SPC BENCHMARK 1™
FULL DISCLOSURE REPORT

IBM CORPORATION
IBM POWER 780 SERVER *(WITH SSDS)*

SPC-1 V1.13

Submitted for Review: April 11, 2013
Submission Identifier: A00130

First Edition – April 2013

Trademarks

SPC Benchmark-1, SPC-1, SPC-1 IOPS, SPC-1 LRT and SPC-1 Price-Performance are trademarks of the Storage Performance Council. IBM, Power 7+ and the IBM logo are trademarks or registered trademarks of IBM 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

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

April 10, 2013

The SPC Benchmark 1™ Reported Data listed below for the IBM Power 780 server *(with SSDs)* was produced in compliance with the SPC Benchmark 1™ v1.13 Remote Audit requirements.

SPC Benchmark 1™ v1.13 Reported Data	
Tested Storage Product (TSP) Name: IBM Power 780 server *(with SSDs)*	
Metric	**Reported Result**
SPC-1 IOPS™	780,081.02
SPC-1 Price-Performance	$4.56/SPC-1 IOPS™
Total ASU Capacity	28,400.000 GB
Data Protection Level	Protected 1 *(Mirroring)*
Total Price (including three-year maintenance)	$3,557,709.00
Currency Used	U.S. Dollars
Target Country for availability, sales and support	USA

The following SPC Benchmark 1™ Remote Audit requirements were reviewed and found compliant with 1.13 of the SPC Benchmark 1™ specification:

- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository storage items were verified by information supplied by IBM Corporation:
  - ✓ Physical Storage Capacity and requirements.
  - ✓ Configured Storage Capacity and requirements.
  - ✓ Addressable Storage Capacity and requirements.
  - ✓ Capacity of each Logical Volume and requirements.
  - ✓ Capacity of each Application Storage Unit (ASU) and requirements.
- 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).
- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters that were changed from default values.
- SPC-1 Workload Generator commands and parameters used for the audited SPC Test Runs.
- The following Host System requirements were verified by information supplied by IBM Corporation:
  - ✓ The type of Host System including the number of processors and main memory.
  - ✓ The presence and version number of the SPC-1 Workload Generator on the Host System.
  - ✓ The TSC boundary within the Host System.
- The Test Results Files and resultant Summary Results Files received from IBM Corporation for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4 and 5 of the SPC-1 Benchmark Specification:
  - ✓ "Ramp-Up" Test Run
  - ✓ Data Persistence Test
  - ✓ Sustainability Test Phase
  - ✓ IOPS Test Phase
  - ✓ Response Time Ramp Test Phase
  - ✓ Repeatability Test
- There were no differences between the Tested Storage Configuration and Priced Storage Configuration.
- The submitted pricing information met all of the requirements and constraints of Clause 8 of the SPC-1 Benchmark Specification.
- The Full Disclosure Report (FDR) met all of the requirements in Clause 9 of the SPC-1 Benchmark Specification.
- This successfully audited SPC measurement is not subject to an SPC Confidential Review.

Audit Notes:

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

Vice President and Business Line Executive, IBM Power Enterprise Systems
Systems & Technology Group
294 Route 100,
Somers, NY 10589
Phone 914-766-4949

March 8, 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 IBM Power 780 with EXP30 Flash Storage

IBM Corporation is the SPC-1 Test Sponsor for the above listed product. To the best of our knowledge and belief, the required SPC-1 benchmark results and materials we have submitted for that product are complete, accurate, and in full compliance with Version 1.13 of the SPC-1 benchmark specification.

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

Sincerely,

Terri Virnig
Vice President and Business Line Executive
IBM Power Enterprise Systems

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact	IBM Corporation – http://www.ibm.com Bruce McNutt – bmcnutt@us.ibm.com 650 Harry Road San Jose, CA 95120 Phone: (408) 927-2717 FAX: (408) 927-2050
Test Sponsor Alternate Contact	IBM Corporation – http://www.ibm.com Clark Anderson – clarkand@us.ibm.com 3605 Hwy 52 N Rochester, MN 55901 Phone: (507) 253-1427 FAX: (507) 253-2482
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	V1.13
SPC-1 Workload Generator revision number	V2.3.0
Date Results were first used publicly	April 11, 2013
Date the FDR was submitted to the SPC	April 11, 2013
Date the Priced Storage Configuration is available for shipment to customers	May 2, 2012
Date the TSC completed audit certification	April 10, 2013

Tested Storage Product (TSP) Description

Designed for virtualized consolidation of business critical workloads, the IBM® Power® 780 Server (Model 9179-MHD) is a symmetric multiprocessing, rack-mounted server. This modular system uses one to four enclosures that are four EIA units tall and housed in a 19-inch rack. Each enclosure contains four powerful POWER7+ processor modules, high density memory DIMMs using 4 Gb technology, and a high-performance PCIe Gen2 I/O backplane.

The EXP30 Ultra SSD I/O Drawer (#EDR1) enables the attachment of up to 30 solid state drives (SSDs) in just 1U of rack space without using PCIe slots. This ultra-dense SSD option is attached using a new GX++ 2-port, PCIe2 x8 Adapter (#1914), which provides a pair of PCIe2 connections from the EXP30 drawer directly into a high bandwidth server bus (GX++). A Power 780 server can support the attachment of up to 8 EXP30 drawers.

Summary of Results

SPC-1 Reported Data	
Tested Storage Product (TSP) Name: IBM Power 780 server *(with SSDs)*	
Metric	**Reported Result**
SPC-1 IOPS™	780,081.02
SPC-1 Price-Performance™	$4.56/SPC-1 IOPS™
Total ASU Capacity	28,400.000 GB
Data Protection Level	Protected 1 *(Mirroring)*
Total Price	$3,557,709.00
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 1** using ***Mirroring*** configures two or more identical copies of user data.

> ***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.*

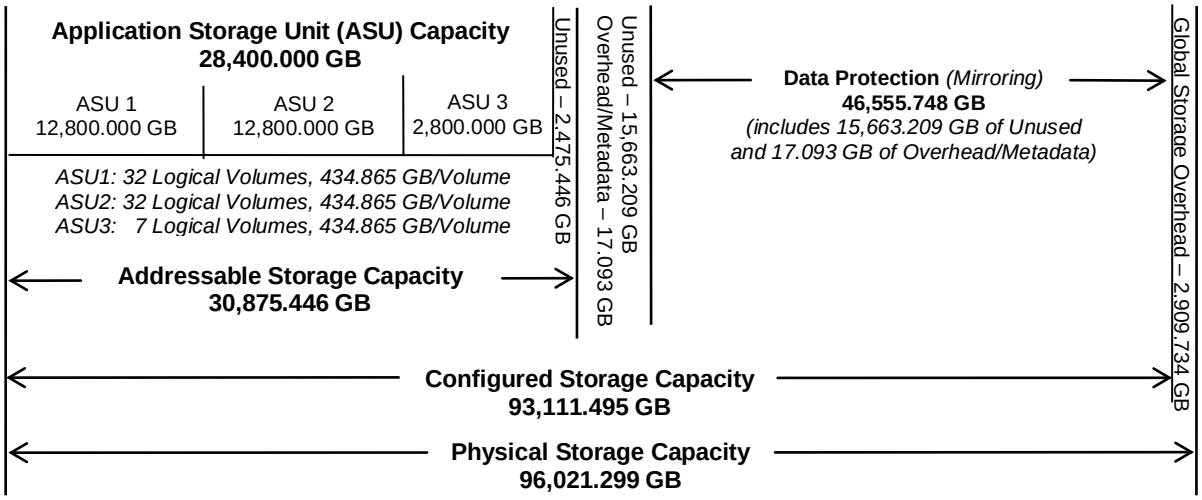
Total Price includes the cost of the Priced Storage Configuration plus three years of hardware maintenance and software support as detailed on page 14.

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 diagram *(not to scale)* and table document the various storage capacities, used in this benchmark, and their relationships, as well as the storage utilization values required to be reported.



SPC-1 Storage Capacity Utilization	
Application Utilization	29.58%
Protected Application Utilization	61.75%
Unused Storage Ratio	37.78%

Application Utilization: Total ASU Capacity *(28,400.000 GB)* divided by Physical Storage Capacity *(96,021.299 GB)*.

Protected Application Utilization: Total ASU Capacity *(28,400.000 GB)* plus total Data Protection Capacity *(46,555.748 GB)* minus unused Data Protection Capacity *(15,663.209 GB)* divided by Physical Storage Capacity *(96,021.299 GB)*.

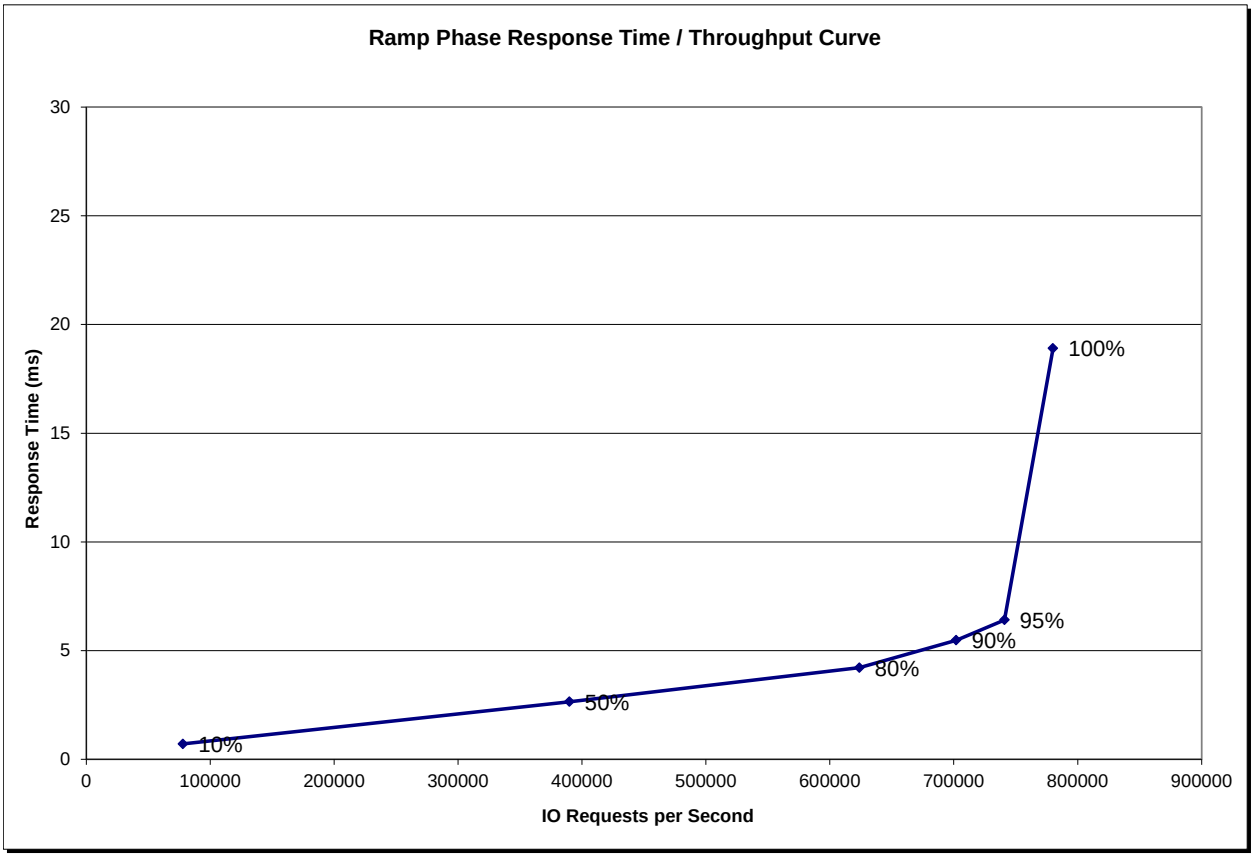
Unused Storage Ratio: Total Unused Capacity *(36,277.310 GB)* divided by Physical Storage Capacity *(96,021.299 GB)* and may not exceed 45%.

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

Response Time – Throughput Curve

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

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



Response Time – Throughput Data

	10% Load	50% Load	80% Load	90% Load	95% Load	100% Load
I/O Request Throughput	77,992.95	389,956.78	623,942.41	702,036.09	740,956.08	780,081.02
Average Response Time (ms):						
All ASUs	0.71	2.65	4.22	5.48	6.41	18.90
ASU-1	0.66	2.59	4.14	5.38	6.31	18.77
ASU-2	0.70	2.64	4.22	5.47	6.42	18.90
ASU-3	0.83	2.79	4.40	5.68	6.63	19.16
Reads	0.52	2.41	3.90	5.12	6.03	18.43
Writes	0.84	2.81	4.43	5.71	6.66	19.20

Priced Storage Configuration Pricing

Product	Description	Qty	Unit Price	Extended Price
9179-MHD	Server 1:9179 Model MHD	1	$10,195.00	$10,195.00
1769	Integrated Multifunction card with SR Optical	4	$3,358.00	$13,432.00
1886	146GB 15K RPM SFF SAS Disk Drive (AIX/Linux)	1	$652.00	$652.00
1914	GX++ 2-port PCIe2 x8 Adapter	8	$3,300.00	$26,400.00
3671	Serv Interface Cable- 2, 3, and 4 Enclosure	1	$2,000.00	$2,000.00
3672	Serv Interface Cable- 3 and 4 Enclosure	1	$3,000.00	$3,000.00
3673	Serv Interface Cable- 4 Enclosure	1	$4,000.00	$4,000.00
3716	Processor Cable, 2--4-Drawer System, 4 socket	1	$5,000.00	$5,000.00
3717	Processor Cable, 3--4-Drawer System, 4 socket	1	$10,000.00	$10,000.00
3718	Processor Cable, 4-Drawer System, 4 socket	1	$12,000.00	$12,000.00
5287	PCIe2 2-port 10GbE SR Adapter	4	$3,930.00	$15,720.00
5532	System AC Power Supply, 1925 W	8	$1,502.00	$12,016.00
5652	Disk/Media Backplane	4	$4,000.00	$16,000.00
5665	FSP/Clock Pass Through Card	2	$900.00	$1,800.00
5771	SATA Slimline DVD-RAM Drive	1	$392.00	$392.00
5899	PCIe2 4-port 1GbE Adapter	4	$394.00	$1,576.00
6006	Power Control Cable (SPCN) - 3 meter	1	$52.00	$52.00
6577	Power Cable - Drawer to IBM PDU, 200-240V/10A	24	$19.00	$456.00
EB95	System CEC Enclosure	4	$12,000.00	$48,000.00
EC53	Operator Panel	1	$1,000.00	$1,000.00
EDR1	EXP30 Ultra SSD I/O Drawer	8	$32,092.00	$256,736.00
EM42	0/128GB CoD DDR3 Memory (4X32GB) DIMMS	16	$2,200.00	$35,200.00
EMA3	Activation of 100 GB DDR3 POWER7+ Memory	10	$18,500.00	$185,000.00
EN07	PCIe x8 Cable 3m	16	$445.00	$7,120.00
EPH2	0/32 Core POWER7+, 16 DDR3 Memory Slots	4	$77,877.00	$311,508.00
EPHC	1-Core Activation for Processor Feature EPH2	64	$5,678.00	$363,392.00
ES02	387GB 1.8in SAS SSD for AIX/Linux with eMLC	240	$7,990.00	$1,917,600.00
EU09	Service Processor-3	2	$4,000.00	$8,000.00
7014-T42	Rack 1:Rack Model T42	1	$3,970.00	$3,970.00
6069	Front door (Black) for High Perforation (2m racks)	1	$550.00	$550.00
6098	Side Panel (Black)	2	$150.00	$300.00
6492	PDU to Wall Powercord 14'	4	$400.00	$1,600.00
7188	Power Dist Unit-Side Mount	3	$1,000.00	$3,000.00
ESC1	Rack Shipping and Handling - A	1	$400.00	$400.00
7316-TF3	Rack-Mounted Flat Panel Console Kit	1	$3,459.00	$3,459.00
7042-CR7	HMC Rack-mounted Hardw.Mgmt.Console	1	$8,735.00	$8,735.00
5692-A6P	System Software / DVD Process Charge	2	$118.00	$236.00
5765-G99	IBM AIX Enterprise Edition Version 7.1 per processor	64	$4,225.00	$270,400.00
5765-PVE	PowerVM Enterprise Edition per processor	64	$2,800.00	$179,200.00
5771-AEZ	AIX SW Maintenance, 1 Year per processor	192	$1,326.00	$254,592.00
5771-PVE	PowerVM Enterprise Edition SW Maintenance: 1 Yr	192	$884.00	$169,728.00
5771-RS1	HMC SW Maintenance, 1 year	3	$337.00	$1,011.00
	Monthly HW Maintenance	24	$24,091.00	$578,184.00
	Total Extended Price			***$4,743,612.00***
	Field Delegation Discount			25.00%
	Discounted Price			**$3,557,709.00**

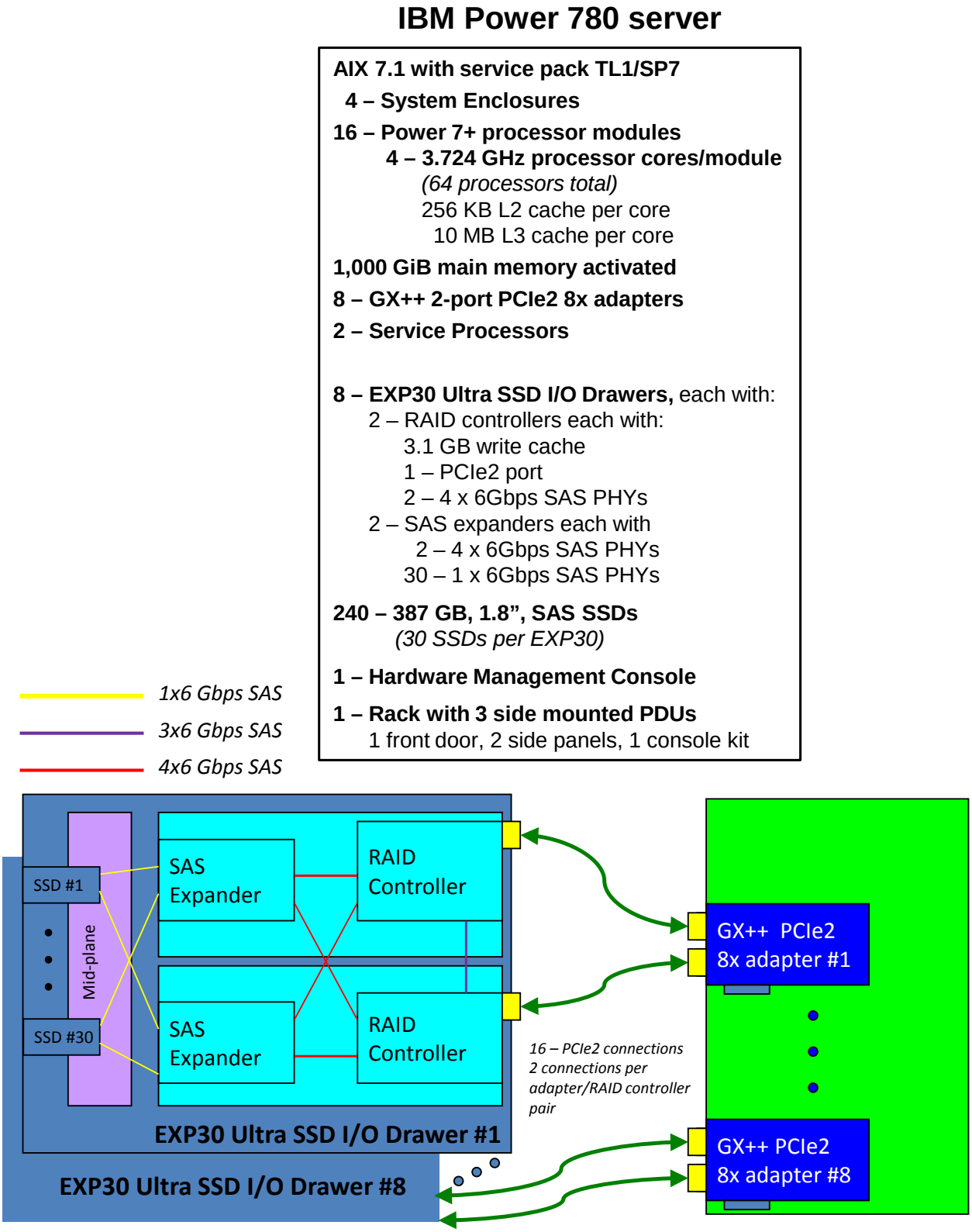
The above pricing includes hardware maintenance and software support for three years, 7 days per week, 24 hours per day. The hardware maintenance and software support provides the following:

- 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

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

Priced Storage Configuration Diagram



Priced Storage Configuration Components

Priced Storage Configuration:
4 – System Enclosures
IBM Power 780 server with AIX 7.1 with service pack TL1/SP7 16 – Power 7+ processor modules 4 – 3.724 GHz processor cores per module *(64 processors total)* 256 KB L2 cache per core 10 MB L3 cache per core 2,048 GiB main memory *(1,000 GiB activated)* 8 – GX++ 2-port PCIe2 adapters 4 – Disk/Media Backplanes 2 – Service Processors 8 – System AC Power Supplies, 1925W
8 – EXP30 Ultra SSD I/O Drawers, each with 2 – RAID controllers, each with 3.1 GB write cache 1 – PCIe2 port 2 – 4 x 6Gbps SAS PHYs 2 – SAS expanders, each with 2 – 4 x 6Gbps SAS PHYs *(to RAID controller)* 30 – 1 x 6Gbps SAS PHYs *(to SSDs)*
240 – 387 GB, 1.8”, SAS SSDs *(30 SSDs per EXP30)*
1 – Hardware Management Console
1 – Rack with 3 side mounted PDUs 1 front door, 2 side panels, 1 console kit

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

Storage Network Configuration

Clause 9.4.3.4.1

…

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

Clause 9.4.3.4.2

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

The Benchmark Configuration (BC)/Tested Storage Configuration (TSC) was configured with local storage and, as such, did not employ a storage network.

