part, provided the copyright notice as printed above is set forth in full text on the title page of each item reproduced.

Trademarks

SPC Benchmark-1, SPC-1, SPC-1 IOPS, SPC-1 LRT and SPC-1 Price-Performance are trademarks of the Storage Performance Council. Hitachi Data Systems, Hitachi, HDS and the Hitachi Data Systems logo are trademarks or registered trademarks of Hitachi Data Systems Corporation in the United States and other countries. All other brands, trademarks, and product names are the property of their respective owners.

Table of Contents

Audit Certification viii
Audit Certification *(cont.)* ix
Letter of Good Faith x
Executive Summary 11
Test Sponsor and Contact Information 11
Revision Information and Key Dates 11
Tested Storage Product (TSP) Description 12
Summary of Results 13
Storage Capacities, Relationships, and Utilization 14
Response Time – Throughput Curve 17
Response Time – Throughput Data 17
Priced Storage Configuration Pricing 18
Priced Storage Configuration Pricing *(continued)* 19
Differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration 19
Priced Storage Configuration Diagram 20
Priced Storage Configuration Components 21
Storage Network Configuration Diagram 22
Configuration Information 23
Benchmark Configuration (BC)/Tested Storage Configuration (TSC) Diagram 23
Storage Network Configuration 23
Host System(s) and Tested Storage Configuration (TSC) Table of Components 26
Benchmark Configuration/Tested Storage Configuration Diagram 27
Host Systems and Tested Storage Configuration Components 28
Customer Tunable Parameters and Options 29
Tested Storage Configuration (TSC) Description 29
SPC-1 Workload Generator Storage Configuration 29
ASU Pre-Fill 30
SPC-1 Data Repository 31
Storage Capacities and Relationships 31
SPC-1 Storage Capacities 31
SPC-1 Storage Hierarchy Ratios 32
SPC-1 Storage Capacity Charts 32
Storage Capacity Utilization 34
Logical Volume Capacity and ASU Mapping 35
SPC-1 Benchmark Execution Results 36

SPC-1 Tests, Test Phases, and Test Runs **36**
"Ramp-Up" Test Runs **37**
Primary Metrics Test – Sustainability Test Phase **37**
SPC-1 Workload Generator Input Parameters 38
Sustainability Test Results File 38
Sustainability – Data Rate Distribution Data (MB/second) 38
Sustainability – Data Rate Distribution Graph 38
Sustainability – I/O Request Throughput Distribution Data 39
Sustainability – I/O Request Throughput Distribution Graph 39
Sustainability – Average Response Time (ms) Distribution Data 40
Sustainability – Average Response Time (ms) Distribution Graph 40
Sustainability – Response Time Frequency Distribution Data 41
Sustainability – Response Time Frequency Distribution Graph 41
Sustainability – Measured Intensity Multiplier and Coefficient of Variation 42
Primary Metrics Test – IOPS Test Phase **43**
SPC-1 Workload Generator Input Parameters 43
IOPS Test Results File 43
IOPS Test Run – I/O Request Throughput Distribution Data 44
IOPS Test Run – I/O Request Throughput Distribution Graph 44
IOPS Test Run – Average Response Time (ms) Distribution Data 45
IOPS Test Run – Average Response Time (ms) Distribution Graph 45
IOPS Test Run –Response Time Frequency Distribution Data 46
IOPS Test Run –Response Time Frequency Distribution Graph 46
IOPS Test Run – I/O Request Information 47
IOPS Test Run – Measured Intensity Multiplier and Coefficient of Variation 47
Primary Metrics Test – Response Time Ramp Test Phase **48**
SPC-1 Workload Generator Input Parameters 48
Response Time Ramp Test Results File 48
Response Time Ramp Distribution (IOPS) Data 49
Response Time Ramp Distribution (IOPS) Data *(continued)* 50
Response Time Ramp Distribution (IOPS) Graph 50
SPC-1 LRT™ Average Response Time (ms) Distribution Data 51
SPC-1 LRT™ Average Response Time (ms) Distribution Graph 51
SPC-1 LRT™ (10%) – Measured Intensity Multiplier and Coefficient of Variation 52
Repeatability Test **53**
SPC-1 Workload Generator Input Parameters 53
Repeatability Test Results File 54
Repeatability 1 LRT – I/O Request Throughput Distribution Data 55
Repeatability 1 LRT – I/O Request Throughput Distribution Graph 55

Repeatability 1 LRT –Average Response Time (ms) Distribution Data 56
Repeatability 1 LRT –Average Response Time (ms) Distribution Graph 56
Repeatability 1 IOPS – I/O Request Throughput Distribution Data 57
Repeatability 1 IOPS – I/O Request Throughput Distribution Graph 57
Repeatability 1 IOPS –Average Response Time (ms) Distribution Data 58
Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph 58
Repeatability 2 LRT – I/O Request Throughput Distribution Data 59
Repeatability 2 LRT – I/O Request Throughput Distribution Graph 59
Repeatability 2 LRT –Average Response Time (ms) Distribution Data 60
Repeatability 2 LRT –Average Response Time (ms) Distribution Graph 60
Repeatability 2 IOPS – I/O Request Throughput Distribution Data 61
Repeatability 2 IOPS – I/O Request Throughput Distribution Graph 61
Repeatability 2 IOPS –Average Response Time (ms) Distribution Data 62
Repeatability 2 IOPS –Average Response Time (ms) Distribution Graph 62
Repeatability 1 (LRT) Measured Intensity Multiplier and Coefficient of Variation 63
Repeatability 1 (IOPS) Measured Intensity Multiplier and Coefficient of Variation 63
Repeatability 2 (LRT) Measured Intensity Multiplier and Coefficient of Variation 63
Repeatability 2 (IOPS) Measured Intensity Multiplier and Coefficient of Variation 64
Data Persistence Test 65
SPC-1 Workload Generator Input Parameters 65
Data Persistence Test Results File 65
0.26 66
Priced Storage Configuration Availability Date 67
Pricing Information 67
Tested Storage Configuration (TSC) and Priced Storage Configuration Differences 67
Anomalies or Irregularities 67
Appendix A: SPC-1 Glossary 68
"Decimal" *(powers of ten)* Measurement Units 68
"Binary" *(powers of two)* Measurement Units 68
SPC-1 Data Repository Definitions 68
SPC-1 Data Protection Levels 69
SPC-1 Test Execution Definitions 69
I/O Completion Types 71
SPC-1 Test Run Components 71
Appendix B: Customer Tunable Parameters and Options 72
Appendix C: Tested Storage Configuration (TSC) Creation 73

1. Pre-Configured RAID-10 Parity Groups 73
2. Create Logical Devices 73
3. Format Logical Devices 73
4. Name Logical Devices 73
5. Create Four Text Files Listing VSP FED Ports to be used in the TSC 74
6. Map LUNs to Front-End Ports 74
7. Discover LUNs 74
8. Initialize Disks for Logical Volume Manager 75
9. Map Linux Raw Device Names to VSP Logical Device Names 75
10. Create Twelve Linux LVM Volume Groups 75
11. Create Twelve Striped Logical Volumes 75
12. Activate Logical Volumes 75
12. Set Parameters and Options 75
Logical Device Mapping 76
TSC Creation/Configuration Scripts 79
make_ldev.ksh 79
format_ldev.ksh 80
label_ldev.ksh 80
spcmlun.ksh *(invoked from* label_ldev.ksh*)* 81
mml.ksh 82
mmll.ksh *(invoked from* mml.ksh*)* 82
smml.ksh *(invoked from* mml.ksh*)* 83
portlist.cb26 84
portlist.cb27 84
portlist.cb28 84
portlist.cb29 84
pvcreate.sh 84
mapsd2ldev.ksh 84
vgcreate.ksh 85
lvcreate.ksh 85
lvactivate.ksh 86
Appendix D: SPC-1 Workload Generator Storage Commands and Parameters 87
ASU Pre-Fill 87
Primary Metrics Test, and Repeatability Tests 87
SPC-1 Persistence Test Run 1 88
SPC-2 Persistence Test 88
SPC-2 Persistence Test Run 1 *(write phase)* 88
SPC-2 Persistence Test Run 2 *(read phase)* 88

Slave JVMs **89**

Appendix E: SPC-1 Workload Generator Input Parameters **90**

ASU Pre-Fill, Primary Metrics Test, Repeatability and Persistence Test **90**

startem.ksh **91**

Appendix F: Third-Party Quotations **92**

Brocade 5320 Switch **92**

8 Gbps Dual-Port PCIe (LPE12002 E) HBAs **93**

LC/LC 50/125 Fiber Cables **94**

AUDIT CERTIFICATION

Mel Boksenbaum
Hitachi Data Systems Corporation
750 Central Expressway M/S U9922
Santa Clara, CA 95050

December 4, 2013

The SPC Benchmark 1™ Reported Data listed below for the Hitachi Virtual Storage Platform *(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 Virtual Storage Platform *(with Hitachi Accelerated Flash)*	
Metric	**Reported Result**
SPC-1 IOPS™	602,019.47
SPC-1 Price-Performance	$2.91/SPC-1 IOPS™
Total ASU Capacity	11,610.883 GB
Data Protection Level	Protected 2 *(Mirroring)*
Total Price (including three-year maintenance)	$1,749,937.95
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.

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

AUDIT CERTIFICATION *(CONT.)*

- An appropriate diagram of the Benchmark Configuration (BC)/Tested Storage Configuration (TSC).
- Physical verification of the components to match the above diagram.
- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters that were changed from default values.
- SPC-1 Workload Generator commands and parameters used for the audited SPC Test Runs.
- The following Host System requirements were verified by physical inspection and information supplied by Hitachi Data Systems Corporation:
  - ✓ The type of Host Systems including the number of processors and main memory.
  - ✓ The presence and version number of the SPC-1 Workload Generator on each Host System.
  - ✓ The TSC boundary within each Host System.
- The execution of each Test, Test Phase, and Test Run was 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 24-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, 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

Walter E. Baker
SPC Auditor

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

LETTER OF GOOD FAITH

HITACHI
Inspire the Next

Date: May 17, 2013

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 Virtual Storage Platform

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.

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

Regards,

Alan Cade
Vice President
Technical Operations

Hitachi Data Systems 2845 Lafayette Street · Santa Clara, CA 95050 408-970-7113

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact	Hitachi Data Systems Corporation –http://www.hds.com David Cordero – david.cordero@hds.com 750 Central Expressway M/S U9922 Santa Clara, CA 95050 Phone: (617) 838-4040 FAX: (617) 838-4040
Test Sponsor Alternate Contact	Hitachi Data Systems Corporation –http://www.hds.com Mel Boksenbaum – mel.boksenbaum@hds.com 750 Central Expressway M/S U9922 Santa Clara, CA 95050 Phone: (408) 970-7922 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	July 30, 2013
Date revised FDR was submitted to the SPC Revised pricing *(page 18)* Revised price-related SPC-1 Reported Data *(page 13)* New third-party quote *(page 92)*	March 20, 2014
Date the FDR was submitted to the SPC	July 30, 2013
Date the Priced Storage Configuration is available for shipment to customers	currently available
Date the TSC completed audit certification	June 24, 2013

Tested Storage Product (TSP) Description

Hitachi Virtual Storage Platform is the only 3D scaling storage platform designed for all data types. It is the only enterprise storage architecture that flexibly adapts for performance, capacity and multivendor storage. Combined with unique Hitachi Command Suite management software, it transforms the data center.

- Scale up by dynamically adding resources to a control chassis to provide the highest performance for both open and mainframe environments.
- Scale out by dynamically combining multiple control chassis into a logical system with shared resources to support increased demand in virtualized server environments.
- Scale deep by dynamically virtualizing new and existing external storage systems to extend the advanced functions to multivendor storage, offloading less demanding data to external tiers.

Summary of Results

SPC-1 Reported Data	
Tested Storage Product (TSP) Name: Hitachi Virtual Storage Platform *(with Hitachi Accelerated Flash)*	
Metric	**Reported Result**
SPC-1 IOPS™	602,019.47
SPC-1 Price-Performance™	$2.91/SPC-1 IOPS™
Total ASU Capacity	11,610.843 GB
Data Protection Level	Protected 2 *(Mirroring)*
Total Price	$1,749,937.95
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 18.

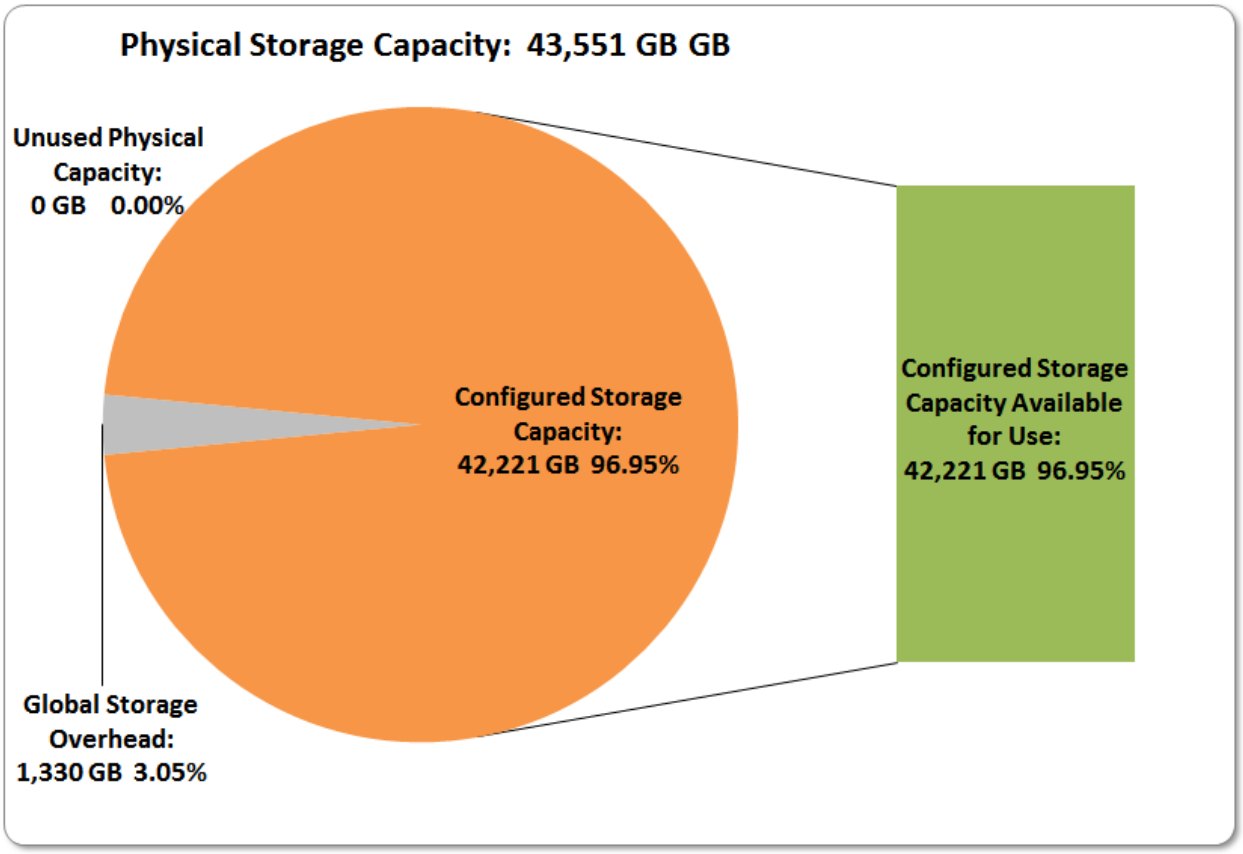
Currency Used is formal name for the currency used in calculating the **Total Price** and **SPC-1 Price-Performance™**. That currency may be the local currency of the **Target Country** or the currency of a difference country *(non-local currency)*.

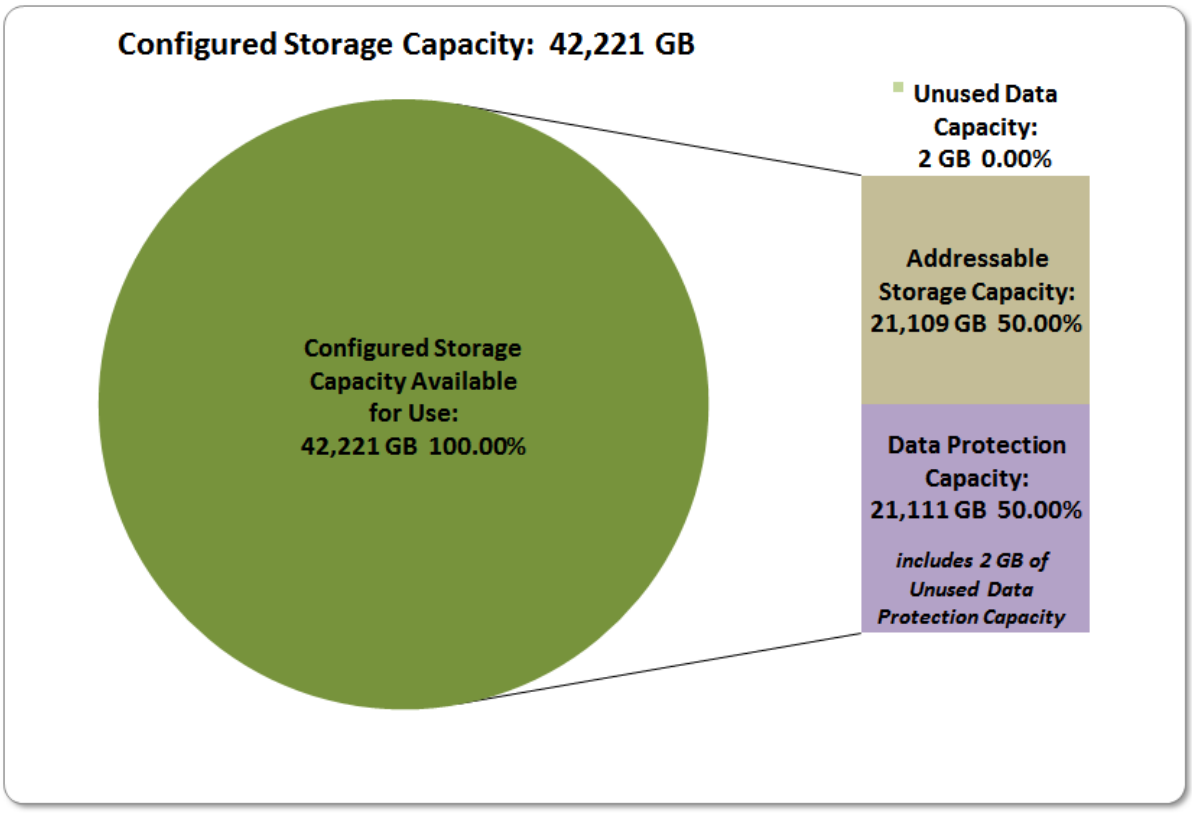
The **Target Country** is the country in which the Priced Storage Configuration is available for sale and in which the required hardware maintenance and software support is provided either directly from the Test Sponsor or indirectly via a third-party supplier.

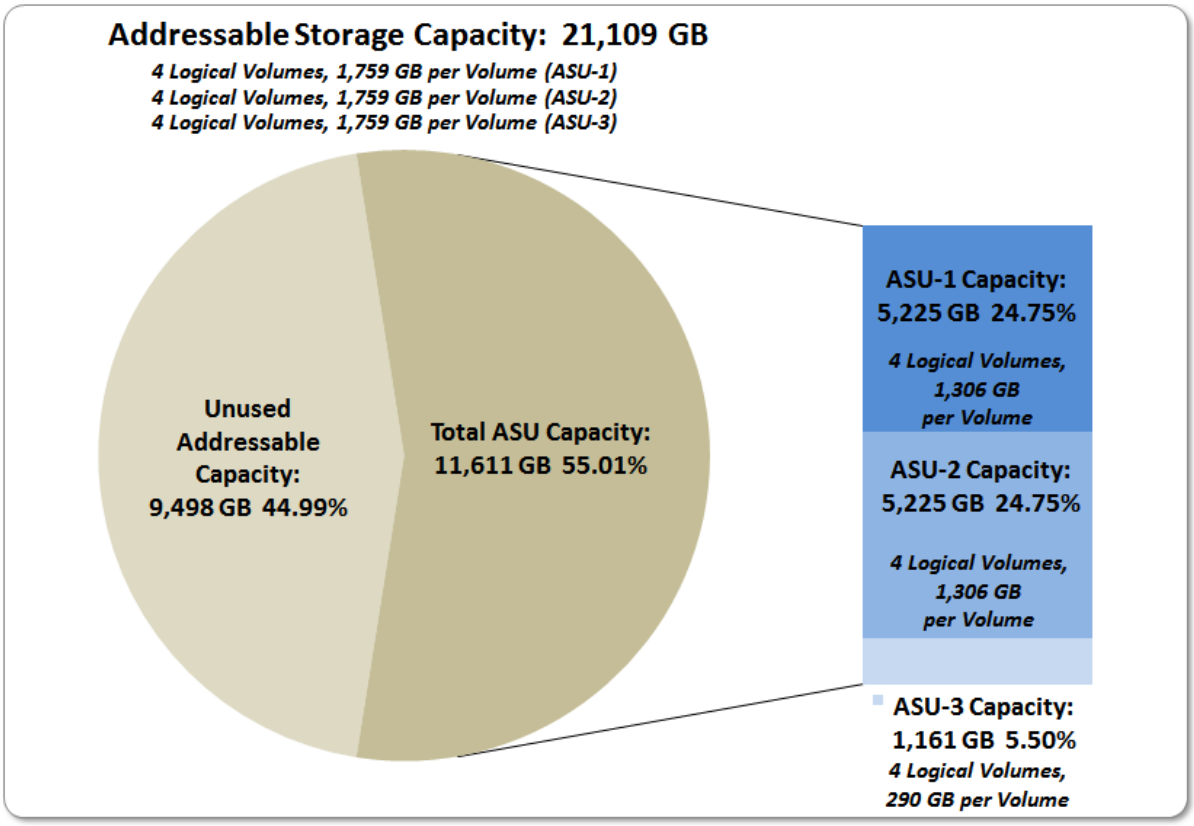
Storage Capacities, Relationships, and Utilization

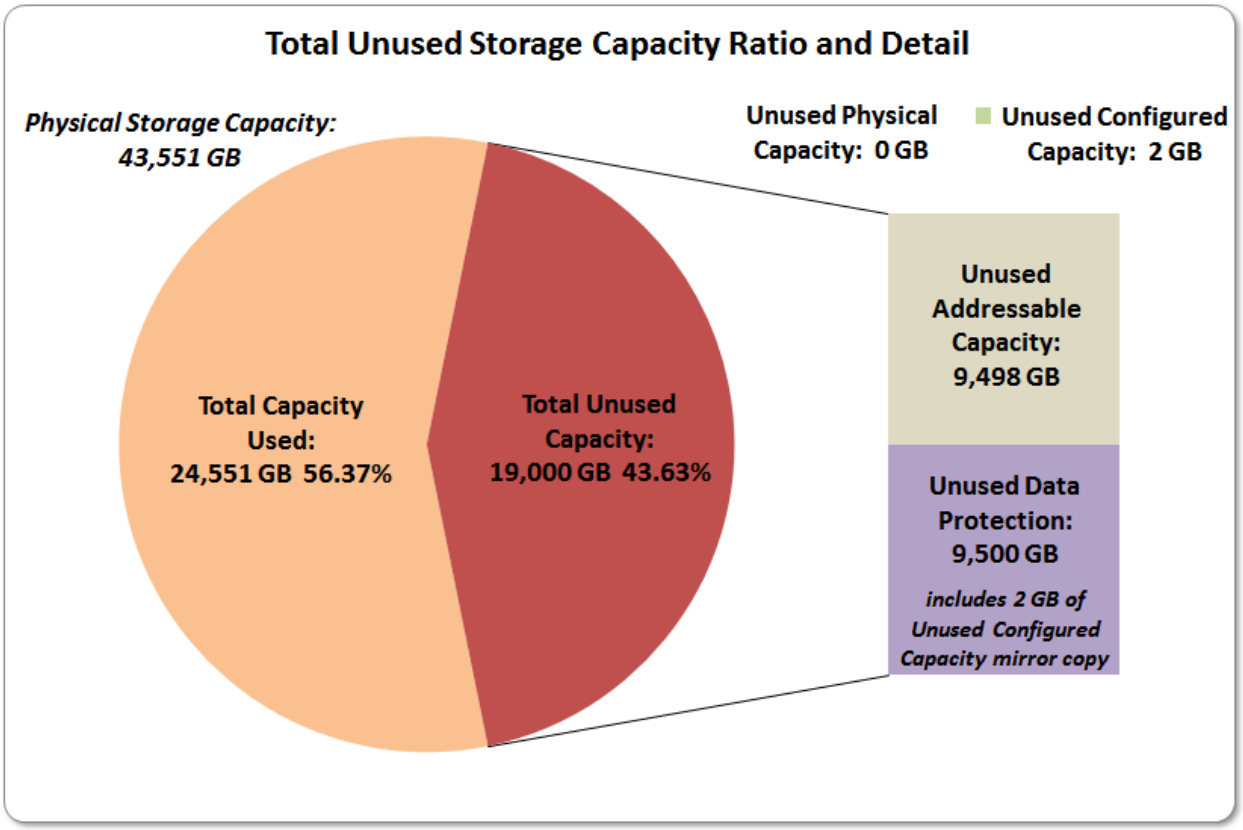
The following four charts and table document the various storage capacities, used in this benchmark, and their relationships, as well as the storage utilization values required to be reported.

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: 42,221 GB
Configured Storage Capacity Available for Use:
42,221 GB 100.00%
Unused Data Capacity:
2 GB 0.00%
Addressable Storage Capacity:
21,109 GB 50.00%
Data Protection Capacity:
21,111 GB 50.00%
includes 2 GB of Unused Data Protection Capacity


Addressable Storage Capacity: 21,109 GB
4 Logical Volumes, 1,759 GB per Volume (ASU-1)
4 Logical Volumes, 1,759 GB per Volume (ASU-2)
4 Logical Volumes, 1,759 GB per Volume (ASU-3)
Unused Addressable Capacity:
9,498 GB 44.99%
Total ASU Capacity:
11,611 GB 55.01%
ASU-1 Capacity:
5,225 GB 24.75%
4 Logical Volumes, 1,306 GB per Volume
ASU-2 Capacity:
5,225 GB 24.75%
4 Logical Volumes, 1,306 GB per Volume
ASU-3 Capacity:
1,161 GB 5.50%
4 Logical Volumes, 290 GB per Volume



SPC-1 Storage Capacity Utilization	
Application Utilization	26.66%
Protected Application Utilization	53.32%
Unused Storage Ratio	43.63%

Application Utilization: Total ASU Capacity *(11,610.843 GB)* divided by Physical Storage Capacity *(43,550.927 GB)*.

