SPC BENCHMARK 1™

FULL DISCLOSURE REPORT

HEWLETT-PACKARD COMPANY
HP STORAGEWORKS ENTERPRISE VIRTUAL ARRAY MODEL 2C12D

SPC-1 V1.5

Submitted for Review: October 2, 2002
Accepted: December 1, 2002
Revised: December 6, 2002

First Edition – October 2002

Trademarks

SPC Benchmark 1, SPC-1 IOPS, and SPC-1 LRT are trademarks of the Storage Performance Council. hp, the HP logo, and StorageWorks are trademarks of the Hewlett-Packard Company in the United States and/or other countries.

Notes

The following terms, used in this document, are defined as:

- Kilobyte (KB) is equal to 1,000 (10^3) bytes.
- Megabyte (MB) is equal to 1,000,000 (10^6) bytes.
- Gigabyte (GB) is equal to 1,000,000,000 (10^9) bytes.
- Terabyte (TB) is equal to 1,000,000,000,000 (10^{12}) bytes.

Table of Contents

AUDIT CERTIFICATION

Hewlett-Packard Company
Ken Bates
CXO 1-2/N27
301 Rockrimmon Blvd. S
San Colorado Springs, CO 80919

September 23, 2002

The SPC Benchmark 1™ results listed below for the hp StorageWorks Enterprise Virtual Array Model 2C12D were produced in compliance with the SPC Benchmark 1™ Remote Audit requirements.

SPC Benchmark 1™ Results	
Tested Storage Configuration (TSC) Name: hp StorageWorks Enterprise Virtual Array Model 2C12D	
Metric	**Reported Result**
SPC-1 IOPS™	24,005.54
SPC-1 Price-Performance	$22.00/SPC-1 IOPS™
Total ASU Capacity	2,596.3 GB
Data Protection Level	Mirroring
SPC-1 LRT™	2.29 ms
Total TSC Price (including three-year maintenance)	$528,018

The following SPC Benchmark 1™ Remote Audit requirements were verified:

- A Letter of Good Faith, signed by a senior executive on company letterhead.
- The following Data Repository storage items were remotely verified by information supplied by the Test Sponsor:
  - ✓ 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.
- An appropriate diagram of the Benchmark Configuration (BC)/Tested Storage Configuration (TSC).
- Listings and commands to configure the BC/TSC.

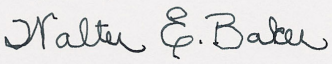
Storage Performance Council
1060 El Camino Real, Suite F
Redwood City, CA 94062-1623
AuditService@storageperformance.org
650.556.9384

- The type of Host System including the number of processors and main memory.
- The presence and version number of each Workload Generator on each Host System.
- Each host system in the multi-host configuration produced compliant results.
- The TSC boundary within each Host System.
- The Test Results Files and resultant Summary Results Files received for each of following were authentic, accurate, and compliant:
  - ✓ Data Persistence Test
  - ✓ Sustainability Test Phase
  - ✓ IOPS Test Phase
  - ✓ Response Time Ramp Test Phase
  - ✓ Repeatability Test
- There were no differences between the benchmarked TSC and priced TSC.
- A preliminary copy of the pricing spreadsheet.
- The Full Disclosure Report (FDR) meets all of the requirements in Clause 9 of the SPC-1 Benchmark Specification.

Audit Notes:

There were no additional audit notes or exceptions.

Respectfully,



Walter E. Baker
SPC Auditor

Storage Performance Council
1060 El Camino Real, Suite F
Redwood City, CA 94062-1623
AuditService@storageperformance.org
650.556.9384

LETTER OF GOOD FAITH

Compaq Computer Corporation
20555 SH 249
Houston, TX 77070-2698
www.hp.com

Date: September 6, 2002

From: Hewlett-Packard Company / Ken Bates

To: Walter Baker / Gradient Systems

Subject: Letter of Good Faith for the SPC Benchmark-1™ results published on the hp StorageWorks Enterprise Virtual Array Model 2C12D Configuration

This Letter of Good Faith between Hewlett-Packard Company ("hereafter known as the Test Sponsor") and the Storage Performance Council (hereafter know as the SPC), documents that:

1. Fidelity and candor has been and will be maintained in reporting any anomalies in the SPC Benchmark-1™ results, even if not explicitly required for disclosure in the SPC Benchmark-1™ specification.
2. No attempt has been or will be made to deceive the SPC Audit Service, SPC, customers, or the public regarding the authenticity or accuracy of SPC Benchmark-1™ results on the hp StorageWorks Enterprise Virtual Array Model 2C12D Configuration. As such, the SPC-1 Full Disclosure Report that will document SPC Benchmark-1™ results (per Clause 10 of the SPC Benchmark-1™ Specification) on the hp StorageWorks Enterprise Virtual Array Model 2C12D Configuration is authentic and accurate.
3. The hp StorageWorks Enterprise Virtual Array Model 2C12D configuration used for reporting SPC Benchmark-1™ results, as documented in the Full Disclosure Report (per Clause 10 of the SPC Benchmark-1™ Specification), has not been misrepresented to the SPC or SPC Audit Service in any way.
4. The SPC Benchmark-1™ results on the hp StorageWorks Enterprise Virtual Array Model 2C12D Configuration are compliant with the spirit, intent, and letter of the SPC Benchmark-1™.
5. The SPC Benchmark-1™ results do not represent a "Benchmark Special" as documented in Clause 0.2 of the SPC Benchmark-1™ specification.

Signed: Peter Korce Date: 12 Sept 02

Peter Korce
Enterprise Business Segment Manager

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact	Hewlett-Packard Company www.hp.com Ken Bates ken.bates@hp.com CXO 1-2/N27 301 Rockrimmon Blvd. S Colorado Springs, CO 80919 Phone: (719) 548-2039 FAX: (719) 548-2362
Test Sponsor Alternate Contact	Hewlett-Packard Company www.hp.com James D. Myers jimmy.myers@hp.com 301 Rockrimmon Blvd. S Colorado Springs, CO 80919 Phone: (719) 548-3592 FAX: (719) 548-3699
Auditor	Storage Performance Council www.storageperformance.org Walter E. Baker AuditService@storageperformance.org 1060 El Camino Real, Suite F 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	V1.5
SPC-1 Workload Generator revision number	V1.1
Date Results were first used publicly	October 2, 2002
Date FDR was submitted to the SPC	October 2, 2002
Date revised FDR was submitted to the SPC **December 6, 2002:** Updated pricing and price-performance (pricing, page 12) **October 7, 2002:** Updated part number for EVA Model 2C12D (pricing, page 12) Updated TSC/BC diagrams (pages 13 & 14) Expanded Host System information (page 16) Corrected TSC configuration script (page 17) Added Storage Capacities & Relationship illustration (page 19) Corrected Sustainability Data Rate Table (page 23) Corrected Data Persistence metrics (page 49)	December 6, 2002
Date the TSC is/was available for shipment to customers	July 30, 2002 (pricing effective December 2, 2002)
Date the TSC completed audit certification	September 23, 2002

Summary of Results

SPC-1 Results	
Tested Storage Configuration (TSC) Name: hp StorageWorks Enterprise Virtual Array Model 2C12D	
Metric	**Reported Result**
SPC-1 IOPS™	24,005.54
SPC-1 Price-Performance	$19.99/SPC-1 IOPS™
Total ASU Capacity	2,596.3GB
Data Protection Level	Mirroring
SPC-1 LRT™	2.29 ms
Total TSC Price (including three-year maintenance)	$479,860

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

Total ASU (Application Storage Unit) **Capacity** represents the total storage capacity read and written in the course of executing the SPC-1 benchmark. The actual Configured Storage Capacity was 5,193.99 GB, which included the multiple copies of user data required by a Data Protection Level of Mirroring. The Configured Storage Capacity utilized 84.91% of the priced Physical Storage Capacity of 6,117 GB.

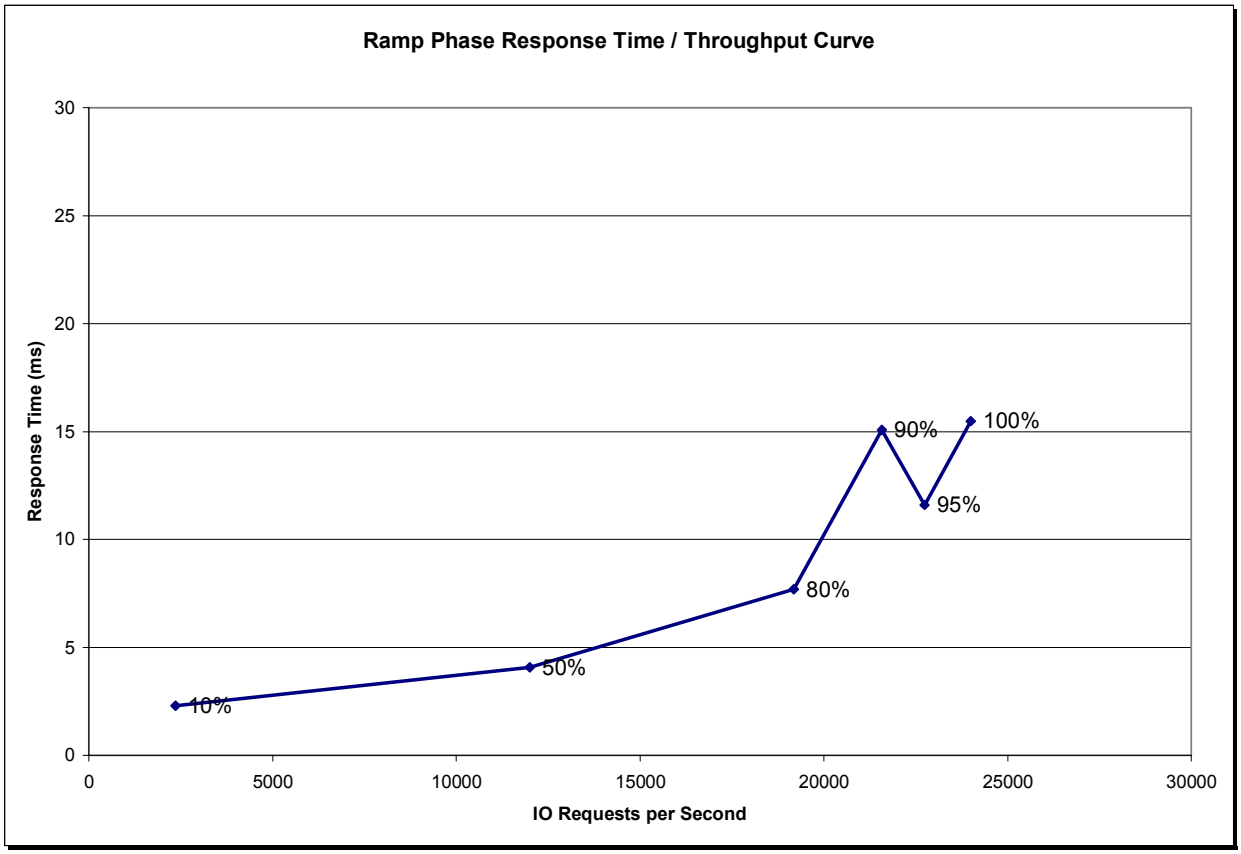
A **Data Protection Level** of Mirroring configures two or more identical copies of user data, maintained on separate disks.

The **SPC-1 LRT™** metric is the Average Response Time measured at the 10% load point, as illustrated on the next page. SPC-1 LRT™ represents the Average Response Time measured on a lightly loaded Tested Storage Configuration (TSC).

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 the 100% load point cannot exceed 30 milliseconds or the benchmark measurement is invalid.