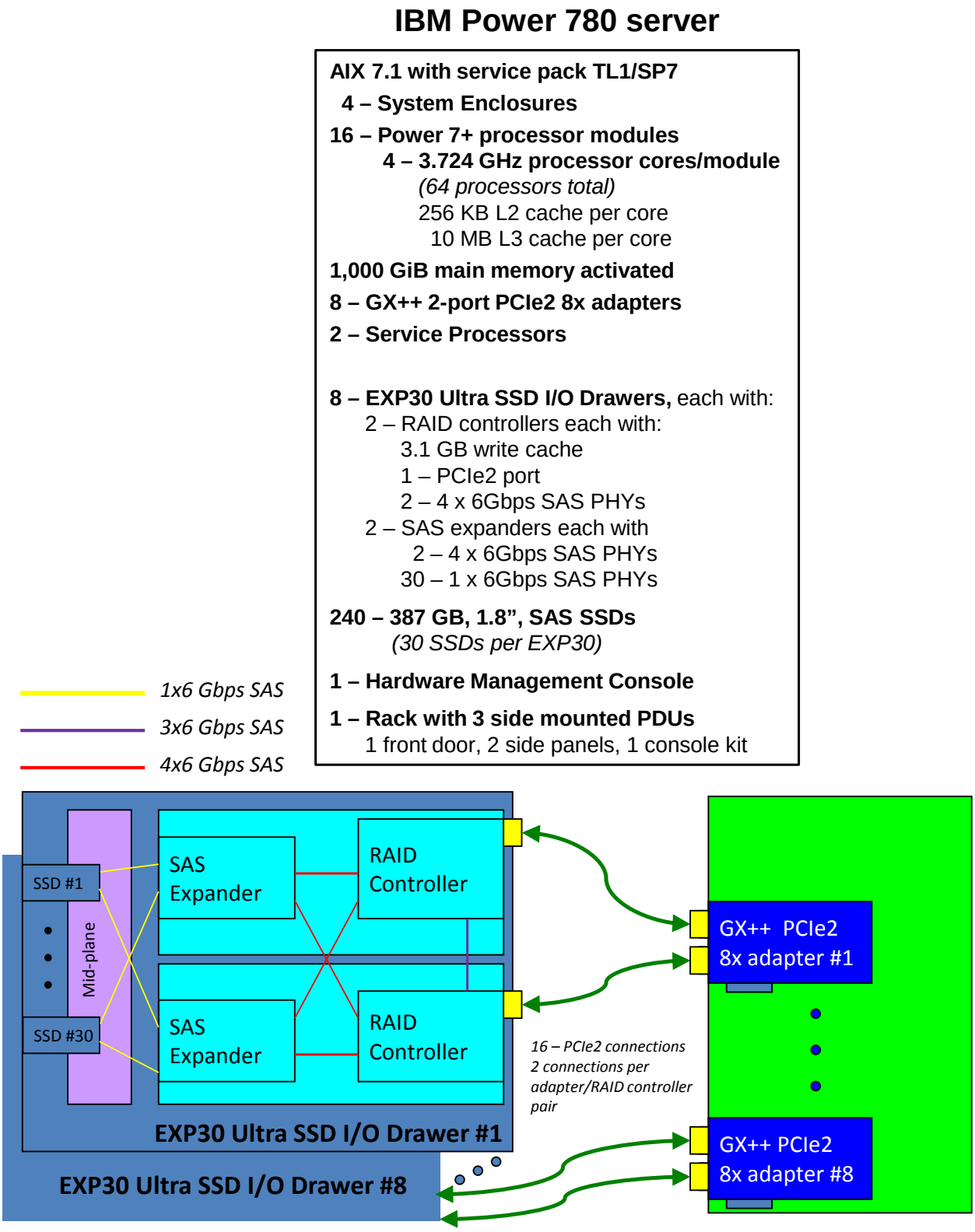
Host System(s) and Tested Storage Configuration (TSC) Table of Components

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). Table 9-10 specifies the content, format, and appearance of the table.

The Host System(s) and TSC table of components may be found on page20 *(Host System and Tested Storage Configuration Components)*.

Benchmark Configuration/Tested Storage Configuration Diagram



Host System and Tested Storage Configuration Components

Host System and Tested Storage Configuration Components:
4 – System Enclosures
IBM Power 780 server with AIX 7.1 with service pack TL1/SP7 16 – Power 7+ processor modules 4 – 3.724 GHz processor cores per module *(64 processors total)* 256 KB L2 cache per core 10 MB L3 cache per core 2,048 GiB main memory *(1,000 GiB activated)* 8 – GX++ 2-port PCIe2 adapters 4 – Disk/Media Backplanes 2 – Service Processors 8 – System AC Power Supplies, 1925W
8 – EXP30 Ultra SSD I/O Drawers, each with 2 – RAID controllers, each with 3.1 GB write cache 1 – PCIe2 port 2 – 4 x 6Gbps SAS PHYs 2 – SAS expanders, each with 2 – 4 x 6Gbps SAS PHYs *(to RAID controller)* 30 – 1 x 6Gbps SAS PHYs *(to SSDs)*
240 – 387 GB, 1.8”, SAS SSDs *(30 SSDs per EXP30)*
1 – Hardware Management Console
1 – Rack with 3 side mounted PDUs 1 front door, 2 side panels, 1 console kit

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 62 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 63 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 68.

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 68.

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

Storage Capacities and Relationships

Clause 9.4.3.6.1

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

SPC-1 Storage Capacities

The Physical Storage Capacity consisted of 96,021.229 GB distributed over 240 SSDs, each with a formatted capacity of 400.088 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 2,909.734 GB (3.03%) of the Physical Storage Capacity. There was 31,326 4.18 GB (33.64%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 91.98% of the Addressable Storage Capacity resulting in 2,475.446 GB (8.02%) of Unused Storage within the Addressable Storage Capacity. The Data Protection *(Mirroring)* capacity was 46,555.748 GB of which 28,417.093 GB was utilized. The total Unused Storage capacity was 36,277.310 GB.

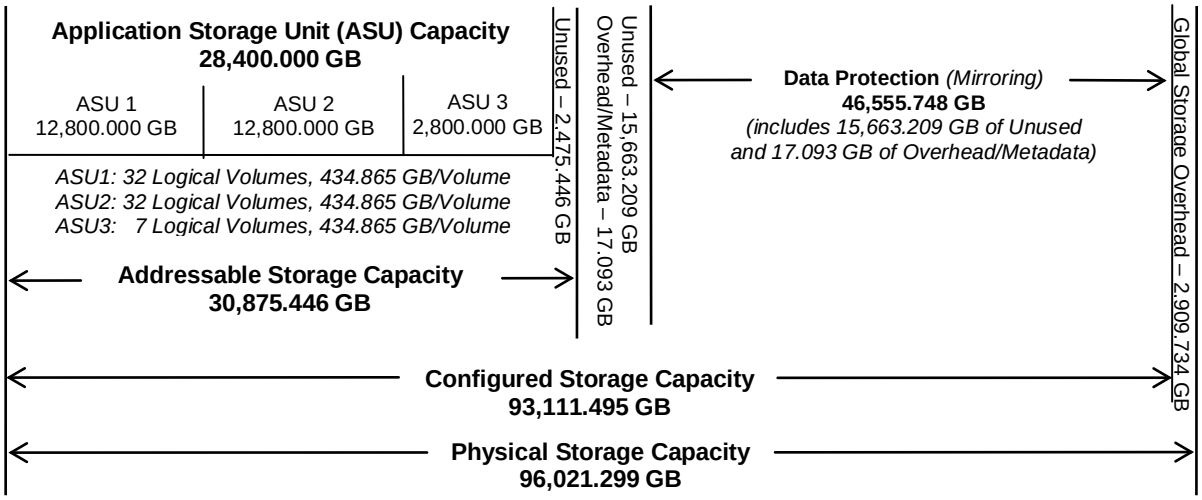
Note: The configured Storage Devices may include additional storage capacity reserved for system overhead, which is not accessible for application use. That storage capacity may not be included in the value presented for Physical Storage Capacity.

SPC-1 Storage Capacities

Storage Hierarchy Component	Units	Capacity
Total ASU Capacity	Gigabytes (GB)	28,400.000
Addressable Storage Capacity	Gigabytes (GB)	30,875.446
Configured Storage Capacity	Gigabytes (GB)	93,111.495
Physical Storage Capacity	Gigabytes (GB)	96,021.299
Data Protection *(Mirroring)*	Gigabytes (GB)	46,555.748
Required Storage	Gigabytes (GB)	34.185
Global Storage Overhead	Gigabytes (GB)	2,909.734
Total Unused Storage	Gigabytes (GB)	36,277.310

SPC-1 Storage Capacities and Relationships Illustration

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



SPC-1 Storage Hierarchy Ratios

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	91.98%	30.50%	29.58%
Required for Data Protection *(Mirroring)*		50.00%	48.48%
Addressable Storage Capacity		33.16%	32.15%
Required Storage		0.04%	0.04%
Configured Storage Capacity			96.97%
Global Storage Overhead			3.03%
Unused Storage:			
Addressable	8.02%		
Configured		33.64%	
Physical			0.00%

Storage Capacity Utilization

Clause 9.4.3.6.2

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

Clause 2.8.1

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

Clause 2.8.2

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

Clause 2.8.3

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

SPC-1 Storage Capacity Utilization	
Application Utilization	29.58%
Protected Application Utilization	61.75%
Unused Storage Ratio	37.78%

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 (34,310.000 GB)	**ASU-2 (34,310.000 GB)**	**ASU-3 (7,625.000 GB)**
10 Logical Volumes 3,684.277 GB per Logical Volume (3,431.000 GB used per Logical Volume)	10 Logical Volumes 3,684.277 GB per Logical Volume (3,431.000 GB used per Logical Volume)	1 Logical Volume 8,187.281 GB per Logical Volume (7,625.000 GB used per Logical Volume)

The Data Protection Level used for all Logical Volumes was **Protected 1** using ***Mirroring*** as described on page 11. 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 58 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

A Test Sponsor is allowed to execute one ore more Test Runs to act as a gradual, initial ramp-up for the Sustainability Test Phase. Those Test Runs must immediately precede the Sustainability Test Phase as part of an uninterrupted execution sequence.

The details for the one specified "Ramp-Up" Test Run are listed below:

	BSU Level	Start-Up Duration	Measurement Interval	IOPS	Response Time *(ms)*
Test Run 1	12000	3 minutes	720 minutes	34,921.14	46.27

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 9.4.3.7.1

For the Sustainability Test Phase the FDR shall contain:

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

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in *Appendix E: SPC-1 Workload Generator Input Parameters* on Page 78.