Protected Application Utilization: Total ASU Capacity *(11,610.843 GB)* plus total Data Protection Capacity *(21,110.600 GB)* minus unused Data Protection Capacity *(9,499.757 GB)* divided by Physical Storage Capacity *(43,550.927 GB)*.

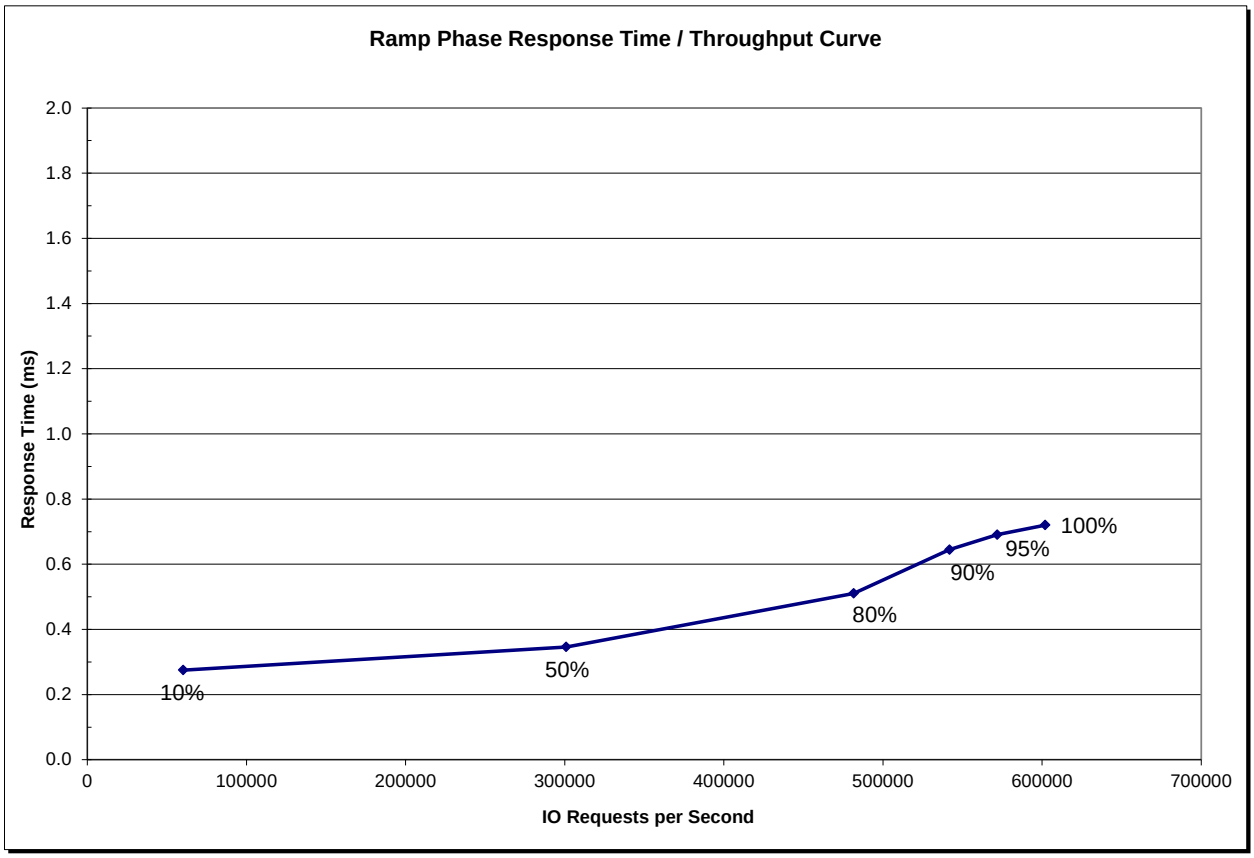
Unused Storage Ratio: Total Unused Capacity *(18,999.514 GB)* divided by Physical Storage Capacity *(43,550.927 GB)* and may not exceed 45%.

Detailed information for the various storage capacities and utilizations is available on pages 31-32.

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	60,202.66	301,004.02	481,596.47	541,844.78	571,915.98	602,019.47
Average Response Time (ms):						
All ASUs	0.28	0.35	0.51	0.64	0.69	0.72
ASU-1	0.29	0.29	0.46	0.60	0.65	0.68
ASU-2	0.27	0.36	0.65	0.88	0.96	1.02
ASU-3	0.25	0.47	0.56	0.64	0.67	0.67
Reads	0.35	0.30	0.57	0.77	0.85	0.90
Writes	0.23	0.37	0.47	0.56	0.59	0.61

Priced Storage Configuration Pricing

Product	Product Description	Qty	List Price	Extended Price
041-100065-01.P	Virtual Storage Platform Microcode Kit	1	$0.00	$0.00
041-100066-01.P	Virtual Storage Platform Product Documentation Library	1	$0.00	$0.00
043-991826-01.P	VSP Installation Planning	1	$5,000.00	$5,000.00
043-991828-01.P	VSP Installation - Control Frame	2	$6,500.00	$13,000.00
900-1115-C.P	Americas VSP Universal PDU Mounting Bracket Kit	8	$655.00	$5,240.00
DKC-F710I-16UFC.P	Front End Director Pair (Fibre 16-Port HOST Adapter--8Gbps)	8	$23,610.00	$188,880.00
DKC-F710I-1R6FM.P	1.6TB Flash Module Drive	24	$48,760.00	$1,170,240.00
DKC-F710I-APC.P	Additional Controller PS	2	$7,990.00	$15,980.00
DKC-F710I-BCH.P	Bezel Kit - DKC	2	$1,930.00	$3,860.00
DKC-F710I-BFC.P	Device Interface Cable BF	2	$5,800.00	$11,600.00
DKC-F710I-BFH.P	Flash Module Drive Chassis Bezel	2	$2,030.00	$4,060.00
DKC-F710I-BM128.P	Cache Flash Memory Module (128GB)	8	$59,650.00	$477,200.00
DKC-F710I-C32G.P	Cache Memory Module (32GB)	32	$7,690.00	$246,080.00
DKC-F710I-CPC.P	Cache Memory Adapter Pair (CMA)	6	$80,030.00	$480,180.00
DKC-F710I-DECO.P	Decoration Panel - HDS	2	$640.00	$1,280.00
DKC-F710I-ESW.P	PCI-Express Switch Adapter (Grid Switch Pair)	2	$27,420.00	$54,840.00
DKC-F710I-FBX.P	Flash Module Drive Chassis	2	$87,000.00	$174,000.00
DKC-F710I-FIHT.P	Filler Panel	40	$70.00	$2,800.00
DKC-F710I-HBFC.P	Device Interface Cable HBF	1	$11,600.00	$11,600.00
DKC-F710I-HUB.P	Hub Kit	1	$10,280.00	$10,280.00
DKC-F710I-MDEXC.P	Inter-Controller Connecting Kit	1	$130,690.00	$130,690.00
DKC-F710I-MP.P	Processor Blade (Virtual Storage Director Pair)	2	$42,690.00	$85,380.00
DKC-F710I-PFUC.P	DKU (FBX) Power Cord Kit (1-phase 10A for USA)	2	$2,030.00	$4,060.00
DKC-F710I-PLUC.P	DKC Power Cord Kit (USA)	2	$660.00	$1,320.00
DKC-F710I-RK42.P	Rack - 42U	2	$7,130.00	$14,260.00
DKC-F710I-SCA.P	Back End Director (BED Pair)	4	$15,230.00	$60,920.00
DKC-F710I-SCOV.P	Side Cover	1	$1,630.00	$1,630.00
DKC-F710I-SVP.P	Service Processor	1	$16,340.00	$16,340.00
DKC710I-CBXA.P	Primary Controller Chassis (1 Grid Switch Pair, 1 VSD Pair, and 1 CMA Pair Bundled)	1	$74,010.00	$74,010.00
DKC710I-CBXB.P	Second Controller Chassis (1 Grid Switch Pair, 1 VSD Pair, and 1 CMA Pair Bundled)	1	$255,870.00	$255,870.00
DTI4GL.P	4GB USB memory stick with lanyard	1	$0.00	$0.00
IP0662-14.P	LAN Cable 14ft	1	$0.00	$0.00
IP0665-11.P	RJ-11 Modular In-Line Coupler 4 Conductor	1	$2.50	$2.50
IP0665-45.P	RJ-45 Modular In-Line Coupler 6 Conductor	1	$4.00	$4.00
PDU-121112F10.P	PDU 0RU 12xC13 1Phase 208V 30A NEMA L6-30P	8	$735.00	$5,880.00

	Ext. Total	Discount	Total
Total VSP Hardware	*$3,526,486.50*	*58*	*$1,481,124.33*

Priced Storage Configuration Pricing *(continued)*

	Product Description	Qty	List Price	Ext. Price
044-230001-010.P	VSP Basic Operating System 10TB Block License	1	$25,700.00	$25,700.00
044-230001-03.P	VSP Basic Operating System 20TB Base License	1	$46,800.00	$46,800.00
044-230001-04B.P	VSP Basic Operating System 4-VSD Pair Base License	1	$112,800.00	$112,800.00
304-230001-010.P	VSP BOS 10TB Block License - 36 Month Software Support	36	$321.25	$11,565.00
304-230001-03.P	VSP BOS 20TB Base License - 36 Month Software Support	36	$585.00	$21,060.00
304-230001-04B.P	VSP BOS 4-VSD Pair Base - 36 Month Sofware Support	36	$1,410.00	$50,760.00
044-230043-03.P	VSP Flash Acceleration License	1	$28,500.00	$28,500.00
304-230043-03.P	VSP Flash Acceleration License - 36 Month SW Support	36	$356.25	$12,825.00

	Ext. Total	Discount	Total
Total VSP License	*$310,010.00*	*39*	*$189,106.10*
Total VSP			*$1,670,230.43*

	Third-Party Product Description - External	Qty	List Price	Ext. Price
HD-5320-0008-M	Brocade 5320 w/ 48 active ports + SFPs, rack mount	2	$19,621.00	$39,242.00
XBR-MENTPOD8-01	Port on Demand 16port Upgrade, 16 SWL 8GB BR SFPs	2	$6,965.00	$13,930.00
HD-5320-0008-M	13 Mos Maintenance	1	$1,731.00	$1,731.00
HD-5320-0008-M	3 year Brocade support	1	$5,193.00	$5,193.00
LPE12002-E	Emulex LP12002-E Dual-Port FC Host Bus Adapter	16	$1,161.28	$18,580.48
2-LCLC-Z50RT-010F	FC Cables 2-LCLC-Z50RT-010F - 10FR LC - LC MM - 50	64	$16.11	$1,031.04

	Ext. Total	Discount	Total
Total Third-Party	*$79,707.52*	*0*	*$79,707.52*
Grand Total	*$3,916,204.02*		$1,749,937.95

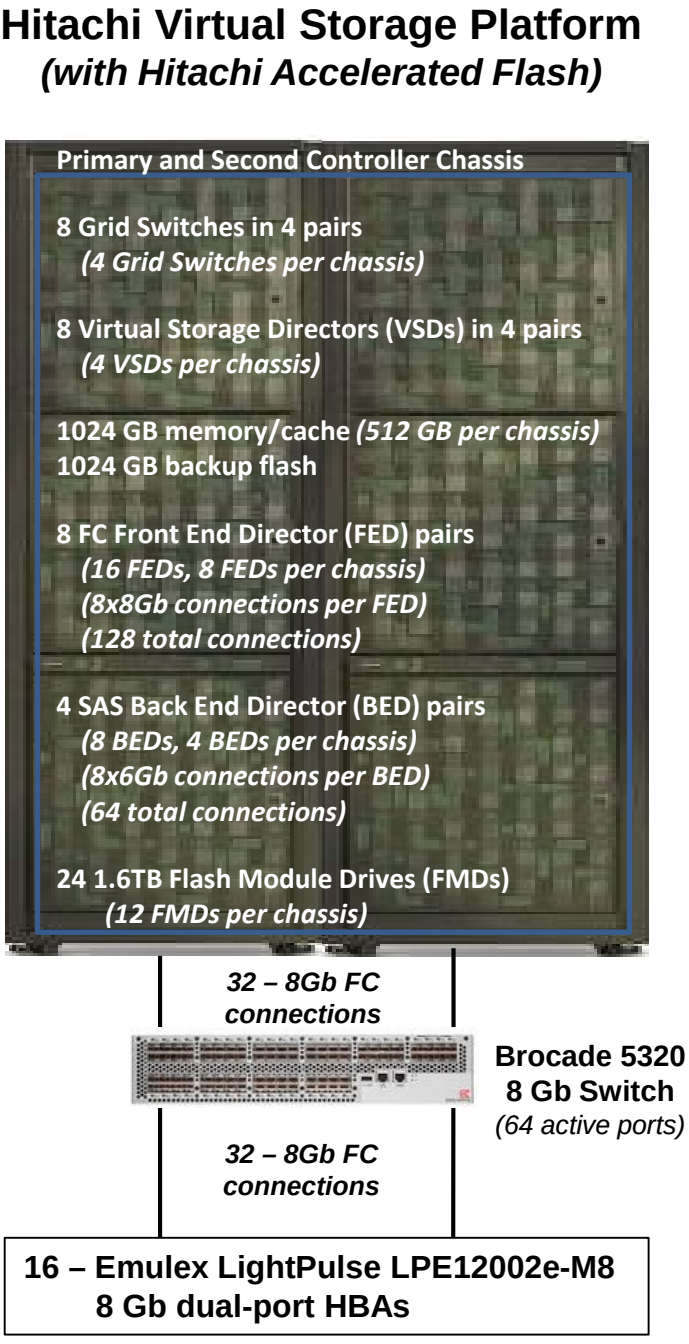
The above pricing includes hardware maintenance and software support for three years, 7 days per week, 24 hours per day. The hardware maintenance and software support provides the following:

- Acknowledgement of new and existing problems with four (4) hours.
- Onsite 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 64-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**.

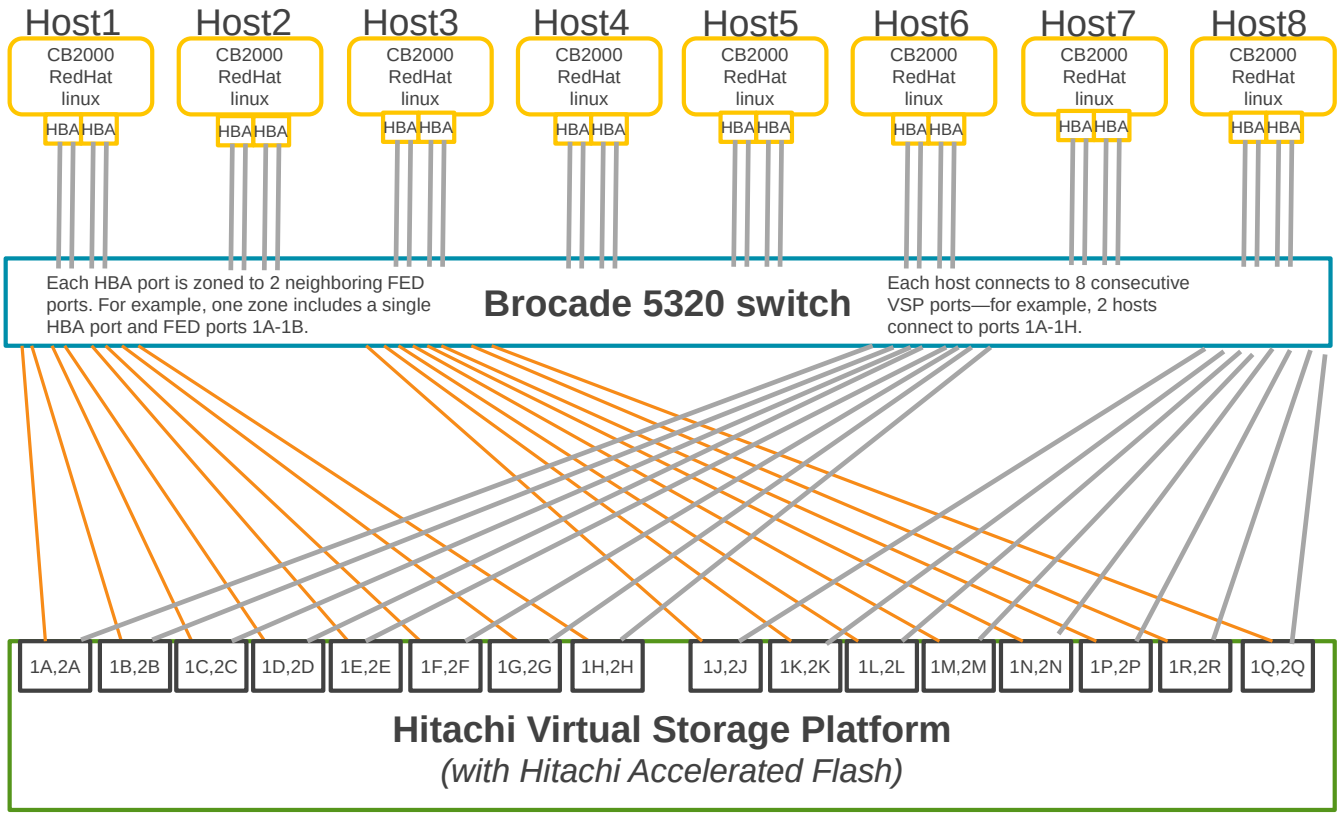
Priced Storage Configuration Diagram



Priced Storage Configuration Components

Priced Storage Configuration:
16 – Emulex LightPulse LPE12002e-M8 8 Gb dual-port HBAs
2 – Brocade 5320 8 Gb Switches with SFPs *(64 active ports)* *(the second switch is included as a spare)*
Hitachi Virtual Storage Platform (VSP) Primary and Second Controller Chassis 8 Grid Switches in 4 pairs *(4 Grid Switches per chassis)* 8 Virtual Storage Directors (VSDs) in 4 pairs *(4 VSDs per chassis)* 16 Cache Memory Adapters (CMAs) in 8 pairs *(8 CMAs per chassis)* 32 Cache Memory Modules *(32 GB per module)* *(1024 GB memory/cache, 512 GB per chassis)* 8 Cache Flash Memory Modules *(128 GB per module)* *(1024 GB backup flash)* 8 FC Front End Director (FED) pairs *(16 FEDs, 8 FEDs per chassis)* *(8x8Gb connections per FED, 128 total connections)* *(32 connections used)* 4 SAS Back End Director (BED) pairs *(8 BEDs, 4 BEDs per chassis)* *(8x6Gb connections per BED, 64 total connection)* *(64 connections used)*
1 – Additional Controller PS
2 – Flash Module Drive Chassis
24 – 1.6 TB Flash Module Drives (FMDs) *(12 FMDs per chassis)*
1 – Service Processor
8 – 1Phase 208V 30A PDUs
2 – 42U racks

Storage Network Configuration Diagram



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

Storage Network Configuration

Clause 9.4.3.4.1

…

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

Clause 9.4.3.4.2

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

The storage network configuration is illustrated on page 22 *(Storage Network Configuration Diagram)*.

The Benchmark Configuration contains 8 Host Systems, each of which has four HBA ports connected to the Hitachi Virtual Storage Platform (VSP). Each HBA port is zoned with two VSP ports, so that each Host System connects to a total of 8 VSP ports.

The members of the storage network configuration are as follows:

Zone: cb26hba0 *(3 members)*	10:00:00:90:fa:0b:62:20 50:06:0e:80:06:cf:3e:00 (port1a) 50:06:0e:80:06:cf:3e:01 (port1b)
Zone: cb26hba1 *(3 members)*	10:00:00:90:fa:0b:62:21 50:06:0e:80:06:cf:3e:02 (port1c) 50:06:0e:80:06:cf:3e:03 (port1d)
Zone: cb26hba2 *(3 members)*	10:00:00:90:fa:0b:81:96 50:06:0e:80:06:cf:3e:04 (port 1e) 50:06:0e:80:06:cf:3e:05 (port 1f)

Zone: cb26hba3 *(3 members)*	10:00:00:90:fa:0b:81:97 50:06:0e:80:06:cf:3e:06 (port 1g) 50:06:0e:80:06:cf:3e:07 (port 1h)
Zone: cb27hba0 *(3 members)*	10:00:00:90:fa:0b:82:66 50:06:0e:80:06:cf:3e:08 (port 1j) 50:06:0e:80:06:cf:3e:09 (port 1k)
Zone: cb27hba1 *(3 members)*	10:00:00:90:fa:0b:82:67 50:06:0e:80:06:cf:3e:0a (port 1l) 50:06:0e:80:06:cf:3e:0b (port 1m)
Zone: cb27hba2 *(3 members)*	10:00:00:90:fa:0b:80:04 50:06:0e:80:06:cf:3e:0c (port 1n) 50:06:0e:80:06:cf:3e:0d (port 1p)
Zone: cb27hba3 *(3 members)*	10:00:00:90:fa:0b:80:05 50:06:0e:80:06:cf:3e:0e (port 1q) 50:06:0e:80:06:cf:3e:0f (port 1r)
Zone: cb28hba0 *(3 members)*	10:00:00:90:fa:0b:63:b8 50:06:0e:80:06:cf:3e:10 (port 2a) 50:06:0e:80:06:cf:3e:11 (port 2b)
Zone: cb28hba1 *(3 members)*	10:00:00:90:fa:0b:63:b9 50:06:0e:80:06:cf:3e:12 (port 2c) 50:06:0e:80:06:cf:3e:13 (port 2d)
Zone: cb28hba2 *(3 members)*	10:00:00:90:fa:0b:83:58 50:06:0e:80:06:cf:3e:14 (port 2e) 50:06:0e:80:06:cf:3e:15 (port 2f)
Zone: cb28hba3 *(3 members)*	10:00:00:90:fa:0b:83:59 50:06:0e:80:06:cf:3e:16 (port 2g) 50:06:0e:80:06:cf:3e:17 (port 2h)
Zone: cb29hba0 *(3 members)*	10:00:00:90:fa:0b:7f:8e 50:06:0e:80:06:cf:3e:18 (port 2j) 50:06:0e:80:06:cf:3e:19 (port 2k)
Zone: cb29hba1 *(3 members)*	10:00:00:90:fa:0b:7f:8f 50:06:0e:80:06:cf:3e:1a (port 2l) 50:06:0e:80:06:cf:3e:1b (port 2m)
Zone: cb29hba2 *(3 members)*	10:00:00:90:fa:0b:7f:66 50:06:0e:80:06:cf:3e:1c (port 2n) 50:06:0e:80:06:cf:3e:1d (port 2p)
Zone: cb29hba3 *(3 members)*	10:00:00:90:fa:0b:7f:67 50:06:0e:80:06:cf:3e:1e (port 2q) 50:06:0e:80:06:cf:3e:1f (port 2r)
Zone: cb30hba0 *(3 members)*	10:00:00:90:fa:0b:62:62 50:06:0e:80:06:cf:3e:18 (port 2j) 50:06:0e:80:06:cf:3e:19 (port 2k)

Zone: cb30hba1 *(3 members)*	10:00:00:90:fa:0b:62:63 50:06:0e:80:06:cf:3e:1a (port 2l) 50:06:0e:80:06:cf:3e:1b (port 2m)
Zone: cb30hba2 *(3 members)*	10:00:00:90:fa:0b:82:8e 50:06:0e:80:06:cf:3e:1c (port 2n) 50:06:0e:80:06:cf:3e:1d (port 2p)
Zone: cb30hba3 *(3 members)*	10:00:00:90:fa:0b:82:8f 50:06:0e:80:06:cf:3e:1e (port 2q) 50:06:0e:80:06:cf:3e:1f (port 2r)
Zone: cb31hba0 *(3 members)*	10:00:00:90:fa:0b:62:f0 50:06:0e:80:06:cf:3e:10 (port 2a) 50:06:0e:80:06:cf:3e:11 (port 2b)
Zone: cb31hba1 *(3 members)*	10:00:00:90:fa:0b:62:f1 50:06:0e:80:06:cf:3e:12 (port 2c) 50:06:0e:80:06:cf:3e:13 (port 2d)
Zone: cb31hba2 *(3 members)*	10:00:00:90:fa:0b:61:26 50:06:0e:80:06:cf:3e:14 (port 2e) 50:06:0e:80:06:cf:3e:15 (port 2f)
Zone: cb31hba3 *(3 members)*	10:00:00:90:fa:0b:61:27 50:06:0e:80:06:cf:3e:16 (port 2g) 50:06:0e:80:06:cf:3e:17 (port 2h)
Zone: cb32hba0 *(3 members)*	10:00:00:90:fa:0b:62:ca 50:06:0e:80:06:cf:3e:08 (port 1j) 50:06:0e:80:06:cf:3e:09 (port 1k)
Zone: cb32hba1 *(3 members)*	10:00:00:90:fa:0b:62:cb 50:06:0e:80:06:cf:3e:0a (port 1l) 50:06:0e:80:06:cf:3e:0b (port 1m)
Zone: cb32hba2 *(3 members)*	10:00:00:90:fa:0b:95:6c 50:06:0e:80:06:cf:3e:0c (port 1n) 50:06:0e:80:06:cf:3e:0d (port 1p)
Zone: cb32hba3 *(3 members)*	10:00:00:90:fa:0b:95:6d 50:06:0e:80:06:cf:3e:0e (port 1q) 50:06:0e:80:06:cf:3e:0f (port 1r)
Zone: cb33hba0 *(3 members)*	10:00:00:90:fa:0b:61:6e 50:06:0e:80:06:cf:3e:00 (port 1a) 50:06:0e:80:06:cf:3e:01 (port 1b)
Zone: cb33hba1 *(3 members)*	10:00:00:90:fa:0b:61:6f 50:06:0e:80:06:cf:3e:02 (port 1c) 50:06:0e:80:06:cf:3e:03 (port 1d)
Zone: cb33hba2 *(3 members)*	10:00:00:90:fa:0b:82:d2 50:06:0e:80:06:cf:3e:04 (port 1e) 50:06:0e:80:06:cf:3e:05 (port 1f)

Zone: cb33hba3 *(3 members)*	10:00:00:90:fa:0b:82:d3
	50:06:0e:80:06:cf:3e:06 (port 1g)
	50:06:0e:80:06:cf:3e:07 (port 1h)

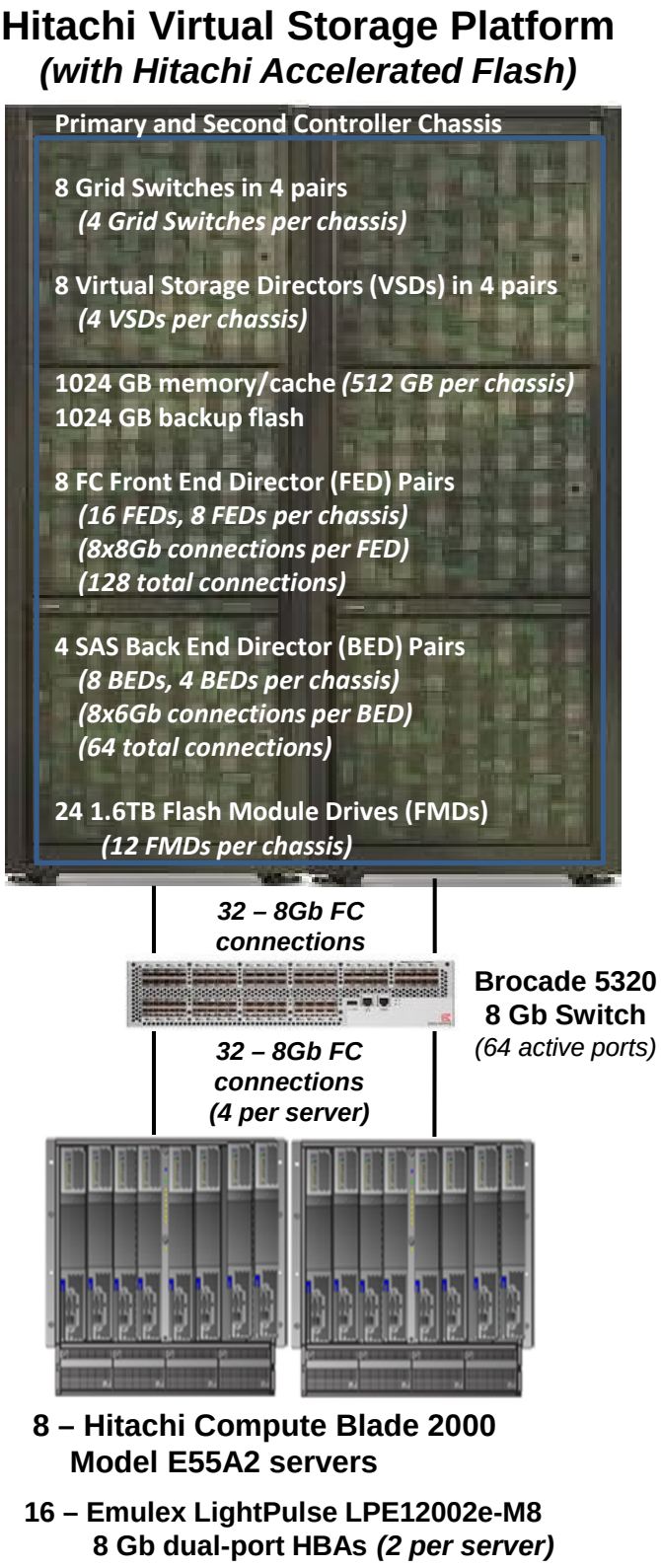
Host System(s) and Tested Storage Configuration (TSC) Table of Components

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 28 *(Host Systems and Tested Storage Configuration Components)*.