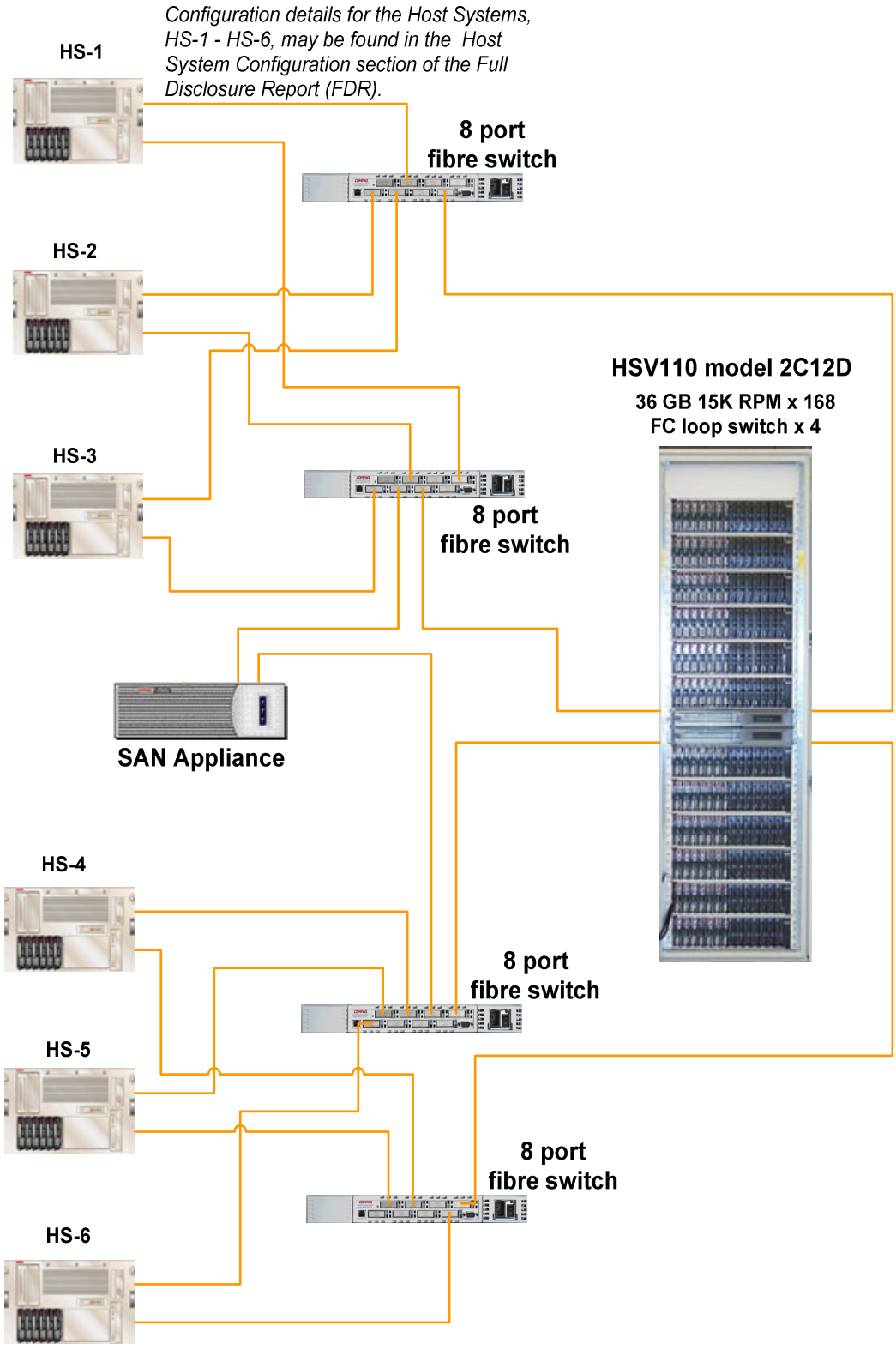
Response Time – Throughput Data

	10% Load	50% Load	80% Load	90% Load	95% Load	100% Load
I/O Request Throughput	2,356.44	11,997.74	19,188.91	21,584.27	22,745.03	24,005.54
Average Response Time (ms):						
All ASUs	2.29	4.08	7.69	15.07	11.59	15.49
ASU-1	3.07	5.58	11.04	22.75	17.13	23.43
ASU-2	3.15	5.31	8.00	10.02	10.00	11.00
ASU-3	0.27	0.35	0.44	1.02	0.54	0.61
Reads	5.46	9.83	16.87	27.95	23.64	29.61
Writes	0.24	0.33	1.71	6.70	3.75	6.29

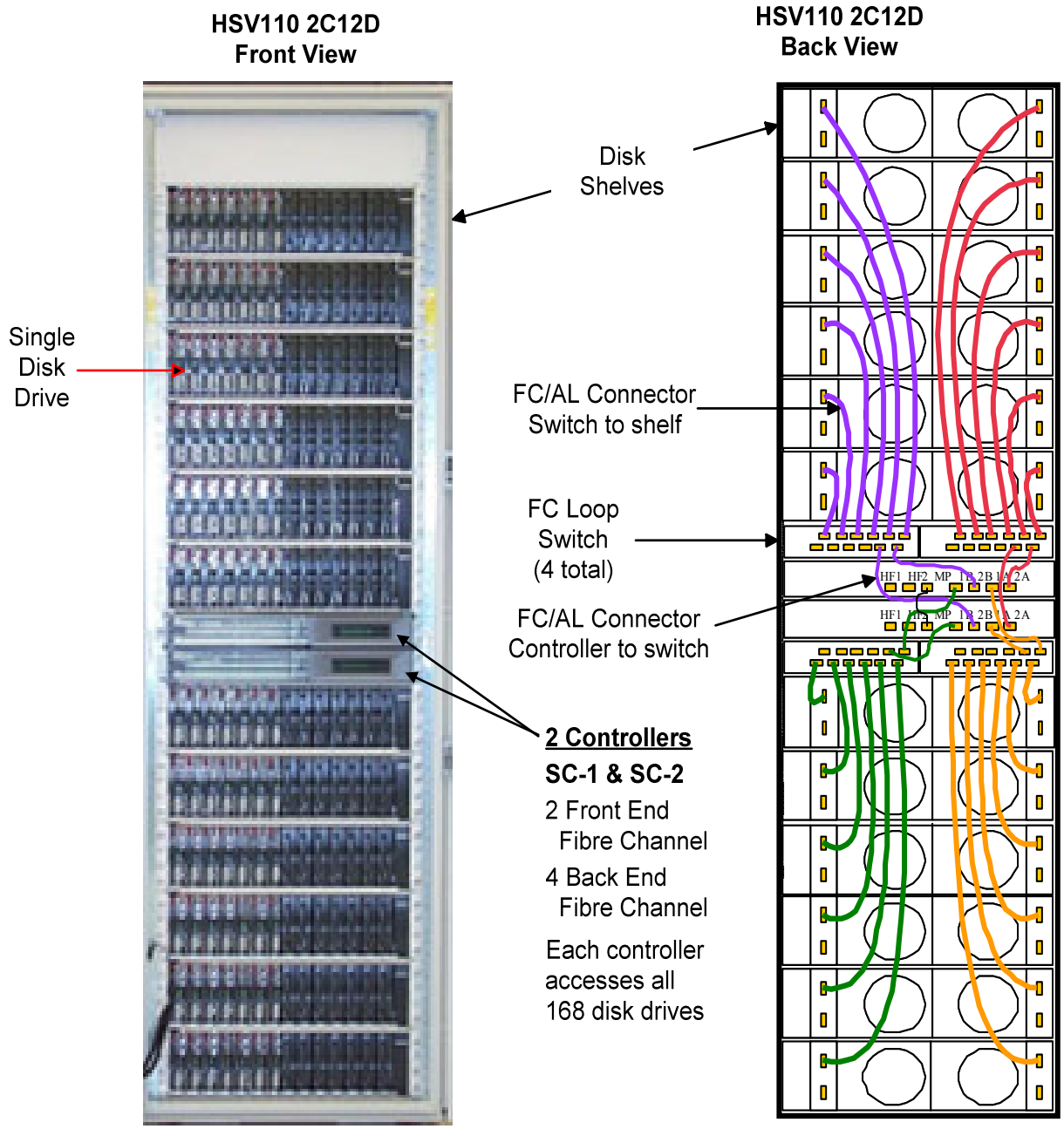
Tested Storage Configuration Pricing

Part Number	Description / Notes	Qty	List	Extended US List Price	Extended Avg US Sell Price
	Storage Hardware / Software				
283198-B21	EVA, Model 2C12D-B 60Hz	1	$193,020	$193,020	$135,114
236205-B21	36GB FC Drive, 15K	168	$2,100	$352,800	$246,960
258158-888	Configure-To-Order	1	$0	$0	$0
250203-B23	VCS v2.0 Dual HSV Cntlr (base software license)	1	$31,900	$31,900	$22,330
250195-B22	WNT/W2K KIT v2.0 ENT VIR ARY	1	$100	$100	$70
189715-002	Management Appliance II	1	$10,500	$10,500	$7,350
281380-002	Software CarePaq Priority Service Extension	1	$30,941	$30,941	$21,659
	Interconnect Hardware				
258707-B21	SAN Switch 2/8-EL	4	$6,400	$25,600	$22,528
176479-B21	FC PCI HBA for WinNT/X86	12	$1,705	$20,460	$18,005
221692-B22	5-meter LC-LC Multi-Mode Fibre Cable	18	$82	$1,476	$1,299
221470-B21	2Gb/s SFP	14	$369	$5,166	$4,546
	Extended Total			$671,963	$479,860

Benchmark Configuration/Tested Storage Configuration Diagram



Tested Storage Configuration (TSC) Diagram – Front and Rear View



CONFIGURATION INFORMATION

Benchmark Configuration (BC)/Tested Storage Configuration (TSC) Diagram

Clause 9.2.4.4.1

A one page Benchmark Configuration (BC)/Tested Storage Configuration (TSC) diagram shall be included in the Executive Summary…

The BC/TSC are illustrated on pages 13 *(Benchmark Configuration/Tested Storage Configuration Diagram)* and 14 *(Tested Storage Configuration (TSC) Diagram – Front and Rear View).*

Storage Network Configuration

Clause 9.2.4.4.2

If a storage network is employed in the BC/TSC, the FDR shall contain a topology diagram… . This diagram should include, but is not limited to the following components:

1. *Storage Controller and Domain Controllers (see Clause 9.2.4.4.1)*
2. *Host Systems (see Clause 9.2.4.4.1)*
3. *Routers and Bridges*
4. *Hubs and Switches*
5. *HBAs to Host Systems and Front End Port to Storage Controllers*

Additionally the diagram shall:

- *Illustrate the physical connection between components.*
- *Describe the type of each physical connection.*
- *Describe the network protocol used over each physical connection.*
- *The maximum theoretical transfer rate of each class of interconnect used in the configuration.*
- *Correlate with the BC Configuration Diagram in Clause 9.2.4.4.1.*

The Test Sponsor shall additionally supply (referenced in an appendix) a wiring diagram of the physical connections and physical port assignments used in the storage network. The diagram should allow anyone to exactly replicate the physical configuration of the storage network.

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

Host System Configuration

Clause 9.2.4.4.3

The FDR shall minimally contain, for each Host System running the Workload Generator, a listing of the following:

1. *Number and type of CPUs.*
2. *Main memory capacity.*
3. *Cache memory capacity.*
4. *Number and type of disk controllers or Host Bus Adapters.*

Configuration information for the Host Systems, **HS-1 – HS-6**, used in this benchmark measurement is listed below.