Sustainability Test Results File

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

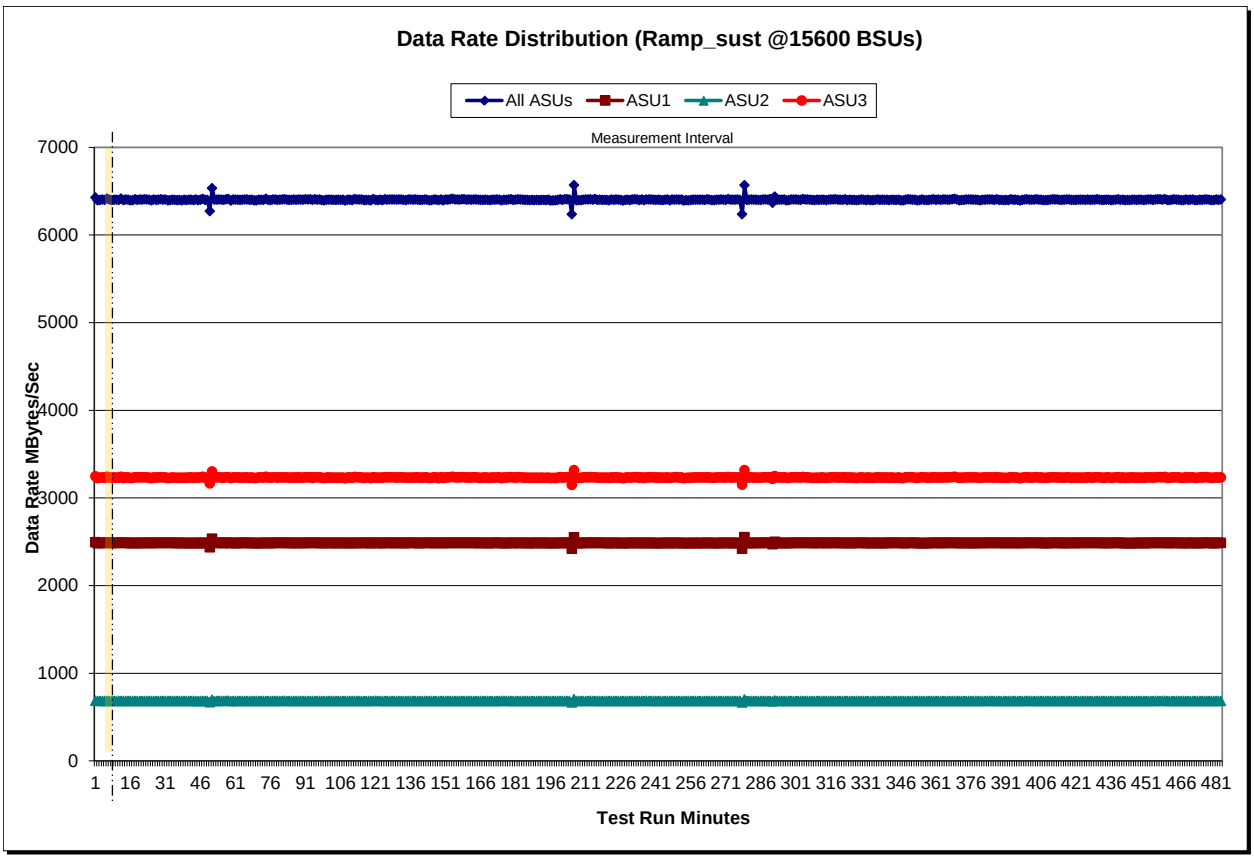
Sustainability Test Results File

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

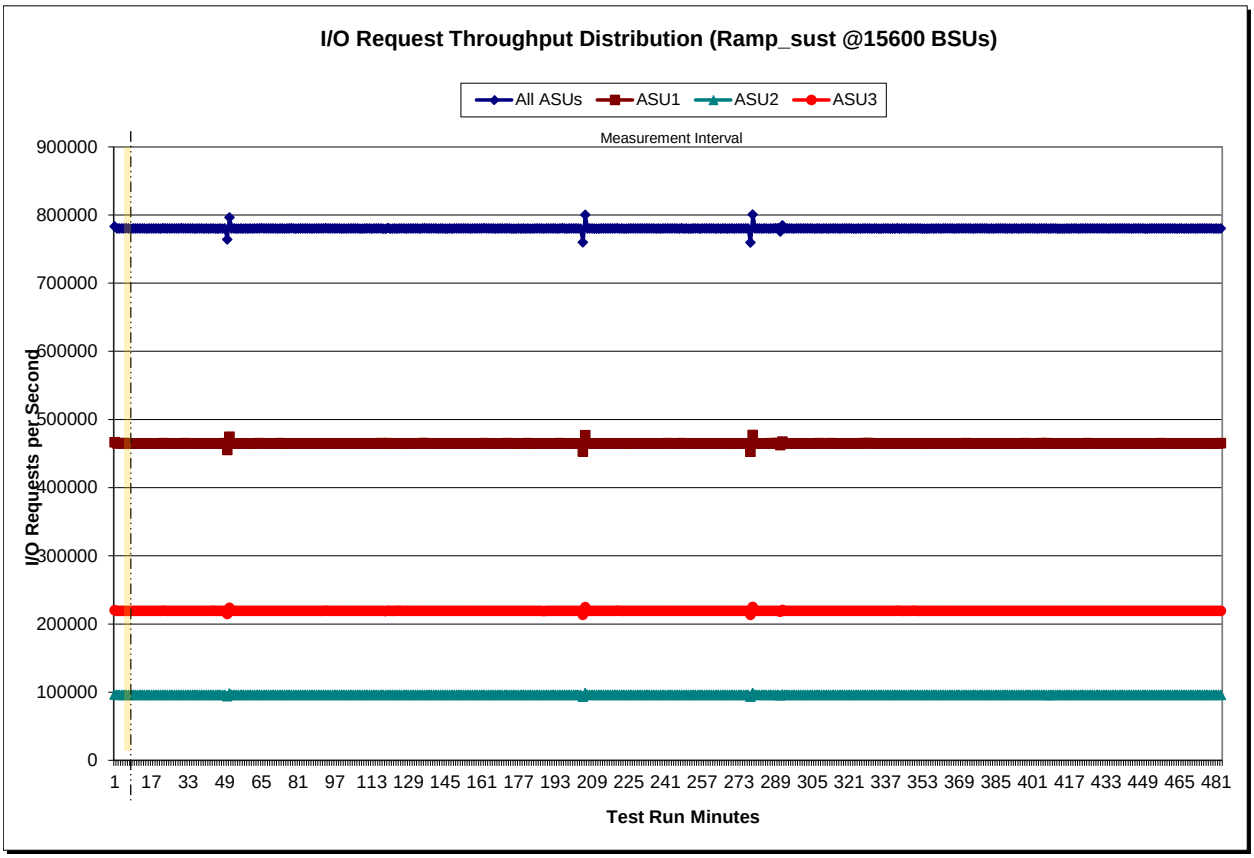


Sustainability – I/O Request Throughput Distribution Data

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

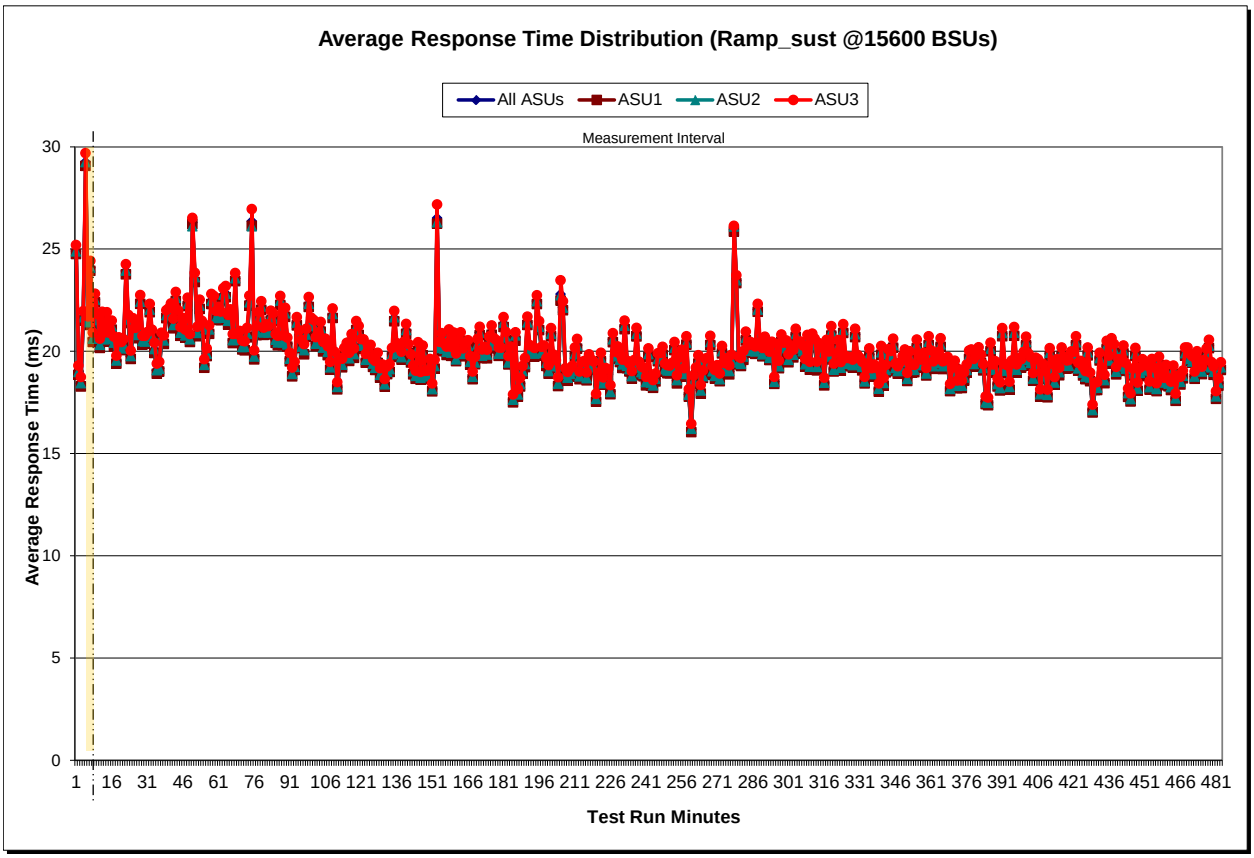


Sustainability – Average Response Time (ms) Distribution Data

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



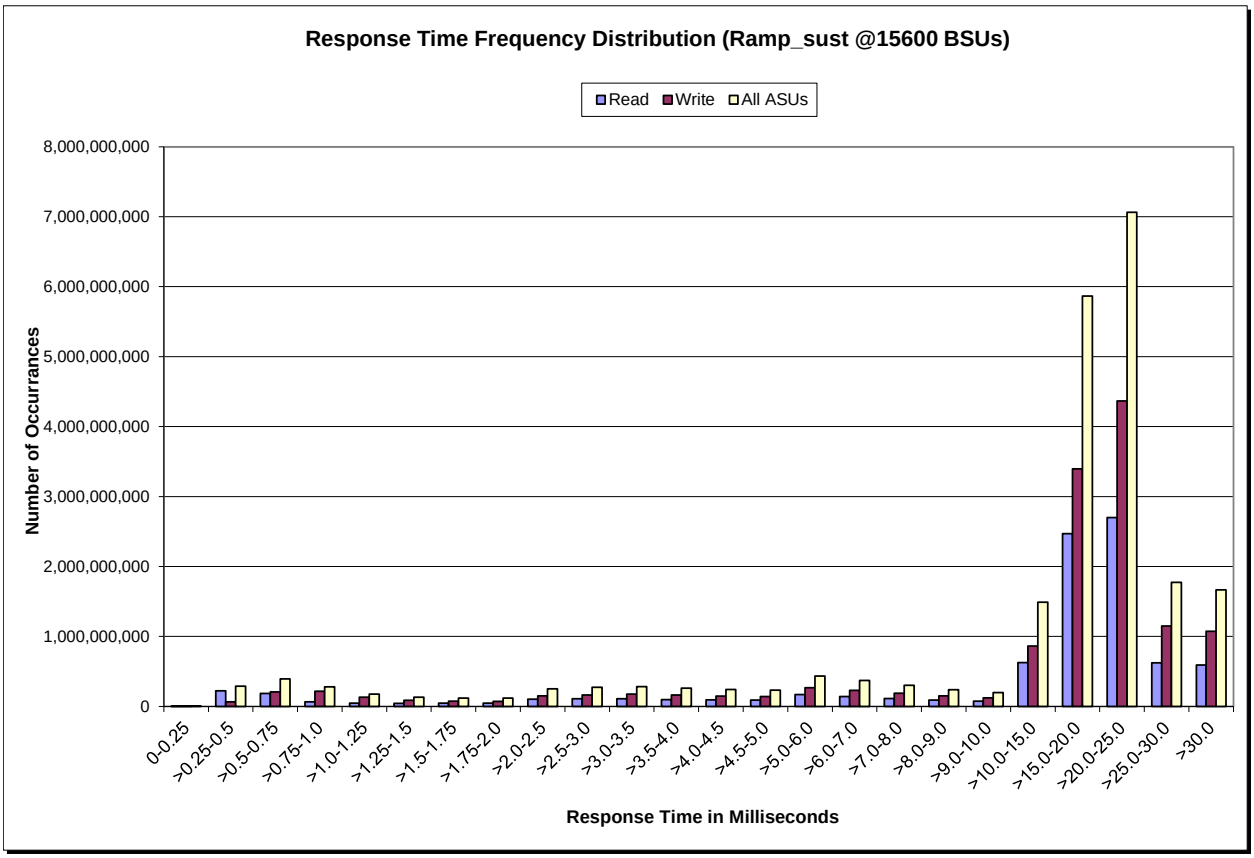
Sustainability – Response Time Frequency Distribution Data

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	2,225,199	223,293,692	184,448,338	65,618,221	45,614,205	43,429,590	45,136,423	47,528,595
Write	2,984,755	65,745,319	207,341,085	215,643,123	131,073,799	87,097,436	73,856,018	71,515,343
All ASUs	5,209,954	289,039,011	391,789,423	281,261,344	176,688,004	130,527,026	118,992,441	119,043,938
ASU1	2,078,552	202,739,526	237,522,078	156,664,766	98,155,341	75,297,981	70,667,355	71,689,845
ASU2	302,291	35,112,553	48,815,614	34,675,366	21,096,965	15,788,907	14,628,237	14,776,102
ASU3	2,829,111	51,186,932	105,451,731	89,921,212	57,435,698	39,440,138	33,696,849	32,577,991

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	102,279,302	110,524,543	109,013,883	97,106,763	94,383,971	91,449,591	168,283,105	141,458,253
Write	150,458,059	164,324,895	174,873,510	164,035,217	147,576,003	142,081,169	266,424,467	229,410,728
All ASUs	252,737,361	274,849,438	283,887,393	261,141,980	241,959,974	233,530,760	434,707,572	370,868,981
ASU1	153,032,998	166,404,782	169,959,926	153,900,342	143,726,658	139,049,683	258,491,918	220,053,924
ASU2	31,553,429	34,411,065	35,360,185	31,928,111	29,655,669	28,698,186	53,457,585	45,645,244
ASU3	68,150,934	74,033,591	78,567,282	75,313,527	68,577,647	65,782,891	122,758,069	105,169,813

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	113,437,616	89,797,591	74,391,354	627,055,569	2,469,352,622	2,698,855,743	623,394,972	591,651,411
Write	187,838,384	150,135,697	122,438,886	863,228,521	3,396,174,692	4,364,992,692	1,150,404,529	1,074,388,597
All ASUs	301,276,000	239,933,288	196,830,240	1,490,284,090	5,865,527,314	7,063,848,435	1,773,799,501	1,666,040,008
ASU1	178,396,687	141,848,843	116,471,778	897,795,073	3,537,253,322	4,197,711,292	1,038,047,424	961,460,194
ASU2	37,105,123	29,522,095	24,200,763	183,002,602	721,030,561	871,158,853	218,199,579	202,887,666
ASU3	85,774,190	68,562,350	56,157,699	409,486,415	1,607,243,431	1,994,978,290	517,552,498	501,692,148

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 9.4.3.7.2

For the IOPS Test Phase the FDR shall contain:

1. *I/O Request Throughput Distribution (data and graph).*
2. *A Response Time Frequency Distribution.*
3. *An Average Response Time Distribution.*
4. *The human readable Test Run Results File produced by the Workload Generator.*
5. *A listing or screen image of all input parameters supplied 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 78.

IOPS Test Results File

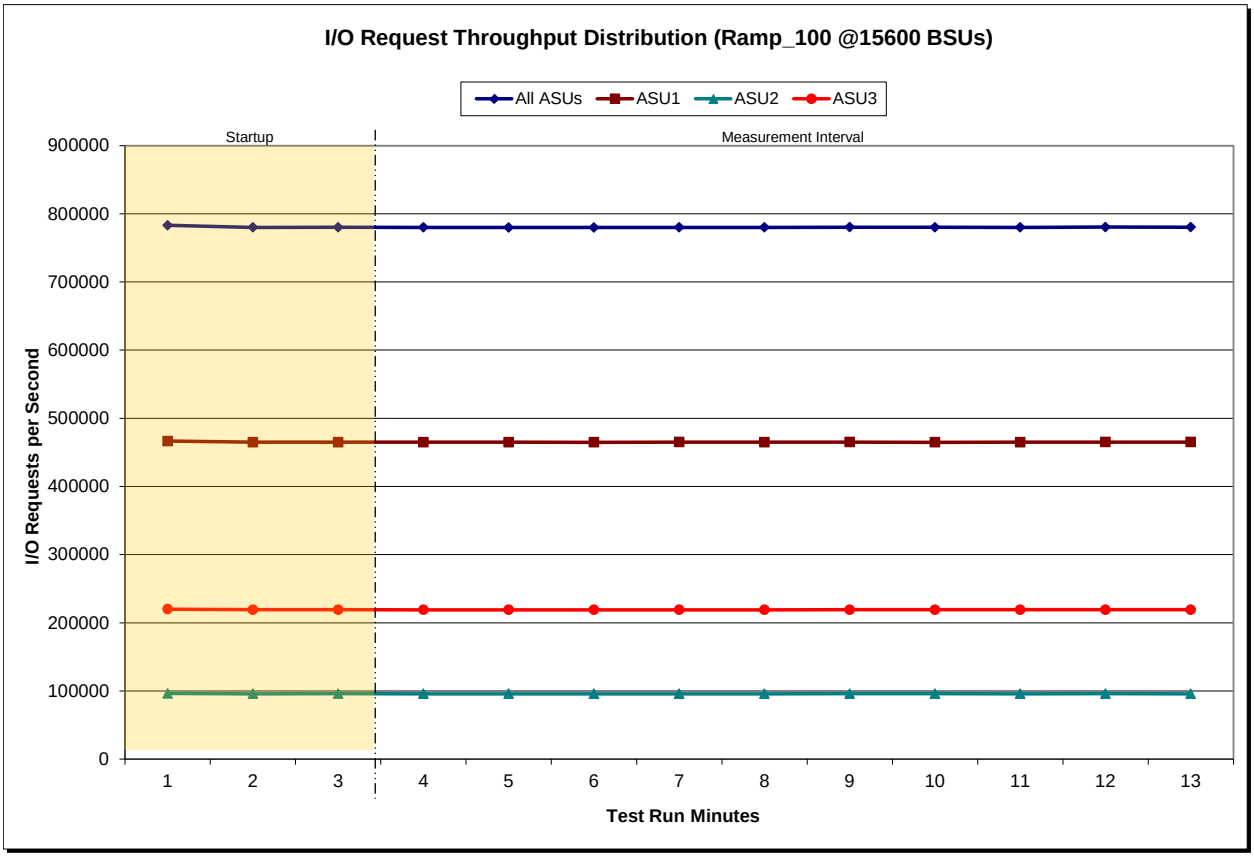
A link to the test results file generated from the IOPS Test Run is listed below.

IOPS Test Results File

IOPS Test Run – I/O Request Throughput Distribution Data

15,600 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	11:41:19	11:44:19	0-2	0:03:00
Measurement Interval	11:44:19	11:54:42	3-12	0:10:23
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	782,979.85	466,591.08	96,331.88	220,056.88
1	779,961.55	464,912.90	95,851.33	219,197.32
2	780,165.00	464,883.77	95,975.43	219,305.80
3	779,984.77	464,949.73	95,925.08	219,109.95
4	779,901.33	464,854.75	95,913.28	219,133.30
5	779,864.12	464,781.50	95,946.80	219,135.82
6	780,033.70	465,072.73	95,896.52	219,064.45
7	779,933.83	464,928.95	95,923.17	219,081.72
8	780,287.85	465,052.35	96,010.62	219,224.88
9	780,114.03	464,838.97	96,014.98	219,260.08
10	780,057.42	464,930.07	95,961.40	219,165.95
11	780,392.10	465,140.05	95,984.05	219,268.00
12	780,241.08	465,071.38	95,946.15	219,223.55
Average	***780,081.02***	***464,962.05***	***95,952.21***	***219,166.77***

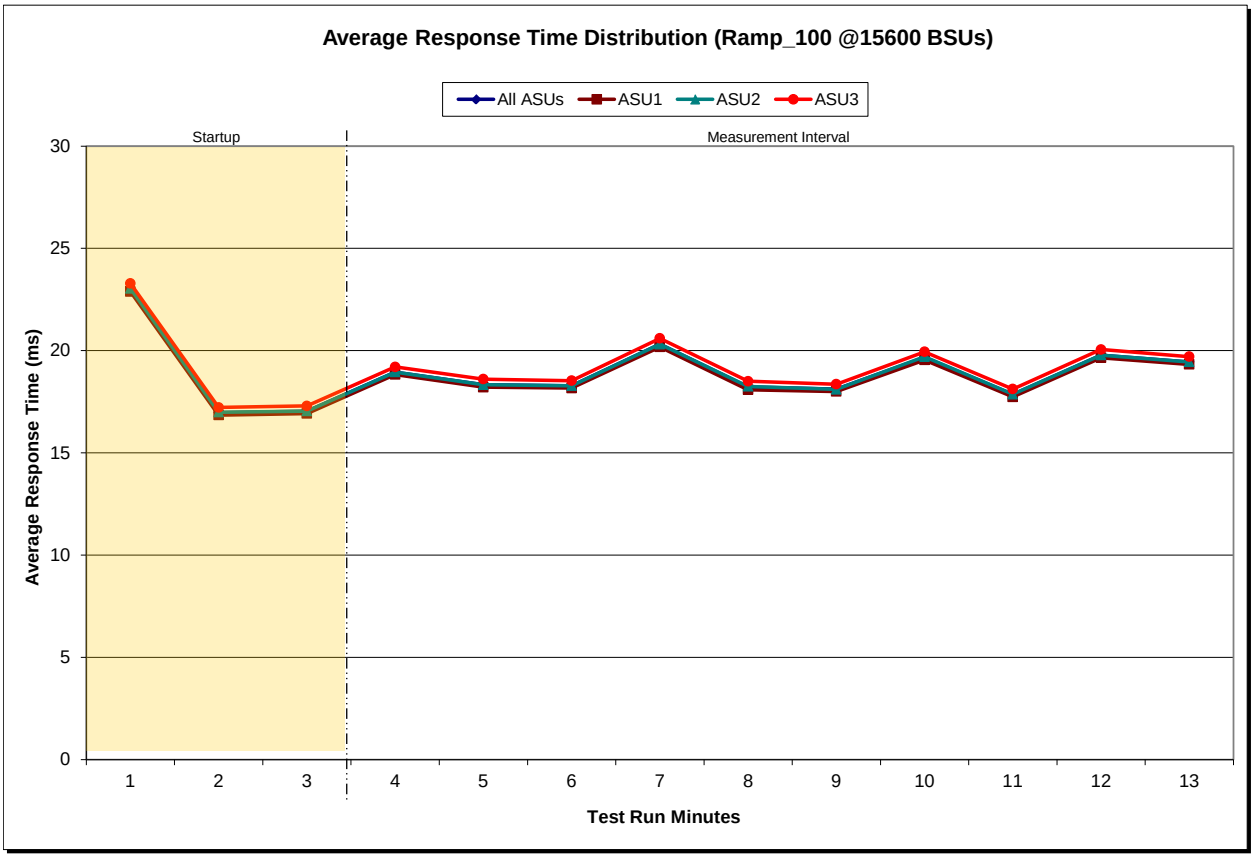
IOPS Test Run – I/O Request Throughput Distribution Graph



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

15,600 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	11:41:19	11:44:19	0-2	0:03:00
Measurement Interval	11:44:19	11:54:42	3-12	0:10:23
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	23.02	22.89	23.04	23.29
1	16.97	16.85	16.99	17.22
2	17.04	16.92	17.05	17.30
3	18.95	18.83	18.95	19.21
4	18.34	18.21	18.33	18.60
5	18.29	18.17	18.28	18.53
6	20.31	20.18	20.32	20.60
7	18.23	18.09	18.25	18.51
8	18.11	18.00	18.11	18.36
9	19.67	19.54	19.70	19.94
10	17.86	17.74	17.87	18.12
11	19.78	19.65	19.78	20.05
12	19.45	19.33	19.45	19.71
Average	***18.90***	***18.77***	***18.90***	***19.16***