Benchmark Configuration/Tested Storage Configuration Diagram



Host Systems and Tested Storage Configuration Components

Host Systems:	Tested Storage Configuration (TSC):
8 – 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 Hat Enterprise Linux 6.3 (x86_64) Linux Logical Volume Manager LVM version 2.02.95-10 PCIe	16 – Emulex LightPulse LPE 12002e-M8 8 GB dual-port HBAs
	1 – Brocade 5320 8 Gb Switch with 64 SFPs *(64 active ports)*
	Hitachi Virtual Storage Platform (VSP) Primary and Second Controller Chassis 8 Grid Switches in 4 pairs *(4 Grid Switches per chassis)* 8 Virtual Storage Directors (VSDs) in 4 pairs *(4 VSDs per chassis)* 16 Cache Memory Adapters (CMAs) in 8 pairs *(8 CMAs per chassis)* 32 Cache Memory Modules *(32 GB per modules)* *(1024 GB memory/cache, 512 per chassis)* 8 Cache Flash Memory Modules *(128 GB per module)* *(1024 GB backup flash)* 8 FC Front End Director (FED) pairs *(16 FEDs, 8 FEDs per chassis)* *(8x8Gb connections per FED)* *(128 total connections, 32 connections used)* 4 SAS Back End Director (BED) pairs *(8 BEDs, 4 BEDs per chassis)* *(8x6Gb connections per BED)* *(64 total connections, 64 connections used)*
	1 – Additional Controller PS
	2 – Flash Module Drive Chassis
	24 – 1.6 TB Flash Module Drives (FMDs) *(12 FMDs per chassis)*
	1 – Service Processor
	8 – 1Phase 208V 30A PDUs
	2 – 42U racks

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 72 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 73 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 87.

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 87.

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 68 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 43,550.927 GB distributed over 24 solid state storage devices, each with a formatted capacity of 1,814.622 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 1,329.727 GB (3.05%) of the Physical Storage Capacity. There was 1.909 GB (0.005%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 55.01% of the Addressable Storage Capacity resulting in 9,497.848 GB (44.99%) of Unused Storage within the Addressable Storage Capacity. The Data Protection *(Mirroring)* capacity was 21,110.600 GB of which 11,610.843 GB was utilized. The total Unused Storage capacity was 18,999.514 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.

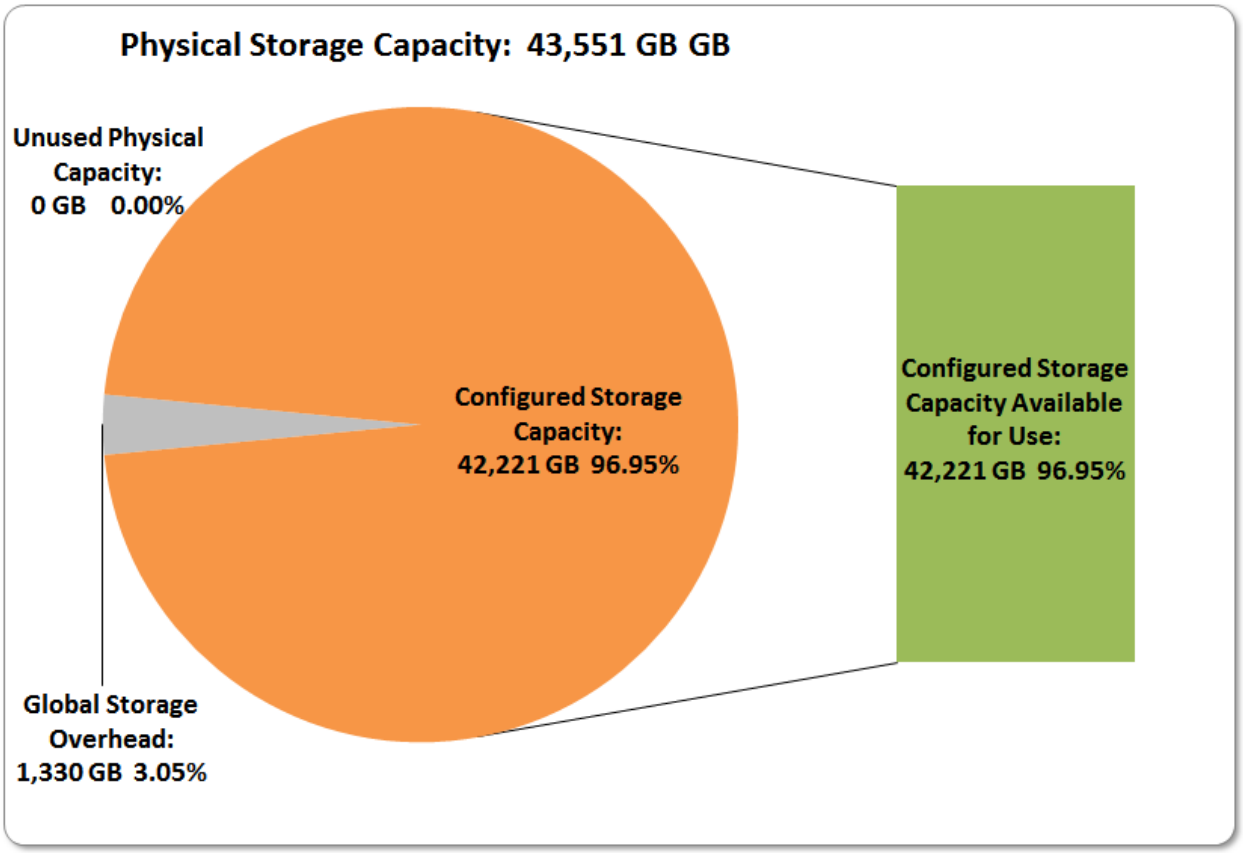
SPC-1 Storage Capacities

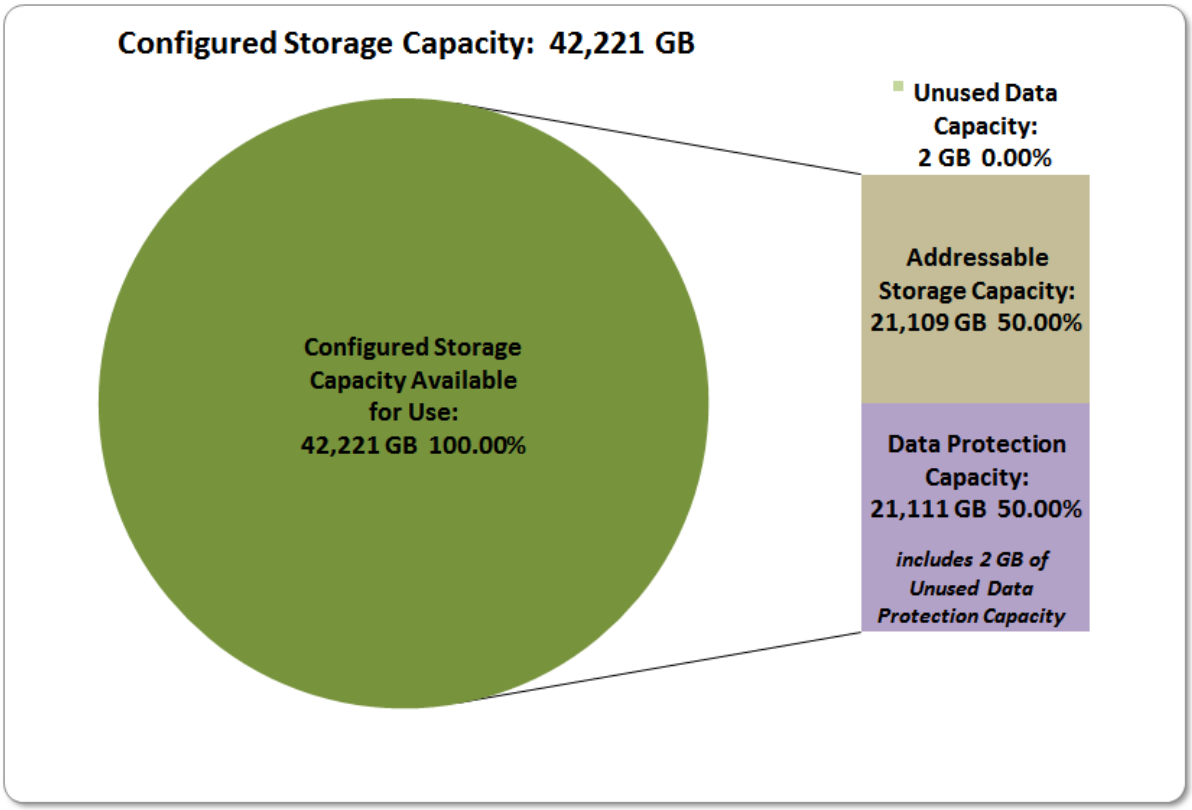
Storage Hierarchy Component	Units	Capacity
Total ASU Capacity	Gigabytes (GB)	11,610.843
Addressable Storage Capacity	Gigabytes (GB)	21,108.691
Configured Storage Capacity	Gigabytes (GB)	42,221.200
Physical Storage Capacity	Gigabytes (GB)	43,550.927
Data Protection *(Mirroring)*	Gigabytes (GB)	21,110.600
Required Storage *(spares, metadata)*	Gigabytes (GB)	0.000
Global Storage Overhead	Gigabytes (GB)	1,329.727
Total Unused Storage	Gigabytes (GB)	18,999.514

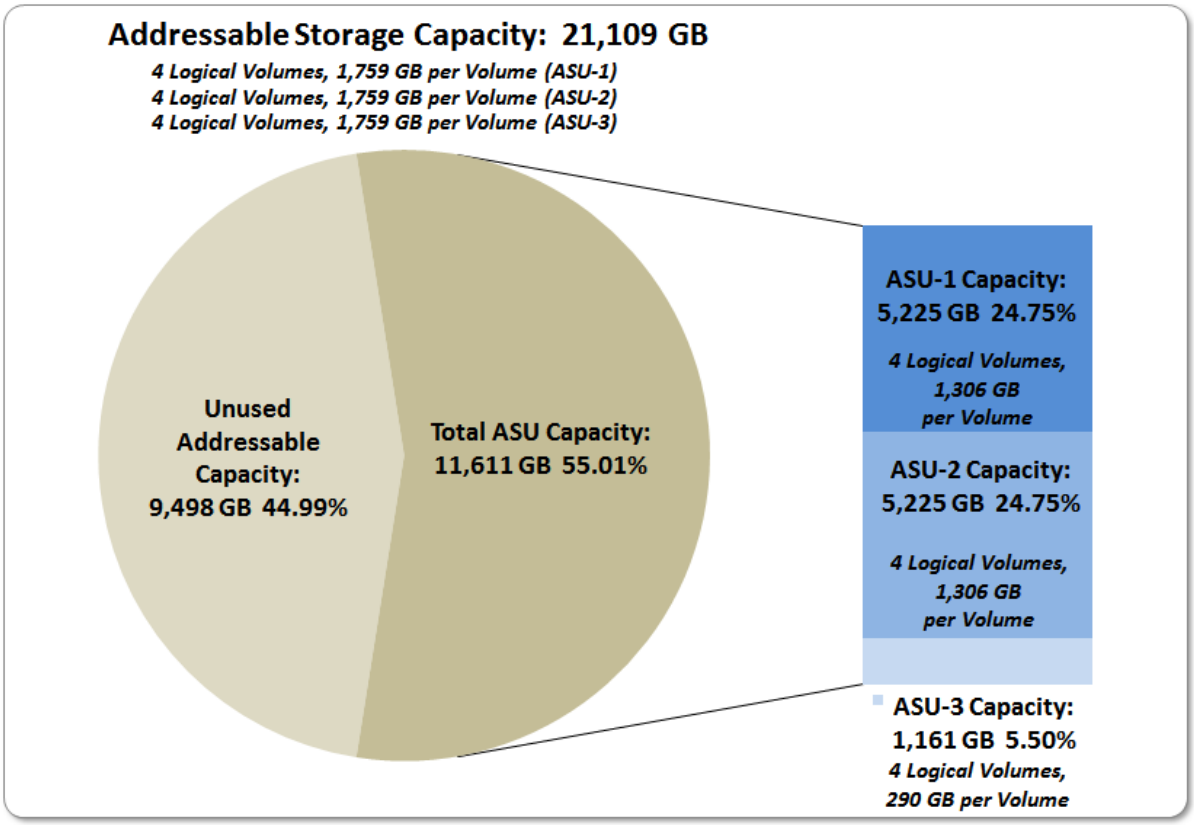
SPC-1 Storage Hierarchy Ratios

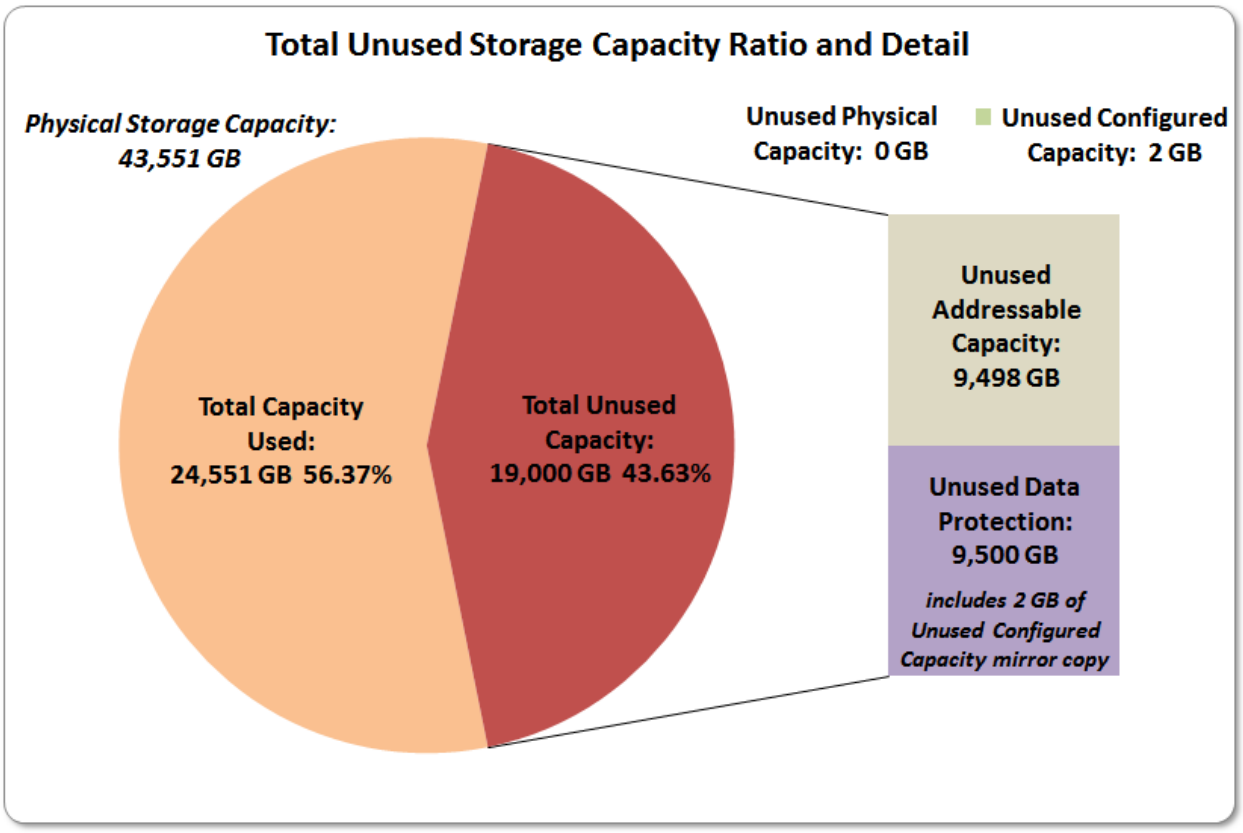
	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	55.01%	27.50%	26.66%
Required for Data Protection *(Mirroring)*		50.00%	48.47%
Addressable Storage Capacity		50.00%	48.47%
Required Storage *(spares, metadata)*		0.00%	0.00%
Configured Storage Capacity			96.95%
Global Storage Overhead			3.05%
Unused Storage:			
Addressable	44.99%		
Configured		0.005%	
Physical			0.00%

SPC-1 Storage Capacity Charts




Configured Storage Capacity: 42,221 GB
Configured Storage Capacity Available for Use: 42,221 GB 100.00%
Unused Data Capacity: 2 GB 0.00%
Addressable Storage Capacity: 21,109 GB 50.00%
Data Protection Capacity: 21,111 GB 50.00%
includes 2 GB of Unused Data Protection Capacity


Addressable Storage Capacity: 21,109 GB
4 Logical Volumes, 1,759 GB per Volume (ASU-1)
4 Logical Volumes, 1,759 GB per Volume (ASU-2)
4 Logical Volumes, 1,759 GB per Volume (ASU-3)
Unused Addressable Capacity: 9,498 GB 44.99%
Total ASU Capacity: 11,611 GB 55.01%
ASU-1 Capacity: 5,225 GB 24.75%
4 Logical Volumes, 1,306 GB per Volume
ASU-2 Capacity: 5,225 GB 24.75%
4 Logical Volumes, 1,306 GB per Volume
ASU-3 Capacity: 1,161 GB 5.50%
4 Logical Volumes, 290 GB per Volume



Storage Capacity Utilization

Clause 9.4.3.6.2

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

Clause 2.8.1

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

Clause 2.8.2

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

Clause 2.8.3

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

SPC-1 Storage Capacity Utilization	
Application Utilization	26.66%
Protected Application Utilization	53.32%
Unused Storage Ratio	43.63%

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 (5,224,879 GB)	**ASU-2 (5,224,879 GB)**	**ASU-3 (1,161.084 GB)**
4 Logical Volumes 1,759.058 GB per Logical Volume (1,306.220 GB used per Logical Volume)	4 Logical Volumes 1,759.058 GB per Logical Volume (1,306.220 GB used per Logical Volume)	4 Logical Volumes 1,759.058 GB per Logical Volume (290.271 GB used per Logical Volume)

The Data Protection Level used for all Logical Volumes was **Protected 2** using ***Mirroring*** as described on page 13. 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 68 contains definitions of terms specific to the SPC-1 Tests, Test Phases, and Test Runs.

Clause 5.4.3

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

SPC-1 Tests, Test Phases, and Test Runs

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

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

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

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

"Ramp-Up" Test Runs

Clause 5.3.13

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

Clause 5.3.13.3

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

Clause 9.4.3.7.1

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

There were no "Ramp-Up" Test Runs executed in this set of benchmark measurements.

Primary Metrics Test – Sustainability Test Phase

Clause 5.4.4.1.1

The Sustainability Test Phase has exactly one Test Run and shall demonstrate the maximum sustainable I/O Request Throughput within at least a continuous eight (8) hour Measurement Interval. This Test Phase also serves to insure that the TSC has reached Steady State prior to reporting the final maximum I/O Request Throughput result (SPC-1 IOPS™).

Clause 5.4.4.1.2

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

Clause 5.4.4.1.4

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

Clause 9.4.3.7.2

For the Sustainability Test Phase the FDR shall contain:

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

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in Appendix E: SPC-1 Workload Generator Input Parameters on Page 90.