Quantity	Type	# CPUs	CPU Type	CPU MHz	Memory	Operating System	System I/O Interconnect	HBAs	HBA to Storage Interconnect	Workload Generator
2	ML-530	2	P III Xeon	800	512	Window 2000 Server	PCI	2 x LP952	Fibre Channel	Yes
2	ML-530	2	P III Xeon	933	512	Window 2000 Server	PCI	2 x LP952	Fibre Channel	Yes
1	ML-530	2	P III Xeon	1000	512	Window 2000 Server	PCI	2 x LP952	Fibre Channel	Yes
1	ML-530	2	P III Xeon	1000	768	Window 2000 Server	PCI	2 x LP952	Fibre Channel	Yes

Customer Tuning Parameters and Options

Clause 9.2.4.5.1

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.

Two customer tuning parameters and/or options were altered from their default value. The driver parameter "QueueDepth" for all Host Bus Adapters (HBAs) value was changed from the default value of 16 (decimal) to 128 (decimal). The WRITEBACK parameter was changed from the default value of MIRRORED to NOMIRRORED.

Tested Storage Configuration (TSC) Description

Clause 9.2.4.5.2

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 Benchmark Configuration (BC) diagram in Clause 9.2.4.4.1 and, if applicable, 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.*

In addition the FDR may include listings of scripts and/or commands used to configure the physical components that comprise the TSC.

The Tested Storage Configuration (TSC) and its components are illustrated on pages 13 *(Benchmark Configuration/Tested Storage Configuration Diagram)* and 14 *(Tested Storage Configuration (TSC) Diagram – Front and Rear View)*. The following commands were used to create the logical representation of the TSC used in the benchmark measurement.

```
SET OPTIONS ON_ERROR=HALT_ON_ERROR
Sel Manager x.x.x.x User=administrator Password=xxx
Sel Cell "Uninitialized Storage System1"
ADD CELL "SPE" DEVICE_COUNT=168 SPARE_POLICY=NONE CONSOLE_LUN_ID=0
SELECT CELL "SPE"
SET GROUP "\Disk Groups\Default Disk Group" OCCUPANCY_ALARM=95
ADD HOST "\Hosts\Binkie bottom" OPERATING_SYSTEM=WINDOWS WORLD_WIDE_NAME=1000-0000-C92B-67CE COMMENT="Bottom adapter on Binkie"
ADD HOST "\Hosts\Binkie top" OPERATING_SYSTEM=WINDOWS WORLD_WIDE_NAME=1000-0000-C92B-65B1 COMMENT="Top adapter on Binkie"
ADD HOST "\Hosts\Bito1 top" OPERATING_SYSTEM=WINDOWS WORLD_WIDE_NAME=1000-0000-C92B-638B COMMENT="Top adapter on Bito1"
ADD HOST "\Hosts\Bito1 bottom" OPERATING_SYSTEM=WINDOWS WORLD_WIDE_NAME=1000-0000-C92B-67B9 COMMENT="Bottom adapter on Bito1"
ADD HOST "\Hosts\Bito2 bottom" OPERATING_SYSTEM=WINDOWS WORLD_WIDE_NAME=1000-0000-C92B-68A3 COMMENT="Bottom adapter on Bito2"
ADD HOST "\Hosts\Bito2 top" OPERATING_SYSTEM=WINDOWS WORLD_WIDE_NAME=1000-0000-C92B-6836 COMMENT="Top adapter on Bito2"
ADD HOST "\Hosts\Godsmack bottom" OPERATING_SYSTEM=WINDOWS WORLD_WIDE_NAME=1000-0000-C92B-671F COMMENT="Bottom adapter on Godsmack"
ADD HOST "\Hosts\Godsmack top" OPERATING_SYSTEM=WINDOWS WORLD_WIDE_NAME=1000-0000-C92B-679C COMMENT="Top adapter on Godsmack"
ADD HOST "\Hosts\Guerre bottom" OPERATING_SYSTEM=WINDOWS WORLD_WIDE_NAME=1000-0000-C92B-6849 COMMENT="Bottom adapter on Guerre"
ADD HOST "\Hosts\Guerre top" OPERATING_SYSTEM=WINDOWS WORLD_WIDE_NAME=1000-0000-C92B-68D4 COMMENT="Top adapter on Guerre"
ADD HOST "\Hosts\Raton bottom" OPERATING_SYSTEM=WINDOWS WORLD_WIDE_NAME=1000-0000-C92B-6462 COMMENT="Bottom adapter on Raton"
ADD HOST "\Hosts\Raton top" OPERATING_SYSTEM=WINDOWS WORLD_WIDE_NAME=1000-0000-C92B-6867 COMMENT="Top adapter on Raton"
ADD STORAGE "\Virtual Disks\ASU-1" GROUP="\Disk Groups\Default Disk Group" SIZE=1088 REDUNDANCY=VRAID1 NOMIRRORED_WRITEBACK READ_CACHE NOWRITE_PROTECT OS_UNIT_ID=0 PREFERRED_PATH=PATH_A_BOTH
ADD LUN 1 STORAGE="\Virtual Disks\ASU-1\ACTIVE" HOST="\Hosts\Binkie top"
ADD LUN 1 STORAGE="\Virtual Disks\ASU-1\ACTIVE" HOST="\Hosts\Bito1 top"
ADD LUN 1 STORAGE="\Virtual Disks\ASU-1\ACTIVE" HOST="\Hosts\Bito2 top"
ADD LUN 1 STORAGE="\Virtual Disks\ASU-1\ACTIVE" HOST="\Hosts\Godsmack top"
ADD LUN 1 STORAGE="\Virtual Disks\ASU-1\ACTIVE" HOST="\Hosts\Guerre top"
ADD LUN 1 STORAGE="\Virtual Disks\ASU-1\ACTIVE" HOST="\Hosts\Raton top"
ADD STORAGE "\Virtual Disks\ASU-2" GROUP="\Disk Groups\Default Disk Group" SIZE=1088 REDUNDANCY=VRAID1 NOMIRRORED_WRITEBACK READ_CACHE NOWRITE_PROTECT OS_UNIT_ID=0 PREFERRED_PATH=PATH_B_BOTH
ADD LUN 1 STORAGE="\Virtual Disks\ASU-2\ACTIVE" HOST="\Hosts\Binkie bottom"
ADD LUN 1 STORAGE="\Virtual Disks\ASU-2\ACTIVE" HOST="\Hosts\Bito1 bottom"
ADD LUN 1 STORAGE="\Virtual Disks\ASU-2\ACTIVE" HOST="\Hosts\Bito2 bottom"
ADD LUN 1 STORAGE="\Virtual Disks\ASU-2\ACTIVE" HOST="\Hosts\Godsmack bottom"
```

```
ADD LUN 1 STORAGE="\Virtual Disks\ASU-2\ACTIVE" HOST="\Hosts\Guerre bottom"
ADD LUN 1 STORAGE="\Virtual Disks\ASU-2\ACTIVE" HOST="\Hosts\Raton bottom"
ADD STORAGE "\Virtual Disks\ASU-3" GROUP="\Disk Groups\Default Disk Group" SIZE=242
REDUNDANCY=VRAID1 NOMIRRORED_WRITEBACK READ_CACHE NOWRITE_PROTECT OS_UNIT_ID=0
PREFERRED_PATH=PATH_B_BOTH
ADD LUN 2 STORAGE="\Virtual Disks\ASU-3\ACTIVE" HOST="\Hosts\Binkie bottom"
ADD LUN 2 STORAGE="\Virtual Disks\ASU-3\ACTIVE" HOST="\Hosts\Bito1 bottom"
ADD LUN 2 STORAGE="\Virtual Disks\ASU-3\ACTIVE" HOST="\Hosts\Bito2 bottom"
ADD LUN 2 STORAGE="\Virtual Disks\ASU-3\ACTIVE" HOST="\Hosts\Godsmack bottom"
ADD LUN 2 STORAGE="\Virtual Disks\ASU-3\ACTIVE" HOST="\Hosts\Guerre bottom"
ADD LUN 2 STORAGE="\Virtual Disks\ASU-3\ACTIVE" HOST="\Hosts\Raton bottom"
```

DATA REPOSITORY

Definitions

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

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.

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.

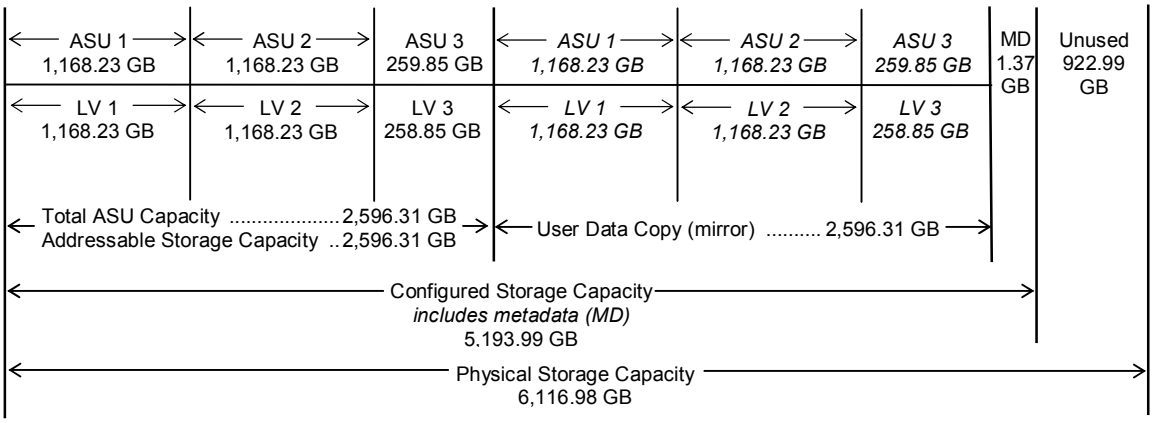
Logical Volume: The division of Addressable Storage Capacity into individually addressable logical units of storage used in the SPC-1 benchmark. Each Logical Volume is implemented as a single, contiguous address space.

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.

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

Storage Capacities and Relationships

The various storage capacities configured in the benchmark result are illustrated below.



Storage Hierarchy Capacity

Clause 9.2.4.6.1

A table illustrating the size of key components of the Storage Hierarchy shall be included in the FDR.

Storage Hierarchy Capacity		
Storage Hierarchy Component	**Units**	**Capacity**
Total ASU Capacity	Gigabytes (GB)	2,596.31
Addressable Storage Capacity	Gigabytes (GB)	2,596.31
Configured Storage Capacity	Gigabytes (GB)	5,193.99
Physical Storage Capacity	Gigabytes (GB)	6116.98

Logical Volume Capacity and ASU Mapping

Clause 9.2.4.6.2

A table illustrating the capacity of each ASU and the mapping of Logical Volumes to ASUs shall be provided in the FDR. Logical Volumes shall be sequenced in the table from top to bottom per its position in the contiguous address space of each ASU. The capacity of each Logical Volume shall be stated. … In conjunction with this table, the Test Sponsor shall provide a complete description of the type of data protection (see Clause 2.4.5) used on each Logical Volume.

Logical Volume Capacity and Mapping		
ASU-1 (1,168.23 GB)	**ASU-2 (1,168.23 GB)**	**ASU-3 (259.85 GB)**
1 Logical Volume 1,168.23 GB per Logical Volume (1,168.23 GB used/Logical Volume)	1 Logical Volume 1,168.23 GB per Logical Volume (1,168.23 GB used/Logical Volume)	1 Logical Volume 259.85 GB per Logical Volume (259.85 GB used/Logical Volume)

The Data Protection Level used for all Logical Volumes was Mirroring as described on page 10. See "ASU Configuration" in the IOPS Test Results File for more detailed configuration information.