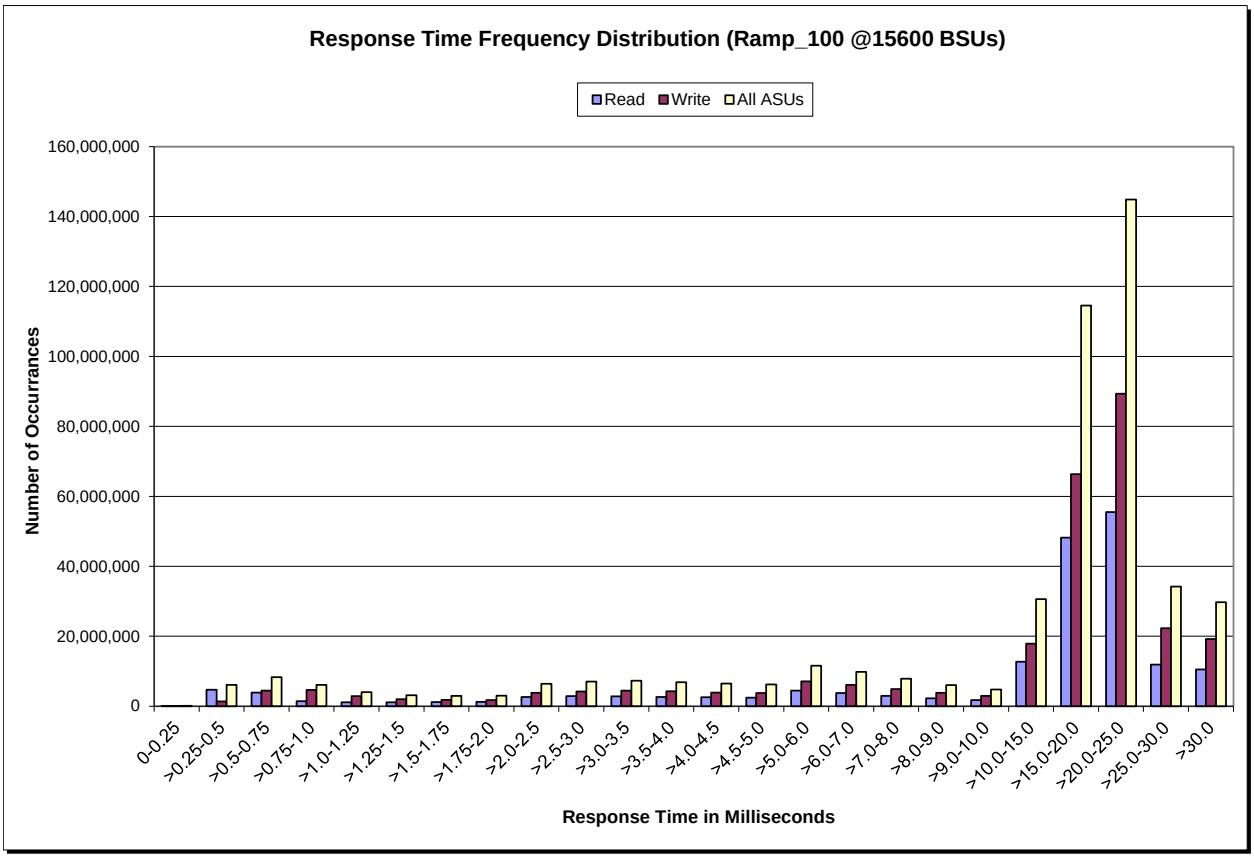
IOPS Test Run – Average Response Time (ms) Distribution Graph



IOPS Test Run –Response Time Frequency Distribution Data

Response Time (ms)	0-0.25	>0.25-0.5	>0.5-0.75	>0.75-1.0	>1.0-1.25	>1.25-1.5	>1.5-1.75	>1.75-2.0
Read	50,231	4,737,558	3,872,125	1,456,018	1,097,870	1,092,692	1,154,374	1,221,024
Write	61,343	1,390,798	4,437,291	4,644,261	2,891,814	2,031,413	1,798,546	1,783,413
All ASUs	111,574	6,128,356	8,309,416	6,100,279	3,989,684	3,124,105	2,952,920	3,004,437
ASU1	47,179	4,309,464	5,035,943	3,400,647	2,229,813	1,815,781	1,759,444	1,810,362
ASU2	6,445	744,743	1,039,701	751,465	476,572	377,581	363,069	372,315
ASU3	57,950	1,074,149	2,233,772	1,948,167	1,283,299	930,743	830,407	821,760
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	2,643,284	2,861,363	2,849,859	2,604,822	2,540,778	2,452,680	4,489,857	3,741,021
Write	3,803,551	4,180,430	4,465,131	4,261,412	3,922,664	3,791,784	7,095,497	6,073,002
All ASUs	6,446,835	7,041,793	7,314,990	6,866,234	6,463,442	6,244,464	11,585,354	9,814,023
ASU1	3,905,196	4,263,476	4,384,268	4,061,591	3,845,540	3,720,116	6,889,875	5,825,805
ASU2	802,621	878,665	908,852	841,329	792,771	767,658	1,424,942	1,206,747
ASU3	1,739,018	1,899,652	2,021,870	1,963,314	1,825,131	1,756,690	3,270,537	2,781,471
Response Time (ms)	**>7.0-8.0**	**>8.0-9.0**	**>9.0-10.0**	**>10.0-15.0**	**>15.0-20.0**	**>20.0-25.0**	**>25.0-30.0**	**>30.0**
Read	2,940,363	2,250,094	1,775,609	12,728,307	48,212,469	55,502,497	11,889,870	10,506,059
Write	4,905,623	3,809,649	2,980,821	17,854,555	66,312,170	89,329,410	22,314,846	19,223,465
All ASUs	7,845,986	6,059,743	4,756,430	30,582,862	114,524,639	144,831,907	34,204,716	29,729,524
ASU1	4,640,422	3,579,041	2,807,296	18,392,681	69,075,609	86,075,392	19,981,028	17,112,476
ASU2	967,168	745,456	584,512	3,753,136	14,079,484	17,858,645	4,206,855	3,618,770
ASU3	2,238,396	1,735,246	1,364,622	8,437,045	31,369,546	40,897,870	10,016,833	8,998,278

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
468,033,713	438,304,189	29,729,524

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	0.001	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 13.

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

Clause 9.4.3.7.3

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

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

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in *Appendix E: SPC-1 Workload Generator Input Parameters* on Page 78.

Response Time Ramp Test Results File

A link to each test result file generated from each Response Time Ramp Test Run list listed below.

95% Load Level

90% Load Level

80% Load Level

50% Load Level

10% Load Level

Response Time Ramp Distribution (IOPS) Data

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

100% Load Level - 15,600 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	11:41:19	11:44:19	0-2	0:03:00
Measurement Interval	11:44:19	11:54:42	3-12	0:10:23

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	782,979.85	466,591.08	96,331.88	220,056.88
1	779,961.55	464,912.90	95,851.33	219,197.32
2	780,165.00	464,883.77	95,975.43	219,305.80
3	779,984.77	464,949.73	95,925.08	219,109.95
4	779,901.33	464,854.75	95,913.28	219,133.30
5	779,864.12	464,781.50	95,946.80	219,135.82
6	780,033.70	465,072.73	95,896.52	219,064.45
7	779,933.83	464,928.95	95,923.17	219,081.72
8	780,287.85	465,052.35	96,010.62	219,224.88
9	780,114.03	464,838.97	96,014.98	219,260.08
10	780,057.42	464,930.07	95,961.40	219,165.95
11	780,392.10	465,140.05	95,984.05	219,268.00
12	780,241.08	465,071.38	95,946.15	219,223.55
Average	***780,081.02***	***464,962.05***	***95,952.21***	***219,166.77***

95% Load Level - 14,820 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:05:52	12:08:52	0-2	0:03:00
Measurement Interval	12:08:52	12:19:01	3-12	0:10:09

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	743,884.78	443,347.73	91,494.78	209,042.27
1	740,950.28	441,735.40	91,125.60	208,089.28
2	741,055.60	441,579.27	91,169.43	208,306.90
3	740,864.32	441,633.57	91,073.08	208,157.67
4	740,957.15	441,722.53	91,104.62	208,130.00
5	741,105.08	441,784.02	91,100.78	208,220.28
6	741,164.65	441,715.57	91,189.25	208,259.83
7	740,928.03	441,541.25	91,150.77	208,236.02
8	740,878.80	441,610.65	91,117.87	208,150.28
9	740,898.70	441,572.78	91,091.92	208,234.00
10	740,970.85	441,633.95	91,170.00	208,166.90
11	740,953.13	441,561.82	91,140.03	208,251.28
12	740,840.07	441,509.67	91,173.48	208,156.92
Average	***740,956.08***	***441,628.58***	***91,131.18***	***208,196.32***

90% Load Level - 14,040 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:29:49	12:32:49	0-2	0:03:00
Measurement Interval	12:32:49	12:42:57	3-12	0:10:08

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	704,497.83	419,919.98	86,639.17	197,938.68
1	702,014.25	418,388.15	86,328.37	197,297.73
2	701,875.80	418,316.15	86,332.60	197,227.05
3	701,965.02	418,382.47	86,311.08	197,271.47
4	702,138.23	418,483.83	86,353.30	197,301.10
5	701,896.40	418,363.90	86,335.48	197,197.02
6	702,056.33	418,419.57	86,346.95	197,289.82
7	702,110.43	418,457.33	86,315.65	197,337.45
8	702,114.33	418,589.22	86,334.48	197,190.63
9	701,915.85	418,377.08	86,286.48	197,252.28
10	702,164.77	418,504.75	86,440.18	197,219.83
11	701,943.77	418,318.70	86,371.75	197,253.32
12	702,055.72	418,414.15	86,360.75	197,280.82
Average	***702,036.09***	***418,431.10***	***86,345.61***	***197,259.37***

80% Load Level - 12,480 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:52:54	12:55:54	0-2	0:03:00
Measurement Interval	12:55:54	13:06:00	3-12	0:10:06

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	625,785.58	372,950.72	76,974.23	175,860.63
1	624,113.28	372,016.05	76,708.90	175,388.33
2	624,013.40	371,934.60	76,779.43	175,299.37
3	623,937.03	371,796.90	76,793.82	175,346.32
4	623,719.63	371,801.23	76,684.78	175,233.62
5	623,984.22	371,869.93	76,744.17	175,370.12
6	624,118.08	372,037.82	76,733.32	175,346.95
7	624,015.45	371,913.68	76,755.63	175,346.13
8	623,765.02	371,750.55	76,759.95	175,254.52
9	623,902.32	371,879.53	76,712.98	175,309.80
10	623,949.38	371,799.17	76,750.53	175,399.68
11	624,124.03	372,006.00	76,802.55	175,315.48
12	623,908.90	371,765.20	76,737.72	175,405.98
Average	***623,942.41***	***371,862.00***	***76,747.55***	***175,332.86***

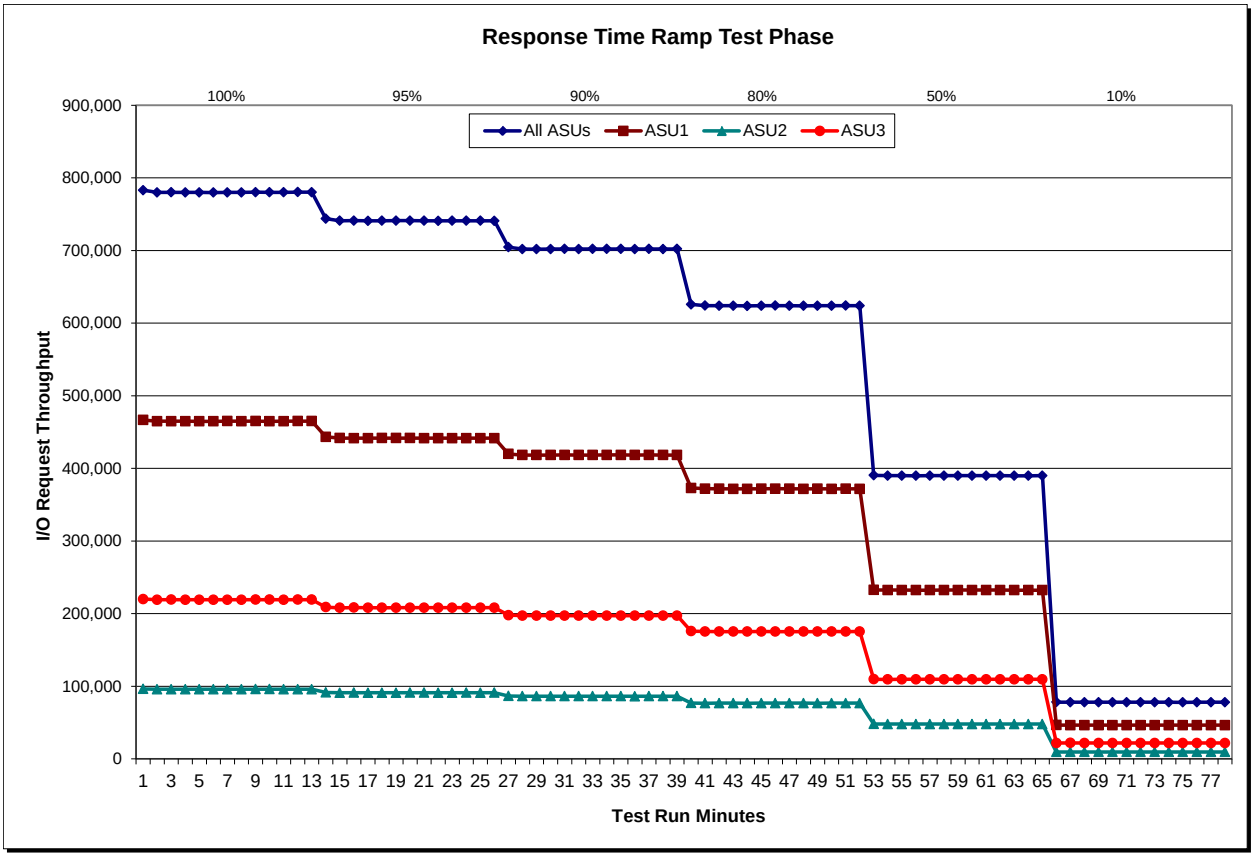
50% Load Level - 7,800 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:13:39	13:16:39	0-2	0:03:00
Measurement Interval	13:16:39	13:26:42	3-12	0:10:03

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	390,450.88	232,683.48	48,069.33	109,698.07
1	389,928.90	232,466.45	47,959.25	109,503.20
2	390,018.10	232,468.93	47,952.98	109,596.18
3	389,850.97	232,402.13	47,937.02	109,511.82
4	389,920.53	232,350.23	47,964.95	109,605.35
5	390,042.80	232,499.95	48,002.65	109,540.20
6	390,001.58	232,476.22	47,958.88	109,566.48
7	390,033.52	232,481.55	48,046.43	109,505.53
8	389,956.22	232,439.23	47,956.97	109,560.02
9	390,055.40	232,488.98	47,981.42	109,585.00
10	389,905.57	232,341.83	47,946.37	109,617.37
11	389,846.10	232,316.53	47,957.98	109,571.58
12	389,955.13	232,412.27	47,973.62	109,569.25
Average	***389,956.78***	***232,420.89***	***47,972.63***	***109,563.26***

10% Load Level - 1,560 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:31:22	13:34:22	0-2	0:03:00
Measurement Interval	13:34:22	13:44:24	3-12	0:10:02

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	78,104.78	46,549.45	9,619.82	21,935.52
1	78,029.87	46,469.52	9,599.30	21,961.05
2	78,000.82	46,490.57	9,598.97	21,911.28
3	77,996.15	46,477.48	9,607.22	21,911.45
4	77,945.33	46,443.27	9,576.35	21,925.72
5	77,972.27	46,468.40	9,590.32	21,913.55
6	77,984.62	46,494.02	9,583.82	21,906.78
7	78,020.08	46,511.38	9,576.52	21,932.18
8	78,014.30	46,510.17	9,590.17	21,913.97
9	77,903.10	46,451.25	9,572.85	21,879.00
10	78,023.12	46,521.67	9,582.58	21,918.87
11	78,025.47	46,483.13	9,600.43	21,941.90
12	78,045.02	46,510.65	9,607.95	21,926.42
Average	***77,992.95***	***46,487.14***	***9,588.82***	***21,916.98***

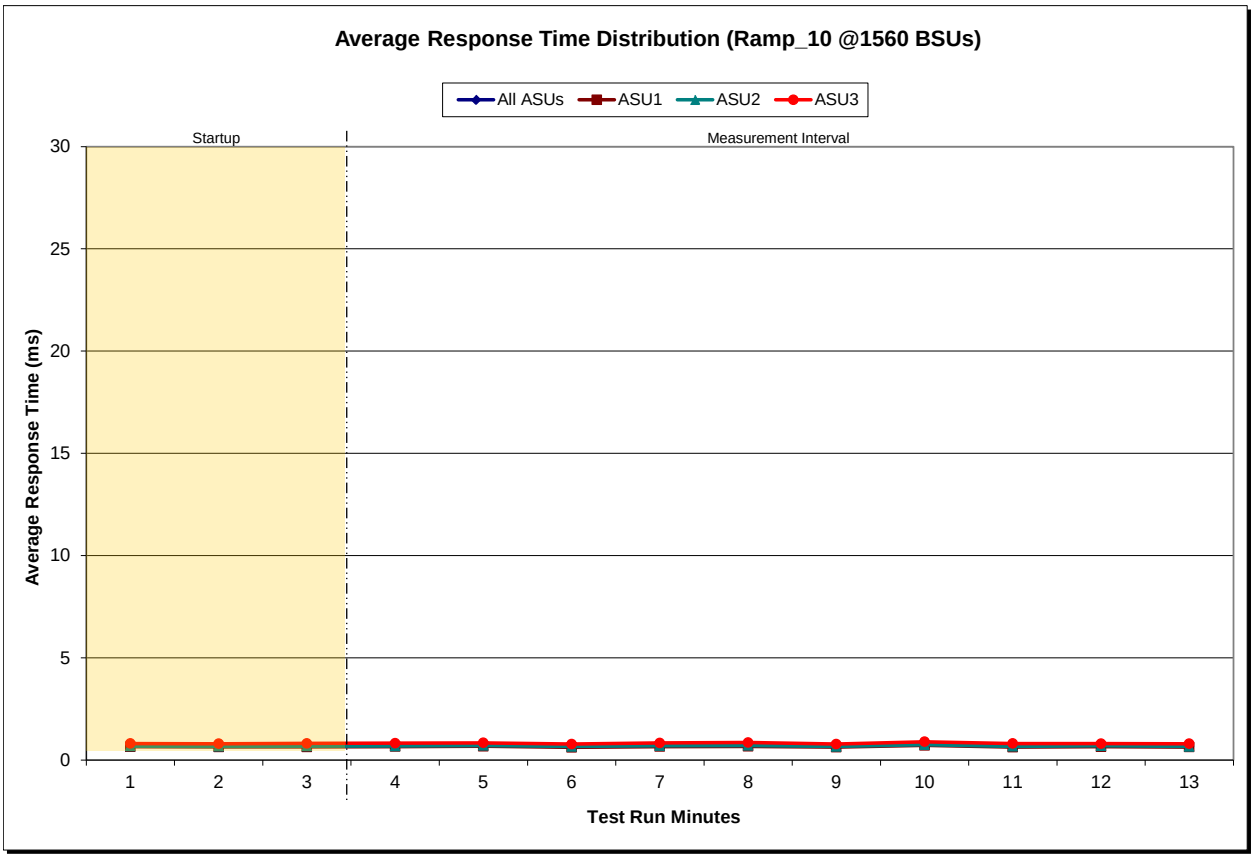
Response Time Ramp Distribution (IOPS) Graph



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

1,560 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:31:22	13:34:22	0-2	0:03:00
Measurement Interval	13:34:22	13:44:24	3-12	0:10:02
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.71	0.66	0.69	0.81
1	0.69	0.65	0.68	0.80
2	0.70	0.65	0.68	0.82
3	0.72	0.67	0.69	0.83
4	0.73	0.68	0.72	0.85
5	0.68	0.63	0.67	0.79
6	0.72	0.66	0.70	0.84
7	0.73	0.67	0.72	0.86
8	0.68	0.64	0.67	0.79
9	0.78	0.72	0.75	0.90
10	0.69	0.64	0.67	0.81
11	0.71	0.66	0.70	0.81
12	0.69	0.64	0.67	0.80
Average	***0.71***	***0.66***	***0.70***	***0.83***

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	0.0700	0.2101	0.0180	0.0700	0.0350.	0.2810
COV	0.003	0.001	0.001	0.001	0.005	0.002	0.003	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 9.4.3.7.4

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

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

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in *Appendix E: SPC-1 Workload Generator Input Parameters* on Page 78.