Sustainability Test Results File

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

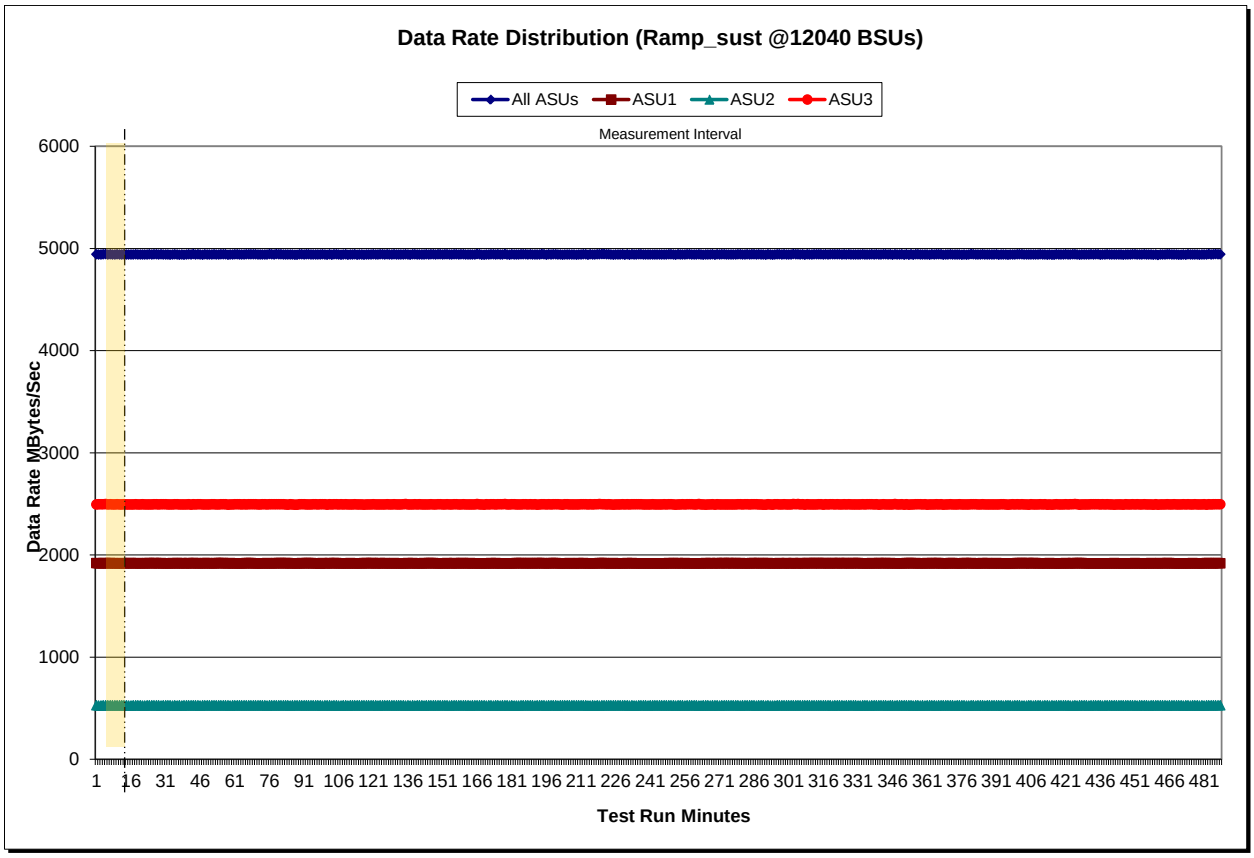
Sustainability Test Results File

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

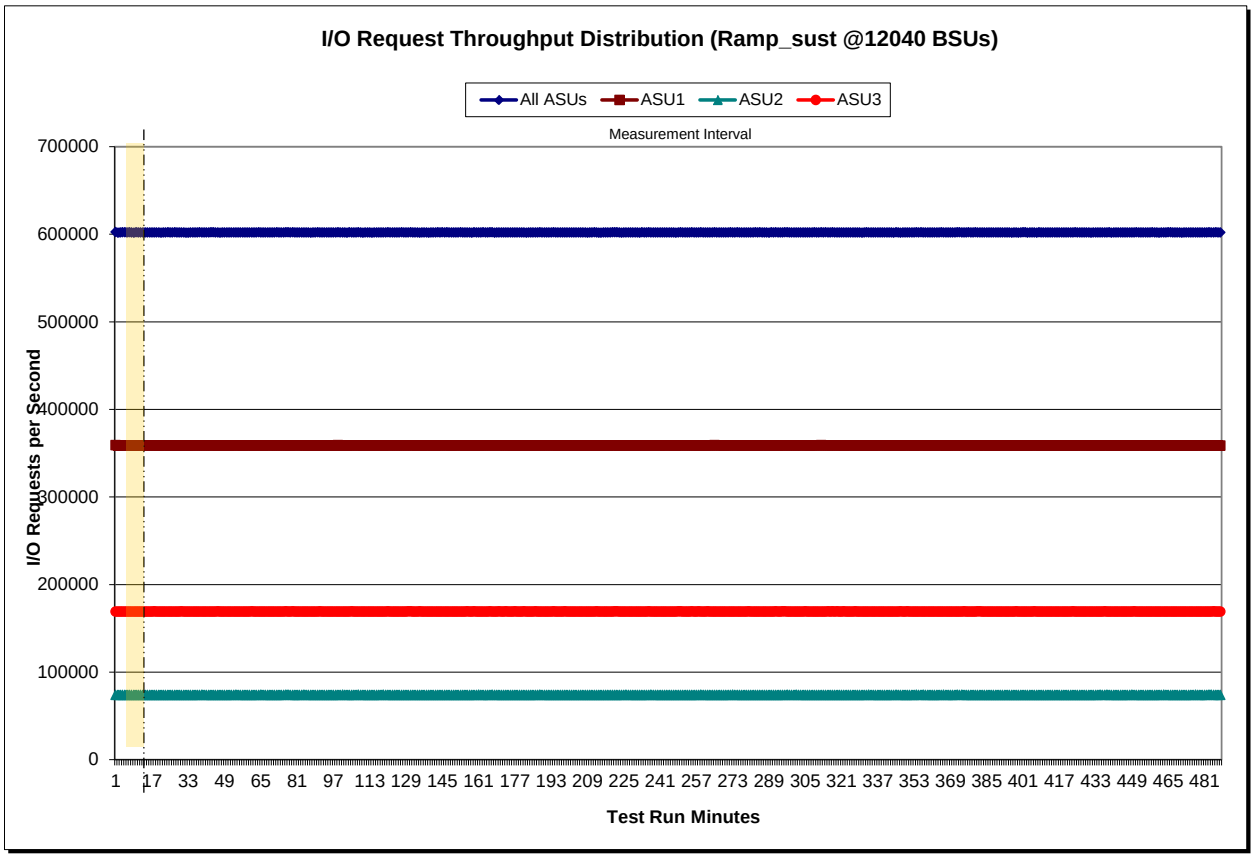


Sustainability – I/O Request Throughput Distribution Data

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

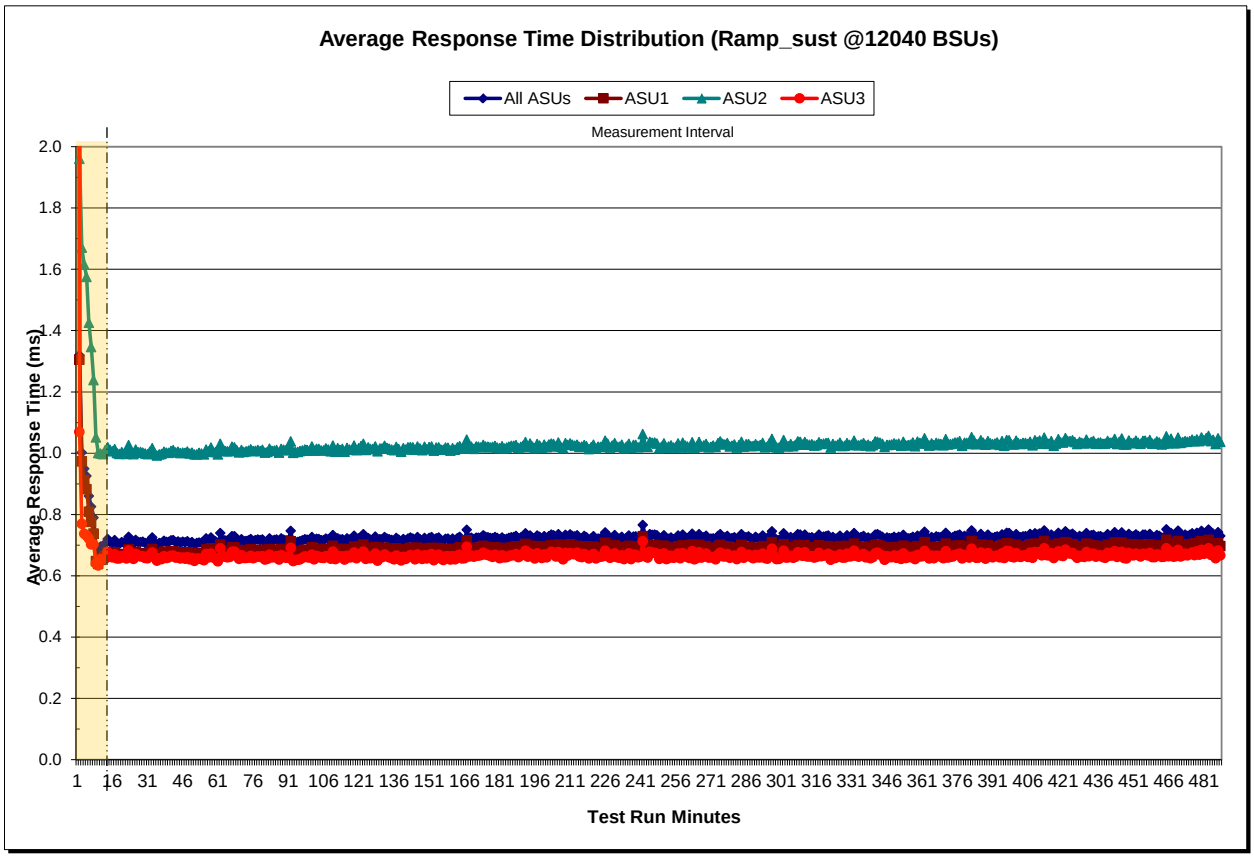


Sustainability – Average Response Time (ms) Distribution Data

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

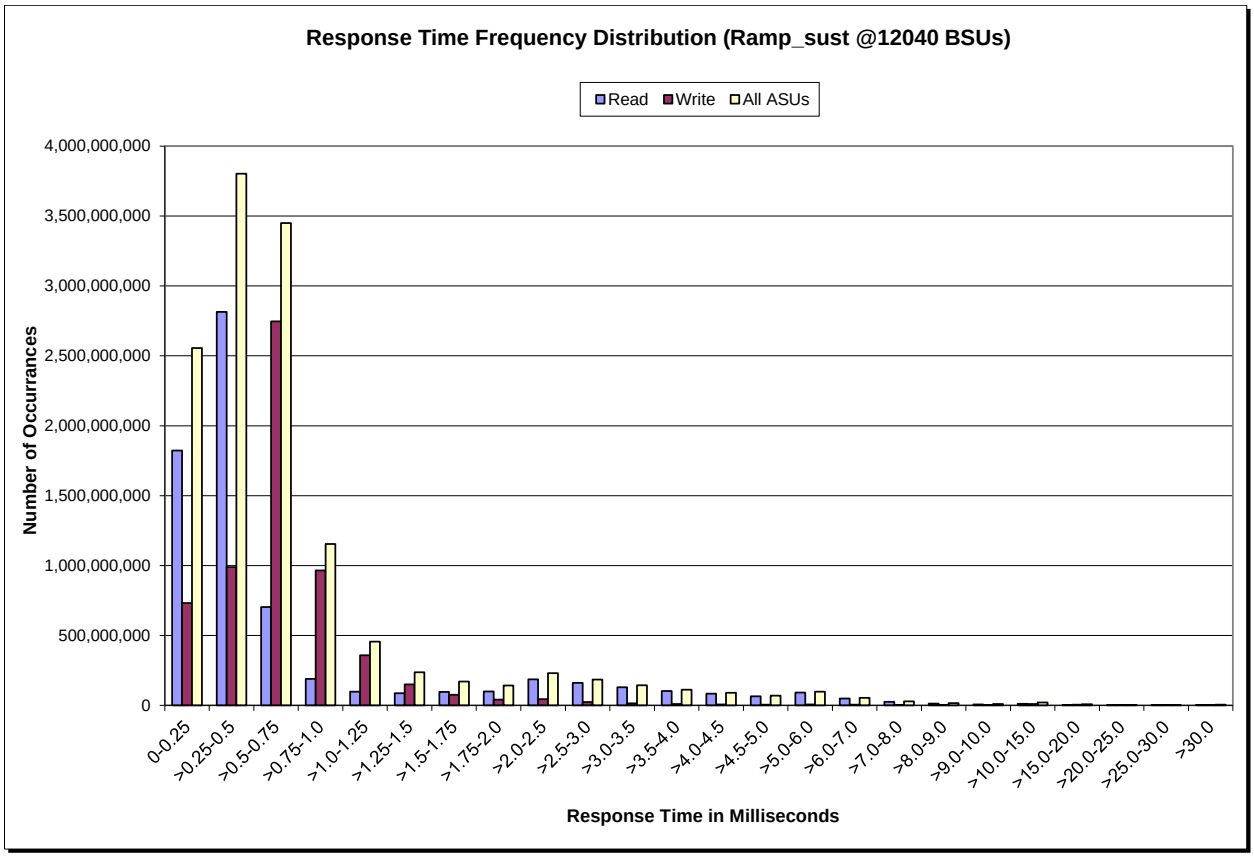
Sustainability – Average Response Time (ms) Distribution Graph



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	1,823,428,210	2,814,128,474	703,345,757	188,572,092	97,861,204	87,203,948	95,559,975	100,112,101
Write	731,934,350	988,120,582	2,746,695,016	965,599,338	357,968,154	150,224,441	75,501,395	41,860,284
All ASUs	2,555,362,560	3,802,249,056	3,450,040,773	1,154,171,430	455,829,358	237,428,389	171,061,370	141,972,385
ASU1	2,020,189,986	4,908,590,732	1,711,611,497	513,368,239	206,172,886	119,210,290	95,417,162	84,764,055
ASU2	281,686,922	920,368,302	348,849,111	111,223,790	51,312,727	36,623,439	35,499,443	35,350,931
ASU3	253,485,652	(2,026,709,978)	1,389,580,165	529,579,401	198,343,745	81,594,660	40,144,765	21,857,399
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	185,852,687	160,874,818	128,759,087	102,406,383	84,220,144	65,135,500	91,094,331	48,850,173
Write	44,259,905	24,083,514	14,572,716	9,350,176	6,241,136	4,514,142	6,432,569	4,799,627
All ASUs	230,112,592	184,958,332	143,331,803	111,756,559	90,461,280	69,649,642	97,526,900	53,649,800
ASU1	143,385,769	117,853,280	92,106,101	72,159,507	58,631,558	45,134,859	62,946,438	33,953,282
ASU2	63,870,744	54,502,663	43,321,735	34,287,651	28,059,178	21,627,285	30,089,430	16,043,814
ASU3	22,856,079	12,602,389	7,903,967	5,309,401	3,770,544	2,887,498	4,491,032	3,652,704
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	25,094,299	13,117,335	7,143,318	10,479,797	2,351,092	882,883	435,856	718,667
Write	3,982,072	3,303,377	2,896,569	10,249,091	4,954,157	2,272,342	1,307,019	3,605,296
All ASUs	29,076,371	16,420,712	10,039,887	20,728,888	7,305,249	3,155,225	1,742,875	4,323,963
ASU1	17,675,326	9,395,755	5,257,309	8,528,386	2,457,104	1,242,021	800,970	2,073,504
ASU2	8,197,749	4,241,940	2,291,193	3,304,610	760,783	331,079	195,258	479,965
ASU3	3,203,296	2,783,017	2,491,385	8,895,892	4,087,362	1,582,125	746,647	1,770,494

Sustainability – Response Time Frequency Distribution Graph



Sustainability – Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.15.2

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

Clause 5.3.15.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.001	0.000	0.001	0.000	0.001	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 90.

IOPS Test Results File

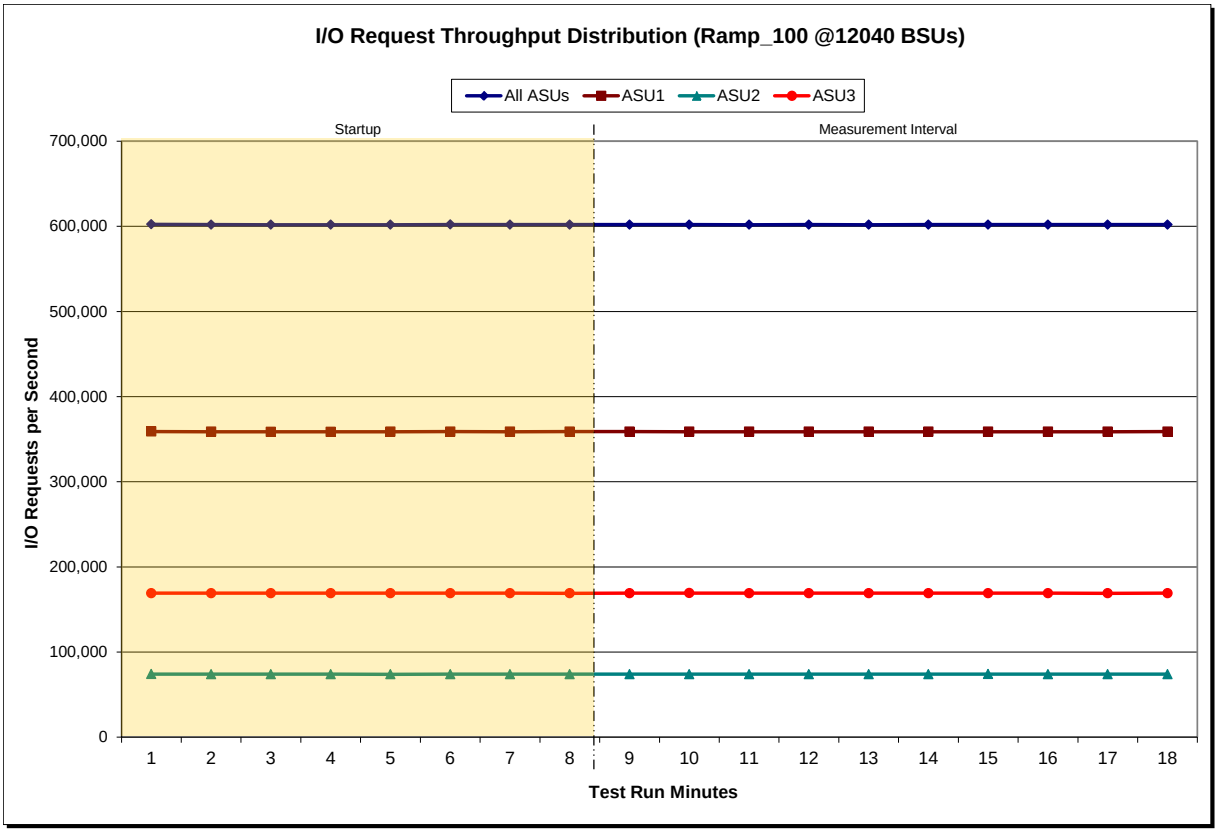
A link to the test results file generated from the IOPS Test Run is listed below.

IOPS Test Results File

IOPS Test Run – I/O Request Throughput Distribution Data

12,040 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	4:40:38	4:48:39	0-7	0:08:01
Measurement Interval	4:48:39	4:58:39	8-17	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	602,363.98	359,047.18	74,098.20	169,218.60
1	601,993.85	358,761.78	74,037.67	169,194.40
2	601,852.90	358,708.17	73,986.40	169,158.33
3	601,899.27	358,661.42	74,054.08	169,183.77
4	601,866.40	358,756.13	73,966.42	169,143.85
5	602,166.67	358,907.78	74,051.48	169,207.40
6	602,001.08	358,759.25	74,071.45	169,170.38
7	601,998.57	358,898.97	74,028.63	169,070.97
8	602,018.00	358,871.23	73,987.37	169,159.40
9	602,090.53	358,794.65	74,044.53	169,251.35
10	601,867.63	358,734.63	74,010.08	169,122.92
11	602,079.07	358,836.60	74,020.08	169,222.38
12	601,933.68	358,761.13	74,038.02	169,134.53
13	601,997.95	358,840.57	74,039.53	169,117.85
14	602,074.67	358,784.97	74,143.98	169,145.72
15	602,060.92	358,817.98	74,083.33	169,159.60
16	601,999.90	358,855.82	74,043.23	169,100.85
17	602,072.37	358,888.40	74,069.85	169,114.12
Average	***602,019.47***	***358,818.60***	***74,048.00***	***169,152.87***

IOPS Test Run – I/O Request Throughput Distribution Graph

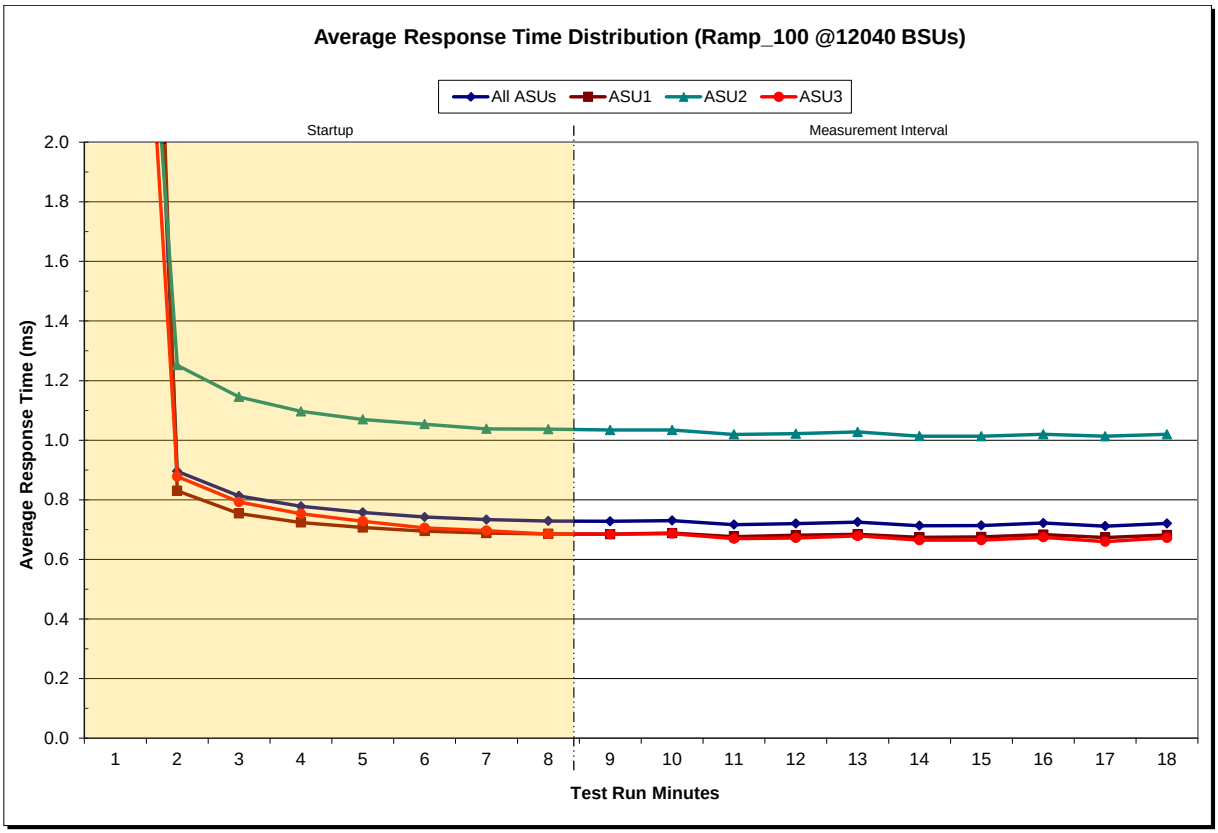


IOPS Test Run – Average Response Time (ms) Distribution Data

12,040 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	4:40:38	4:48:39	0-7	0:08:01
Measurement Interval	4:48:39	4:58:39	8-17	0:10:00

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	5.71	6.70	4.20	4.28
1	0.90	0.83	1.25	0.88
2	0.81	0.75	1.15	0.79
3	0.78	0.72	1.10	0.75
4	0.76	0.71	1.07	0.73
5	0.74	0.70	1.05	0.71
6	0.73	0.69	1.04	0.70
7	0.73	0.69	1.04	0.69
8	0.73	0.68	1.03	0.68
9	0.73	0.69	1.03	0.69
10	0.72	0.68	1.02	0.67
11	0.72	0.68	1.02	0.67
12	0.73	0.68	1.03	0.68
13	0.71	0.67	1.01	0.66
14	0.71	0.68	1.01	0.66
15	0.72	0.68	1.02	0.67
16	0.71	0.67	1.01	0.66
17	0.72	0.68	1.02	0.67
Average	***0.72***	***0.68***	***1.02***	***0.67***

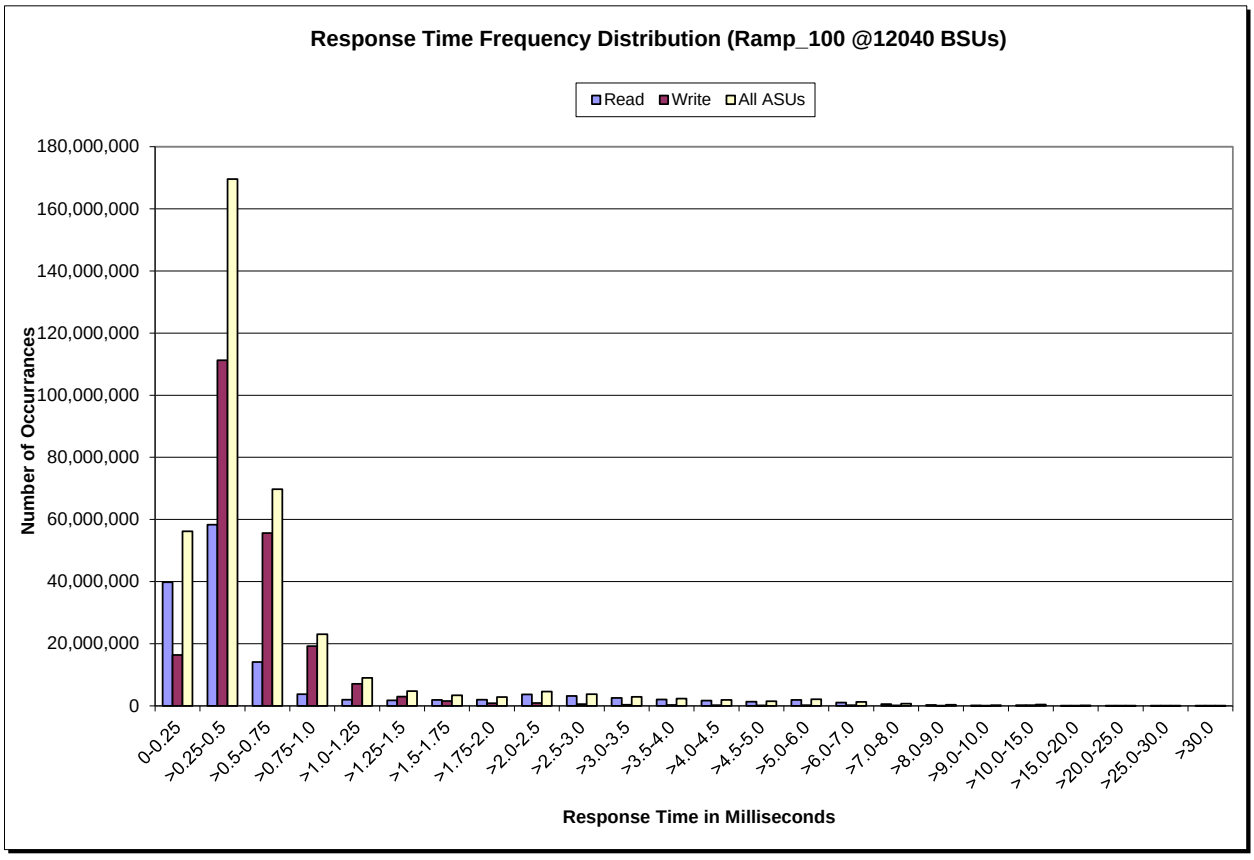
IOPS Test Run – Average Response Time (ms) Distribution Graph



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	39,775,839	58,303,966	14,120,906	3,771,053	1,966,061	1,759,160	1,904,909	1,991,292
Write	16,408,736	111,265,070	55,616,769	19,261,277	7,075,966	3,005,369	1,536,601	870,917
All ASUs	56,184,575	169,569,036	69,737,675	23,032,330	9,042,027	4,764,529	3,441,510	2,862,209
ASU1	44,267,005	102,455,535	34,440,437	10,195,959	4,084,204	2,391,373	1,911,630	1,696,851
ASU2	6,240,310	19,308,075	7,032,676	2,210,612	1,017,186	734,974	708,573	708,086
ASU3	5,677,260	47,805,426	28,264,562	10,625,759	3,940,637	1,638,182	821,307	457,272
Response Time (ms)	**>2.0-2.5**	**>2.5-3.0**	**>3.0-3.5**	**>3.5-4.0**	**>4.0-4.5**	**>4.5-5.0**	**>5.0-6.0**	**>6.0-7.0**
Read	3,701,439	3,203,125	2,575,685	2,067,720	1,712,183	1,343,580	1,901,609	1,051,059
Write	949,705	554,149	354,402	256,021	188,336	156,349	254,420	216,787
All ASUs	4,651,144	3,757,274	2,930,087	2,323,741	1,900,519	1,499,929	2,156,029	1,267,846
ASU1	2,875,025	2,363,930	1,854,780	1,471,007	1,204,330	943,651	1,339,420	756,767
ASU2	1,280,044	1,095,692	878,534	702,743	581,302	457,534	649,778	364,288
ASU3	496,075	297,652	196,773	149,991	114,887	98,744	166,831	146,791
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	562,746	285,743	156,690	228,663	47,576	17,456	8,358	10,145
Write	183,586	87,234	59,257	206,466	102,315	46,467	26,351	61,747
All ASUs	746,332	372,977	215,947	435,129	149,891	63,923	34,709	71,892
ASU1	417,670	205,987	112,547	179,974	49,079	24,691	15,634	33,433
ASU2	200,849	97,268	52,146	73,882	15,857	6,584	3,842	7,904
ASU3	127,813	69,722	51,254	181,273	84,955	32,648	15,233	30,555

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
361,211,260	316,139,368	71,892

IOPS Test Run – Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.15.2

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

Clause 5.3.15.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.001	0.000	0.000	0.000	0.001	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 17.