SPC-1 BENCHMARK EXECUTION RESULTS

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.*

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.*

Measurement Interval: *The finite and contiguous time period, after the Tested Storage Configuration (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.*

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. Comment: Steady Stated is achieved only after caches in the TSC have filled and as a result the I/O Request throughput of the TSC has stabilized.*

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

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.*

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 Figure 5-1 below. All SPC-1 Test Runs shall have a Steady State period and a Measurement Interval.*

Sustainability Test Phase

Clause 5.4.2.1

The Sustainability Test Phase consists of one Test Run at the 100% load point with a Measurement Interval of three (3) hours. The intent is to demonstrate a sustained maximum I/O Request Throughput as well as insuring the Tested Storage Configuration (TSC) has reached steady state prior to measuring the maximum I/O Request Throughput (SPC-1™ IOPS).

The reported I/O Request Throughput of the Sustainability Test Run must be within 5% of the reported SPC-1™ IOPS primary metric. The Average Response Time measured in Sustainability Test Run cannot exceed thirty (30) milliseconds.

Clause 9.2.4.7.1

For the Sustainability Test Phase the FDR shall contain:

1. *A Data Rate Distribution (data table and graph).*
2. *I/O Request Throughput Distribution (data table and graph).*
3. *The human readable Test Run Results File produced by the Workload Generator.*
4. *A listing or screen image of all input parameters supplied to the Workload Generator.*
5. *The Measured Intensity Multiplier for each I/O stream.*
6. *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, and Response Time Ramp Test Runs are listed below.

```
java metrics -b 481
```

Sustainability Test Results File

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

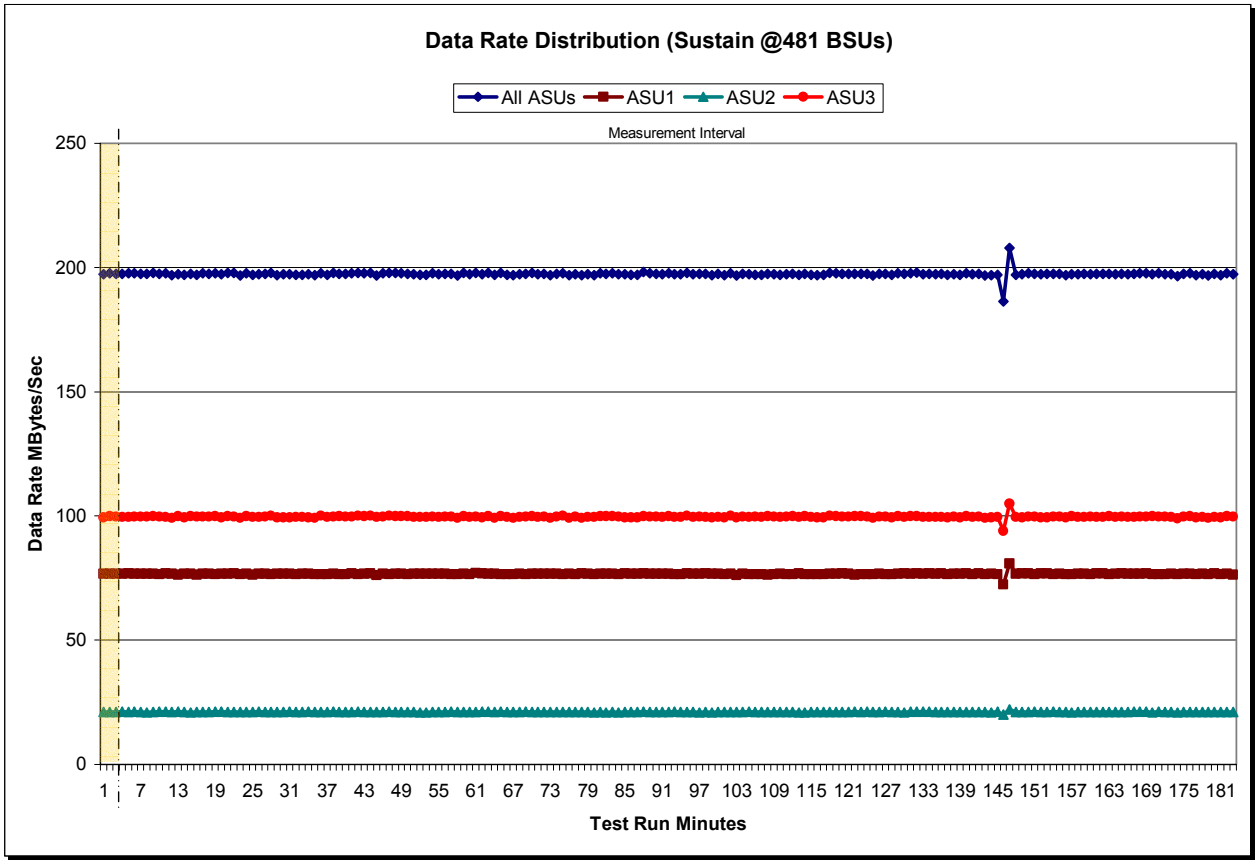
Sustainability Test Results File

Sustainability – Data Rate Distribution Data *(MB / second)*

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	23:10:39	23:13:39	0-2	0:03:00
Measurement Interval	23:13:39	2:13:39	3-182	3:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	197.19	76.72	21.05	99.43	60	197.78	77.03	20.98	99.76	120	197.42	76.71	21.00	99.71
1	197.67	76.72	21.12	99.82	61	197.33	76.77	21.16	99.40	121	197.38	76.37	21.16	99.85
2	197.36	76.59	21.10	99.67	62	197.78	76.64	21.16	99.98	122	197.36	76.50	21.05	99.80
3	197.44	76.74	21.17	99.53	63	197.04	76.70	21.12	99.21	123	197.48	76.53	21.16	99.80
4	197.56	76.89	21.12	99.55	64	197.74	76.58	21.21	99.95	124	196.75	76.41	21.10	99.24
5	197.67	76.74	21.22	99.71	65	197.13	76.58	21.02	99.54	125	197.48	76.63	21.05	99.80
6	197.42	76.67	20.97	99.78	66	196.92	76.58	21.12	99.22	126	197.45	76.51	21.23	99.71
7	197.43	76.73	20.96	99.74	67	197.21	76.59	21.12	99.49	127	197.04	76.57	21.08	99.39
8	197.76	76.70	21.07	99.98	68	197.46	76.57	21.22	99.67	128	197.71	76.65	21.13	99.93
9	197.47	76.56	21.19	99.72	69	197.84	76.75	21.14	99.95	129	197.43	76.92	20.95	99.56
10	197.62	76.87	21.26	99.50	70	197.19	76.63	21.00	99.57	130	197.67	76.64	21.16	99.87
11	196.91	76.68	21.05	99.18	71	197.46	76.76	21.08	99.63	131	197.97	76.88	21.17	99.92
12	197.26	76.30	21.15	99.81	72	196.93	76.68	21.01	99.24	132	197.23	76.60	21.16	99.47
13	197.02	76.68	20.98	99.36	73	197.45	76.68	21.14	99.63	133	197.52	76.78	21.18	99.56
14	197.37	76.63	20.91	99.83	74	197.65	76.48	21.07	100.10	134	197.19	76.73	20.99	99.48
15	197.08	76.39	21.03	99.66	75	196.91	76.69	21.12	99.09	135	197.37	76.77	21.04	99.56
16	197.58	76.70	21.15	99.73	76	197.32	76.47	21.06	99.79	136	197.07	76.52	21.12	99.43
17	197.41	76.59	21.08	99.74	77	196.98	76.79	21.04	99.15	137	197.32	76.63	21.05	99.65
18	197.68	76.52	21.26	99.89	78	197.31	76.63	21.08	99.60	138	197.15	76.60	21.12	99.43
19	197.20	76.66	21.17	99.37	79	196.87	76.53	20.82	99.52	139	197.59	76.79	20.98	99.82
20	197.78	76.72	21.11	99.95	80	197.71	76.63	21.15	99.93	140	197.25	76.55	21.11	99.60
21	197.74	76.86	21.14	99.74	81	197.48	76.67	20.84	99.97	141	197.53	76.81	21.02	99.70
22	196.68	76.54	21.00	99.14	82	197.57	76.63	21.02	99.91	142	196.81	76.58	21.09	99.13
23	197.65	76.70	21.06	99.89	83	197.24	76.56	20.89	99.79	143	196.91	76.67	20.92	99.32
24	197.07	76.36	21.15	99.56	84	197.27	76.81	21.08	99.38	144	197.15	76.49	21.20	99.46
25	197.31	76.60	21.15	99.56	85	197.11	76.67	21.08	99.36	145	186.20	72.37	19.89	93.94
26	197.48	76.73	21.11	99.65	86	197.17	76.64	21.11	99.42	146	207.92	80.75	22.19	104.98
27	197.73	76.55	21.07	100.11	87	198.09	76.94	21.21	99.93	147	197.15	76.64	20.99	99.53
28	196.98	76.60	21.06	99.31	88	197.67	76.75	21.12	99.79	148	197.26	76.80	21.03	99.44
29	197.20	76.69	21.07	99.44	89	197.47	76.74	21.05	99.68	149	197.63	76.83	21.02	99.79
30	197.23	76.73	21.15	99.34	90	197.29	76.64	21.08	99.57	150	197.45	76.53	21.15	99.76
31	197.10	76.50	21.13	99.47	91	197.64	76.68	21.09	99.87	151	197.19	76.78	21.12	99.29
32	197.14	76.61	20.97	99.56	92	197.19	76.52	21.21	99.46	152	197.40	76.93	21.14	99.33
33	197.21	76.65	21.17	99.39	93	197.22	76.54	21.07	99.60	153	197.36	76.50	21.18	99.67
34	196.85	76.53	21.12	99.20	94	197.85	76.80	21.06	99.98	154	197.44	76.59	21.15	99.70
35	197.63	76.58	21.05	99.99	95	197.21	76.59	21.00	99.62	155	196.92	76.50	21.01	99.41
36	197.09	76.52	21.09	99.48	96	197.39	76.69	20.91	99.79	156	197.35	76.55	20.89	99.91
37	197.72	76.63	21.30	99.79	97	197.36	76.82	21.09	99.45	157	197.32	76.76	21.00	99.56
38	197.47	76.52	21.07	99.89	98	196.98	76.74	20.89	99.35	158	197.39	76.76	21.06	99.56
39	197.39	76.58	21.05	99.76	99	197.40	76.71	21.08	99.61	159	197.34	76.57	21.15	99.62
40	197.69	76.88	21.08	99.72	100	196.85	76.54	21.01	99.30	160	197.38	76.83	21.05	99.50
41	197.85	76.58	21.17	100.10	101	197.70	76.63	21.06	100.01	161	197.39	76.80	20.97	99.61
42	197.63	76.63	21.10	99.89	102	196.73	76.19	21.12	99.42	162	197.41	76.44	21.09	99.89
43	197.80	76.78	21.01	100.01	103	197.51	76.59	21.15	99.77	163	197.24	76.70	21.03	99.51
44	196.77	76.19	21.04	99.55	104	197.31	76.56	21.19	99.56	164	197.45	76.78	21.03	99.64
45	197.55	76.73	21.14	99.68	105	197.13	76.41	21.05	99.67	165	197.32	76.72	21.07	99.53
46	197.74	76.58	21.15	100.01	106	197.02	76.46	21.09	99.47	166	197.45	76.67	21.17	99.61
47	197.80	76.72	21.10	99.97	107	197.38	76.39	21.12	99.86	167	197.66	76.75	21.20	99.71
48	197.70	76.64	21.10	99.96	108	197.20	76.45	21.07	99.68	168	197.62	76.78	21.17	99.67
49	197.36	76.52	21.02	99.82	109	197.11	76.59	21.07	99.45	169	197.35	76.54	20.92	99.89
50	197.31	76.67	21.08	99.56	110	197.23	76.47	21.03	99.73	170	197.54	76.56	21.20	99.78
51	197.16	76.75	20.93	99.49	111	197.46	76.55	21.08	99.83	171	197.19	76.48	20.98	99.73
52	197.05	76.61	20.94	99.51	112	197.17	76.78	20.92	99.47	172	197.25	76.65	21.03	99.57
53	197.55	76.71	21.07	99.77	113	197.44	76.55	20.96	99.94	173	196.55	76.58	20.92	99.06
54	197.26	76.71	21.10	99.45	114	197.11	76.50	21.13	99.48	174	197.46	76.68	21.08	99.70
55	197.38	76.72	21.03	99.63	115	196.94	76.53	21.01	99.40	175	197.69	76.68	21.12	99.89
56	197.39	76.58	21.15	99.66	116	197.06	76.58	21.07	99.41	176	196.98	76.46	21.11	99.42
57	196.75	76.54	21.10	99.11	117	197.85	76.73	21.12	99.99	177	197.24	76.66	21.06	99.53
58	197.72	76.72	21.14	99.86	118	197.55	76.62	21.12	99.80	178	196.71	76.54	21.02	99.14
59	197.25	76.58	21.04	99.62	119	197.46	76.80	21.03	99.63	179	197.39	76.78	21.07	99.54
										180	196.92	76.44	21.06	99.42
										181	197.69	76.75	21.01	99.93
										182	197.23	76.37	21.13	99.73