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	***780,081.02***
Repeatability Test Phase 1	779,943.36
Repeatability Test Phase 2	787,347.69

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	***0.71 ms***
Repeatability Test Phase 1	0.70 ms
Repeatability Test Phase 2	0.72 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).

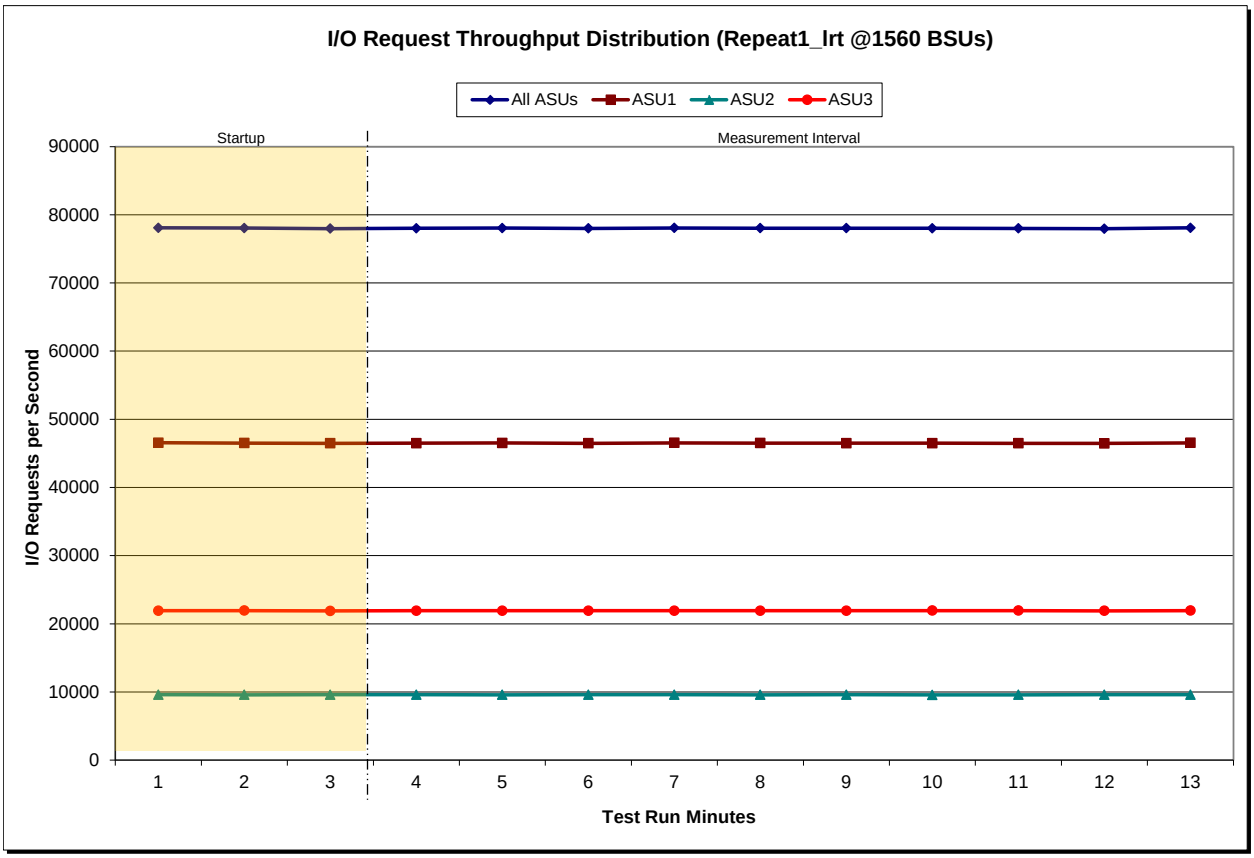
A link to the test result file generated from each Repeatability Test Run is listed below.

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

1,560 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:49:04	13:52:04	0-2	0:03:00
Measurement Interval	13:52:04	14:02:06	3-12	0:10:02
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	78,082.15	46,555.42	9,598.05	21,928.68
1	78,046.15	46,516.57	9,588.63	21,940.95
2	77,964.18	46,476.03	9,597.55	21,890.60
3	78,012.12	46,487.07	9,598.00	21,927.05
4	78,043.00	46,523.23	9,592.90	21,926.87
5	78,002.40	46,480.27	9,597.15	21,924.98
6	78,067.10	46,540.80	9,610.33	21,915.97
7	78,022.83	46,511.00	9,593.85	21,917.98
8	78,023.13	46,499.25	9,608.68	21,915.20
9	78,011.28	46,492.10	9,579.30	21,939.88
10	78,004.45	46,477.88	9,595.65	21,930.92
11	77,952.83	46,453.82	9,597.27	21,901.75
12	78,086.58	46,546.57	9,598.60	21,941.42
Average	***78,022.57***	***46,501.20***	***9,597.17***	***21,924.20***

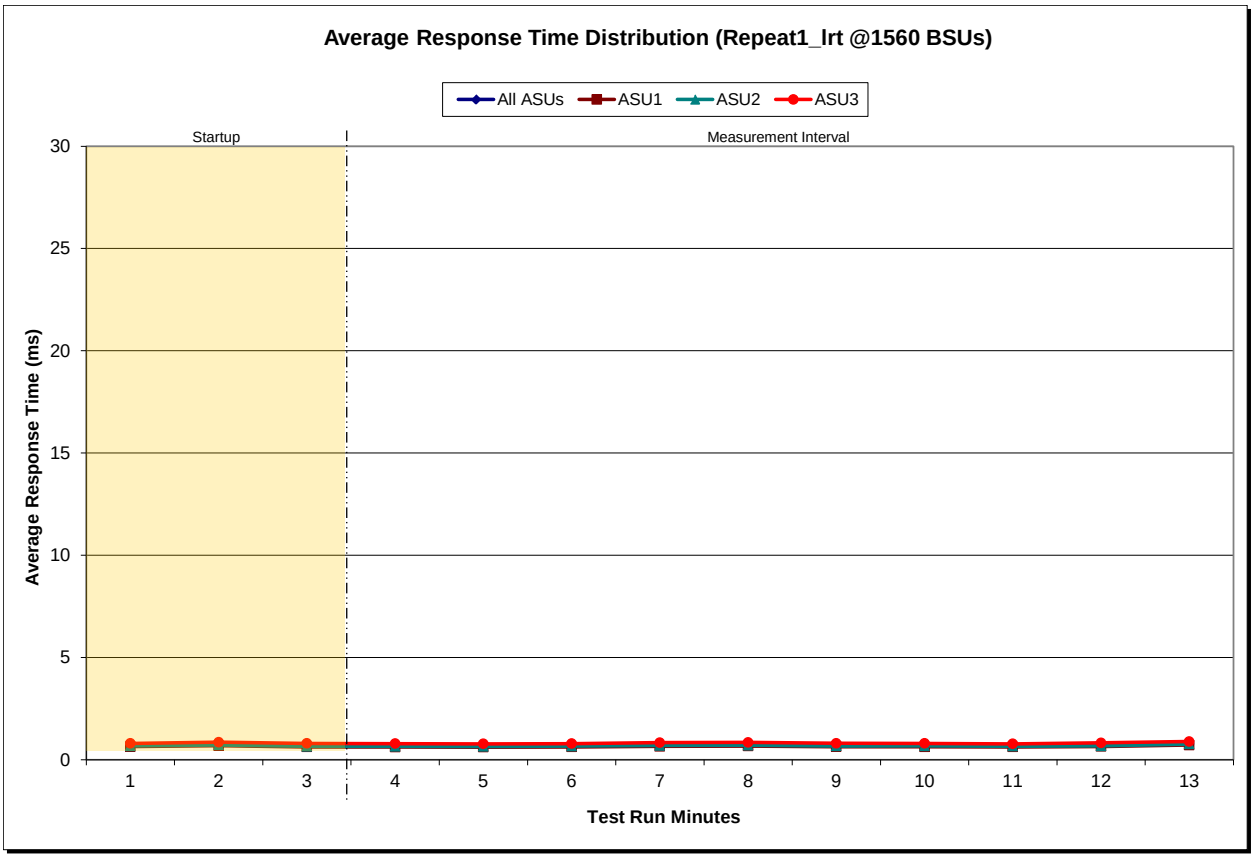
Repeatability 1 LRT – I/O Request Throughput Distribution Graph



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

1,560 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:49:04	13:52:04	0-2	0:03:00
Measurement Interval	13:52:04	14:02:06	3-12	0:10:02
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.69	0.64	0.68	0.80
1	0.75	0.69	0.73	0.86
2	0.68	0.63	0.66	0.80
3	0.68	0.63	0.66	0.79
4	0.67	0.62	0.65	0.78
5	0.68	0.63	0.67	0.79
6	0.72	0.66	0.70	0.84
7	0.73	0.68	0.71	0.85
8	0.69	0.64	0.67	0.81
9	0.69	0.64	0.68	0.80
10	0.68	0.63	0.66	0.78
11	0.71	0.65	0.68	0.83
12	0.78	0.72	0.77	0.89
Average	***0.70***	***0.65***	***0.69***	***0.82***

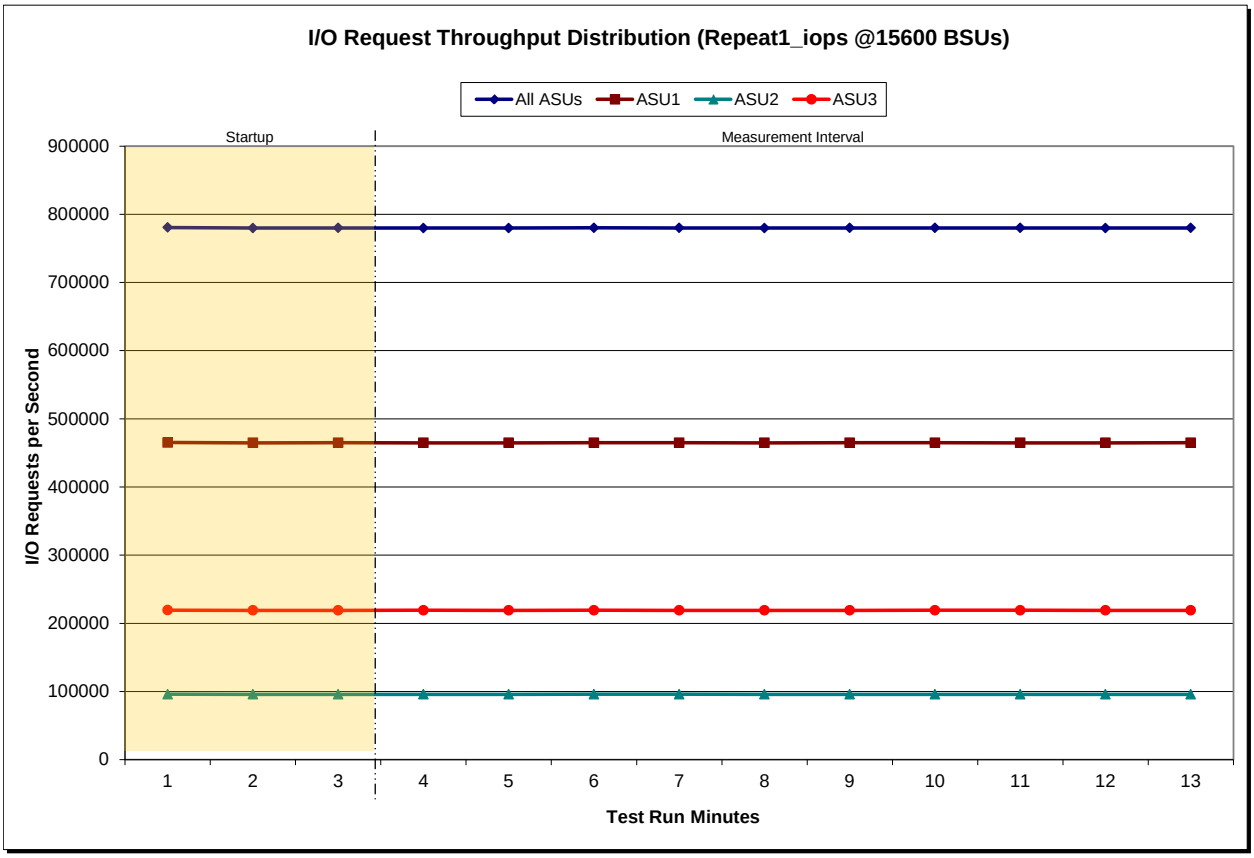
Repeatability 1 LRT –Average Response Time (ms) Distribution Graph



Repeatability 1 IOPS – I/O Request Throughput Distribution Data

15,600 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:11:47	14:14:48	0-2	0:03:01
Measurement Interval	14:14:48	14:24:58	3-12	0:10:10
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	780,659.93	465,269.67	96,022.57	219,367.70
1	779,855.92	464,771.73	95,943.67	219,140.52
2	779,991.78	464,939.55	95,911.18	219,141.05
3	779,835.35	464,748.07	95,928.35	219,158.93
4	779,817.97	464,831.13	95,896.07	219,090.77
5	780,189.97	464,945.72	95,979.60	219,264.65
6	780,012.58	464,893.15	95,986.25	219,133.18
7	779,857.88	464,814.62	95,958.38	219,084.88
8	779,940.08	464,891.37	95,914.47	219,134.25
9	780,056.28	464,929.33	95,954.70	219,172.25
10	780,049.95	464,841.68	95,965.42	219,242.85
11	779,751.62	464,727.07	95,936.90	219,087.65
12	779,921.92	464,889.00	95,901.05	219,131.87
Average	***779,943.36***	***464,851.11***	***95,942.12***	***219,150.13***

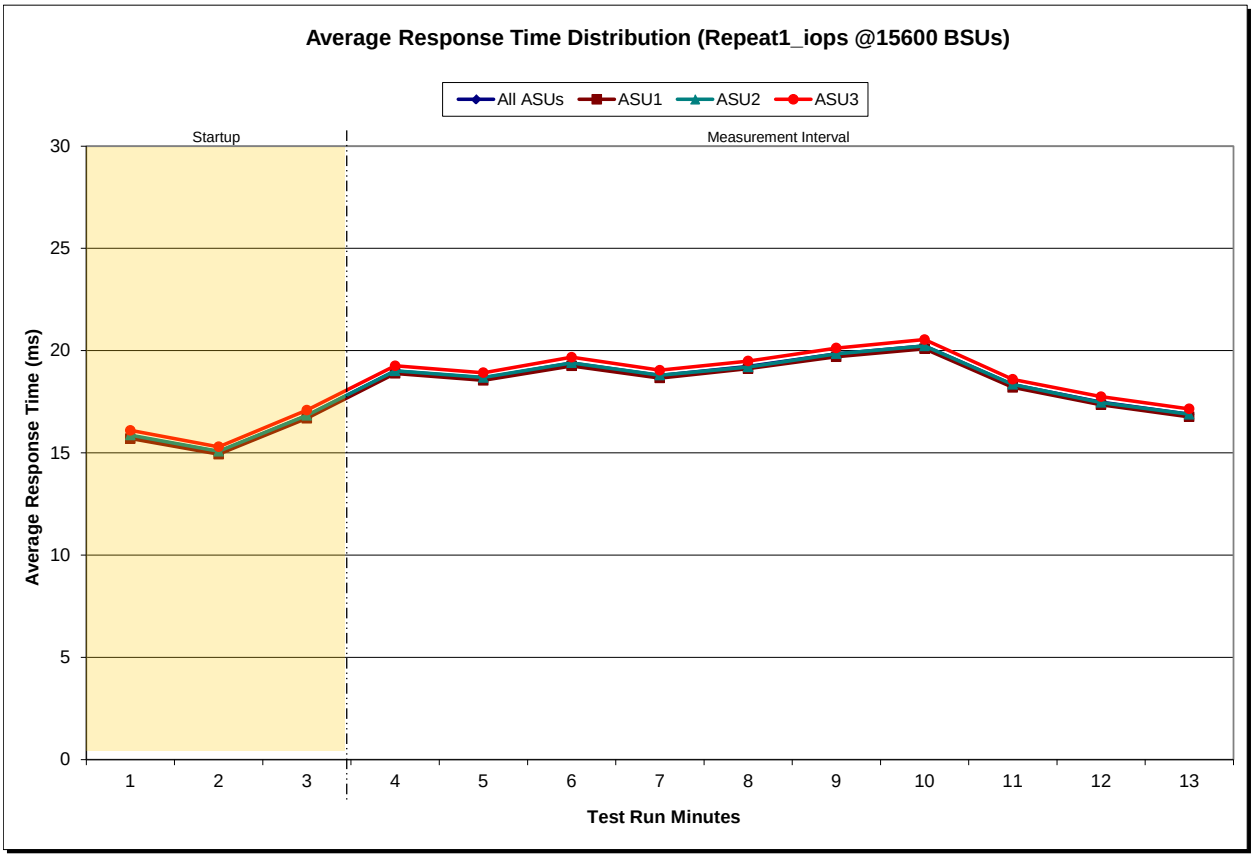
Repeatability 1 IOPS – I/O Request Throughput Distribution Graph



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

15,600 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:11:47	14:14:48	0-2	0:03:01
Measurement Interval	14:14:48	14:24:58	3-12	0:10:10
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	15.84	15.70	15.87	16.10
1	15.06	14.94	15.08	15.30
2	16.82	16.69	16.84	17.09
3	19.01	18.89	19.01	19.26
4	18.67	18.55	18.69	18.92
5	19.39	19.25	19.41	19.68
6	18.78	18.66	18.80	19.04
7	19.23	19.12	19.20	19.49
8	19.84	19.70	19.85	20.13
9	20.24	20.09	20.23	20.54
10	18.33	18.20	18.35	18.60
11	17.48	17.36	17.46	17.75
12	16.89	16.76	16.89	17.15
Average	***18.79***	***18.66***	***18.79***	***19.06***