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 90.

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

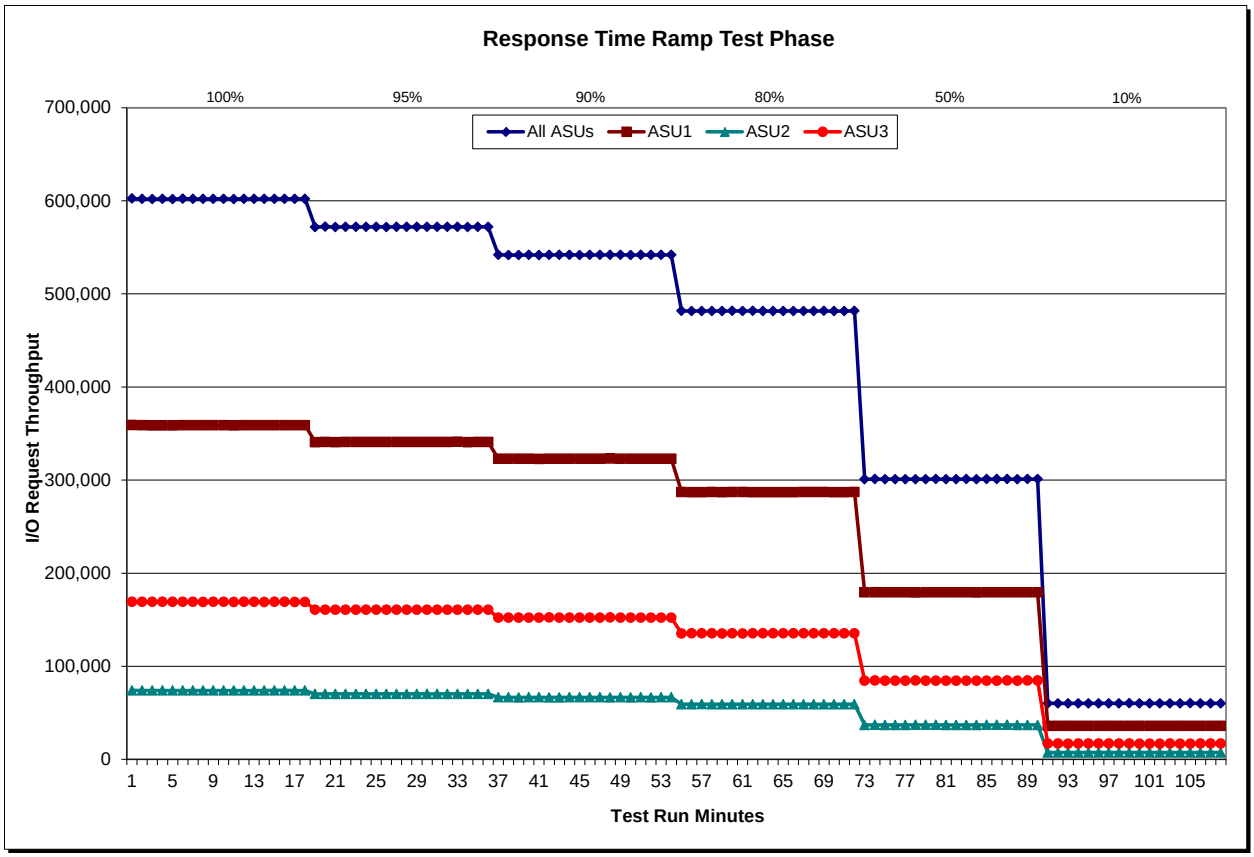
The five Test Runs that comprise the Response Time Ramp Phase are executed at 95%, 90%, 80%, 50%, and 10% of the Business Scaling Unit (BSU) load level used to produce the SPC-1 IOPS™ primary metric. The 100% BSU load level is included in the following Response Time Ramp data table and graph for completeness.

100% Load Level: 12,040 BSUs	Start	Stop	Interval	Duration	95% Load Level: 11,438 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	4:40:38	4:48:39	0-7	0:08:01	Start-Up/Ramp-Up	5:00:04	5:08:05	0-7	0:08:01
Measurement Interval	4:48:39	4:58:39	8-17	0:10:00	Measurement Interval	5:08:05	5:18:05	8-17	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	602,363.98	359,047.18	74,098.20	169,218.60	0	571,725.75	340,687.50	70,269.57	160,768.68
1	601,993.85	358,761.78	74,037.67	169,194.40	1	572,063.25	340,982.07	70,344.48	160,736.70
2	601,852.90	358,708.17	73,986.40	169,158.33	2	571,731.33	340,710.45	70,347.57	160,673.32
3	601,899.27	358,661.42	74,054.08	169,183.77	3	571,869.08	340,845.22	70,350.12	160,673.75
4	601,866.40	358,756.13	73,966.42	169,143.85	4	571,935.50	340,913.12	70,380.30	160,642.08
5	602,166.67	358,907.78	74,051.48	169,207.40	5	571,909.25	340,879.05	70,333.13	160,697.07
6	602,001.08	358,759.25	74,071.45	169,170.38	6	571,976.45	340,840.03	70,350.63	160,785.78
7	601,998.57	358,898.97	74,028.63	169,070.97	7	571,760.45	340,800.75	70,345.30	160,614.40
8	602,018.00	358,871.23	73,987.37	169,159.40	8	572,033.47	340,877.62	70,372.78	160,783.07
9	602,090.53	358,794.65	74,044.53	169,251.35	9	571,890.22	340,856.42	70,339.62	160,694.18
10	601,867.63	358,734.63	74,010.08	169,122.92	10	571,918.85	340,846.95	70,358.80	160,713.10
11	602,079.07	358,836.60	74,020.08	169,222.38	11	571,867.55	340,862.53	70,312.32	160,692.70
12	601,933.68	358,761.13	74,038.02	169,134.53	12	571,858.90	340,842.98	70,350.08	160,665.83
13	601,997.95	358,840.57	74,039.53	169,117.85	13	571,916.95	340,843.78	70,361.45	160,711.72
14	602,074.67	358,784.97	74,143.98	169,145.72	14	572,045.18	341,019.85	70,334.47	160,690.87
15	602,060.92	358,817.98	74,083.33	169,159.60	15	571,739.42	340,762.22	70,339.33	160,637.87
16	601,999.90	358,855.82	74,043.23	169,100.85	16	571,959.55	340,867.25	70,350.93	160,741.37
17	602,072.37	358,888.40	74,069.85	169,114.12	17	571,929.70	340,868.60	70,316.83	160,744.27
Average	***602,019.47***	***358,818.60***	***74,048.00***	***169,152.87***	***Average***	***571,915.98***	***340,864.82***	***70,343.66***	***160,707.50***
90% Load Level: 10,836 BSUs	**Start**	**Stop**	**Interval**	**Duration**	**80% Load Level: 9,632 BSUs**	**Start**	**Stop**	**Interval**	**Duration**
Start-Up/Ramp-Up	5:19:24	5:27:25	0-7	0:08:01	Start-Up/Ramp-Up	5:38:39	5:46:40	0-7	0:08:01
Measurement Interval	5:27:25	5:37:25	8-17	0:10:00	Measurement Interval	5:46:40	5:56:40	8-17	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	541,918.45	323,001.22	66,632.62	152,284.62	0	481,648.48	287,147.90	59,248.47	135,252.12
1	541,739.70	322,835.88	66,674.30	152,229.52	1	481,532.65	286,965.12	59,232.42	135,335.12
2	541,632.60	322,824.58	66,619.53	152,188.48	2	481,619.03	287,006.87	59,318.80	135,293.37
3	541,784.68	322,911.62	66,649.70	152,223.37	3	481,607.68	287,054.28	59,199.42	135,353.98
4	541,640.83	322,723.62	66,689.83	152,227.38	4	481,518.08	287,001.17	59,243.42	135,273.50
5	541,774.18	322,835.90	66,612.45	152,325.83	5	481,713.72	287,124.52	59,254.37	135,334.83
6	541,877.63	322,944.43	66,612.68	152,320.52	6	481,554.38	287,084.78	59,208.33	135,261.27
7	541,879.78	322,918.77	66,683.95	152,277.07	7	481,630.85	287,025.13	59,221.67	135,384.05
8	541,725.90	322,833.07	66,659.12	152,233.72	8	481,619.03	287,020.42	59,225.05	135,373.57
9	541,869.72	322,950.40	66,639.90	152,279.42	9	481,469.82	286,968.63	59,195.85	135,305.33
10	541,871.13	322,910.55	66,653.40	152,307.18	10	481,603.68	287,002.00	59,193.78	135,407.90
11	541,979.15	323,042.58	66,606.52	152,330.05	11	481,616.72	287,012.48	59,234.10	135,370.13
12	541,926.03	322,977.88	66,676.03	152,272.12	12	481,591.68	287,080.48	59,175.03	135,336.17
13	541,687.47	322,847.38	66,590.43	152,249.65	13	481,620.38	287,103.15	59,191.87	135,325.37
14	541,854.03	322,932.38	66,698.25	152,223.40	14	481,700.40	287,049.48	59,231.35	135,419.57
15	541,791.80	322,955.77	66,578.53	152,257.50	15	481,495.72	286,965.62	59,224.70	135,305.40
16	541,859.82	322,915.40	66,676.38	152,268.03	16	481,593.12	286,997.40	59,265.02	135,330.70
17	541,882.78	322,957.63	66,648.77	152,276.38	17	481,654.12	287,051.43	59,228.78	135,373.90
Average	***541,844.78***	***322,932.31***	***66,642.73***	***152,269.75***	***Average***	***481,596.47***	***287,025.11***	***59,216.55***	***135,354.80***

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

50% Load Level: 6,020 BSUs	Start	Stop	Interval	Duration	10% Load Level: 1,204 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	5:57:35	6:05:36	0-7	0:08:01	Start-Up/Ramp-Up	6:16:05	6:24:06	0-7	0:08:01
Measurement Interval	6:05:36	6:15:36	8-17	0:10:00	Measurement Interval	6:24:06	6:34:06	8-17	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	300,993.10	179,411.65	37,026.27	84,555.18	0	60,206.02	35,878.08	7,394.48	16,933.45
1	301,071.90	179,417.45	37,033.38	84,621.07	1	60,194.82	35,897.95	7,383.45	16,913.42
2	300,879.73	179,339.83	36,994.67	84,545.23	2	60,214.47	35,914.57	7,405.37	16,894.53
3	300,990.92	179,388.23	37,025.55	84,577.13	3	60,219.53	35,877.18	7,400.62	16,941.73
4	300,907.95	179,358.72	37,024.33	84,524.90	4	60,215.83	35,885.35	7,391.32	16,939.17
5	300,990.37	179,310.55	37,059.63	84,620.18	5	60,198.97	35,872.77	7,403.88	16,922.32
6	300,976.43	179,372.98	37,035.77	84,567.68	6	60,223.72	35,898.12	7,413.13	16,912.47
7	301,105.65	179,486.05	37,052.50	84,567.10	7	60,226.48	35,895.27	7,411.55	16,919.67
8	300,960.27	179,346.43	37,025.78	84,588.05	8	60,233.35	35,880.97	7,410.77	16,941.62
9	300,935.30	179,337.07	37,023.95	84,574.28	9	60,182.48	35,887.95	7,406.05	16,888.48
10	301,028.57	179,402.88	37,030.67	84,595.02	10	60,183.72	35,897.48	7,380.47	16,905.77
11	300,844.98	179,244.38	37,008.57	84,592.03	11	60,170.97	35,869.68	7,408.48	16,892.80
12	301,020.25	179,468.07	37,034.30	84,517.88	12	60,212.97	35,876.10	7,420.90	16,915.97
13	301,102.78	179,460.53	37,033.07	84,609.18	13	60,178.47	35,873.15	7,399.02	16,906.30
14	301,053.08	179,392.38	37,041.55	84,619.15	14	60,231.68	35,929.88	7,398.05	16,903.75
15	300,928.87	179,334.22	36,987.08	84,607.57	15	60,220.48	35,898.20	7,381.80	16,940.48
16	301,112.25	179,475.23	37,001.32	84,635.70	16	60,184.35	35,854.95	7,405.62	16,923.78
17	301,053.87	179,375.47	37,028.77	84,649.63	17	60,228.10	35,863.50	7,413.55	16,951.05
Average	301,004.02	179,383.67	37,021.51	84,598.85	*Average*	***60,202.66***	***35,883.19***	***7,402.47***	***16,917.00***

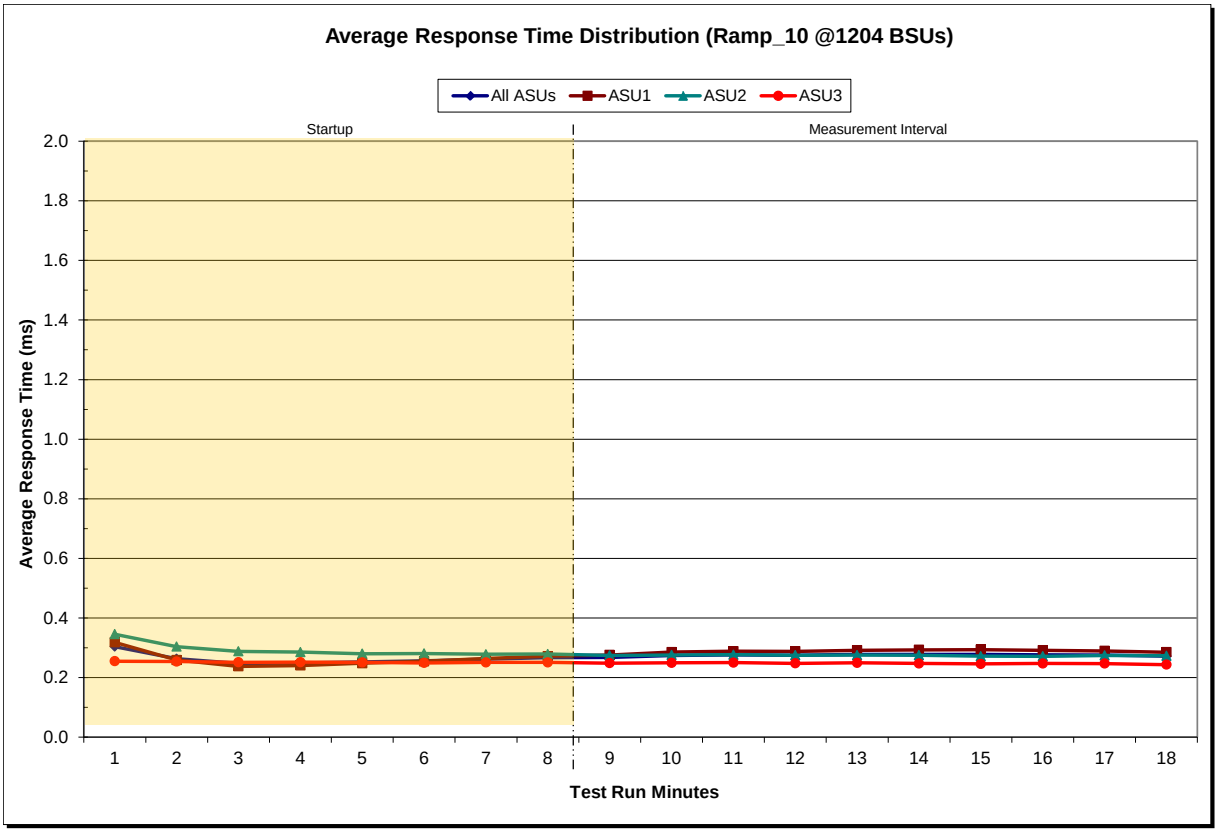
Response Time Ramp Distribution (IOPS) Graph



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

1,204 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	6:16:05	6:24:06	0-7	0:08:01
Measurement Interval	6:24:06	6:34:06	8-17	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.30	0.32	0.35	0.26
1	0.26	0.26	0.30	0.25
2	0.25	0.24	0.29	0.25
3	0.25	0.24	0.29	0.25
4	0.25	0.25	0.28	0.25
5	0.26	0.25	0.28	0.25
6	0.26	0.26	0.28	0.25
7	0.27	0.27	0.28	0.25
8	0.27	0.28	0.27	0.25
9	0.27	0.29	0.28	0.25
10	0.28	0.29	0.28	0.25
11	0.28	0.29	0.28	0.25
12	0.28	0.29	0.28	0.25
13	0.28	0.29	0.28	0.25
14	0.28	0.29	0.27	0.25
15	0.28	0.29	0.27	0.25
16	0.28	0.29	0.27	0.25
17	0.27	0.29	0.27	0.24
Average	***0.28***	***0.29***	***0.27***	***0.25***

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	0.2810	0.0701	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.003	0.001	0.002	0.001	0.005	0.002	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 90.

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	***602,019.47***
Repeatability Test Phase 1	602,005.54
Repeatability Test Phase 2	601.967.54

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	***0.28 ms***
Repeatability Test Phase 1	0.26 ms
Repeatability Test Phase 2	0.26 ms

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

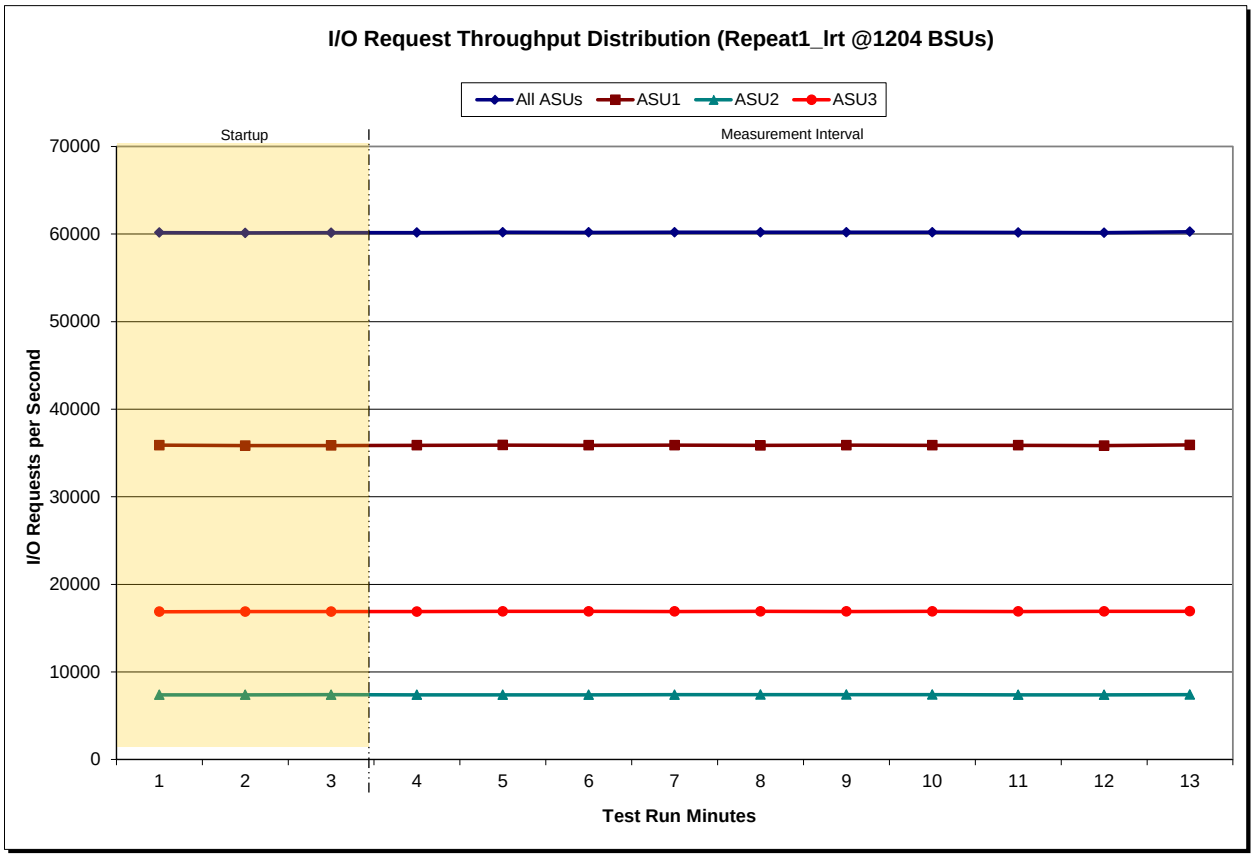
A link to the test result file generated from each Repeatability Test Run is listed below.

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

Repeatability 1 LRT – I/O Request Throughput Distribution Data

1,204 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	6:34:49	6:37:49	0-2	0:03:00
Measurement Interval	6:37:49	6:47:49	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	60,170.53	35,889.52	7,396.13	16,884.88
1	60,125.85	35,839.27	7,390.82	16,895.77
2	60,155.97	35,855.75	7,409.05	16,891.17
3	60,162.70	35,880.68	7,394.77	16,887.25
4	60,206.22	35,901.48	7,392.37	16,912.37
5	60,188.18	35,882.60	7,393.42	16,912.17
6	60,203.10	35,897.98	7,398.55	16,906.57
7	60,200.90	35,870.85	7,411.70	16,918.35
8	60,204.58	35,886.68	7,414.63	16,903.27
9	60,207.58	35,877.63	7,409.88	16,920.07
10	60,174.98	35,879.45	7,394.13	16,901.40
11	60,157.30	35,845.27	7,395.77	16,916.27
12	60,265.78	35,916.63	7,415.37	16,933.78
Average	***60,197.13***	***35,883.93***	***7,402.06***	***16,911.15***

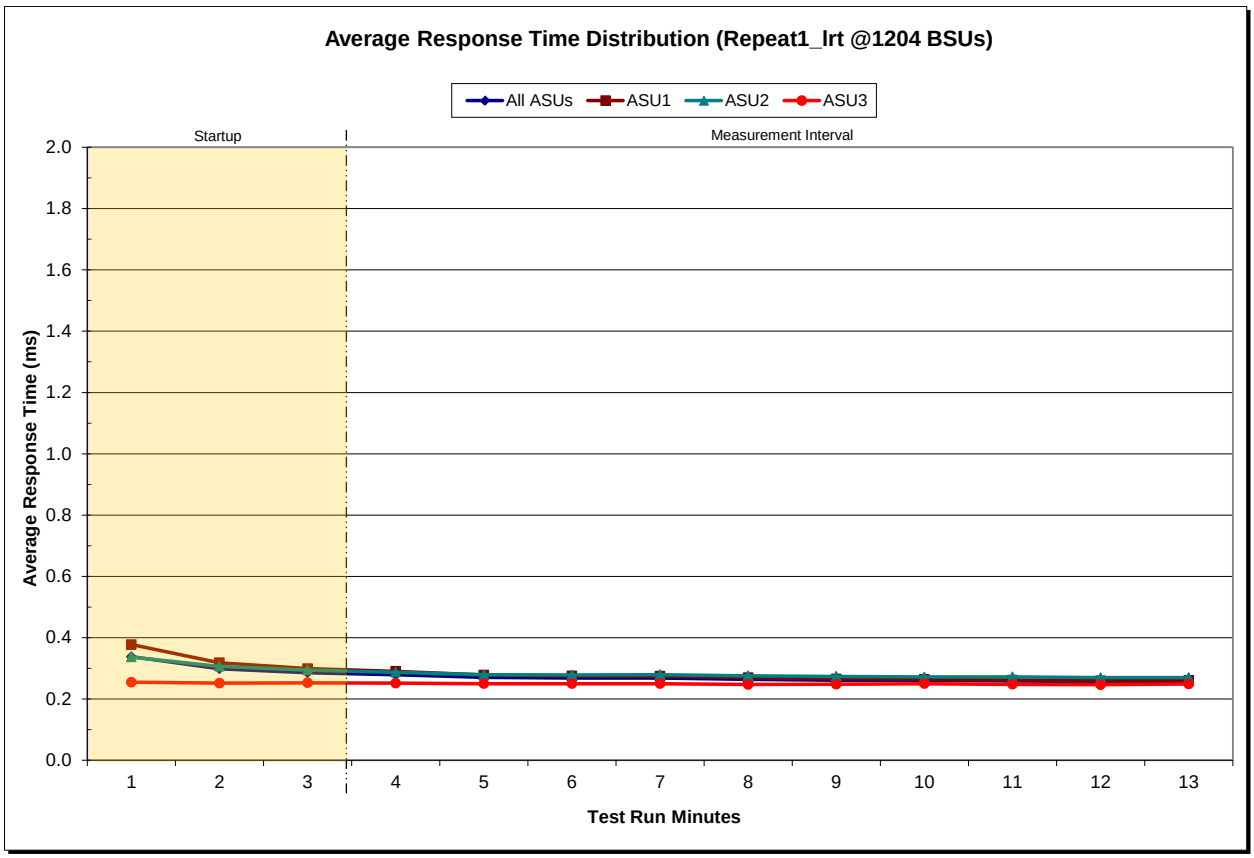
Repeatability 1 LRT – I/O Request Throughput Distribution Graph



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

1,204 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	6:34:49	6:37:49	0-2	0:03:00
Measurement Interval	6:37:49	6:47:49	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.34	0.38	0.34	0.25
1	0.30	0.32	0.31	0.25
2	0.29	0.30	0.29	0.25
3	0.28	0.29	0.29	0.25
4	0.27	0.28	0.28	0.25
5	0.27	0.28	0.28	0.25
6	0.27	0.27	0.28	0.25
7	0.26	0.27	0.28	0.25
8	0.26	0.27	0.27	0.25
9	0.26	0.26	0.27	0.25
10	0.26	0.26	0.27	0.25
11	0.26	0.26	0.27	0.25
12	0.26	0.26	0.27	0.25
Average	***0.26***	***0.27***	***0.28***	***0.25***