Sustainability – Data Rate Distribution Graph

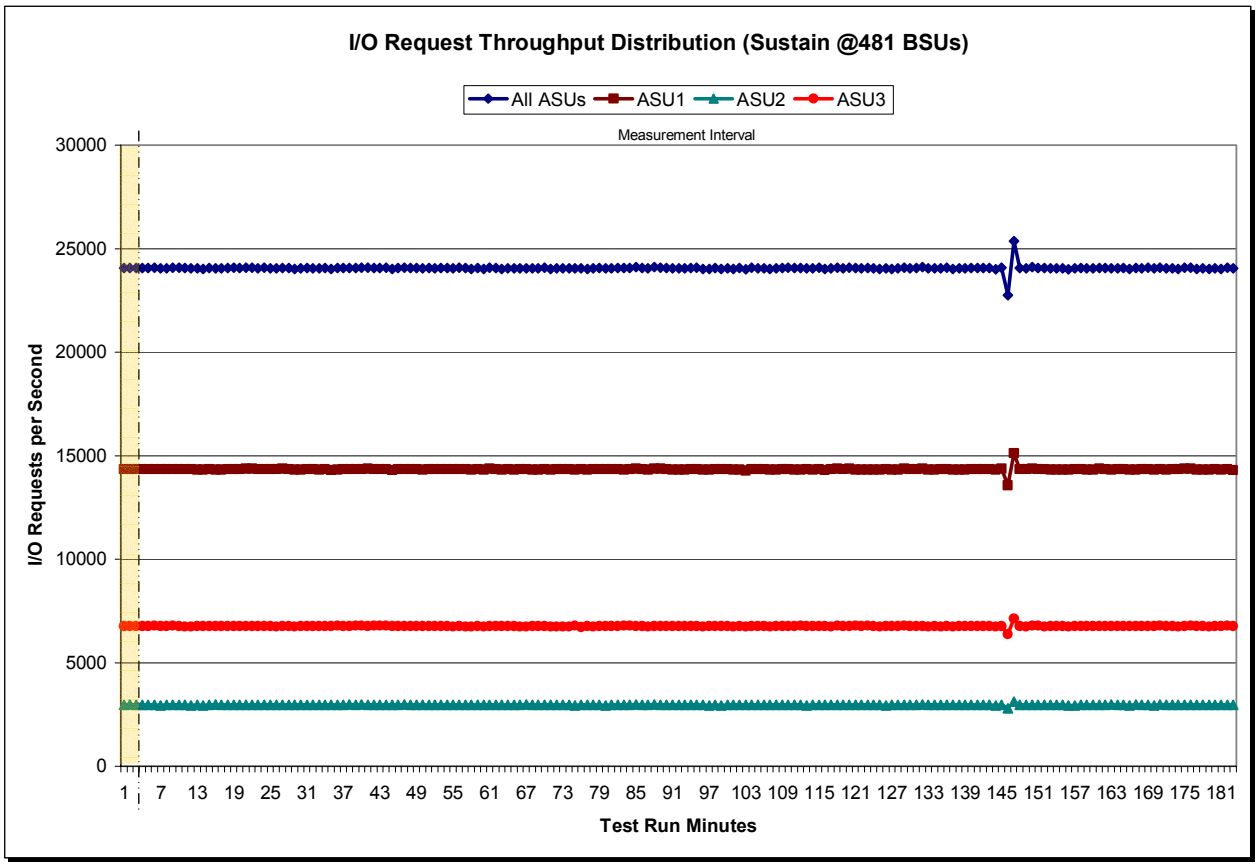


Sustainability – I/O Request Throughput Distribution Data

	Start	Stop	Interval	Duration
Ramp-Up/Start-Up	23:10:39	23:13:39	0-2	0:03:00
Measurement Interval	23:13:39	2:13:39	3-182	3:00:00

Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3
0	24,058.18	14,340.37	2,953.72	6,764.10	60	24,074.13	14,358.90	2,949.07	6,766.17	120	24,053.32	14,322.80	2,956.53	6,773.98
1	24,061.20	14,333.38	2,973.13	6,754.68	61	24,068.23	14,343.68	2,968.88	6,755.67	121	24,042.72	14,309.75	2,965.75	6,767.22
2	24,061.67	14,344.77	2,956.08	6,760.82	62	24,027.70	14,321.78	2,954.07	6,751.85	122	24,070.05	14,328.52	2,960.18	6,781.35
3	24,053.15	14,342.57	2,954.58	6,756.00	63	24,043.88	14,335.30	2,952.32	6,756.27	123	24,030.87	14,316.83	2,959.52	6,754.52
4	24,053.30	14,346.47	2,956.10	6,750.73	64	24,037.33	14,319.62	2,959.50	6,758.22	124	24,022.27	14,327.07	2,958.78	6,736.42
5	24,073.70	14,336.93	2,965.50	6,771.27	65	24,045.83	14,338.75	2,962.63	6,744.45	125	24,044.98	14,346.42	2,943.25	6,755.32
6	24,042.43	14,337.00	2,942.07	6,763.37	66	24,041.83	14,332.38	2,974.42	6,735.03	126	24,027.45	14,311.75	2,957.92	6,757.78
7	24,043.68	14,335.27	2,954.30	6,754.12	67	24,037.07	14,312.30	2,967.87	6,756.90	127	24,037.75	14,321.05	2,962.53	6,754.17
8	24,077.28	14,335.92	2,963.13	6,778.23	68	24,047.78	14,327.35	2,967.92	6,752.52	128	24,092.00	14,354.07	2,961.92	6,776.02
9	24,071.28	14,340.35	2,965.67	6,765.27	69	24,080.48	14,343.75	2,967.47	6,769.27	129	24,043.87	14,338.68	2,951.15	6,754.03
10	24,054.97	14,344.72	2,961.85	6,748.40	70	24,020.02	14,315.38	2,960.15	6,744.48	130	24,054.63	14,337.43	2,962.58	6,754.62
11	24,035.47	14,351.45	2,945.80	6,738.22	71	24,034.53	14,330.57	2,955.33	6,748.63	131	24,099.88	14,358.15	2,973.22	6,768.52
12	24,035.17	14,326.27	2,959.43	6,749.47	72	24,042.27	14,346.15	2,957.80	6,738.32	132	24,028.12	14,329.85	2,953.90	6,744.37
13	24,024.20	14,323.78	2,947.98	6,752.43	73	24,044.62	14,336.87	2,965.65	6,742.10	133	24,043.40	14,324.25	2,966.15	6,753.00
14	24,061.60	14,338.07	2,953.20	6,770.33	74	24,042.83	14,320.93	2,946.47	6,775.43	134	24,046.73	14,338.37	2,960.05	6,748.32
15	24,046.07	14,315.70	2,973.48	6,756.88	75	24,042.90	14,349.07	2,967.37	6,726.47	135	24,072.58	14,348.98	2,958.03	6,765.57
16	24,030.88	14,312.60	2,965.35	6,752.93	76	24,023.88	14,309.10	2,960.65	6,754.13	136	24,017.95	14,318.43	2,951.05	6,748.47
17	24,064.33	14,335.32	2,963.72	6,765.30	77	24,049.35	14,346.48	2,960.58	6,742.28	137	24,047.33	14,330.08	2,956.37	6,760.88
18	24,073.65	14,341.07	2,967.75	6,764.83	78	24,068.85	14,346.90	2,962.73	6,759.22	138	24,042.35	14,326.83	2,960.80	6,754.72
19	24,064.88	14,335.52	2,968.02	6,761.35	79	24,035.62	14,331.47	2,939.15	6,765.00	139	24,060.48	14,345.63	2,951.18	6,763.67
20	24,081.63	14,357.17	2,962.47	6,762.00	80	24,047.85	14,333.87	2,962.65	6,751.33	140	24,067.02	14,339.38	2,964.50	6,763.13
21	24,086.25	14,366.03	2,954.37	6,765.85	81	24,062.60	14,347.72	2,952.88	6,762.00	141	24,055.33	14,338.32	2,959.37	6,757.65
22	24,042.00	14,333.30	2,955.13	6,753.57	82	24,054.72	14,323.23	2,953.95	6,777.53	142	24,055.22	14,338.08	2,962.43	6,754.70
23	24,076.13	14,344.83	2,961.57	6,769.73	83	24,066.82	14,338.25	2,956.72	6,771.85	143	24,004.07	14,317.95	2,943.25	6,742.87
24	24,049.37	14,335.43	2,960.28	6,753.65	84	24,096.52	14,362.88	2,975.55	6,758.08	144	24,081.25	14,353.87	2,969.60	6,757.78
25	24,042.77	14,331.10	2,962.62	6,749.05	85	24,055.02	14,341.40	2,955.38	6,758.23	145	22,734.03	13,566.45	2,787.53	6,380.05
26	24,067.17	14,359.15	2,955.47	6,752.55	86	24,034.65	14,321.10	2,965.82	6,747.73	146	25,346.22	15,109.55	3,113.03	7,123.63
27	24,064.60	14,333.03	2,960.97	6,770.60	87	24,106.02	14,363.87	2,976.48	6,765.67	147	24,063.43	14,333.55	2,965.27	6,764.62
28	24,016.27	14,319.73	2,951.75	6,744.78	88	24,072.10	14,352.77	2,966.45	6,752.88	148	24,040.18	14,337.73	2,953.63	6,748.82
29	24,042.20	14,323.20	2,965.37	6,753.63	89	24,064.77	14,342.33	2,961.35	6,761.08	149	24,094.40	14,360.62	2,958.80	6,774.98
30	24,053.62	14,337.65	2,959.32	6,756.65	90	24,039.17	14,328.60	2,950.60	6,759.97	150	24,070.53	14,344.40	2,951.97	6,774.17
31	24,045.33	14,331.77	2,960.17	6,753.40	91	24,029.35	14,316.10	2,956.08	6,757.17	151	24,050.23	14,338.13	2,964.03	6,748.07
32	24,029.40	14,318.15	2,954.58	6,756.67	92	24,034.63	14,318.82	2,953.35	6,762.47	152	24,045.78	14,327.88	2,955.87	6,762.03
33	24,070.93	14,336.63	2,966.47	6,767.83	93	24,051.35	14,332.55	2,961.08	6,757.72	153	24,039.23	14,311.75	2,964.17	6,763.32
34	24,024.40	14,308.38	2,966.38	6,749.63	94	24,078.17	14,346.20	2,964.32	6,767.65	154	24,031.90	14,312.08	2,958.68	6,761.13
35	24,053.88	14,330.20	2,952.17	6,771.52	95	24,026.57	14,323.58	2,954.35	6,748.63	155	24,006.03	14,315.62	2,943.92	6,746.50
36	24,060.88	14,331.93	2,965.57	6,763.38	96	24,026.07	14,323.03	2,939.92	6,763.12	156	24,036.53	14,332.70	2,941.08	6,762.75
37	24,059.62	14,333.62	2,970.23	6,755.77	97	24,051.87	14,342.47	2,949.82	6,759.58	157	24,062.67	14,337.68	2,959.40	6,765.58
38	24,069.87	14,334.83	2,961.82	6,773.22	98	24,024.27	14,331.43	2,941.50	6,751.33	158	24,044.82	14,329.93	2,955.35	6,759.53
39	24,087.27	14,337.78	2,969.98	6,779.50	99	24,040.60	14,331.20	2,953.70	6,755.70	159	24,028.32	14,314.95	2,954.33	6,759.03
40	24,077.08	14,356.05	2,957.65	6,763.38	100	24,022.13	14,320.23	2,959.23	6,742.67	160	24,061.30	14,357.02	2,950.15	6,754.13
41	24,056.15	14,330.83	2,952.15	6,773.17	101	24,056.83	14,325.47	2,960.87	6,770.50	161	24,064.30	14,345.83	2,953.58	6,764.88
42	24,065.40	14,331.73	2,959.27	6,774.40	102	23,992.07	14,280.95	2,963.77	6,747.35	162	24,049.02	14,321.20	2,970.95	6,756.87
43	24,072.18	14,340.42	2,948.95	6,782.82	103	24,074.57	14,351.48	2,964.90	6,758.18	163	24,043.18	14,336.38	2,952.78	6,754.02
44	24,018.40	14,305.23	2,954.95	6,758.22	104	24,038.52	14,331.77	2,952.40	6,754.35	164	24,064.50	14,343.47	2,956.33	6,764.70
45	24,054.62	14,349.72	2,948.60	6,756.30	105	24,048.07	14,337.65	2,956.67	6,753.75	165	24,025.67	14,321.17	2,946.87	6,757.63
46	24,081.77	14,339.25	2,972.40	6,770.12	106	24,026.15	14,327.13	2,957.05	6,741.97	166	24,068.40	14,329.90	2,971.82	6,766.68
47	24,066.23	14,341.63	2,954.15	6,770.45	107	24,039.82	14,311.07	2,963.30	6,765.45	167	24,048.80	14,334.48	2,962.77	6,751.55
48	24,068.28	14,337.98	2,965.15	6,765.15	108	24,058.85	14,345.15	2,954.75	6,758.95	168	24,075.02	14,350.90	2,963.07	6,761.05
49	24,041.77	14,322.53	2,958.28	6,760.95	109	24,073.67	14,348.52	2,960.10	6,765.05	169	24,033.23	14,320.93	2,944.10	6,768.20
50	24,069.10	14,343.52	2,967.33	6,758.25	110	24,054.60	14,327.45	2,959.83	6,767.32	170	24,078.10	14,335.30	2,970.40	6,772.40
51	24,044.33	14,338.28	2,954.20	6,751.85	111	24,059.92	14,324.98	2,961.27	6,773.67	171	24,040.15	14,323.98	2,954.83	6,761.33
52	24,049.82	14,340.90	2,956.07	6,752.85	112	24,048.65	14,339.97	2,945.55	6,763.13	172	24,046.27	14,338.83	2,952.17	6,755.27
53	24,049.88	14,342.28	2,957.03	6,750.57	113	24,029.65	14,313.25	2,951.90	6,764.50	173	24,023.08	14,331.32	2,948.38	6,743.38
54	24,043.52	14,342.45	2,956.12	6,744.95	114	24,071.68	14,336.20	2,968.32	6,767.17	174	24,084.55	14,356.88	2,962.80	6,764.87
55	24,075.50	14,351.03	2,963.88	6,760.58	115	24,019.97	14,307.05	2,956.50	6,756.42	175	24,089.82	14,352.15	2,955.85	6,781.82
56	24,053.27	14,340.23	2,964.73	6,748.30	116	24,047.10	14,336.68	2,961.63	6,748.78	176	24,025.65	14,320.62	2,953.87	6,751.17
57	24,017.30	14,316.30	2,965.90	6,735.10	117	24,078.57	14,355.87	2,951.00	6,771.70	177	24,040.92	14,316.47	2,959.32	6,765.13
58	24,069.62	14,340.22	2,963.17	6,766.23	118	24,037.23	14,330.60	2,955.20	6,751.43	178	24,022.85	14,325.45	2,956.93	6,740.47
59	24,011.70	14,313.85	2,951.33	6,746.52	119	24,083.20	14,360.30	2,963.55	6,759.35	179	24,045.93	14,333.08	2,956.32	6,756.53
										180	24,027.95	14,312.30	2,963.80	6,751.85
										181	24,074.40	14,335.35	2,963.23	6,775.82
										182	24,029.30	14,306.15	2,959.42	6,763.73
										Average	24,050.82	14,333.73	2,958.57	6,758.52