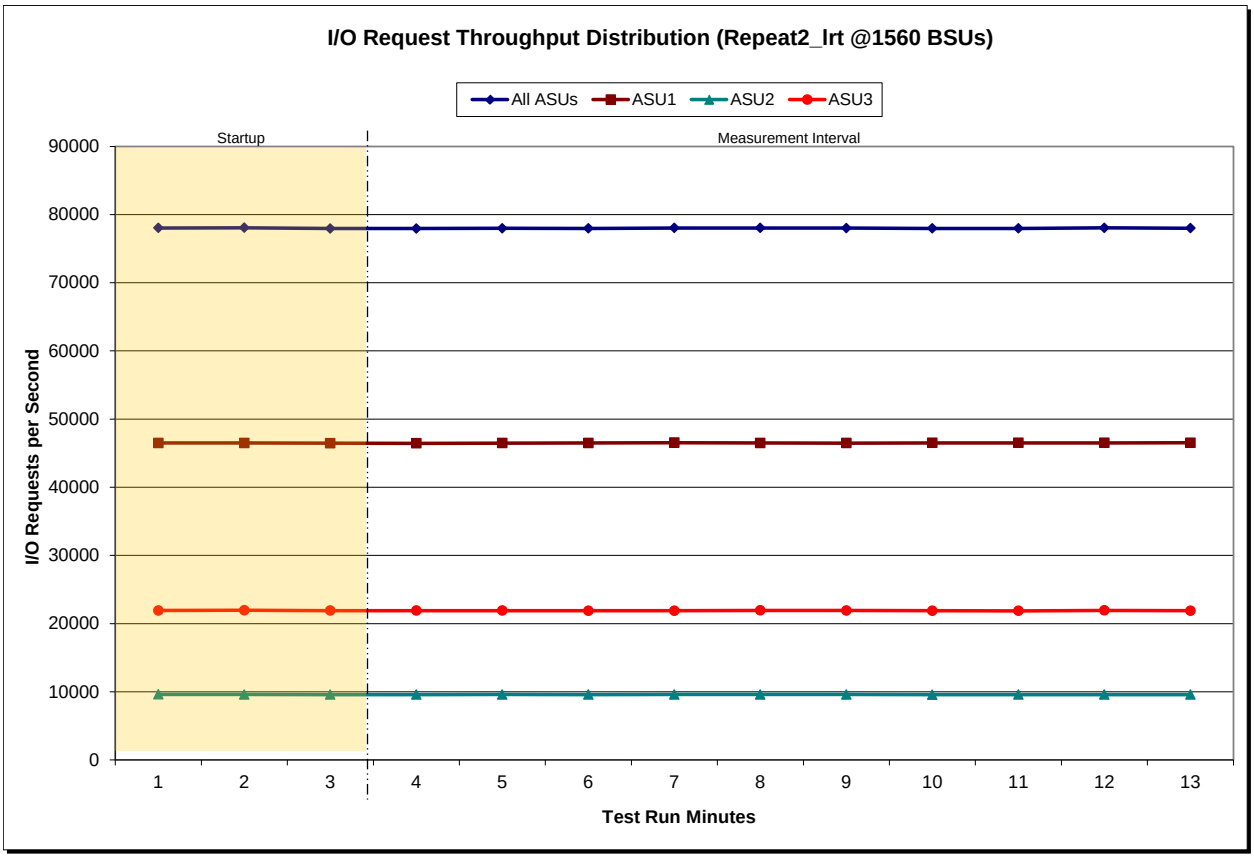
Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph



Repeatability 2 LRT – I/O Request Throughput Distribution Data

1,560 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:29:37	14:32:37	0-2	0:03:00
Measurement Interval	14:32:37	14:42:39	3-12	0:10:02
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	78,034.20	46,489.83	9,616.25	21,928.12
1	78,058.82	46,494.60	9,602.82	21,961.40
2	77,944.52	46,455.97	9,588.93	21,899.62
3	77,951.52	46,446.20	9,592.47	21,912.85
4	77,984.60	46,471.08	9,600.50	21,913.02
5	77,959.22	46,491.12	9,581.75	21,886.35
6	78,030.52	46,540.88	9,598.52	21,891.12
7	78,028.67	46,494.28	9,600.02	21,934.37
8	78,008.38	46,470.87	9,608.63	21,928.88
9	77,968.58	46,503.35	9,579.93	21,885.30
10	77,968.95	46,506.12	9,593.77	21,869.07
11	78,044.33	46,505.10	9,596.67	21,942.57
12	77,995.70	46,518.62	9,582.92	21,894.17
Average	***77,994.05***	***46,494.76***	***9,593.52***	***21,905.77***

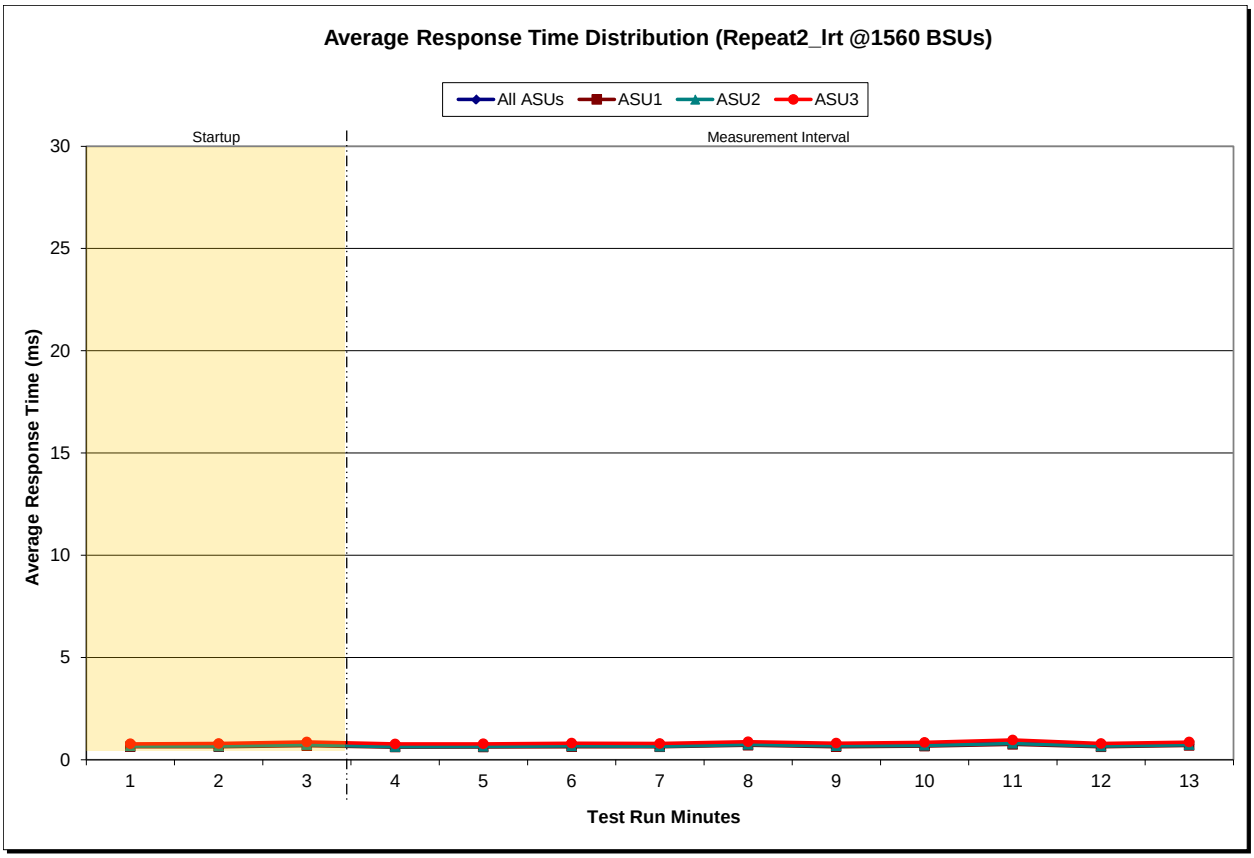
Repeatability 2 LRT – I/O Request Throughput Distribution Graph



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

1,560 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:29:37	14:32:37	0-2	0:03:00
Measurement Interval	14:32:37	14:42:39	3-12	0:10:02
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.69	0.64	0.68	0.78
1	0.69	0.64	0.67	0.80
2	0.75	0.69	0.74	0.87
3	0.67	0.62	0.64	0.78
4	0.67	0.63	0.65	0.78
5	0.69	0.64	0.68	0.81
6	0.69	0.64	0.66	0.80
7	0.77	0.71	0.75	0.88
8	0.69	0.64	0.69	0.81
9	0.72	0.67	0.71	0.85
10	0.82	0.75	0.80	0.97
11	0.69	0.64	0.67	0.80
12	0.75	0.70	0.74	0.87
Average	***0.72***	***0.66***	***0.70***	***0.84***

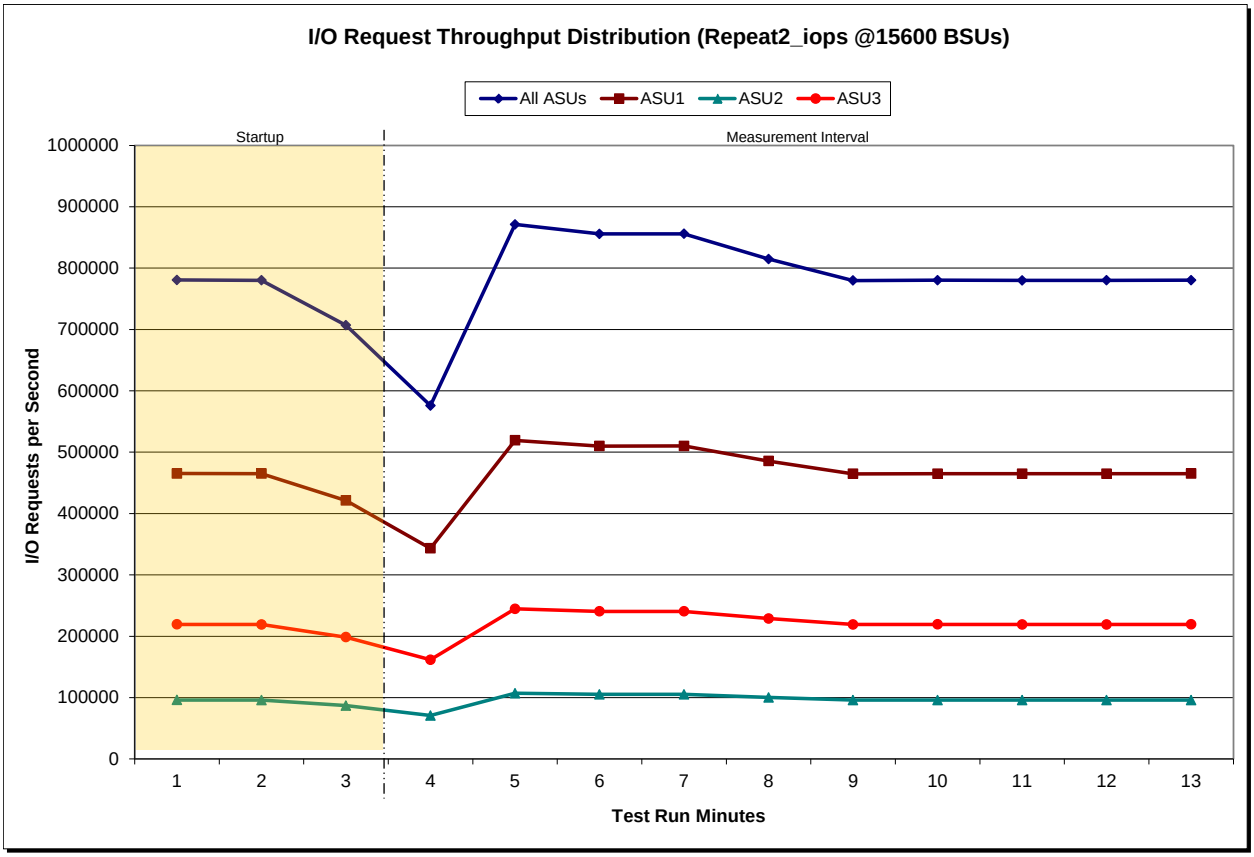
Repeatability 2 LRT –Average Response Time (ms) Distribution Graph



Repeatability 2 IOPS – I/O Request Throughput Distribution Data

15,600 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:52:20	14:55:21	0-2	0:03:01
Measurement Interval	14:55:21	15:05:37	3-12	0:10:16
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	780,536.93	465,193.67	96,057.57	219,285.70
1	780,127.85	464,989.02	95,967.00	219,171.83
2	706,708.03	421,175.08	86,964.13	198,568.82
3	575,864.60	343,277.53	70,822.93	161,764.13
4	871,190.08	519,343.38	107,146.93	244,699.77
5	855,718.40	510,012.55	105,245.55	240,460.30
6	855,920.27	510,193.83	105,257.02	240,469.42
7	814,720.65	485,511.33	100,287.83	228,921.48
8	779,676.22	464,659.55	95,861.15	219,155.52
9	780,171.82	464,950.50	95,972.97	219,248.35
10	779,984.75	464,847.65	95,970.60	219,166.50
11	780,018.27	464,836.85	95,945.02	219,236.40
12	780,211.85	464,952.92	95,937.12	219,321.82
Average	***787,347.69***	***469,258.61***	***96,844.71***	***221,244.37***

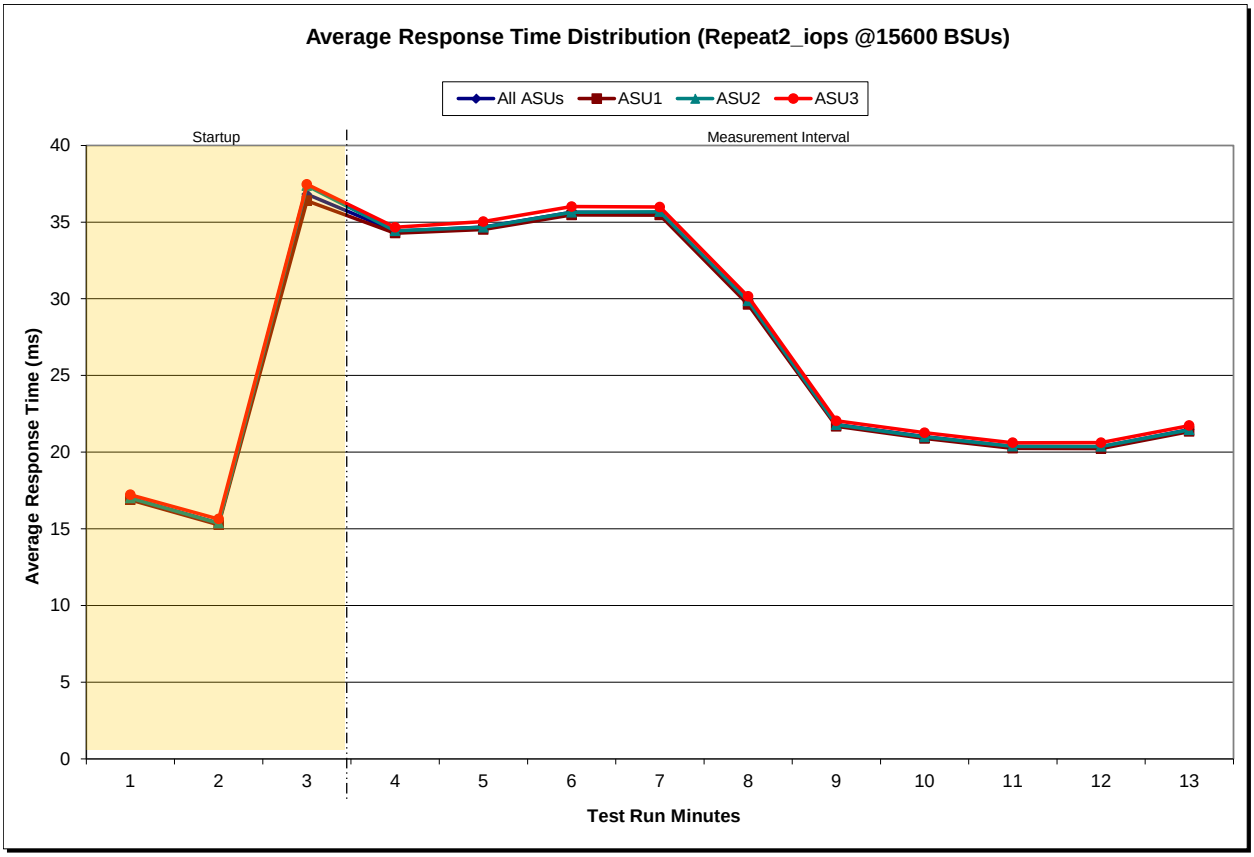
Repeatability 2 IOPS – I/O Request Throughput Distribution Graph



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

15,600 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:52:20	14:55:21	0-2	0:03:01
Measurement Interval	14:55:21	15:05:37	3-12	0:10:16
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	17.00	16.89	17.00	17.23
1	15.38	15.27	15.37	15.64
2	36.81	36.39	37.37	37.46
3	34.40	34.28	34.43	34.66
4	34.68	34.52	34.66	35.03
5	35.64	35.46	35.63	36.01
6	35.63	35.46	35.68	35.98
7	29.80	29.63	29.86	30.15
8	21.80	21.69	21.78	22.04
9	21.01	20.90	21.00	21.27
10	20.37	20.25	20.38	20.61
11	20.36	20.23	20.37	20.62
12	21.47	21.35	21.45	21.74
Average	***27.52***	***27.38***	***27.52***	***27.81***

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	0.0349	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.002	0.001	0.001	0.001	0.003	0.002	0.002	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	0.000	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	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.002	0.001	0.002	0.001	0.002	0.002	0.002	0.001

Repeatability 2 (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	0.000	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 78.

Data Persistence Test Results File

A link to each test result file generated from each Data Persistence Test is listed below.

Persistence 1 Test Results File

Persistence 2 Test Results File

Data Persistence Test Results

Data Persistence Test Results	
Data Persistence Test Run Number: 1	
Total Number of Logical Blocks Written	5,239,,697
Total Number of Logical Blocks Verified	4,758,948
Total Number of Logical Blocks that Failed Verification	0
Time Duration for Writing Test Logical Blocks	5 minutes
Size in bytes of each Logical Block	1,024
Number of Failed I/O Requests in the process of the Test	0

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

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

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

PRICED STORAGE CONFIGURATION AVAILABILITY DATE

Clause 9.4.3.9

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

The IBM Power 780 server as documented in this Full Disclosure Report will become available on May 2, 2012 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 14.

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 15.

ANOMALIES OR IRREGULARITIES

Clause 9.4.3.10

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

There were no anomalies or irregularities encountered during the SPC-1 Remote Audit of the IBM Power 780 server.

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.

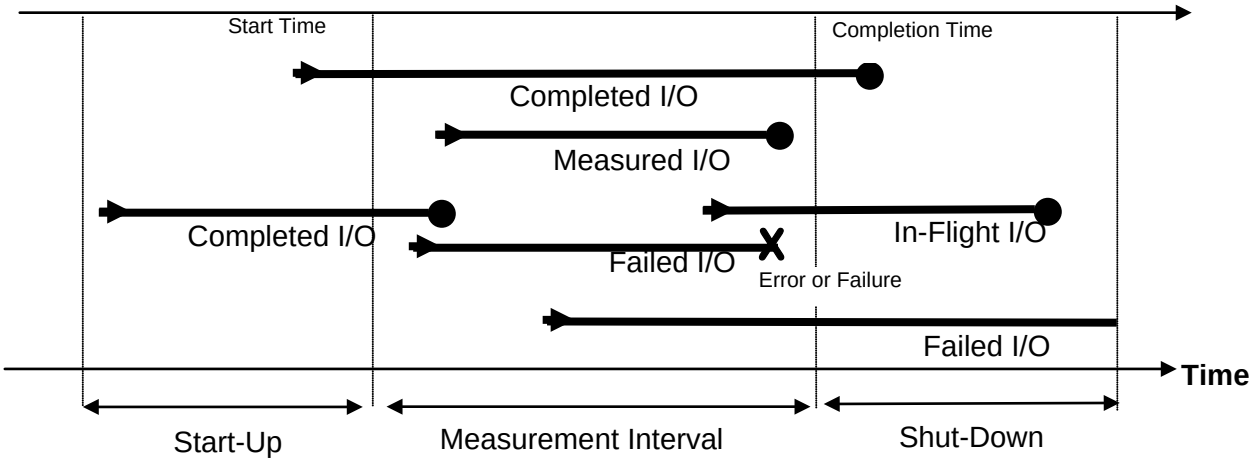
Steady State: The consistent and sustainable throughput of the TSC. During this period the load presented to the TSC by the Workload Generator is constant.