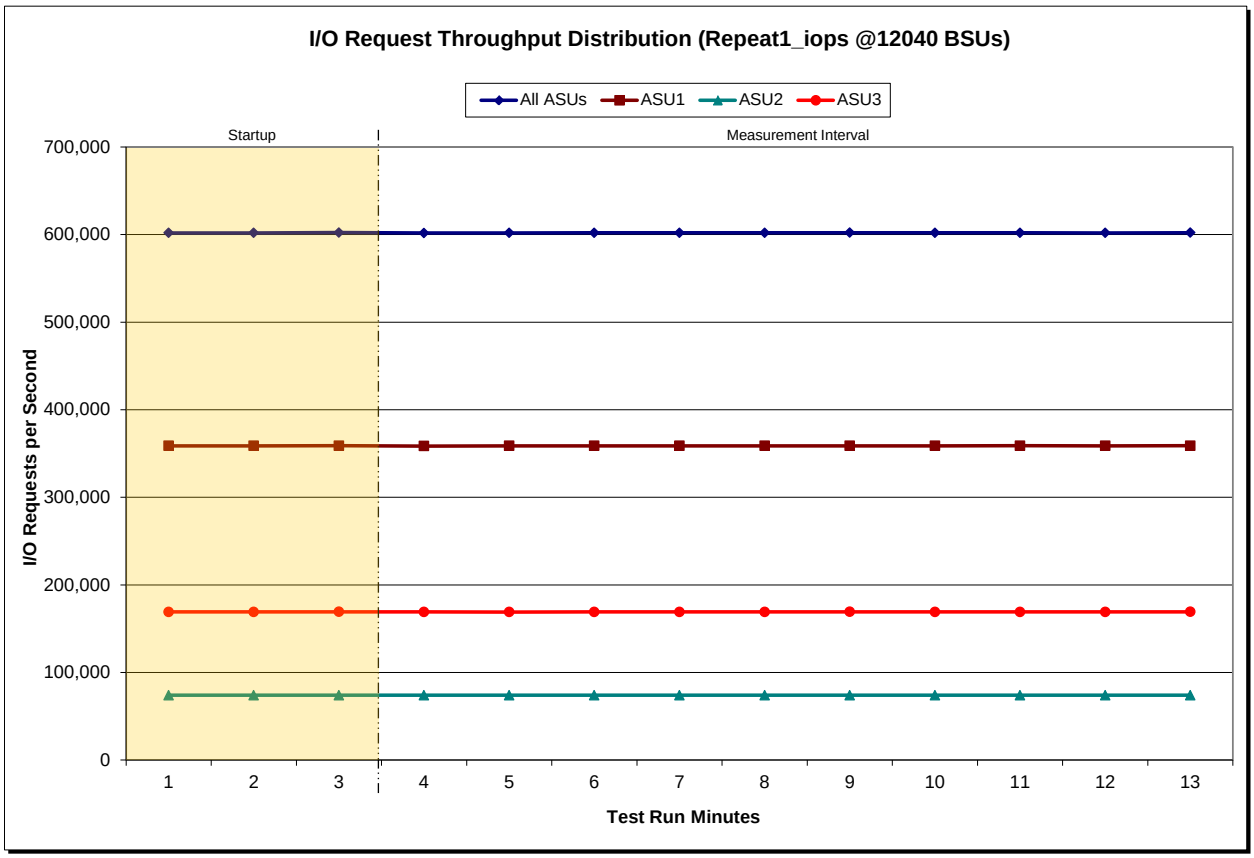
Repeatability 1 LRT –Average Response Time (ms) Distribution Graph



Repeatability 1 IOPS – I/O Request Throughput Distribution Data

12,040 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	6:49:15	6:52:16	0-2	0:03:01
Measurement Interval	6:52:16	7:02:16	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	601,940.28	358,733.57	74,019.22	169,187.50
1	601,913.48	358,738.02	74,015.48	169,159.98
2	602,240.85	358,933.12	74,052.65	169,255.08
3	601,744.07	358,563.70	74,036.17	169,144.20
4	601,866.23	358,764.15	74,045.78	169,056.30
5	601,993.47	358,759.67	74,072.15	169,161.65
6	602,005.63	358,745.70	74,083.52	169,176.42
7	602,065.12	358,842.83	74,017.55	169,204.73
8	602,124.68	358,828.62	74,059.62	169,236.45
9	602,009.95	358,783.78	74,034.50	169,191.67
10	602,084.20	358,867.95	74,055.62	169,160.63
11	601,948.38	358,754.33	74,049.02	169,145.03
12	602,213.62	358,910.82	74,057.57	169,245.23
Average	***602,005.54***	***358,782.16***	***74,051.15***	***169,172.23***

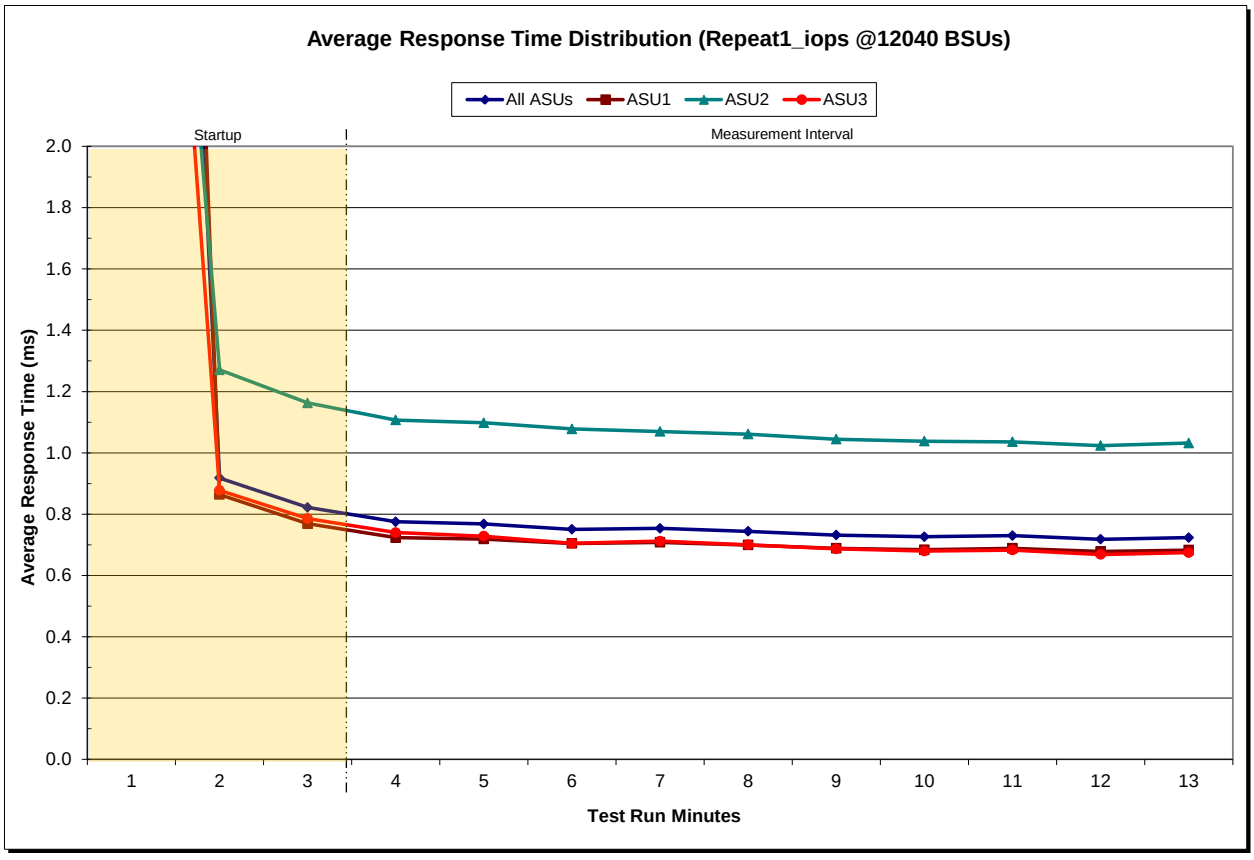
Repeatability 1 IOPS – I/O Request Throughput Distribution Graph



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

12,040 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	6:49:15	6:52:16	0-2	0:03:01
Measurement Interval	6:52:16	7:02:16	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	6.92	8.36	4.73	4.82
1	0.92	0.86	1.27	0.88
2	0.82	0.77	1.16	0.79
3	0.78	0.72	1.11	0.74
4	0.77	0.72	1.10	0.73
5	0.75	0.70	1.08	0.70
6	0.75	0.71	1.07	0.71
7	0.74	0.70	1.06	0.70
8	0.73	0.69	1.04	0.69
9	0.73	0.68	1.04	0.68
10	0.73	0.69	1.04	0.68
11	0.72	0.68	1.02	0.67
12	0.72	0.68	1.03	0.67
Average	***0.74***	***0.70***	***1.06***	***0.70***

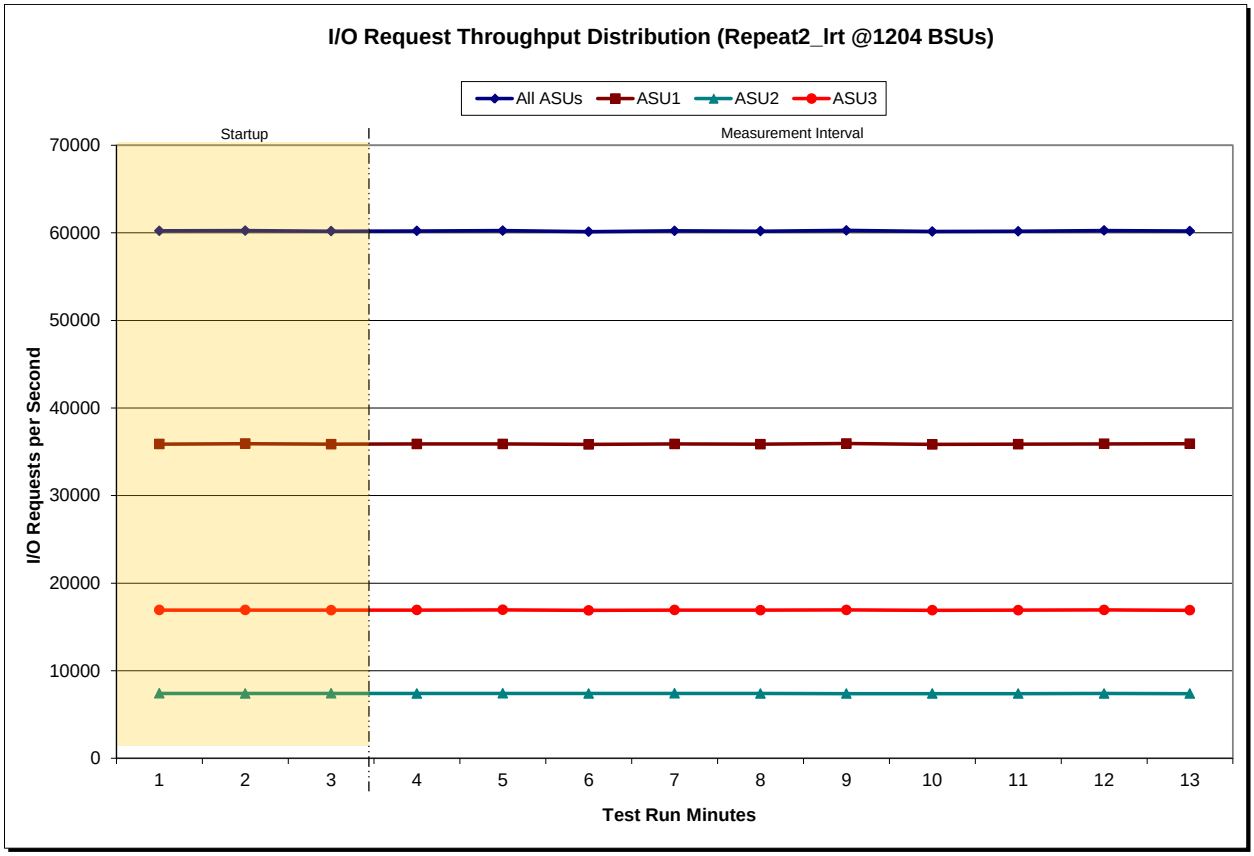
Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph



Repeatability 2 LRT – I/O Request Throughput Distribution Data

1,204 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:02:58	7:05:58	0-2	0:03:00
Measurement Interval	7:05:58	7:15:58	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	60,227.87	35,882.82	7,416.05	16,929.00
1	60,259.10	35,932.73	7,402.03	16,924.33
2	60,196.10	35,868.72	7,413.95	16,913.43
3	60,220.90	35,896.27	7,401.90	16,922.73
4	60,251.48	35,889.40	7,409.75	16,952.33
5	60,133.57	35,838.40	7,409.37	16,885.80
6	60,225.62	35,889.62	7,411.10	16,924.90
7	60,187.38	35,866.00	7,404.20	16,917.18
8	60,276.98	35,937.02	7,393.68	16,946.28
9	60,151.68	35,847.43	7,396.77	16,907.48
10	60,176.95	35,864.12	7,393.10	16,919.73
11	60,265.18	35,910.33	7,408.12	16,946.73
12	60,207.77	35,911.15	7,388.12	16,908.50
Average	***60,209.75***	***35,884.97***	***7,401.61***	***16,923.17***

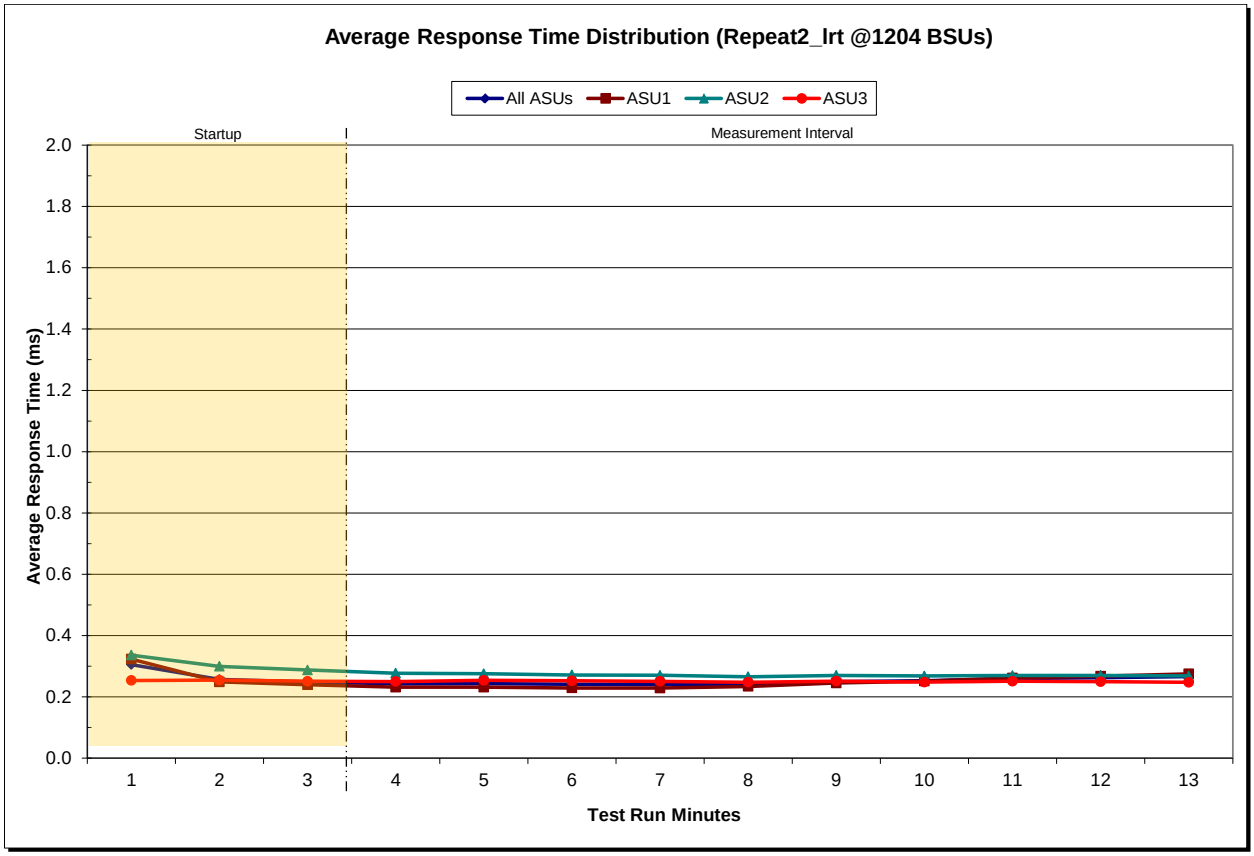
Repeatability 2 LRT – I/O Request Throughput Distribution Graph



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

1,204 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:02:58	7:05:58	0-2	0:03:00
Measurement Interval	7:05:58	7:15:58	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.31	0.32	0.34	0.25
1	0.26	0.25	0.30	0.25
2	0.25	0.24	0.29	0.25
3	0.24	0.23	0.28	0.25
4	0.24	0.23	0.28	0.25
5	0.24	0.23	0.27	0.25
6	0.24	0.23	0.27	0.25
7	0.24	0.23	0.27	0.25
8	0.25	0.25	0.27	0.25
9	0.25	0.25	0.27	0.25
10	0.26	0.26	0.27	0.25
11	0.26	0.27	0.27	0.25
12	0.27	0.28	0.27	0.25
Average	***0.25***	***0.25***	***0.27***	***0.25***

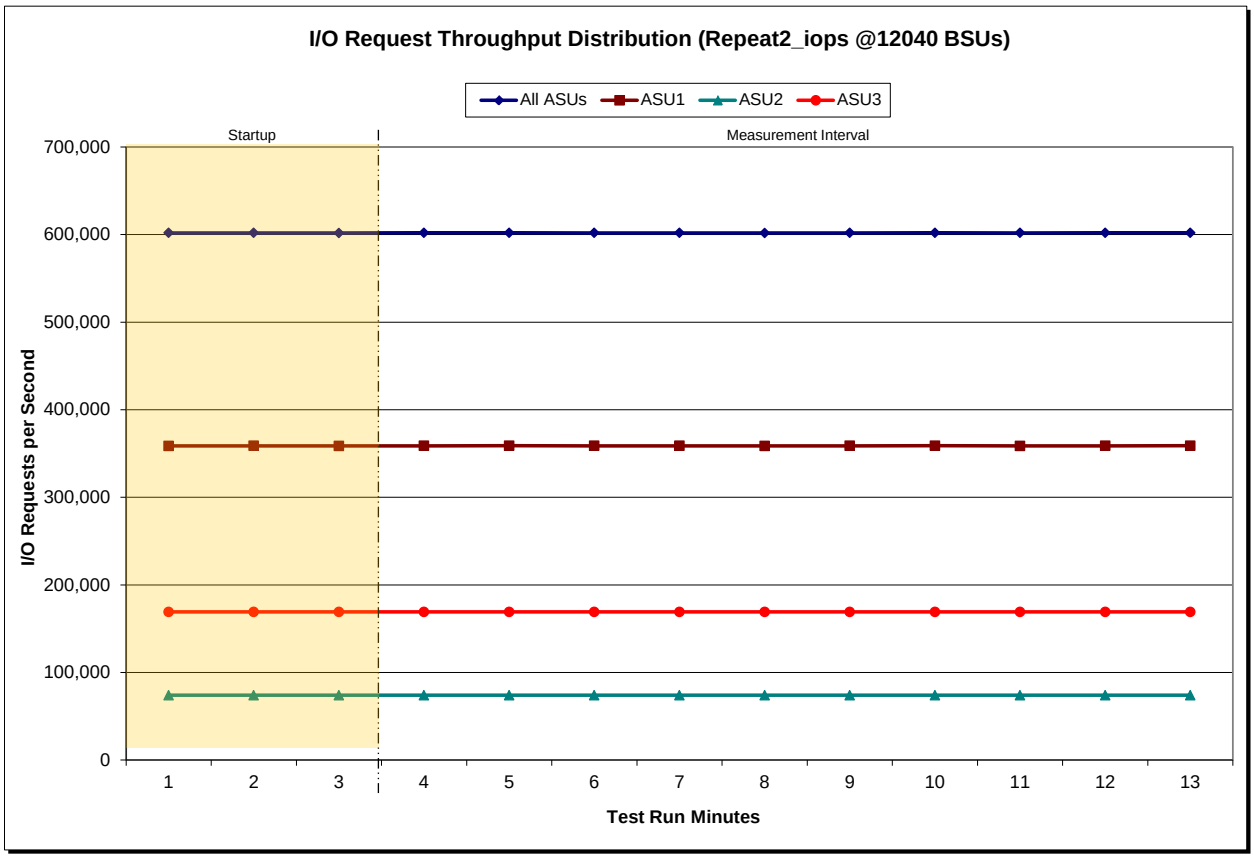
Repeatability 2 LRT –Average Response Time (ms) Distribution Graph



Repeatability 2 IOPS – I/O Request Throughput Distribution Data

12,040 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:17:24	7:20:25	0-2	0:03:01
Measurement Interval	7:20:25	7:30:25	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	601,956.77	358,657.72	74,075.87	169,223.18
1	601,895.40	358,786.40	73,998.95	169,110.05
2	601,842.08	358,657.20	73,983.87	169,201.02
3	601,995.05	358,762.15	74,038.87	169,194.03
4	602,089.83	358,893.77	73,988.28	169,207.78
5	601,900.42	358,736.25	74,049.12	169,115.05
6	601,893.63	358,758.90	74,009.13	169,125.60
7	601,829.62	358,648.03	74,024.60	169,156.98
8	601,951.55	358,858.30	73,977.25	169,116.00
9	602,046.25	358,883.28	74,025.48	169,137.48
10	601,890.98	358,659.13	74,044.25	169,187.60
11	601,987.45	358,757.62	74,017.77	169,212.07
12	602,090.57	358,907.18	74,044.00	169,139.38
Average	***601,967.54***	***358,786.46***	***74,021.88***	***169,159.20***

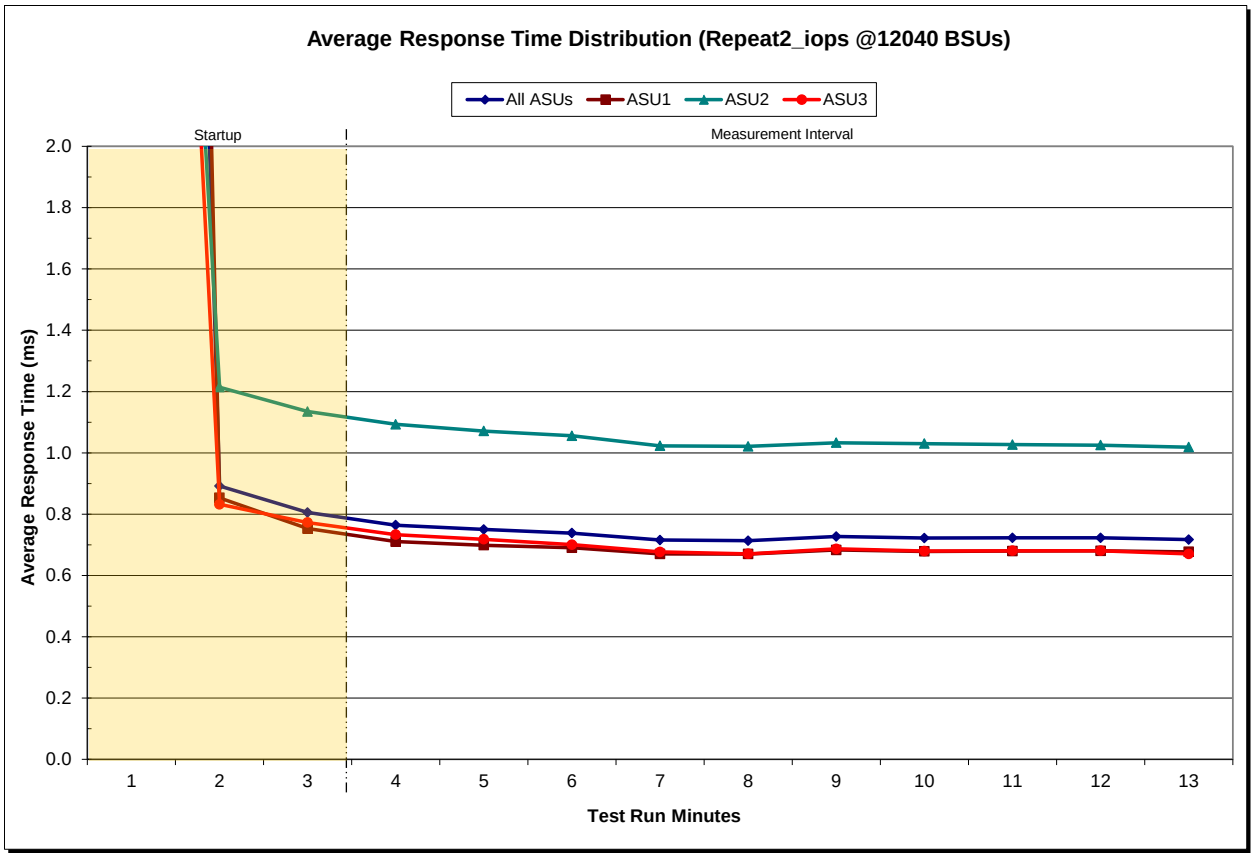
Repeatability 2 IOPS – I/O Request Throughput Distribution Graph



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

12,040 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:17:24	7:20:25	0-2	0:03:01
Measurement Interval	7:20:25	7:30:25	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	10.60	13.46	6.14	6.48
1	0.89	0.85	1.21	0.83
2	0.81	0.75	1.13	0.77
3	0.76	0.71	1.09	0.73
4	0.75	0.70	1.07	0.72
5	0.74	0.69	1.06	0.70
6	0.72	0.67	1.02	0.68
7	0.71	0.67	1.02	0.67
8	0.73	0.68	1.03	0.69
9	0.72	0.68	1.03	0.68
10	0.72	0.68	1.03	0.68
11	0.72	0.68	1.02	0.68
12	0.72	0.68	1.02	0.67
Average	***0.73***	***0.68***	***1.04***	***0.69***

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	0.2101	0.0180	0.0700	0.0350	0.2809
COV	0.002	0.001	0.002	0.001	0.002	0.002	0.003	0.001

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.001	0.000	0.001	0.000	0.001	0.000	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	0.0350	0.2809	0.0699	0.2101	0.0180	0.0699	0.0350	0.2811
COV	0.004	0.001	0.001	0.001	0.004	0.002	0.004	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	0.001	0.000	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 90.