Sustainability – I/O Request Throughput Distribution Graph



Sustainability – Measured Intensity Multiplier and Coefficient of Variation

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.035*	*0.281*	*0.070*	*0.210*	*0.018*	*0.070*	*0.035*	*0.281*
MIM	0.035	0.281	0.070	0.210	0.018	0.070	0.035	0.281
COV	0.005	0.001	0.003	0.002	0.006	0.003	0.004	0.001

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.*

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%.*

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

IOPS Test Phase

Clause 5.4.2.2

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 9.2.4.7.2

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 t 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, and Response Time Ramp Test Runs are listed below.

```
java metrics -b 481
```

IOPS Test Results File

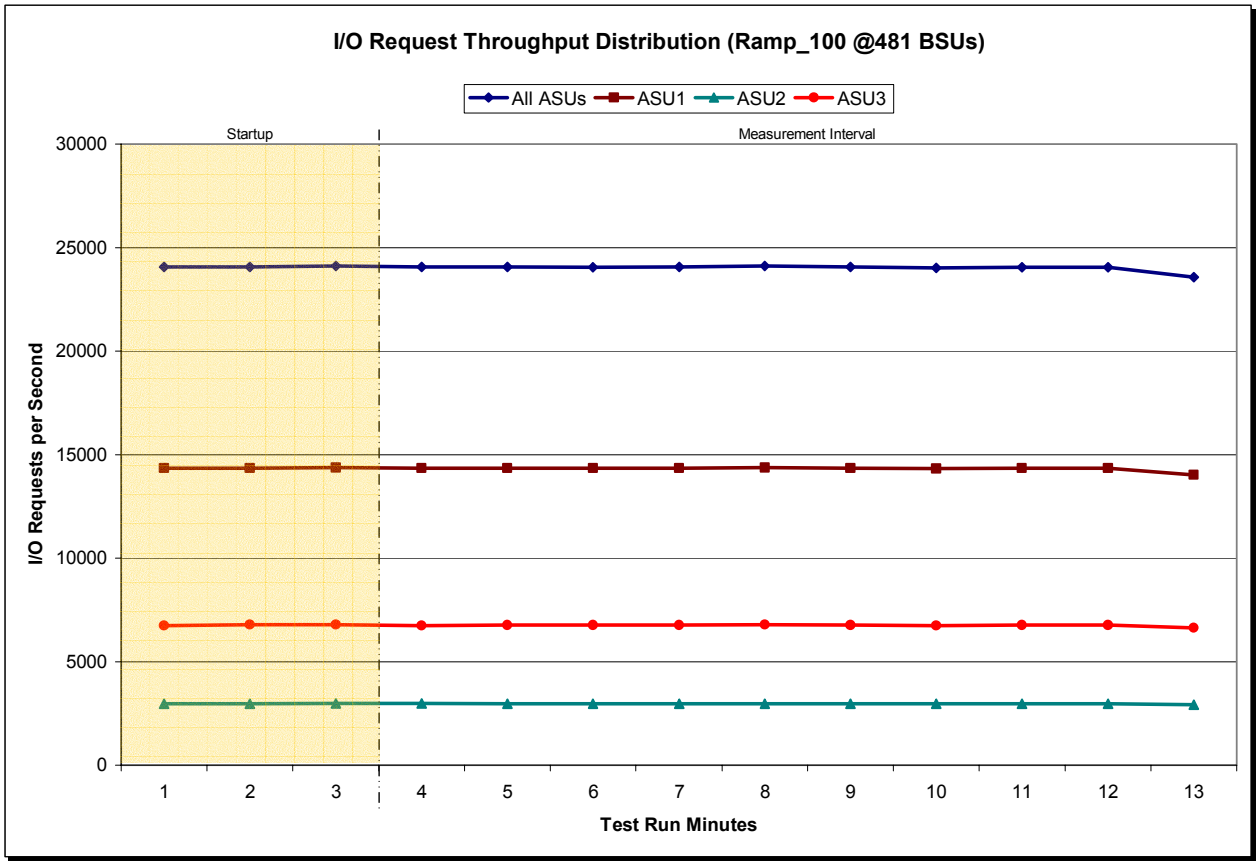
A link to the test results file generated from the IOPS Test Run is listed below.

IOPS Test Results File

IOPS Test Run – I/O Request Throughput Distribution Data

481 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:14:09	2:17:10	0-2	0:03:01
Measurement Interval	2:17:10	2:27:10	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	24,053.67	14,347.10	2,958.12	6,748.45
1	24,067.42	14,334.85	2,955.78	6,776.78
2	24,098.68	14,353.92	2,971.07	6,773.70
3	24,061.17	14,345.67	2,970.32	6,745.18
4	24,062.30	14,342.98	2,950.63	6,768.68
5	24,047.93	14,334.20	2,960.08	6,753.65
6	24,059.43	14,338.63	2,954.62	6,766.18
7	24,109.62	14,366.18	2,965.53	6,777.90
8	24,052.08	14,345.38	2,952.35	6,754.35
9	24,017.17	14,325.97	2,950.98	6,740.22
10	24,038.93	14,332.52	2,948.88	6,757.53
11	24,043.85	14,331.75	2,956.55	6,755.55
12	23,562.95	14,014.90	2,909.03	6,639.02
Average	24,005.54	14,307.82	2,951.90	6,745.83