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

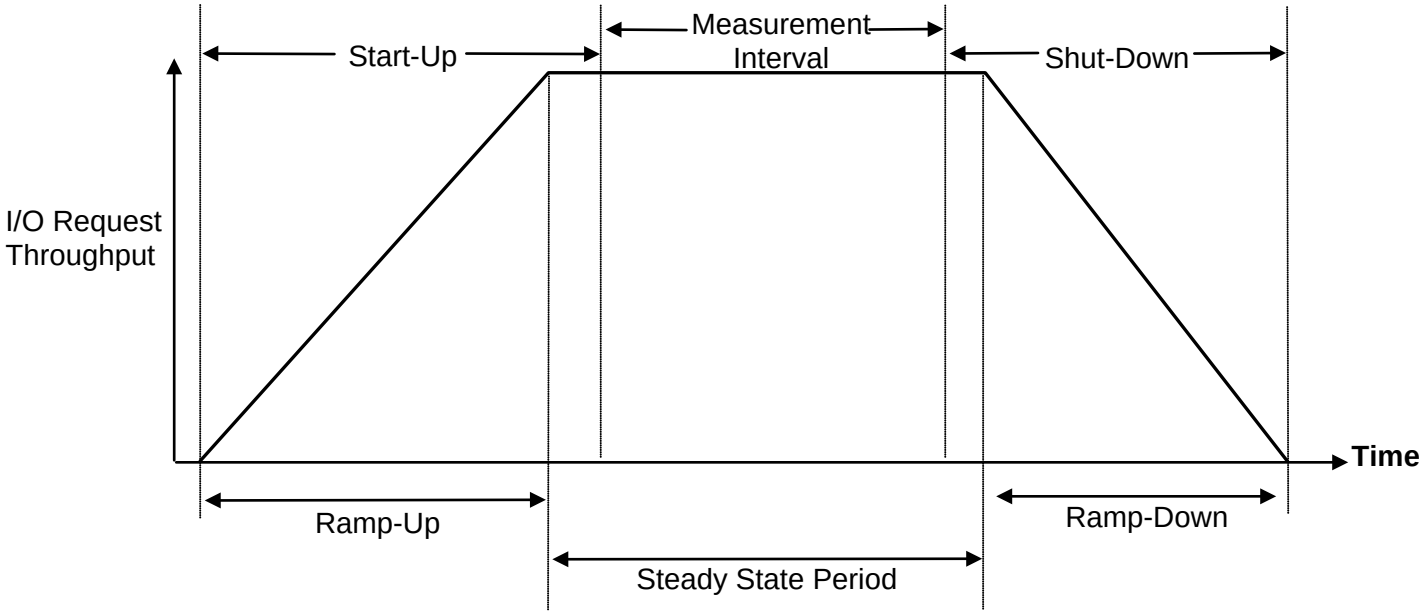
Test Run: The execution of SPC-1 for the purpose of producing or supporting an SPC-1 test result. SPC-1 Test Runs may have a finite and measured Ramp-Up period, Start-Up period, Shut-Down period, and Ramp-Down period as illustrated in the "SPC-1 Test Run Components" below. All SPC-1 Test Runs shall have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

- **schedo -p -o vpm_fold_policy=0** #disable virtual processor management.
- **schedo -p -o smt_snooze_delay=-1** #disable snoozing while idle.
- **schedo -p -o smt_tertiary_snooze_delay=-1** #disable tertiary snoozing.
- **dscrctl -b -n -s 1** #disable stream prefetch
- **smtctl -m off boot** #execute processor instructions in single thread mode.
- **ioo –o spec_accessupdate=1** #disable raw device file access/update times.

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

The following commands and scripts were executed on the Power 780 Host System from an AIX command shell by the root user of the Power 780 Host System. The scripts appear in the TSC Creation/Configuration Scripts section below.

EXP30 Configuration

Step 1: Discover SSDs

Issue the command ***cfmgr***, which will cause AIX to discover the 'pdisks' (pdisk0…pdisk239) that correspond to the 240 SSDs. A 'pdisk' is a device managed by the SAS Disk Array Manager in AIX. The device is not directly available for use as storage, but instead is a candidate for placement into a RAID array.

A side effect of the device discovery is that this creates a default set of 'hdisks' that correspond to the 'pdisks'. Those default 'hdisks' are removed by executing the script **reset_exp30.sh**.

Step 2: Define RAID Arrays

Execute the script **createRaid.pl 10 2 240 0**, which will cause the 240 'pdisks', starting at 'pdisk0' to be formed into RAID10 arrays containing 2 disks each. The resulting arrays appear as 'hdisk4, 'hdisk5'…'hdisk123' *(the exact 'hdisk' identifier can vary)*.

Step 3: Assign Controller/hdisk Mapping

Execute the script **maphdisks.sh**, which will invoke the script **optimizeRaid.pl**. The scripts, taken together, will cause each EXP30 'hdisk' to be mapped to one of the two RAID controllers in the associated EXP30 drawer.

AIX Host System Configuration

The following AIX Host System parameters were changed to permit large levels of IOPS when running on a single AIX Host System.

- **schedo -p -o vpm_fold_policy=0** #disable virtual processor management.
- **schedo -p -o smt_snooze_delay=-1** #disable snoozing while idle.
- **schedo -p -o smt_tertiary_snooze_delay=-1** #disable tertiary snoozing.
- **dscrctl -b -n -s 1** #disable stream prefetch
- **smtctl -m off boot** #execute processor instructions in single thread mode.
- **ioo –o spec_accessupdate=1** #disable raw device file access/update times.

The parameters were changed by executing the above commands in an AIX command shell as root user of the Power 780 Host System.

The effects of the above parameter changes are saved to the boot image with the **bosboot –a** command. The Power 780 Host System is then rebooted.

Logical Volume Configuration

Execute the script **stripethem.sh 6480 64 71**, which will create a logical volume group that will be striped across all of the EXP30 'hdisks'. The logical volume group will consist of 71 logical volumes, each containing 6,480 partitions with a capacity of 64 MiB per partition.

TSC Creation/Configuration Scripts

reset_exp30.sh

```
# remove any pre-existing EXP30 array definitions

clist=`lsdev -C | grep sissas | grep "6Gb x8" | awk '{print $1}'`
for c in $clist
do
   descrip=`sissasraidmgr -L -j1 -l $c | grep Primary`
   if [ -n$descrip ]
   then
   hdisklist=`sissasraidmgr -L -j1 -l $c | grep hdisk | awk '{print $1}'`
   for h in $hdisklist
     do
     sissasraidmgr -D -l $c -d $h
     done
   fi
done
```

createRaid.pl 10 2 240 0

```
#!/usr/bin/perl

if ( $ARGV[0] eq "-h" or $ARGC < 2 ) {
     print "\nUsage: createRaid.pl <raidLevel> <drivesPerArray> [totalDrives] [1st
pdisk#]\n";
     print  "\ncreateRaid.pl will make as many arrays as totalDrives will
permit.\n";
    print  "\n [totalDrives] input parm is optional. Default = drivesPerArray.";
    print  "\n [1st pdisk#] parm is also optional.   Default = zero.\n";
}

$raid           = $ARGV[0];
$drivesPerArray = $ARGV[1];
if ( $ARGV[2] ) {
     $totalDrives = $ARGV[2];
}
else {
     $totalDrives = $drivesPerArray;
}
if ( $ARGV[3] ) {
    $firstpdisk = $ARGV[3];
}
else {
    $firstpdisk = 0;
}


if ( $drivesPerArray > $totalDrives ) {
     print "\ndrivesPerArray must not be greater than totalDrives.\n";
     print "Exiting\n";
     exit;
}

for ( $i = 0 ; $i < $totalDrives ; $i += $drivesPerArray ) {
     $pdiskList = "";
     for ( $j = $i + $firstpdisk ; $j < $i + $firstpdisk + $drivesPerArray ; $j += 1
) {
```

```
            $pdiskList = $pdiskList . 'pdisk' . $j . ' ';
      }
      $command = "sissasraidmgr -C -r $raid -s 256 -z \'$pdiskList\'";
      print "$command";
      system $command;
}
print "\nExiting!";
```

maphdisks.sh

```
#map each EXP30 hdisk to one of the two available controllers.

clist=`lsdev -C | grep sissas | grep "6Gb x8" | awk '{print $1}'`
for c in $clist
do
   starthere=`sissasraidmgr -L -j1 -l $c  | awk '/Primary/ { getline; getline;
getline; print $1 }'`
   if [ -n$starthere ]
   then
   optimizeRaid.pl $c 15 $starthere
   fi
done
```

optimizeRaid.pl

```
#!/usr/bin/perl

if ( $ARGV[0] eq "-h" or $ARGC < 2 ) {
      print "\nUsage: optimizeRaid.pl <primaryIOA#> <#ofhdisks> <1st hdisk#>\n";
      print  "\noptimizeRaid.pl will alternate optimization between 2 IOAs.\n";
}

$ioa = 'sissas' . $ARGV[0];
$numofhdisks = $ARGV[1];
if ( $ARGV[2] ) {
      $firsthdisk = $ARGV[2];
}
else {
      $firsthdisk = 0;
}


if ( $numofhdisks < 2 ) {
      print "\nGive me more drives to work with.\n";
      print "Exiting\n";
      exit;
}

$act_or_pass = 3;

for ( $i = $firsthdisk ; $i < $numofhdisks + $firsthdisk ; $i += 1 ) {
      $hdisk = 'hdisk' . $i ;

     if ( $act_or_pass eq 3 ) {
         $act_or_pass = 2;
     }
     else {
         $act_or_pass = 3;
```

```
    }

     $command = "sissasraidmgr -E -d $hdisk -l $ioa -o $act_or_pass";
     print "\n$command";
     system $command;
}
print "\nExiting!";
```

stripethem.sh 6480 64 71

```
# makes striped volume group from available hdisks; makes vols with a specified
number of specified meg partitions.
# important: assumes MPIO, assumes no. of hdisks divides no. of partitions.
if [[ ($# -lt 2) ]]
then
    echo "usage: stripethem partitions psize [nvols].  Partitions should be
divisible by hdisks"
    exit
fi
partspervol=$1
psize=$2

hfield=$(lsdev -Cc disk | grep 'SSD Array' | awk '{print $1}')
if [ -e /dev/thinstripevg ]
then echo "Volume group already exists, using existing LVG"
else mkvg -fy thinstripevg -S -v 4096 -P 2048 -s $psize $hfield
fi

hnum=`echo $hfield | wc -w`
parts=`lsvg thinstripevg | grep "FREE PPs:" | awk '{print $6}'`
let numlv="parts / partspervol"
let usedparts="partspervol * numlv"
print "At most $numlv logical volumes can be made,"
print "using $usedparts out of $parts available partitions."
if [[ ($# -eq 3) ]]
then making=$3
else making=$numlv
fi
l=1
while [[ $l -le $making ]]
do
mklv -b n -y thin$l -x 32512 -u $hnum -S 256K thinstripevg $partspervol
l=$((l+1))
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.

```
*
* This will produce a random data pattern of the entire LBA range using LSFR 32bit
*
compratio=1
sd=default,threads=1,size=400g
sd=sd1,lun=/dev/rthin1
sd=sd2,lun=/dev/rthin2
sd=sd3,lun=/dev/rthin3
sd=sd4,lun=/dev/rthin4
sd=sd5,lun=/dev/rthin5
sd=sd6,lun=/dev/rthin6
sd=sd7,lun=/dev/rthin7
sd=sd8,lun=/dev/rthin8
sd=sd9,lun=/dev/rthin9
sd=sd10,lun=/dev/rthin10
sd=sd11,lun=/dev/rthin11
sd=sd12,lun=/dev/rthin12
sd=sd13,lun=/dev/rthin13
sd=sd14,lun=/dev/rthin14
sd=sd15,lun=/dev/rthin15
sd=sd16,lun=/dev/rthin16
sd=sd17,lun=/dev/rthin17
sd=sd18,lun=/dev/rthin18
sd=sd19,lun=/dev/rthin19
sd=sd20,lun=/dev/rthin20
sd=sd21,lun=/dev/rthin21
sd=sd22,lun=/dev/rthin22
sd=sd23,lun=/dev/rthin23
sd=sd24,lun=/dev/rthin24
sd=sd25,lun=/dev/rthin25
sd=sd26,lun=/dev/rthin26
sd=sd27,lun=/dev/rthin27
sd=sd28,lun=/dev/rthin28
sd=sd29,lun=/dev/rthin29
sd=sd30,lun=/dev/rthin30
sd=sd31,lun=/dev/rthin31
sd=sd32,lun=/dev/rthin32
sd=sd33,lun=/dev/rthin33
sd=sd34,lun=/dev/rthin34
sd=sd35,lun=/dev/rthin35
sd=sd36,lun=/dev/rthin36
sd=sd37,lun=/dev/rthin37
sd=sd38,lun=/dev/rthin38
sd=sd39,lun=/dev/rthin39
sd=sd40,lun=/dev/rthin40
sd=sd41,lun=/dev/rthin41
sd=sd42,lun=/dev/rthin42
sd=sd43,lun=/dev/rthin43
sd=sd44,lun=/dev/rthin44
sd=sd45,lun=/dev/rthin45
sd=sd46,lun=/dev/rthin46
sd=sd47,lun=/dev/rthin47
```

```
sd=sd48,lun=/dev/rthin48
sd=sd49,lun=/dev/rthin49
sd=sd50,lun=/dev/rthin50
sd=sd51,lun=/dev/rthin51
sd=sd52,lun=/dev/rthin52
sd=sd53,lun=/dev/rthin53
sd=sd54,lun=/dev/rthin54
sd=sd55,lun=/dev/rthin55
sd=sd56,lun=/dev/rthin56
sd=sd57,lun=/dev/rthin57
sd=sd58,lun=/dev/rthin58
sd=sd59,lun=/dev/rthin59
sd=sd60,lun=/dev/rthin60
sd=sd61,lun=/dev/rthin61
sd=sd62,lun=/dev/rthin62
sd=sd63,lun=/dev/rthin63
sd=sd64,lun=/dev/rthin64
sd=sd65,lun=/dev/rthin65
sd=sd66,lun=/dev/rthin66
sd=sd67,lun=/dev/rthin67
sd=sd68,lun=/dev/rthin68
sd=sd69,lun=/dev/rthin69
sd=sd70,lun=/dev/rthin70
sd=sd71,lun=/dev/rthin71

wd=default,rdpct=0,seek=-1,xfersize=256K
wd=wd1,sd=sd1
wd=wd2,sd=sd2
wd=wd3,sd=sd3
wd=wd4,sd=sd4
wd=wd5,sd=sd5
wd=wd6,sd=sd6
wd=wd7,sd=sd7
wd=wd8,sd=sd8
wd=wd9,sd=sd9
wd=wd10,sd=sd10
wd=wd11,sd=sd11
wd=wd12,sd=sd12
wd=wd13,sd=sd13
wd=wd14,sd=sd14
wd=wd15,sd=sd15
wd=wd16,sd=sd16
wd=wd17,sd=sd17
wd=wd18,sd=sd18
wd=wd19,sd=sd19
wd=wd20,sd=sd20
wd=wd21,sd=sd21
wd=wd22,sd=sd22
wd=wd23,sd=sd23
wd=wd24,sd=sd24
wd=wd25,sd=sd25
wd=wd26,sd=sd26
wd=wd27,sd=sd27
wd=wd28,sd=sd28
wd=wd29,sd=sd29
wd=wd30,sd=sd30
wd=wd31,sd=sd31
wd=wd32,sd=sd32
wd=wd33,sd=sd33
wd=wd34,sd=sd34
wd=wd35,sd=sd35
wd=wd36,sd=sd36
```

```
wd=wd37,sd=sd37
wd=wd38,sd=sd38
wd=wd39,sd=sd39
wd=wd40,sd=sd40
wd=wd41,sd=sd41
wd=wd42,sd=sd42
wd=wd43,sd=sd43
wd=wd44,sd=sd44
wd=wd45,sd=sd45
wd=wd46,sd=sd46
wd=wd47,sd=sd47
wd=wd48,sd=sd48
wd=wd49,sd=sd49
wd=wd50,sd=sd50
wd=wd51,sd=sd51
wd=wd52,sd=sd52
wd=wd53,sd=sd53
wd=wd54,sd=sd54
wd=wd55,sd=sd55
wd=wd56,sd=sd56
wd=wd57,sd=sd57
wd=wd58,sd=sd58
wd=wd59,sd=sd59
wd=wd60,sd=sd60
wd=wd61,sd=sd61
wd=wd62,sd=sd62
wd=wd63,sd=sd63
wd=wd64,sd=sd64
wd=wd65,sd=sd65
wd=wd66,sd=sd66
wd=wd67,sd=sd67
wd=wd68,sd=sd68
wd=wd69,sd=sd69
wd=wd70,sd=sd70
wd=wd71,sd=sd71

*===================================
* Use 10 hours as a maximum elapsed time,
* which should ensure the entire LBA range
* will be written before the time elapses
*===================================
*
rd=FILLIT,wd=wd*,iorate=max,elapsed=999990,interval=10
*
* The above "elapsed=36000" may have to be increased to ensure that the utility will
reach
* the end of the LUN ("seek=-1") prior to the end of the specified elapsed time
```

Primary Metrics and Repeatability Tests

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

Common Command Lines – Primary Metrics and Repeatability Tests

The following command lines appear at the beginning of each command and parameter file for the Primary Metrics and Repeatability Test. The command lines are only listed below to eliminate redundancy.