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

0.26

Data Persistence Test Results	
Data Persistence Test Run Number: 1	
Total Number of Logical Blocks Written	617,258
Total Number of Logical Blocks Verified	600,039
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	1024
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 Virtual Storage Platform 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 18.

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 18.

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 Virtual Storage Platform.

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.

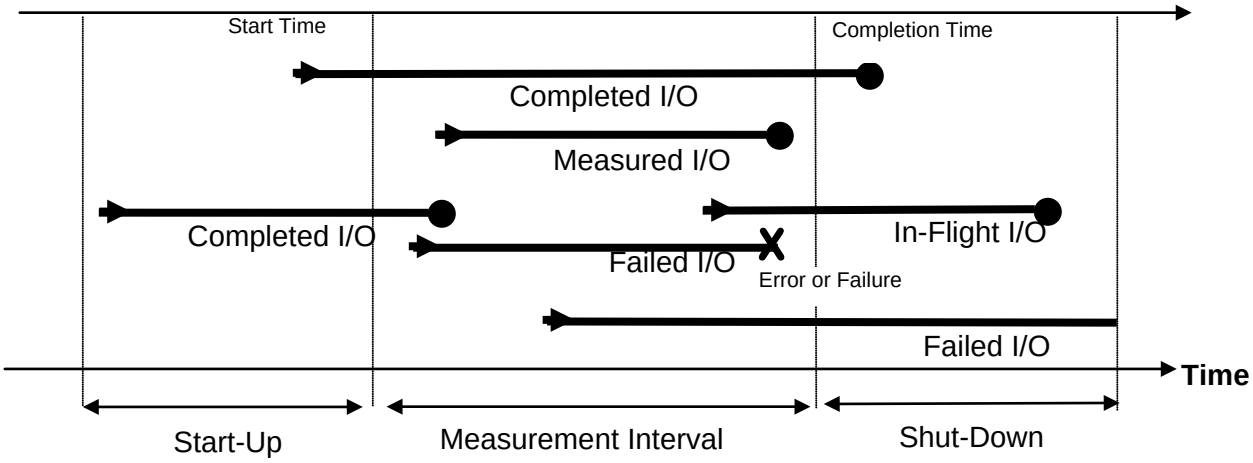
Steady State: The consistent and sustainable throughput of the TSC. During this period the load presented to the TSC by the Workload Generator is constant.

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

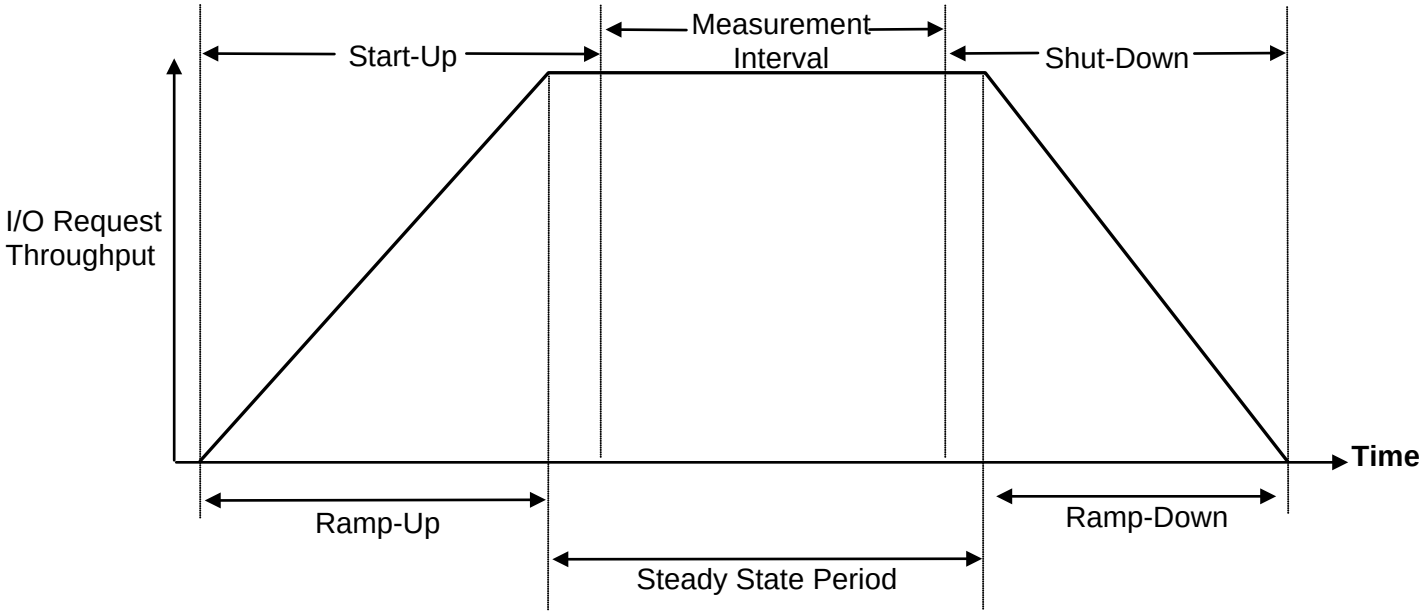
Test Run: The execution of SPC-1 for the purpose of producing or supporting an SPC-1 test result. SPC-1 Test Runs may have a finite and measured Ramp-Up period, Start-Up period, Shut-Down period, and Ramp-Down period as illustrated in the "SPC-1 Test Run Components" below. All SPC-1 Test Runs shall have 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 and options were changed from their default values for this benchmark. The **Set Parameter and Options** section of *"Appendix C: Tested Storage Configuration (TSC) Creation"* documents how those parameters and options were changed.

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***
TCP Maximum Queue Depth (***net.core.somaxconn***)	***128***	***8192***
HBA queue depth on each Host System ***(lpfc_hba_queue_depth)***	***8192***	***256***

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. Pre-Configured RAID-10 Parity Groups

The TSC is delivered with a factory pre-configured RAID-10 (2D+2P) configuration. This resulted in a SPC-1 configuration with 6 parity groups. The table, illustrated below, lists the pre-configured parity groups.

1-1	1-2	1-3	3-1	3-2	3-3

Steps 2-6 are executed from a Unix host with network connectivity to the public IP address of the TSC's service processor (SVP)

2. Create Logical Devices

The **make_ldev.ksh** script is executed as listed below, using the RAID Manager CLI, to create 128 logical devices of 53686272 blocks each, on each of the six parity groups.

```
make_ldev.ksh 1-1 000 53686272 128 2 0 4
make_ldev.ksh 3-1 001 53686272 128 2 4 4
make_ldev.ksh 1-2 100 53686272 128 2 0 4
make_ldev.ksh 3-2 101 53686272 128 2 4 4
make_ldev.ksh 1-3 200 53686272 128 2 0 4
make_ldev.ksh 3-3 201 53686272 128 2 4 4
```

3. Format Logical Devices

The **format_ldev.ksh** script is executed as listed below, using the RAID Manager CLI, to format all 768 logical devices.

```
format_ldev.ksh 0 768 1
```

4. Name Logical Devices

The **label_ldev.ksh** script is executed without any parameters, using the RAID Manager CLI, to give a unique name to each logical device.

.

5. Create Four Text Files Listing VSP FED Ports to be used in the TSC

Using a standard text editor such as "vi", create four text files, named "portlist.suffix[1-4]." "Suffix" can be any unique text string such as a TSC hostname. Each text file will contain the names of eight VSP FED ports, with each port listed on a separate line. The table below shows the contents of each text file:

portlist.suffix1	portlist.suffix2	portlist.suffix3	portlist.suffix4
cl1-a	cl2-a	cl1-j	cl2-j
cl1-b	cl2-b	cl1-k	cl2-k
cl1-c	cl2-c	cl1-l	cl2-l
cl1-d	cl2-d	cl1-m	cl2-m
cl1-e	cl2-e	cl1-n	cl2-n
cl1-f	cl2-f	cl1-p	cl2-p
cl1-g	cl2-g	cl1-q	cl2-q
cl1-h	cl2-h	cl1-r	cl2-r

6. Map LUNs to Front-End Ports

The **mml.ksh** script is executed as listed below, using the RAID Manager CLI, to map logical devices to target ports on the VSP. Suffix" refers to the "portlist.suffix[1-4]" text files created in step 5.

```
mml.ksh suffix1 suffix2 suffix3 suffix4
```

7. Discover LUNs

The SPC-1 Host System is rebooted to discover the newly mapped LUNs.

Steps 8 – 12 are executed from any one of the Host Systems.

8. Initialize Disks for Logical Volume Manager

The **pvcreate.sh** script is executed without any parameters, to initialize disks for use by the Linux LVM.

9. Map Linux Raw Device Names to VSP Logical Device Names

The **mapsd2ldev.ksh** script is executed as listed below, to map Linux raw devices (/dev/sd*) to the VSP logical device names created in step #4.

This step identifies which raw devices will be included in the LVM volume groups for each ASU. The script will produce 12 text file maps, each of which contains 64 device names.

mapsd2.dev.ksh 3 4

10. Create Twelve Linux LVM Volume Groups

The **vgcreate.ksh** script is executed as listed below, to create 12 volume groups, 4 for each ASU. The **vgcreate.ksh** script reads from the maps created in step #9.

vgcreate.ksh 3 4

11. Create Twelve Striped Logical Volumes

The **lvcreate.ksh** script is executed without any parameters, to create twelve 1.6 TiB logical volumes, one from each of the volume groups created in step #10. Each logical volume is striped across 64 logical devices.

The logical device mapping for each striped logical volume is illustrated in a set of tables that appear at the end of this section.

12. Activate Logical Volumes

The **lvactivate.ksh** script is executed without any parameters, on all SPC-1 Host Systems, to activate all logical volumes on all of the Host Systems.

12. Set Parameters and Options

Each customer tunable parameter and option that was changed from a default value for the benchmark execution is described in Appendix B: Customer Tunable Parameters and Options on page 72.

The following lines were added to the **/etc/rc.local** script on each Host System to change the default Linux I/O scheduler algorithm and the default TCP connection queue depth:

```
echo noop > /sys/block/sda/queue/scheduler
sysctl -w net.core.somaxconn=8192
```

The following statement was added to the **/etc/modprobe.d/elx-lpfc.conf** file on each Host System to change the default HBA queue depth.

```
options lpfc lpfc_hba_queue_depth=256
```

Each Host System was rebooted to make the above changes effective.

Logical Device Mapping

Each cell in the tables represents a hexadecimal logical device address.

Table 1: lvasu1_1

0	1	2	3	4	5	6	7
8	9	A	B	C	D	E	F
80	81	82	83	84	85	86	87
88	89	8A	8B	8C	8D	8E	8F
100	101	102	103	104	105	106	107
108	109	10A	10B	10C	10D	10E	10F
180	181	182	183	184	185	186	187
188	189	18A	18B	18C	18D	18E	18F

Table 2: lvasu1_2

10	11	12	13	14	15	16	17
18	19	1A	1B	1C	1D	1E	1F
90	91	92	93	94	95	96	97
98	99	9A	9B	9C	9D	9E	9F
110	111	112	113	114	115	116	117
118	119	11A	11B	11C	11D	11E	11F
190	191	192	193	194	195	196	197
198	199	19A	19B	19C	19D	19E	19F

Table 3: lvasu1_3

20	21	22	23	24	25	26	27
28	29	2A	2B	2C	2D	2E	2F
A0	A1	A2	A3	A4	A5	A6	A7
A8	A9	AA	AB	AC	AD	AE	AF
120	121	122	123	124	125	126	127
128	129	12A	12B	12C	12D	12E	12F
1A0	1A1	1A2	1A3	1A4	1A5	1A6	1A7
1A8	1A9	1AA	1AB	1AC	1AD	1AE	1AF

Table 4: lvasu1_4

30	31	32	33	34	35	36	37
38	39	3A	3B	3C	3D	3E	3F
B0	B1	B2	B3	B4	B5	B6	B7
B8	B9	BA	BB	BC	BD	BE	BF
130	131	132	133	134	135	136	137
138	139	13A	13B	13C	13D	13E	13F
1B0	1B1	1B2	1B3	1B4	1B5	1B6	1B7
1B8	1B9	1BA	1BB	1BC	1BD	1BE	1BF

Table 5: lvasu2_1

40	41	42	43	44	45	46	47
48	49	4A	4B	4C	4D	4E	4F
C0	C1	C2	C3	C4	C5	C6	C7
C8	C9	CA	CB	CC	CD	CE	CF
140	141	142	143	144	145	146	147
148	149	14A	14B	14C	14D	14E	14F
1C0	1C1	1C2	1C3	1C4	1C5	1C6	1C7
1C8	1C9	1CA	1CB	1CC	1CD	1CE	1CF

Table 6: lvasu2_2

50	51	52	53	54	55	56	57
58	59	5A	5B	5C	5D	5E	5F
D0	D1	D2	D3	D4	D5	D6	D7
D8	D9	DA	DB	DC	DD	DE	DF
150	151	152	153	154	155	156	157
158	159	15A	15B	15C	15D	15E	15F
1D0	1D1	1D2	1D3	1D4	1D5	1D6	1D7
1D8	1D9	1DA	1DB	1DC	1DD	1DE	1DF

Table 7: lvasu2_3

60	61	62	63	64	65	66	67
68	69	6A	6B	6C	6D	6E	6F
E0	E1	E2	E3	E4	E5	E6	E7
E8	E9	EA	EB	EC	ED	EE	EF
160	161	162	163	164	165	166	167
168	169	16A	16B	16C	16D	16E	16F
1E0	1E1	1E2	1E3	1E4	1E5	1E6	1E7
1E8	1E9	1EA	1EB	1EC	1ED	1EE	1EF

Table 8: lvasu2_4

70	71	72	73	74	75	76	77
78	79	7A	7B	7C	7D	7E	7F
F0	F1	F2	F3	F4	F5	F6	F7
F8	F9	FA	FB	FC	FD	FE	FF
170	171	172	173	174	175	176	177
178	179	17A	17B	17C	17D	17E	17F
1F0	1F1	1F2	1F3	1F4	1F5	1F6	1F7
1F8	1F9	1FA	1FB	1FC	1FD	1FE	1FF

Table 9: lvasu3_1

200	201	202	203	204	205	206	207
208	209	20A	20B	20C	20D	20E	20F
210	211	212	213	214	215	216	217
218	219	21A	21B	21C	21D	21E	21F
220	221	222	223	224	225	226	227
228	229	22A	22B	22C	22D	22E	22F
230	231	232	233	234	235	236	237
238	239	23A	23B	23C	23D	23E	23F

Table 10: lvasu3_2

240	241	242	243	244	245	246	247
248	249	24A	24B	24C	24D	24E	24F
250	251	252	253	254	255	256	257
258	259	25A	25B	25C	25D	25E	25F
260	261	262	263	264	265	266	267
268	269	26A	26B	26C	26D	26E	26F
270	271	272	273	274	275	276	277
278	279	27A	27B	27C	27D	27E	27F

Table 11: lvasu3_3

280	281	282	283	284	285	286	287
288	289	28A	28B	28C	28D	28E	28F
290	291	292	293	294	295	296	297
298	299	29A	29B	29C	29D	29E	29F
2A0	2A1	2A2	2A3	2A4	2A5	2A6	2A7
2A8	2A9	2AA	2AB	2AC	2AD	2AE	2AF
2B0	2B1	2B2	2B3	2B4	2B5	2B6	2B7
2B8	2B9	2BA	2BB	2BC	2BD	2BE	2BF

Table 12: lvasu3_4

2C0	2C1	2C2	2C3	2C4	2C5	2C6	2C7
2C8	2C9	2CA	2CB	2CC	2CD	2CE	2CF
2D0	2D1	2D2	2D3	2D4	2D5	2D6	2D7
2D8	2D9	2DA	2DB	2DC	2DD	2DE	2DF
2E0	2E1	2E2	2E3	2E4	2E5	2E6	2E7
2E8	2E9	2EA	2EB	2EC	2ED	2EE	2EF
2F0	2F1	2F2	2F3	2F4	2F5	2F6	2F7
2F8	2F9	2FA	2FB	2FC	2FD	2FE	2FF

TSC Creation/Configuration Scripts

make_ldev.ksh

```
#!/bin/ksh
# For example, makeldev.ksh 1-1 000 53686272 128 2 0 4
# For example, makeldev.ksh 3-1 001 53686272 128 2 4 4
# For example, makeldev.ksh 1-2 100 53686272 128 2 0 4
# For example, makeldev.ksh 3-2 101 53686272 128 2 4 4
# For example, makeldev.ksh 1-3 200 53686272 128 2 0 4
# For example, makeldev.ksh 3-3 201 53686272 128 2 4 4
pg=$1
hexldevid=$2;
cap=$3;
count=$4
inc=$5
smpb=$6
mpb=$smpb
nmp=$7
decldevid=16#$hexldevid
typeset -i10 decldevid
ldevid=$hexldevid
j=1;
k=0;
resource_lock=-1;
while [ $resource_lock -ne 0 ] ;
do
   raidcom lock resource -resource_name meta_resource
   resource_lock=$?
   sleep 5;
done
while [ $j -le $count ] ;
do
   k=$(($k+1));
   print raidcom add ldev -parity_grp_id $pg -ldev_id $decldevid -capacity $cap -
emulation open-v -mp_blade_id $mpb
   raidcom add ldev -parity_grp_id $pg -ldev_id $decldevid -capacity $cap -emulation
OPEN-V -mp_blade_id $mpb
   decldevid=$(($decldevid+$inc));
   hexldevid=$decldevid
   typeset -i16 hexldevid
   ldevid=`echo $hexldevid | awk -F"#" '{print $2}'`
   j=$(($j+1));
```

```
    mpb=$(($mpb+1));
    if [ $k -eq $nmp ] ; then
       mpb=$smpb;
       k=0;
    fi
 done
 raidcom unlock resource -resource_name meta_resource
 exit
```

format_ldev.ksh

```
#!/bin/ksh
# For example, format_ldev.ksh 0 768 1
hexldevid=$1;
count=$2
inc=$3
decldevid=16#$hexldevid
typeset -i10 decldevid
ldevid=$hexldevid
j=1;
resource_lock=-1;
while [ $resource_lock -ne 0 ] ;
do
   raidcom lock resource -resource_name meta_resource
   resource_lock=$?
   sleep 5;
done
while [ $j -le $count ] ;
do
   print raidcom initialize ldev -ldev_id $ldevid -operation fmt
   raidcom initialize ldev -ldev_id $decldevid -operation fmt
   decldevid=$(($decldevid+$inc));
   hexldevid=$decldevid
   typeset -i16 hexldevid
   ldevid=`echo $hexldevid | awk -F"#" '{print $2}'`
   j=$(($j+1));
done
raidcom unlock resource -resource_name meta_resource
exit
```

label_ldev.ksh

```
#!/bin/ksh
spcmlun.ksh 1 1 0 16 asu1_1 1
spcmlun.ksh 1 1 80 16 asu1_1 1
spcmlun.ksh 1 1 100 16 asu1_1 1
spcmlun.ksh 1 1 180 16 asu1_1 1
spcmlun.ksh 1 1 10 16 asu1_2 1
spcmlun.ksh 1 1 90 16 asu1_2 1
spcmlun.ksh 1 1 110 16 asu1_2 1
spcmlun.ksh 1 1 190 16 asu1_2 1
spcmlun.ksh 1 1 20 16 asu1_3 1
spcmlun.ksh 1 1 a0 16 asu1_3 1
spcmlun.ksh 1 1 120 16 asu1_3 1
spcmlun.ksh 1 1 1a0 16 asu1_3 1
spcmlun.ksh 1 1 30 16 asu1_4 1
spcmlun.ksh 1 1 b0 16 asu1_4 1
spcmlun.ksh 1 1 130 16 asu1_4 1
spcmlun.ksh 1 1 1b0 16 asu1_4 1
spcmlun.ksh 1 2 40 16 asu2_1 1
spcmlun.ksh 1 2 c0 16 asu2_1 1
spcmlun.ksh 1 2 140 16 asu2_1 1
```

```
spcmlun.ksh 1 2 1c0 16 asu2_1 1
spcmlun.ksh 1 2 50 16 asu2_2 1
spcmlun.ksh 1 2 d0 16 asu2_2 1
spcmlun.ksh 1 2 150 16 asu2_2 1
spcmlun.ksh 1 2 1d0 16 asu2_2 1
spcmlun.ksh 1 2 60 16 asu2_3 1
spcmlun.ksh 1 2 e0 16 asu2_3 1
spcmlun.ksh 1 2 160 16 asu2_3 1
spcmlun.ksh 1 2 1e0 16 asu2_3 1
spcmlun.ksh 1 2 70 16 asu2_4 1
spcmlun.ksh 1 2 f0 16 asu2_4 1
spcmlun.ksh 1 2 170 16 asu2_4 1
spcmlun.ksh 1 2 1f0 16 asu2_4 1
spcmlun.ksh 1 3 200 64 asu3_1 1
spcmlun.ksh 1 3 240 64 asu3_2 1
spcmlun.ksh 1 3 280 64 asu3_3 1
spcmlun.ksh 1 3 2c0 64 asu3_4 1
exit
```

spcmlun.ksh *(invoked from* **label_ldev.ksh***)*

```
#!/bin/ksh
#For example, spcmlun.ksh 1 1 0 8 asu1_1 1
fbx=$1
pg=$2
pgp=1;
hexldevid=$3;
count=$4
suffix=$5
inc=$6
decldevid=16#$hexldevid
typeset -i10 decldevid
ldevid=`echo $hexldevid | awk '{printf "%03s", $1}'`
j=1;
resource_lock=-1;
while [ $resource_lock -ne 0 ] ;
do
   raidcom lock resource -resource_name meta_resource
   resource_lock=$?
   sleep 5;
done
while [ $j -le $count ] ;
do
   print raidcom modify ldev -ldev_id $decldevid -ldev_name "F"$fbx"_PG"$pgp"-
"$pg"_LD"$ldevid"-"$suffix
   raidcom modify ldev -ldev_id $decldevid -ldev_name "F"$fbx"_PG"$pgp"-
"$pg"_LD"$ldevid"-"$suffix
   decldevid=$(($decldevid+$inc));
   hexldevid=$decldevid
   typeset -i16 hexldevid
   ldevid=`echo $hexldevid | awk -F"#" '{printf "%03s", $2}'`
   j=$(($j+1));
   if [ $fbx -eq 1 ] ; then
     fbx=2;
   else
     fbx=1;
   fi
   if [ $pgp -eq 1 ] ; then
     pgp=3;
   else
     pgp=1;
   fi
```

```
done
raidcom unlock resource -resource_name meta_resource
exit
```

mml.ksh

```
#!/bin/ksh
#Suffix is the extension of the "portlist" files
# such as "portlist.cb26". So for example we could
# invoke this script as "mml cb26"
for suffix in $@
do
   mmll.ksh 0 2 $suffix
   mmll.ksh 10 2 $suffix
   mmll.ksh 20 2 $suffix
   mmll.ksh 30 2 $suffix
   mmll.ksh 40 2 $suffix
   mmll.ksh 50 2 $suffix
   mmll.ksh 60 2 $suffix
   mmll.ksh 70 2 $suffix
   smml.ksh 200 2 $suffix
   smml.ksh 240 2 $suffix
   smml.ksh 280 2 $suffix
   smml.ksh 2c0 2 $suffix
done
exit
```

mmll.ksh *(invoked from* mml.ksh*)*

```
#!/bin/ksh
hexldevid=$1;
count=$2
suffix=$3
decldevid=16#$hexldevid
typeset -i10 decldevid
print $decldevid
j=1;
mapped=0;
resource_lock=-1;
while [ $resource_lock -ne 0 ] ;
do
   raidcom lock resource -resource_name meta_resource
   resource_lock=$?
   sleep 5;
done
while [ $mapped -lt 64 ] ;
do
   for port in `cat portlist.$suffix`
   do
      while [ $j -le $count ] ;
      do
         hexldevid=$decldevid
         typeset -i16 hexldevid
         hldevid=`echo $hexldevid | awk -F"#" '{print $2}'`
         print raidcom add lun -port $port -ldev_id $hldevid
         raidcom add lun -port $port -ldev_id $decldevid
         decldevid=$(($decldevid+1));
         j=$(($j+1));
         mapped=$(($mapped+1));
      done
      j=1;
   done
```

```
    decldevid=$(($decldevid+112));
 done
 raidcom unlock resource -resource_name meta_resource
 exit
```

smml.ksh *(invoked from* **mml.ksh***)*

```
#!/bin/ksh
hexldevid=$1;
count=$2
suffix=$3
decldevid=16#$hexldevid
typeset -i10 decldevid
print $decldevid
j=1;
mapped=0;
resource_lock=-1;
while [ $resource_lock -ne 0 ] ;
do
   raidcom lock resource -resource_name meta_resource
   resource_lock=$?
   sleep 5;
done
while [ $mapped -lt 64 ] ;
do
   for port in `cat portlist.$suffix`
   do
      while [ $j -le $count ] ;
      do
         hexldevid=$decldevid
         typeset -i16 hexldevid
         hldevid=`echo $hexldevid | awk -F"#" '{print $2}'`
         print raidcom add lun -port $port -ldev_id $hldevid
         raidcom add lun -port $port -ldev_id $decldevid
         decldevid=$(($decldevid+1));
         j=$(($j+1));
         mapped=$(($mapped+1));
      done
      j=1;
   done
done
raidcom unlock resource -resource_name meta_resource
exit
```

The four "portlist" files below should be created with a standard text editor such as "vi." The text files should be stored in the same directory as the mml.ksh script described on page 74 of this appendix.

portlist.cb26

```
cl1-a
cl1-b
cl1-c
cl1-d
cl1-e
cl1-f
cl1-g
cl1-h
```

portlist.cb27

```
cl2-a
cl2-b
cl2-c
cl2-d
cl2-e
cl2-f
cl2-g
cl2-h
```

portlist.cb28

```
cl1-j
cl1-k
cl1-l
cl1-m
cl1-n
cl1-p
cl1-q
cl1-r
```

portlist.cb29

```
cl2-j
cl2-k
cl2-l
cl2-m
cl2-n
cl2-p
cl2-q
cl2-r
```

pvcreate.sh

```
#!/bin/bash

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

mapsd2ldev.ksh