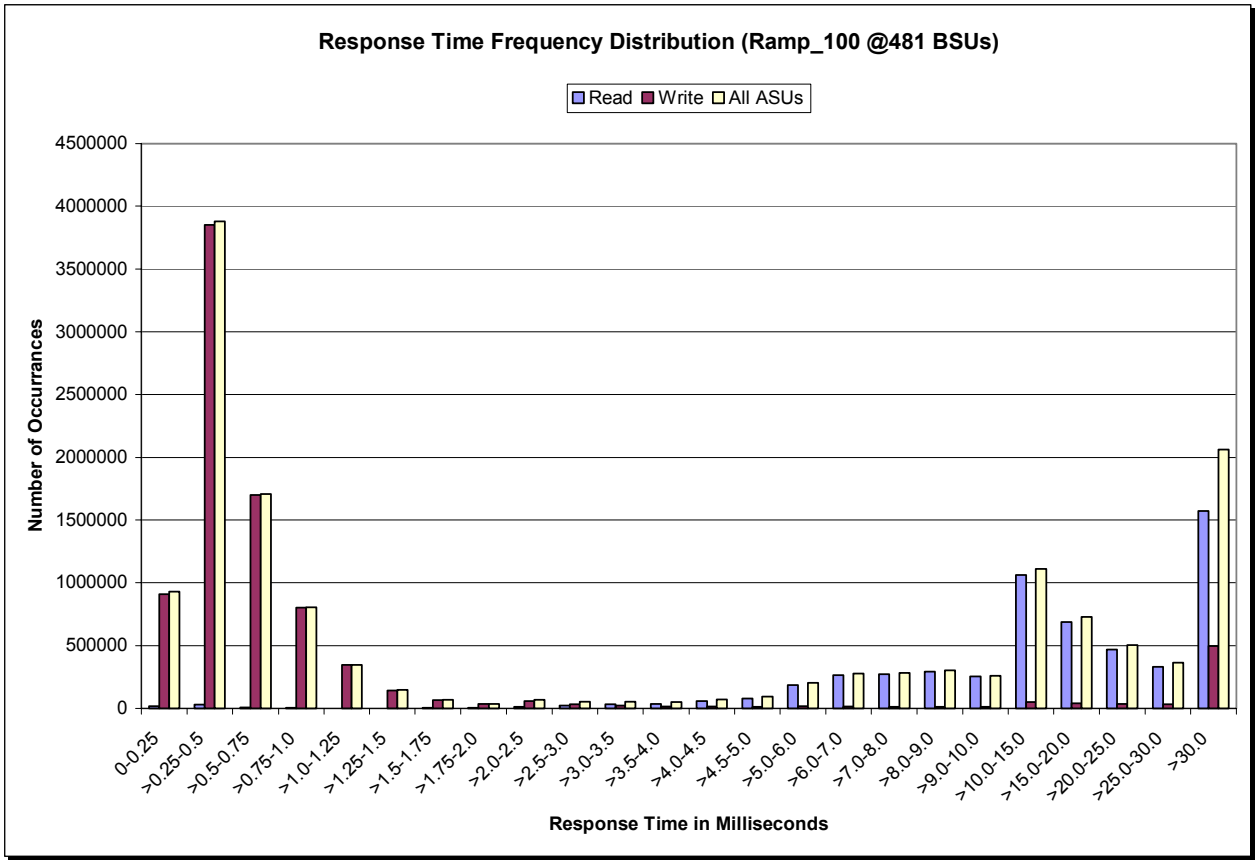
IOPS Test Run – I/O Request Throughput Distribution Graph



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	19,075	29,645	6,970	2,082	1,078	1,165	2,302	2,651
Write	909,306	3,850,284	1,698,410	801,927	345,722	144,120	64,553	34,044
All ASUs	928,381	3,879,929	1,705,380	804,009	346,800	145,285	66,855	36,695
ASU1	321,135	1,407,067	720,748	350,519	150,667	59,591	27,908	16,690
ASU2	134,615	518,429	150,405	47,321	17,232	7,349	3,723	2,485
ASU3	472,631	1,954,433	834,227	406,169	178,901	78,345	35,224	17,520
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	11,854	21,090	31,161	35,594	58,579	79,810	185,204	263,345
Write	55,582	32,915	22,289	14,762	14,457	11,756	17,871	15,636
All ASUs	67,436	54,005	53,450	50,356	73,036	91,566	203,075	278,981
ASU1	39,241	38,893	43,082	42,997	64,831	81,225	177,216	237,473
ASU2	4,073	3,110	2,988	2,836	5,007	8,217	23,224	40,162
ASU3	24,122	12,002	7,380	4,523	3,198	2,124	2,635	1,346
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	269,688	291,103	251,491	1,062,381	686,920	467,183	329,980	1,570,369
Write	11,834	12,049	10,108	48,199	40,837	36,428	33,032	493,663
All ASUs	281,522	303,152	261,599	1,110,580	727,757	503,611	363,012	2,064,032
ASU1	235,671	251,016	217,210	906,405	592,436	414,241	302,562	1,885,343
ASU2	44,983	51,434	43,797	201,070	133,243	88,127	59,565	177,076
ASU3	868	702	592	3,105	2,078	1,243	885	1,613

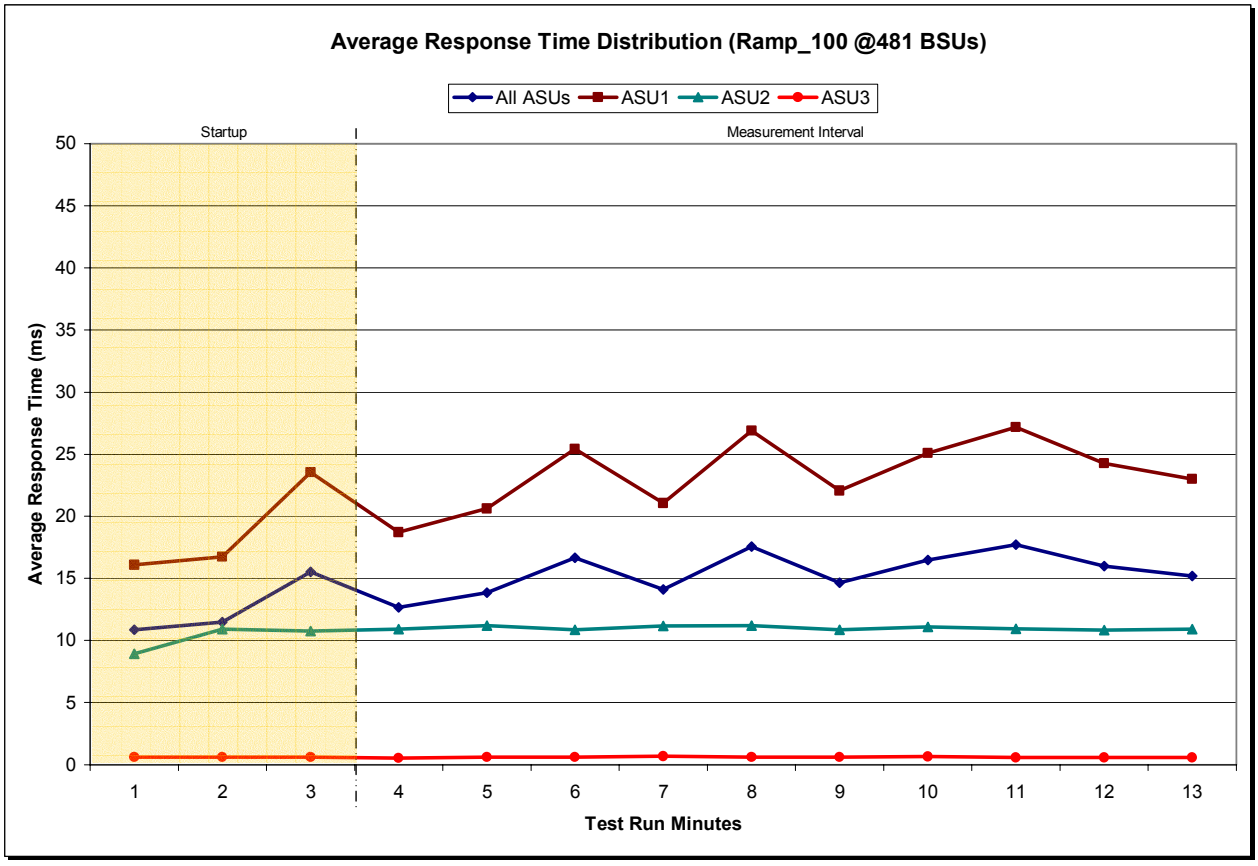
IOPS Test Run –Response Time Frequency Distribution Graph



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

Average Response Time Distribution				
481 BSUs	**Start**	**Stop**	**Interval**	**Duration**
Start-Up/Ramp-Up	2:14:09	2:17:10	0-2	0:03:01
Measurement Interval	2:17:10	2:27:10	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	10.88	16.10	8.93	0.61
1	11.49	16.76	10.91	0.61
2	15.51	23.53	10.77	0.61
3	12.65	18.71	10.89	0.55
4	13.85	20.64	11.20	0.62
5	16.65	25.41	10.86	0.60
6	14.12	21.07	11.17	0.69
7	17.56	26.88	11.21	0.61
8	14.66	22.06	10.88	0.60
9	16.50	25.07	11.08	0.65
10	17.71	27.18	10.93	0.58
11	15.97	24.27	10.85	0.59
12	15.18	22.99	10.89	0.58
Average	15.49	23.43	11.00	0.61

IOPS Test Run – Average Response Time (ms) 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
14,403,326	12,339,294	2,064,032

IOPS Test Run – 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	0.2808	0.0701	0.2101	0.0180	0.0699	0.0350	0.2810
COV	0.0054	0.0013	0.0032	0.0022	0.0088	0.0029	0.0023	0.0014

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.*

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%.*

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

Response Time Ramp Test Phase

Clause 5.4.2.3

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 11.

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

Clause 9.2.4.7.3

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, and Response Time Ramp Test Runs are listed below.

java metrics -b 481

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 - 481 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:14:09	2:17:10	0-2	0:03:01
Measurement Interval	2:17:10	2:27:10	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	24,053.67	14,347.10	2,958.12	6,748.45
1	24,067.42	14,334.85	2,955.78	6,776.78
2	24,098.68	14,353.92	2,971.07	6,773.70
3	24,061.17	14,345.67	2,970.32	6,745.18
4	24,062.30	14,342.98	2,950.63	6,768.68
5	24,047.93	14,334.20	2,960.08	6,753.65
6	24,059.43	14,338.63	2,954.62	6,766.18
7	24,109.62	14,366.18	2,965.53	6,777.90
8	24,052.08	14,345.38	2,952.35	6,754.35
9	24,017.17	14,325.97	2,950.98	6,740.22
10	24,038.93	14,332.52	2,948.88	6,757.53
11	24,043.85	14,331.75	2,956.55	6,755.55
12	23,562.95	14,014.90	2,909.03	6,639.02
Average	24,005.54	14,307.82	2,951.90	6,745.83

95% Load Level - 456 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:27:30	2:30:31	0-2	0:03:01
Measurement Interval	2:30:31	2:40:31	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	22,816.75	13,592.25	2,802.00	6,422.50
1	22,803.12	13,594.35	2,806.58	6,402.18
2	22,792.85	13,576.85	2,803.75	6,412.25
3	22,764.00	13,558.55	2,801.48	6,403.97
4	22,784.37	13,586.43	2,797.32	6,400.62
5	22,791.20	13,576.02	2,807.52	6,407.67
6	22,802.22	13,590.63	2,811.10	6,400.48
7	22,759.85	13,578.28	2,798.28	6,383.28
8	22,774.93	13,573.68	2,794.58	6,406.67
9	22,812.22	13,611.27	2,804.62	6,396.33
10	22,783.02	13,594.40	2,802.98	6,385.63
11	22,767.47	13,568.80	2,797.55	6,401.12
12	22,411.05	13,328.57	2,761.82	6,320.67
Average	22,745.03	13,556.66	2,797.73	6,390.64

90% Load Level - 432 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:40:51	2:43:52	0-2	0:03:01
Measurement Interval	2:43:52	2:53:52	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	21,619.13	12,896.00	2,654.68	6,068.45
1	21,615.73	12,883.68	2,658.50	6,073.55
2	21,595.28	12,858.00	2,649.78	6,087.50
3	21,606.75	12,882.28	2,653.57	6,070.90
4	21,604.73	12,867.33	2,658.73	6,078.67
5	21,609.37	12,887.32	2,663.63	6,058.42
6	21,610.80	12,873.52	2,649.43	6,087.85
7	21,620.30	12,895.25	2,654.88	6,070.17
8	21,638.23	12,906.77	2,653.13	6,078.33
9	21,605.10	12,889.75	2,658.20	6,057.15
10	21,606.28	12,872.70	2,663.45	6,070.13
11	21,629.28	12,886.32	2,654.77	6,088.20
12	21,311.83	12,684.45	2,636.38	5,991.00
Average	21,584.27	12,864.57	2,654.62	6,065.08