```
host=master
slaves=(slav1,slav2,slav3,slav4,slav5,slav6,slav7,slav8,slav9,slav10,slav11,slav12,s
lav13,slav14,slav15,slav16,slav17,slav18,slav19,slav20,slav21,slav22,slav23,slav24,s
lav25,slav26,slav27,slav28,slav29,slav30,slav31,slav32,slav33,slav34,slav35,slav36,s
lav37,slav38,slav39,slav40,slav41,slav42,slav43,slav44,slav45,slav46,slav47,slav48,s
lav49,slav50,slav51,slav52,slav53,slav54,slav55,slav56,slav57,slav58,slav59,slav60,s
lav61,slav62,slav63,slav64,slav65,slav66,slav67,slav68,slav69,slav70,slav71,slav72,s
lav73,slav74,slav75,slav76,slav77,slav78,slav79,slav80,slav81,slav82,slav83,slav84,s
lav85,slav86,slav87,slav88,slav89,slav90,slav91,slav92,slav93,slav94,slav95,slav96,s
lav97,slav98,slav99,slav100,slav101,slav102,slav103,slav104,slav105,slav106,slav107,
slav108,slav109,slav110,slav111,slav112,slav113,slav114,slav115,slav116,slav117,slav
118,slav119,slav120,slav121,slav122,slav123,slav124,slav125,slav126,slav127,slav128,
slav129,slav130,slav131,slav132,slav133,slav134,slav135,slav136,slav137,slav138,slav
139,slav140,slav141,slav142,slav143,slav144,slav145,slav146,slav147,slav148,slav149,
slav150,slav151,slav152,slav153,slav154,slav155,slav156,slav157,slav158,slav159,slav
160,slav161,slav162,slav163,slav164,slav165,slav166,slav167,slav168,slav169,slav170,
slav171,slav172,slav173,slav174,slav175,slav176,slav177,slav178,slav179,slav180,slav
181,slav182,slav183,slav184,slav185,slav186,slav187,slav188,slav189,slav190,slav191,
slav192)
javaparms="-Xms1280m -Xmx1280m -Xss128k -Xgcthreads8 -Xgcpolicy:gencon"
#sd=default,size=343597383680
sd=default,size=400g
sd=asu1_1,lun=/dev/rthin1
sd=asu1_2,lun=/dev/rthin2
sd=asu1_3,lun=/dev/rthin3
sd=asu1_4,lun=/dev/rthin4
sd=asu1_5,lun=/dev/rthin5
sd=asu1_6,lun=/dev/rthin6
sd=asu1_7,lun=/dev/rthin7
sd=asu1_8,lun=/dev/rthin8
sd=asu1_9,lun=/dev/rthin9
sd=asu1_10,lun=/dev/rthin10
sd=asu1_11,lun=/dev/rthin11
sd=asu1_12,lun=/dev/rthin12
sd=asu1_13,lun=/dev/rthin13
sd=asu1_14,lun=/dev/rthin14
sd=asu1_15,lun=/dev/rthin15
sd=asu1_16,lun=/dev/rthin16
sd=asu1_17,lun=/dev/rthin17
sd=asu1_18,lun=/dev/rthin18
sd=asu1_19,lun=/dev/rthin19
sd=asu1_20,lun=/dev/rthin20
sd=asu1_21,lun=/dev/rthin21
sd=asu1_22,lun=/dev/rthin22
sd=asu1_23,lun=/dev/rthin23
sd=asu1_24,lun=/dev/rthin24
sd=asu1_25,lun=/dev/rthin25
sd=asu1_26,lun=/dev/rthin26
```

```
sd=asu1_27,lun=/dev/rthin27
sd=asu1_28,lun=/dev/rthin28
sd=asu1_29,lun=/dev/rthin29
sd=asu1_30,lun=/dev/rthin30
sd=asu1_31,lun=/dev/rthin31
sd=asu1_32,lun=/dev/rthin32
sd=asu2_1,lun=/dev/rthin33
sd=asu2_2,lun=/dev/rthin34
sd=asu2_3,lun=/dev/rthin35
sd=asu2_4,lun=/dev/rthin36
sd=asu2_5,lun=/dev/rthin37
sd=asu2_6,lun=/dev/rthin38
sd=asu2_7,lun=/dev/rthin39
sd=asu2_8,lun=/dev/rthin40
sd=asu2_9,lun=/dev/rthin41
sd=asu2_10,lun=/dev/rthin42
sd=asu2_11,lun=/dev/rthin43
sd=asu2_12,lun=/dev/rthin44
sd=asu2_13,lun=/dev/rthin45
sd=asu2_14,lun=/dev/rthin46
sd=asu2_15,lun=/dev/rthin47
sd=asu2_16,lun=/dev/rthin48
sd=asu2_17,lun=/dev/rthin49
sd=asu2_18,lun=/dev/rthin50
sd=asu2_19,lun=/dev/rthin51
sd=asu2_20,lun=/dev/rthin52
sd=asu2_21,lun=/dev/rthin53
sd=asu2_22,lun=/dev/rthin54
sd=asu2_23,lun=/dev/rthin55
sd=asu2_24,lun=/dev/rthin56
sd=asu2_25,lun=/dev/rthin57
sd=asu2_26,lun=/dev/rthin58
sd=asu2_27,lun=/dev/rthin59
sd=asu2_28,lun=/dev/rthin60
sd=asu2_29,lun=/dev/rthin61
sd=asu2_30,lun=/dev/rthin62
sd=asu2_31,lun=/dev/rthin63
sd=asu2_32,lun=/dev/rthin64
sd=asu3_1,lun=/dev/rthin65
sd=asu3_2,lun=/dev/rthin66
sd=asu3_3,lun=/dev/rthin67
sd=asu3_4,lun=/dev/rthin68
sd=asu3_5,lun=/dev/rthin69
sd=asu3_6,lun=/dev/rthin70
sd=asu3_7,lun=/dev/rthin71
```

Primary Metrics Test: Sustainability Test Phase/Test Run

common command lines

```
rd=sustain,bsus=15600,startup=180,elapsed=28800,interval=60
```

Primary Metrics Test: IOPS Test Phase *(100% Test Run)*

common command lines

```
rd=ramp_100,bsus=15600,startup=180,elapsed=600,interval=60
```

Primary Metrics Test: Response Time Ramp Test Phase *(95% Test Run)*

common command lines

```
rd=ramp_95,bsus=14820,startup=180,elapsed=600,interval=60
```

Primary Metrics Test: Response Time Ramp Test Phase (90% Test Run)

common command lines

```
rd=ramp_90,bsus=14040,startup=180,elapsed=600,interval=60
```

Primary Metrics Test: Response Time Ramp Test Phase (80% Test Run)

common command lines

```
rd=ramp_80,bsus=12480,startup=180,elapsed=600,interval=60
```

Primary Metrics Test: Response Time Ramp Test Phase (50% Test Run)

common command lines

```
rd=ramp_50,bsus=7800,startup=180,elapsed=600,interval=60
```

Primary Metrics Test: Response Time Ramp Test Phase (10% Test Run)

common command lines

```
rd=ramp_10,bsus=1560,startup=180,elapsed=600,interval=60
```

Repeatability Test: Repeatability Test Phase 1 *(10% and 100% Test Runs)*

common command lines

```
rd=repeat1_lrt,bsus=1560,startup=180,elapsed=600,interval=60
rd=repeat1_iops,bsus=15600,startup=180,elapsed=600,interval=60
```

Repeatability Test: Repeatability Test Phase 2 *(10% and 100% Test Runs)*

common command lines

```
rd=repeat2_lrt,bsus=1560,startup=180,elapsed=600,interval=60
rd=repeat2_iops,bsus=15600,startup=180,elapsed=600,interval=60
```

SPC-2 Persistence Test

Common Command Lines – SPC-2 Persistence Test

The following command lines appear at the beginning of each command and parameter file for the two SPC-2 Persistence Test Runs. The command lines are only listed below to eliminate redundancy.

```
host=localhost,jvms=8,maxstreams=200

sd=default,host=localhost
sd=default,size=400000000000
sd=sd1,lun=/dev/rthin1
sd=sd2,lun=/dev/rthin2
sd=sd3,lun=/dev/rthin3
sd=sd4,lun=/dev/rthin4
sd=sd5,lun=/dev/rthin5
sd=sd6,lun=/dev/rthin6
sd=sd7,lun=/dev/rthin7
sd=sd8,lun=/dev/rthin8
sd=sd9,lun=/dev/rthin9
sd=sd10,lun=/dev/rthin10
sd=sd11,lun=/dev/rthin11
sd=sd12,lun=/dev/rthin12
sd=sd13,lun=/dev/rthin13
sd=sd14,lun=/dev/rthin14
sd=sd15,lun=/dev/rthin15
sd=sd16,lun=/dev/rthin16
sd=sd17,lun=/dev/rthin17
sd=sd18,lun=/dev/rthin18
sd=sd19,lun=/dev/rthin19
sd=sd20,lun=/dev/rthin20
sd=sd21,lun=/dev/rthin21
sd=sd22,lun=/dev/rthin22
sd=sd23,lun=/dev/rthin23
sd=sd24,lun=/dev/rthin24
sd=sd25,lun=/dev/rthin25
sd=sd26,lun=/dev/rthin26
sd=sd27,lun=/dev/rthin27
sd=sd28,lun=/dev/rthin28
sd=sd29,lun=/dev/rthin29
sd=sd30,lun=/dev/rthin30
sd=sd31,lun=/dev/rthin31
sd=sd32,lun=/dev/rthin32
sd=sd33,lun=/dev/rthin33
sd=sd34,lun=/dev/rthin34
sd=sd35,lun=/dev/rthin35
sd=sd36,lun=/dev/rthin36
sd=sd37,lun=/dev/rthin37
sd=sd38,lun=/dev/rthin38
sd=sd39,lun=/dev/rthin39
sd=sd40,lun=/dev/rthin40
sd=sd41,lun=/dev/rthin41
sd=sd42,lun=/dev/rthin42
sd=sd43,lun=/dev/rthin43
sd=sd44,lun=/dev/rthin44
sd=sd45,lun=/dev/rthin45
sd=sd46,lun=/dev/rthin46
sd=sd47,lun=/dev/rthin47
sd=sd48,lun=/dev/rthin48
```

```
sd=sd49,lun=/dev/rthin49
sd=sd50,lun=/dev/rthin50
sd=sd51,lun=/dev/rthin51
sd=sd52,lun=/dev/rthin52
sd=sd53,lun=/dev/rthin53
sd=sd54,lun=/dev/rthin54
sd=sd55,lun=/dev/rthin55
sd=sd56,lun=/dev/rthin56
sd=sd57,lun=/dev/rthin57
sd=sd58,lun=/dev/rthin58
sd=sd59,lun=/dev/rthin59
sd=sd60,lun=/dev/rthin60
sd=sd61,lun=/dev/rthin61
sd=sd62,lun=/dev/rthin62
sd=sd63,lun=/dev/rthin63
sd=sd64,lun=/dev/rthin64
sd=sd65,lun=/dev/rthin65
sd=sd66,lun=/dev/rthin66
sd=sd67,lun=/dev/rthin67
sd=sd68,lun=/dev/rthin68
sd=sd69,lun=/dev/rthin69
sd=sd70,lun=/dev/rthin70
sd=sd71,lun=/dev/rthin71


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

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

common command lines

```
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=640
```

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

common command lines

```
maxpersistenceerrors=10
*corruptstreams=3

rd=default,buffers=1,rdpct=100,xfersize=1024k
rd=TR1-5s_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. **slav1**, **slav2**, **slav3**… .

```
master=localhost
host=slav1
#sd=default,size=343597383680
sd=default,size=400g
sd=asu1_1,lun=/dev/rthin1
sd=asu1_2,lun=/dev/rthin2
sd=asu1_3,lun=/dev/rthin3
sd=asu1_4,lun=/dev/rthin4
sd=asu1_5,lun=/dev/rthin5
sd=asu1_6,lun=/dev/rthin6
sd=asu1_7,lun=/dev/rthin7
sd=asu1_8,lun=/dev/rthin8
sd=asu1_9,lun=/dev/rthin9
sd=asu1_10,lun=/dev/rthin10
sd=asu1_11,lun=/dev/rthin11
sd=asu1_12,lun=/dev/rthin12
sd=asu1_13,lun=/dev/rthin13
sd=asu1_14,lun=/dev/rthin14
sd=asu1_15,lun=/dev/rthin15
sd=asu1_16,lun=/dev/rthin16
sd=asu1_17,lun=/dev/rthin17
sd=asu1_18,lun=/dev/rthin18
sd=asu1_19,lun=/dev/rthin19
sd=asu1_20,lun=/dev/rthin20
sd=asu1_21,lun=/dev/rthin21
sd=asu1_22,lun=/dev/rthin22
sd=asu1_23,lun=/dev/rthin23
sd=asu1_24,lun=/dev/rthin24
sd=asu1_25,lun=/dev/rthin25
sd=asu1_26,lun=/dev/rthin26
sd=asu1_27,lun=/dev/rthin27
sd=asu1_28,lun=/dev/rthin28
sd=asu1_29,lun=/dev/rthin29
sd=asu1_30,lun=/dev/rthin30
sd=asu1_31,lun=/dev/rthin31
sd=asu1_32,lun=/dev/rthin32
sd=asu2_1,lun=/dev/rthin33
sd=asu2_2,lun=/dev/rthin34
sd=asu2_3,lun=/dev/rthin35
sd=asu2_4,lun=/dev/rthin36
sd=asu2_5,lun=/dev/rthin37
sd=asu2_6,lun=/dev/rthin38
sd=asu2_7,lun=/dev/rthin39
sd=asu2_8,lun=/dev/rthin40
sd=asu2_9,lun=/dev/rthin41
sd=asu2_10,lun=/dev/rthin42
sd=asu2_11,lun=/dev/rthin43
sd=asu2_12,lun=/dev/rthin44
sd=asu2_13,lun=/dev/rthin45
sd=asu2_14,lun=/dev/rthin46
sd=asu2_15,lun=/dev/rthin47
sd=asu2_16,lun=/dev/rthin48
sd=asu2_17,lun=/dev/rthin49
sd=asu2_18,lun=/dev/rthin50
```

```
sd=asu2_19,lun=/dev/rthin51
sd=asu2_20,lun=/dev/rthin52
sd=asu2_21,lun=/dev/rthin53
sd=asu2_22,lun=/dev/rthin54
sd=asu2_23,lun=/dev/rthin55
sd=asu2_24,lun=/dev/rthin56
sd=asu2_25,lun=/dev/rthin57
sd=asu2_26,lun=/dev/rthin58
sd=asu2_27,lun=/dev/rthin59
sd=asu2_28,lun=/dev/rthin60
sd=asu2_29,lun=/dev/rthin61
sd=asu2_30,lun=/dev/rthin62
sd=asu2_31,lun=/dev/rthin63
sd=asu2_32,lun=/dev/rthin64
sd=asu3_1,lun=/dev/rthin65
sd=asu3_2,lun=/dev/rthin66
sd=asu3_3,lun=/dev/rthin67
sd=asu3_4,lun=/dev/rthin68
sd=asu3_5,lun=/dev/rthin69
sd=asu3_6,lun=/dev/rthin70
sd=asu3_7,lun=/dev/rthin71
```

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

ASU Pre-Fill, Primary Metrics Test, Repeatability Test and Persistence Test Run 1

The **runall.sh** script was used to execute the required ASU pre-fill (**runfill.sh**), one "Ramp-Up" Test Run, 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 load SPC-1 Persistence Test Run 1 and SPC-2 Persistence Test Run 1 (**runpersist1.sh**) in an uninterrupted sequence.

The **numabind.sh** script starts all of the Slave JVM prior to a Test Run execution command. The **rmslaves.sh** script terminates the Slave JVMs upon completion of that Test Run execution.

runall.sh

```
export PATH=/usr/java6/bin:$PATH
export SPC1HOME=/iotest/spc1install
export CLASSPATH=$SPC1HOME
export LIBPATH=$SPC1HOME/aix
export IBM_JAVADUMP_OUTOFMEMORY=false
export IBM_HEAPDUMP_OUTOFMEMORY=false

export HERE=`pwd`

cd ../fill
runfill.sh
cd $HERE

numabind.sh 1 192 $HERE
java -Xoptionsfile=javaopts.cfg spc1 -w SPC1 -flongramp.txt -olongramp
SPCOut_longramp
rmslaves.sh

numabind.sh 1 192 $HERE
java -Xoptionsfile=javaopts.cfg spc1 -w SPC1 -fmetrics1.txt -ometrics1 SPCOut
rmslaves.sh

numabind.sh 1 192 $HERE
java -Xoptionsfile=javaopts.cfg spc1 -w SPC1 -fmetrics2.txt -ometrics2 SPCOut
rmslaves.sh

numabind.sh 1 192 $HERE
java -Xoptionsfile=javaopts.cfg spc1 -w SPC1 -fmetrics3.txt -ometrics3 SPCOut
rmslaves.sh

numabind.sh 1 192 $HERE
java -Xoptionsfile=javaopts.cfg spc1 -w SPC1 -fmetrics4.txt -ometrics4 SPCOut
rmslaves.sh

numabind.sh 1 192 $HERE
java -Xoptionsfile=javaopts.cfg spc1 -w SPC1 -fmetrics5.txt -ometrics5 SPCOut
rmslaves.sh

numabind.sh 1 192 $HERE
java -Xoptionsfile=javaopts.cfg spc1 -w SPC1 -fmetrics6.txt -ometrics6 SPCOut
```

```
rmslaves.sh

numabind.sh 1 192 $HERE
java -Xoptionsfile=javaopts.cfg spc1 -w SPC1 -fmetrics7.txt -ometrics7 SPCOut
rmslaves.sh

numabind.sh 1 192 $HERE
java -Xoptionsfile=javaopts.cfg spc1 -w SPC1 -frepeat1.txt -orepeat1 SPCOut
rmslaves.sh

numabind.sh 1 192 $HERE
java -Xoptionsfile=javaopts.cfg spc1 -w SPC1 -frepeat2.txt -orepeat2 SPCOut
rmslaves.sh

java -Xoptionsfile=javaoptsp.cfg persist1 -b 1600

cd /iotest/spc2persist
rm -fr persistw
./runpersist1.sh
cd $HERE

getaixdata.sh
getssddata.sh
```

runfill.sh

```
#!/usr/bin/ksh
export PATH=$PATH:/usr/java6/bin:/iotest/vdbench503
export VDBHOME=/iotest/vdbench503
export CLASSPATH=$VDBHOME
export LIBPATH=$VDBHOME/aix
export IBM_JAVADUMP_OUTOFMEMORY=false
export IBM_HEAPDUMP_OUTOFMEMORY=false
vdbench -f fill.cfg -o fill_output
```

runpersist1.sh

```
export PATH=$PATH:/usr/java6/bin
export SPC2HOME=/iotest/spc2install
export CLASSPATH=$SPC2HOME
export LIBPATH=$SPC2HOME/aix
export IBM_JAVADUMP_OUTOFMEMORY=false
export IBM_HEAPDUMP_OUTOFMEMORY=false
java -Xoptionsfile=javaopts.cfg vdbench -f persistw.cfg -init -o persistinit
rm -fr persistw
java -Xoptionsfile=javaopts.cfg vdbench -f persistw.cfg -o persistw
```

numabind.sh

This script starts 192 Slave JVMs and binds each to a set of 8 CPUs on the Host System.

```
if [ $# -lt 3 ]
then
   echo "usage: refreshslaves.sh first last directory"
   return
fi
export PATH=/usr/java6/bin:$PATH
export SPC1HOME=/iotest/spc1install
export CLASSPATH=$SPC1HOME
export LIBPATH=$SPC1HOME/aix
export IBM_JAVADUMP_OUTOFMEMORY=false
export IBM_HEAPDUMP_OUTOFMEMORY=false
```

```
i=$1
run_dir=$3
export MEMORY_AFFINITY=MCM
while [[ $i -le $2 ]]
do
ps -ef | grep  slav$i | grep -v grep > /dev/null
if [ $? -ne 0 ]
then
  let ii="i-1"                # assuming the 1st slave is always = 1, start
assigning from cpu 0 in socket 0
  let socket="ii%8"          # assign a socket # (assumes they start @ 0 and end @
15)
  let cpufirst="socket*8"
  let cpulast="cpufirst+7"    # only bind to 4 cores in each socket
  nohup execrset -c $cpufirst-$cpulast -e java -Xoptionsfile=$run_dir/javaopts.cfg
spc1 -f $run_dir/slav$i.txt > $run_dir/slav$i.out &
fi
let i="i+1"
done
unset MEMORY_AFFINITY
```

rmslaves.sh

```
proc_num=$(ps -ef |grep slav|grep -v "grep"|grep -v "rmslaves"|awk '{print $2}')
if [[ -n $proc_num ]];then
kill -9 $proc_num
fi
```

Persistence Test Run 2

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

```
export PATH=/usr/java6/bin:$PATH
export SPC1HOME=/iotest/spc1install
export CLASSPATH=$SPC1HOME
export LIBPATH=$SPC1HOME/aix
export IBM_JAVADUMP_OUTOFMEMORY=false
export IBM_HEAPDUMP_OUTOFMEMORY=false

export HERE=`pwd`

cd ../spc2persist
rm -fr persistr
./runpersist2.sh
cd $HERE
```

runpersist2.sh

```
export PATH=$PATH:/usr/java6/bin
export SPC2HOME=/iotest/spc2install
export CLASSPATH=$SPC2HOME
export LIBPATH=$SPC2HOME/aix
export IBM_JAVADUMP_OUTOFMEMORY=false
export IBM_HEAPDUMP_OUTOFMEMORY=false
rm -fr persistr
java -Xoptionsfile=javaopts.cfg vdbench -f persistr.cfg -o persist
```