```
#!/bin/ksh
#For example, mapsd2ldev.ksh 3 4
```

```
nasu=$1
nsubasu=$2
j=1;
asu=1;
sasu=1;
while [ $j -le $nasu ] ;
do
   k=1;
   while [ $k -le $nsubasu ] ;
   do
     print asu$asu"_"$sasu
     ls /dev/sd*|/HORCM/usr/bin/inqraid -CLI -fn|awk '{print "/dev/"$1" " $9}'|grep
asu$asu"_"$sasu |sort -k2.1 >> "asu"$asu"_"$sasu"map"
     sasu=$(($sasu+1));
     k=$(($k+1));
   done
   sasu=1;
   asu=$(($asu+1));
   j=$(($j+1));
done
exit
```

vgcreate.ksh

```
#!/bin/ksh
nasu=$1
nsubasu=$2
j=1;
asu=1;
sasu=1;
while [ $j -le $nasu ] ;
do
   k=1;
   while [ $k -le $nsubasu ] ;
   do
     print vgcreate "vgasu"$asu"_"$sasu `awk '{print $1}' < "asu"$asu"_"$sasu"map"`
     vgcreate "vgasu"$asu"_"$sasu `awk '{print $1}' < "asu"$asu"_"$sasu"map"`
     sasu=$(($sasu+1));
     k=$(($k+1));
   done
   sasu=1;
   asu=$(($asu+1));
   j=$(($j+1));
done
exit
```

lvcreate.ksh

```
#!/bin/ksh
lvcreate -l 419392 -i 64 -I 4M -n lvasu1_1 vgasu1_1
lvcreate -l 419392 -i 64 -I 4M -n lvasu1_2 vgasu1_2
lvcreate -l 419392 -i 64 -I 4M -n lvasu1_3 vgasu1_3
lvcreate -l 419392 -i 64 -I 4M -n lvasu1_4 vgasu1_4
lvcreate -l 419392 -i 64 -I 4M -n lvasu2_1 vgasu2_1
lvcreate -l 419392 -i 64 -I 4M -n lvasu2_2 vgasu2_2
lvcreate -l 419392 -i 64 -I 4M -n lvasu2_3 vgasu2_3
lvcreate -l 419392 -i 64 -I 4M -n lvasu2_4 vgasu2_4
lvcreate -l 419392 -i 64 -I 4M -n lvasu3_1 vgasu3_1
lvcreate -l 419392 -i 64 -I 4M -n lvasu3_2 vgasu3_2
lvcreate -l 419392 -i 64 -I 4M -n lvasu3_3 vgasu3_3
lvcreate -l 419392 -i 64 -I 4M -n lvasu3_4 vgasu3_4
exit
```

lvactivate.ksh

```
#!/bin/ksh
for fi in `lvscan 2>&1| grep -v duplicate | grep inactive | awk -F"'" '{print $2}'`
do
  lvchange -ay $fi
done
```

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=asu1_1,lun=/dev/vg1_1/lvasu1_1,size=1306219813799,openflags=o_direct
sd=asu1_2,lun=/dev/vg1_2/lvasu1_2,size=1306219813799,openflags=o_direct
sd=asu1_3,lun=/dev/vg1_3/lvasu1_3,size=1306219813799,openflags=o_direct
sd=asu1_4,lun=/dev/vg1_4/lvasu1_4,size=1306219813799,openflags=o_direct
sd=asu2_1,lun=/dev/vg2_1/lvasu2_1,size=1306219813799,openflags=o_direct
sd=asu2_2,lun=/dev/vg2_2/lvasu2_2,size=1306219813799,openflags=o_direct
sd=asu2_3,lun=/dev/vg2_3/lvasu2_3,size=1306219813799,openflags=o_direct
sd=asu2_4,lun=/dev/vg2_4/lvasu2_4,size=1306219813799,openflags=o_direct
sd=asu3_1,lun=/dev/vg3_1/lvasu3_1,size=290271069733,openflags=o_direct
sd=asu3_2,lun=/dev/vg3_2/lvasu3_2,size=290271069733,openflags=o_direct
sd=asu3_3,lun=/dev/vg3_3/lvasu3_3,size=290271069733,openflags=o_direct
sd=asu3_4,lun=/dev/vg3_4/lvasu3_4,size=290271069733,openflags=o_direct

wd=wd_raw,sd=(asu*),seekpct=eof

rd=rd_rd1,wd=wd_raw,elapsed=144000,interval=5,forxfersize=(512k),forrdpct=(0),forthr
eads=(1),iorate=max
```

Primary Metrics Test, and Repeatability Tests

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

```
host=master
slaves=(slave1,slave2,slave3,slave4,slave5,slave6,slave7,slave8,slave9,slave10,slave
11,slave12,slave13,slave14,slave15,slave16,slave17,slave18,slave19,slave20,slave21,s
lave22,slave23,slave24,slave25,slave26,slave27,slave28,slave29,slave30,slave31,slave
32,slave33,slave34,slave35,slave36,slave37,slave38,slave39,slave40,slave41,slave42,s
lave43,slave44,slave45,slave46,slave47,slave48,slave49,slave50,slave51,slave52,slave
53,slave54,slave55,slave56,slave57,slave58,slave59,slave60,slave61,slave62,slave63,s
lave64,slave65,slave66,slave67,slave68,slave69,slave70,slave71,slave72,slave73,slave
74,slave75,slave76,slave77,slave78,slave79,slave80,slave81,slave82,slave83,slave84,s
lave85,slave86,slave87,slave88,slave89,slave90,slave91,slave92,slave93,slave94,slave
95,slave96,slave97,slave98,slave99,slave100,slave101,slave102,slave103,slave104,slav
e105,slave106,slave107,slave108,slave109,slave110,slave111,slave112,slave113,slave11
4,slave115,slave116,slave117,slave118,slave119,slave120,slave121,slave122,slave123,s
lave124,slave125,slave126,slave127,slave128)
sd=asu1_1,lun=/dev/vg1_1/lvasu1_1,size=1306219813799
sd=asu1_2,lun=/dev/vg1_2/lvasu1_2,size=1306219813799
sd=asu1_3,lun=/dev/vg1_3/lvasu1_3,size=1306219813799
sd=asu1_4,lun=/dev/vg1_4/lvasu1_4,size=1306219813799
sd=asu2_1,lun=/dev/vg2_1/lvasu2_1,size=1306219813799
sd=asu2_2,lun=/dev/vg2_2/lvasu2_2,size=1306219813799
sd=asu2_3,lun=/dev/vg2_3/lvasu2_3,size=1306219813799
sd=asu2_4,lun=/dev/vg2_4/lvasu2_4,size=1306219813799
sd=asu3_1,lun=/dev/vg3_1/lvasu3_1,size=290271069733
sd=asu3_2,lun=/dev/vg3_2/lvasu3_2,size=290271069733
sd=asu3_3,lun=/dev/vg3_3/lvasu3_3,size=290271069733
sd=asu3_4,lun=/dev/vg3_4/lvasu3_4,size=290271069733
```

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="-Xms4000m -Xmx4000m -Xss128m"
sd=asu1_1,lun=/dev/vg1_1/lvasu1_1,size=1306219813799
sd=asu1_2,lun=/dev/vg1_2/lvasu1_2,size=1306219813799
sd=asu1_3,lun=/dev/vg1_3/lvasu1_3,size=1306219813799
sd=asu1_4,lun=/dev/vg1_4/lvasu1_4,size=1306219813799
sd=asu2_1,lun=/dev/vg2_1/lvasu2_1,size=1306219813799
sd=asu2_2,lun=/dev/vg2_2/lvasu2_2,size=1306219813799
sd=asu2_3,lun=/dev/vg2_3/lvasu2_3,size=1306219813799
sd=asu2_4,lun=/dev/vg2_4/lvasu2_4,size=1306219813799
sd=asu3_1,lun=/dev/vg3_1/lvasu3_1,size=290271069733
sd=asu3_2,lun=/dev/vg3_2/lvasu3_2,size=290271069733
sd=asu3_3,lun=/dev/vg3_3/lvasu3_3,size=290271069733
sd=asu3_4,lun=/dev/vg3_4/lvasu3_4,size=290271069733
```

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=200
sd=asu1_1,lun=/dev/vg1_1/lvasu1_1,size=1306219813799
sd=asu1_2,lun=/dev/vg1_2/lvasu1_2,size=1306219813799
sd=asu1_3,lun=/dev/vg1_3/lvasu1_3,size=1306219813799
sd=asu1_4,lun=/dev/vg1_4/lvasu1_4,size=1306219813799
sd=asu2_1,lun=/dev/vg2_1/lvasu2_1,size=1306219813799
sd=asu2_2,lun=/dev/vg2_2/lvasu2_2,size=1306219813799
sd=asu2_3,lun=/dev/vg2_3/lvasu2_3,size=1306219813799
sd=asu2_4,lun=/dev/vg2_4/lvasu2_4,size=1306219813799
sd=asu3_1,lun=/dev/vg3_1/lvasu3_1,size=290271069733
sd=asu3_2,lun=/dev/vg3_2/lvasu3_2,size=290271069733
sd=asu3_3,lun=/dev/vg3_3/lvasu3_3,size=290271069733
sd=asu3_4,lun=/dev/vg3_4/lvasu3_4,size=290271069733

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=TR1-5s_SPC-2-persist-w,streams=403
```

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

```
host=localhost,jvms=8,maxstreams=200
sd=asu1_1,lun=/dev/vg1_1/lvasu1_1,size=1306219813799
sd=asu1_2,lun=/dev/vg1_2/lvasu1_2,size=1306219813799
sd=asu1_3,lun=/dev/vg1_3/lvasu1_3,size=1306219813799
sd=asu1_4,lun=/dev/vg1_4/lvasu1_4,size=1306219813799
sd=asu2_1,lun=/dev/vg2_1/lvasu2_1,size=1306219813799
sd=asu2_2,lun=/dev/vg2_2/lvasu2_2,size=1306219813799
sd=asu2_3,lun=/dev/vg2_3/lvasu2_3,size=1306219813799
sd=asu2_4,lun=/dev/vg2_4/lvasu2_4,size=1306219813799
sd=asu3_1,lun=/dev/vg3_1/lvasu3_1,size=290271069733
```

```
sd=asu3_2,lun=/dev/vg3_2/lvasu3_2,size=290271069733
sd=asu3_3,lun=/dev/vg3_3/lvasu3_3,size=290271069733
sd=asu3_4,lun=/dev/vg3_4/lvasu3_4,size=290271069733

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

rd=default,buffers=1,rdpct=100,xfersize=1024k
rd=TR1-200s_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. ***slave1…slave128***, and the **master** parameter value, which was either ***localhost*** for the Slave JVMs executing on the Master Host System or ***172.17.17.26*** for Slave JVMs executing on the Slave Host Systems.

```
host=slave1
master=localhost
sd=asu1_1,lun=/dev/vg1_1/lvasu1_1,size=1306219813799
sd=asu1_2,lun=/dev/vg1_2/lvasu1_2,size=1306219813799
sd=asu1_3,lun=/dev/vg1_3/lvasu1_3,size=1306219813799
sd=asu1_4,lun=/dev/vg1_4/lvasu1_4,size=1306219813799
sd=asu2_1,lun=/dev/vg2_1/lvasu2_1,size=1306219813799
sd=asu2_2,lun=/dev/vg2_2/lvasu2_2,size=1306219813799
sd=asu2_3,lun=/dev/vg2_3/lvasu2_3,size=1306219813799
sd=asu2_4,lun=/dev/vg2_4/lvasu2_4,size=1306219813799
sd=asu3_1,lun=/dev/vg3_1/lvasu3_1,size=290271069733
sd=asu3_2,lun=/dev/vg3_2/lvasu3_2,size=290271069733
sd=asu3_3,lun=/dev/vg3_3/lvasu3_3,size=290271069733
sd=asu3_4,lun=/dev/vg3_4/lvasu3_4,size=290271069733
```

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

ASU Pre-Fill, Primary Metrics Test, Repeatability and Persistence Test

The following script was used to execute the required ASU pre-fill, Primary Metrics Test *(Sustainability Test Phase, IOPS Test Phase, and Response Time Ramp Test Phase)*, Repeatability Test *(Repeatability Test Phase 1 and Repeatability Test Phase 2)*, a reduced level SPC-1 Persistence Test Run 1 and Persistence SPC-2 Persistence Test Run 1 in an uninterrupted sequence when invoked with a parameter value of 1 for the "run phase".

The same script was used to execute SPC-2 Persistence Test Run 2 when invoked with a parameter value greater than 1 for the "run phase".

```
#!/bin/ksh
BSUs=$1
time=$2
phase=$3
startdev=1;
inc=1;
count=16;
function start_slaves {
  for host in `cat ./hosts`
  do
    cmd="/home/benchmark/vdbench/output/spc1/startem.ksh $startdev $inc $count&";
    print "ssh $host $cmd";
    ssh 2>&1 > /dev/null $host "$cmd"&
    startdev=$(($startdev+$count));
  done
}
if [ $# -lt 3 ] ; then
   print "usage: run_all.ksh <BSUs> <time in seconds> <run phase 1 or 2>"
   exit
fi
if [ $phase -eq 1 ] ; then
  export CLASSPATH=/home/benchmark/vdbench/spc1
  export LD_LIBRARY_PATH=/home/benchmark/vdbench/spc1
  cd /home/benchmark/vdbench
  vdbench -f /scripts/charlie/parmfiles/parmfile.spc1.fill -o
output/cb26.master/spc1.prefill
  cd /home/benchmark/vdbench/output/cb26.master
  start_slaves
  java metrics -b $BSUs -t $time -s 480
  java repeat1 -b $BSUs
  java repeat2 -b $BSUs
  /usr/bin/killall java
  mv ./spc1.cfg ./spc1.cfg.128
  mv ./spc1.cfg.1 ./spc1.cfg
  PBSUs=$((BSUs / 4));
  java -Xms4000m -Xmx4000m -Xss128m persist1 -b $PBSUs
  export SHLIB_PATH=/home/benchmark/vdbench/spc2
  export CLASSPATH=/home/benchmark/vdbench/spc2
  export LD_LIBRARY_PATH=/home/benchmark/vdbench/spc2
  /home/benchmark/vdbench/spc2/spc2 -f persistw.cfg -init -o persistinit
  /home/benchmark/vdbench/spc2/spc2 -f persistw.cfg -o persist1-spc2
else
  cd /home/benchmark/vdbench/output/cb26.master
  export SHLIB_PATH=/home/benchmark/vdbench/spc2
  export CLASSPATH=/home/benchmark/vdbench/spc2
  export LD_LIBRARY_PATH=/home/benchmark/vdbench/spc2
```

```
    /home/benchmark/vdbench/spc2/spc2 -f persistr.cfg -o persist2-spc2
    mv ./spc1.cfg ./spc1.cfg.1
    mv ./spc1.cfg.128 ./spc1.cfg
  fi
  exit
```

startem.ksh

The following script was used to invoke the Slave JVMs.

```
#!/bin/ksh
startdev=$1;
inc=$2
count=$3
j=1;
while [ $j -le $count ] ;
do
   cd /home/benchmark/vdbench/output/spc1.`hostname`/slaveout.$startdev
   java spc1 -f /home/benchmark/vdbench/spc1/slave$startdev.cfg&
   startdev=$(($startdev+$inc));
   j=$(($j+1));
done
exit
```

APPENDIX F: THIRD-PARTY QUOTATIONS

Brocade 5320 Switch

BROCADE

09/04/13

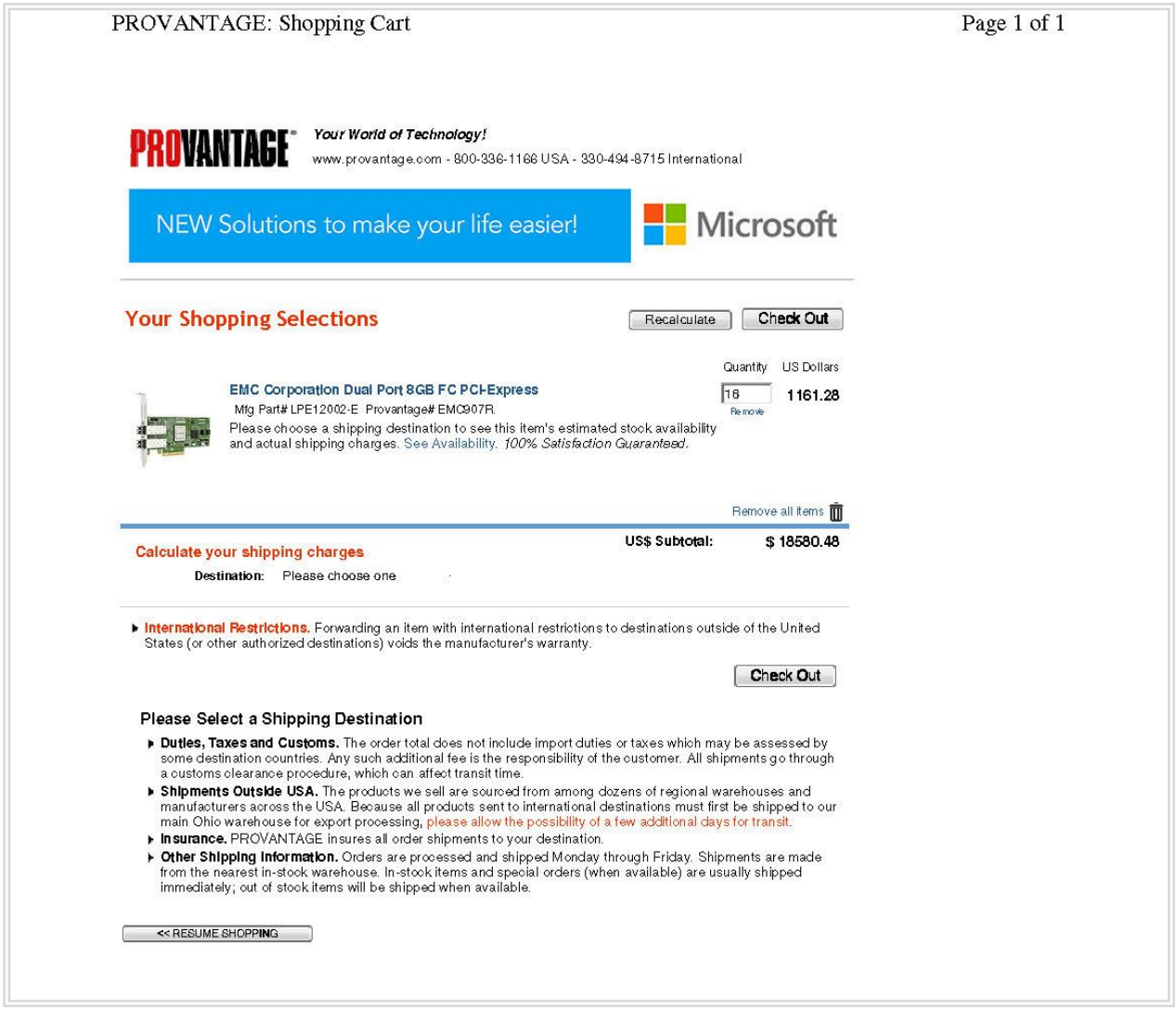
TO: Kien Tran

POs should be e-mailed to: HDS-OMDistribution@brocade.com

Product	Description	QTY	HDS Unit Cost	Total
HD-5320-0008	Brocade 5320 switch w/ 48 active ports,48 SWL 8Gb BR SFPs, slide rack mount, EGM,	1	$ 19,621.00	$ 19,621.00
(-M)	3 year support	1	$ 5,193.00	$ 5,193.00
HD-5320-0008	Brocade 5320 switch w/ 48 active ports,48 SWL 8Gb BR SFPs, slide rack mount, EGM,	1	$ 19,621.00	$ 19,621.00
(-M)	13 mos maintenenace	1	$ 1,731.00	$ 1,731.00
XBR-MENTPOD8-01	Port on demand 16port upgrade, 16 SWL 8GB BR SFP's	2	$ 6,965.00	$ 13,930.00
Total				$ 60,096.00

Yadira Aparicio
Account Manager
Brocade Communications

8 Gbps Dual-Port PCIe (LPE12002 E) HBAs



PROVANTAGE: Shopping Cart Page 1 of 1

PROVANTAGE *Your World of Technology!*
www.provantage.com - 800-336-1166 USA - 330-494-8715 International

NEW Solutions to make your life easier! Microsoft

Your Shopping Selections Recalculate Check Out

	Quantity	US Dollars
EMC Corporation Dual Port 8GB FC PCI-Express Mfg Part# LPE12002-E Provantage# EMC907R. Please choose a shipping destination to see this item's estimated stock availability and actual shipping charges. See Availability. *100% Satisfaction Guaranteed.*	16 Remove	1161.28

Remove all items

Calculate your shipping charges
Destination: Please choose one

US$ Subtotal: $ 18580.48

▸ **International Restrictions.** Forwarding an item with international restrictions to destinations outside of the United States (or other authorized destinations) voids the manufacturer's warranty.

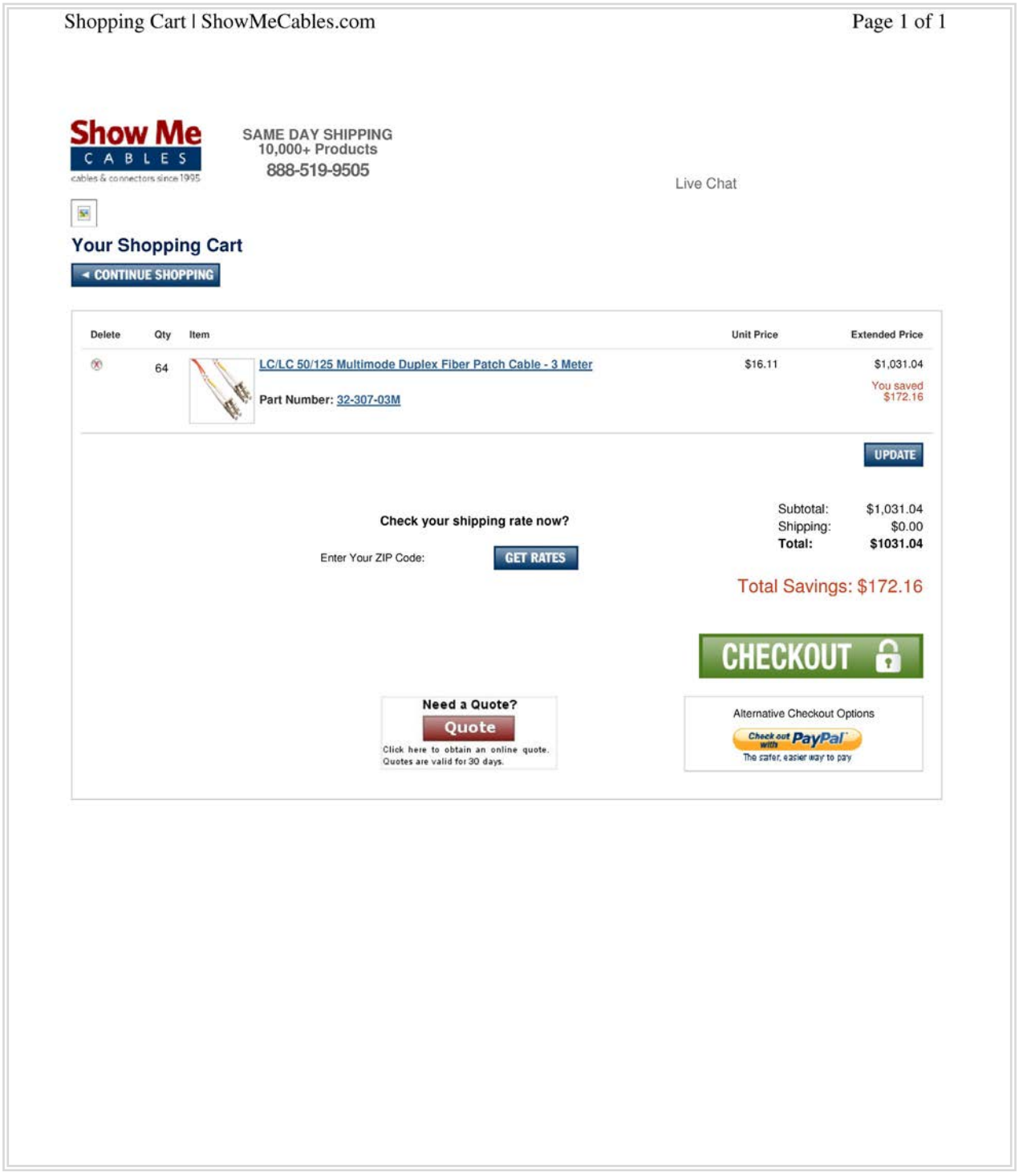
Check Out

Please Select a Shipping Destination

- **Duties, Taxes and Customs.** The order total does not include import duties or taxes which may be assessed by some destination countries. Any such additional fee is the responsibility of the customer. All shipments go through a customs clearance procedure, which can affect transit time.
- **Shipments Outside USA.** The products we sell are sourced from among dozens of regional warehouses and manufacturers across the USA. Because all products sent to international destinations must first be shipped to our main Ohio warehouse for export processing, please allow the possibility of a few additional days for transit.
- **Insurance.** PROVANTAGE insures all order shipments to your destination.
- **Other Shipping Information.** Orders are processed and shipped Monday through Friday. Shipments are made from the nearest in-stock warehouse. In-stock items and special orders (when available) are usually shipped immediately; out of stock items will be shipped when available.

<< RESUME SHOPPING

LC/LC 50/125 Fiber Cables


Shopping Cart | ShowMeCables.com Page 1 of 1

Show Me CABLES
cables & connectors since 1995

SAME DAY SHIPPING
10,000+ Products
888-519-9505

Live Chat

Your Shopping Cart

◄ CONTINUE SHOPPING

Delete	Qty	Item	Unit Price	Extended Price
⊗	64	LC/LC 50/125 Multimode Duplex Fiber Patch Cable - 3 Meter Part Number: 32-307-03M	$16.11	$1,031.04 You saved $172.16

UPDATE

Check your shipping rate now?

Enter Your ZIP Code: GET RATES

Subtotal:	$1,031.04
Shipping:	$0.00
Total:	**$1031.04**

Total Savings: $172.16

CHECKOUT

Need a Quote?
Quote
Click here to obtain an online quote.
Quotes are valid for 30 days.

Alternative Checkout Options
Check out with PayPal
The safer, easier way to pay