80% Load Level - 384 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	2:54:11	2:57:12	0-2	0:03:01
Measurement Interval	2:57:12	3:07:12	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	19,226.90	11,459.35	2,354.60	5,412.95
1	19,186.45	11,431.13	2,359.00	5,396.32
2	19,198.33	11,433.37	2,363.28	5,401.68
3	19,226.42	11,453.47	2,377.68	5,395.27
4	19,194.15	11,429.73	2,369.13	5,395.28
5	19,196.55	11,441.33	2,365.62	5,389.60
6	19,197.33	11,446.63	2,362.68	5,388.02
7	19,206.95	11,464.92	2,366.90	5,375.13
8	19,195.67	11,437.65	2,366.85	5,391.17
9	19,221.35	11,450.87	2,351.27	5,419.22
10	19,178.20	11,435.82	2,356.78	5,385.60
11	19,199.23	11,423.92	2,361.38	5,413.93
12	19,073.27	11,354.25	2,349.37	5,369.65
Average	19,188.91	11,433.86	2,362.77	5,392.29

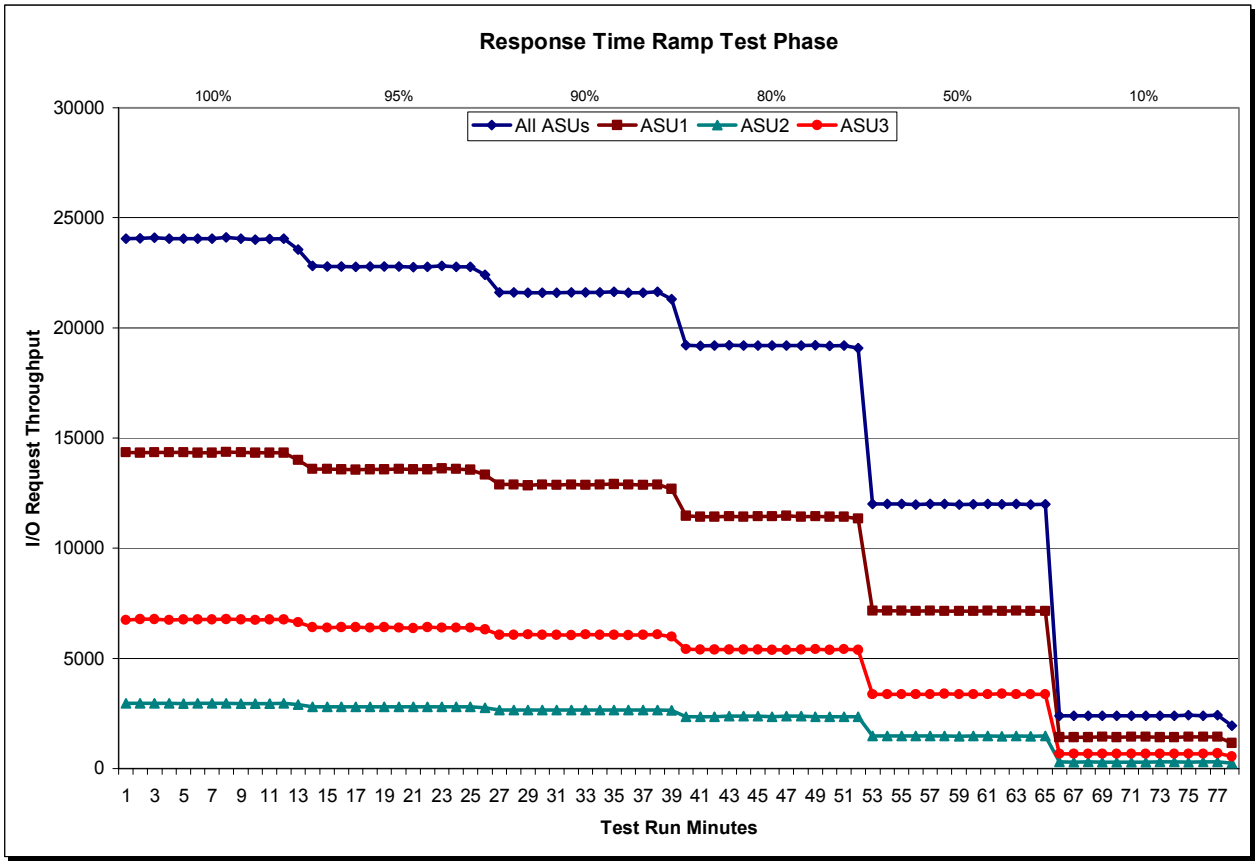
50% Load Level - 240 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	3:07:30	3:10:31	0-2	0:03:01
Measurement Interval	3:10:31	3:20:31	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	12,011.82	7,155.47	1,481.75	3,374.60
1	12,026.28	7,172.53	1,477.17	3,376.58
2	12,014.25	7,164.52	1,477.13	3,372.60
3	11,974.90	7,139.22	1,474.02	3,361.67
4	12,007.78	7,160.28	1,476.22	3,371.28
5	12,009.25	7,146.27	1,473.63	3,389.35
6	11,984.48	7,149.57	1,468.63	3,366.28
7	12,004.07	7,150.33	1,484.02	3,369.72
8	12,014.18	7,157.35	1,481.00	3,375.83
9	11,994.68	7,145.88	1,464.78	3,384.02
10	12,010.52	7,156.82	1,474.73	3,378.97
11	11,982.77	7,143.80	1,471.17	3,367.80
12	11,994.77	7,143.80	1,475.63	3,375.33
Average	11,997.74	7,149.33	1,474.38	3,374.03

10% Load Level - 48 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	3:20:47	3:23:48	0-2	0:03:01
Measurement Interval	3:23:48	3:33:48	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	2,397.62	1,429.58	295.58	672.45
1	2,393.00	1,425.05	292.67	675.28
2	2,400.25	1,429.40	296.13	674.72
3	2,402.43	1,435.78	294.13	672.52
4	2,399.33	1,430.42	294.27	674.65
5	2,398.20	1,431.02	289.93	677.25
6	2,398.07	1,431.73	293.98	672.35
7	2,394.47	1,424.20	298.15	672.12
8	2,396.75	1,428.28	297.23	671.23
9	2,410.98	1,443.35	291.88	675.75
10	2,401.18	1,432.18	294.72	674.28
11	2,409.80	1,433.52	296.05	680.23
12	1,953.18	1,161.40	240.05	551.73
Average	2,356.44	1,405.19	289.04	662.21

Response Time Ramp Distribution (IOPS) Graph

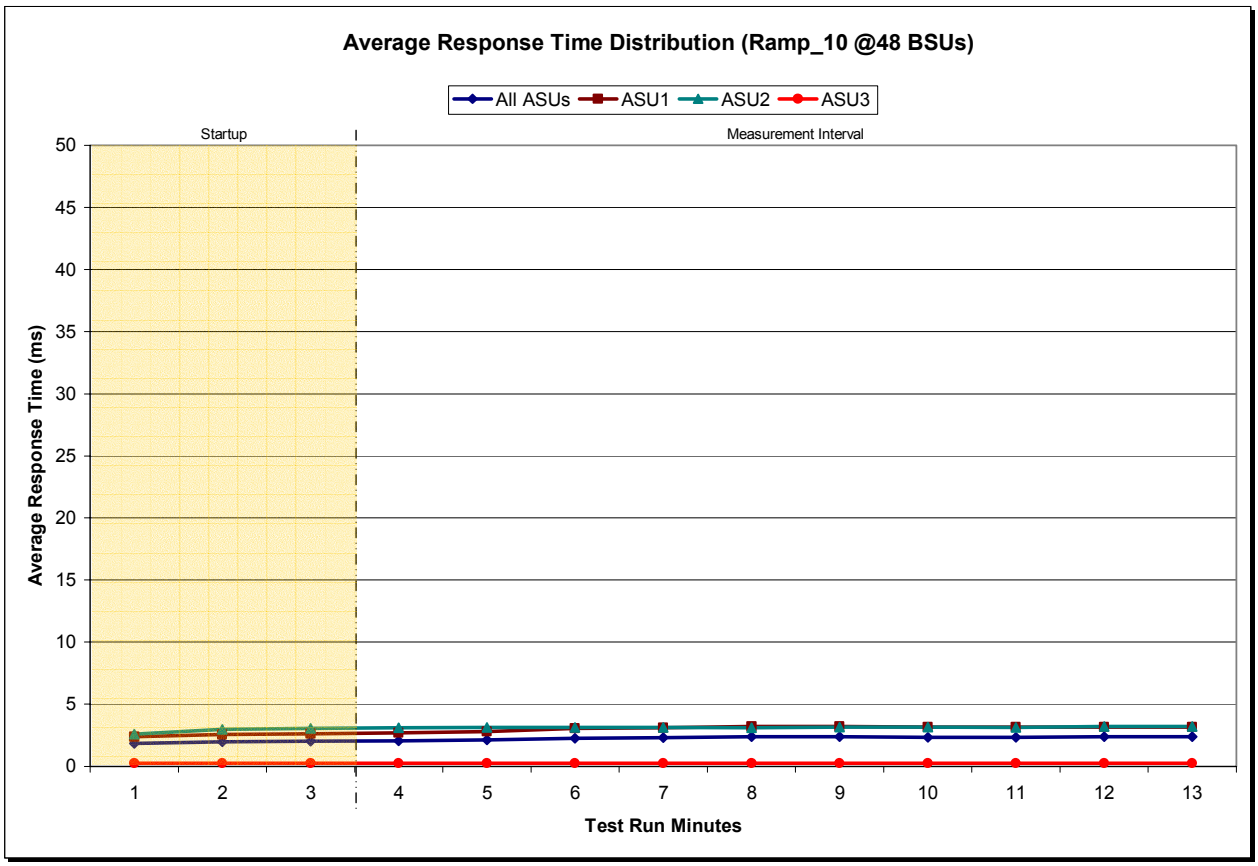


SPC-1 LRT™ Average Response Time (ms) Distribution Data

48 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	3:20:47	3:23:48	0-2	0:03:01
Measurement Interval	3:23:48	3:33:48	3-12	0:10:00

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	1.82	2.39	2.60	0.27
1	1.97	2.57	2.97	0.27
2	2.01	2.62	3.04	0.27
3	2.06	2.68	3.08	0.27
4	2.13	2.81	3.12	0.27
5	2.28	3.06	3.14	0.27
6	2.32	3.11	3.15	0.27
7	2.37	3.20	3.11	0.27
8	2.37	3.19	3.17	0.27
9	2.36	3.17	3.17	0.27
10	2.35	3.16	3.14	0.27
11	2.36	3.18	3.20	0.27
12	2.36	3.18	3.19	0.27
Average	2.29	3.07	3.15	0.27

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



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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0351	0.2808	0.0700	0.2103	0.0179	0.0697	0.0351	0.2810
COV	0.0145	0.0029	0.0074	0.0032	0.0252	0.0080	0.0145	0.0035

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.*

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%.*

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

Repeatability Test

Clause 5.4.3

The Repeatability Test demonstrates the repeatability and reproducibility of the SPC-1 IOPS™ and SPC-1 LRT™ primary metrics 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™ primary metric. Each Average Response Time value must be less than the SPC-1 LRT™ primary metric plus 5%.

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 9.2.4.7.3

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 two Repeatability Test Phases. The content, appearance, and format of the table are specified in Table 9-11.*
2. *An I/O Request Throughput Distribution (data and graph).*
3. *An Average Response Time Distribution (data and graph).*
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 Repeatability Test Runs are listed below.

java repeat1 -b 481

java repeat2 -b 481

Repeatability Test Results File

The values for the SPC-1 IOPS™, SPC-1 LRT™, and the Repeatability Test measurements are listed below.

	SPC-1 IOPS™	SPC-1 LRT™
Primary Metrics	*24,005.54*	*2.29*
Repeatability Test Phase 1	24,022.56	2.29
Repeatability Test Phase 2	24,016.28	2.30

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

Repeatability Test Phase 1, Test Run 2 (IOPS)

Repeatability Test Phase 1, Test Run 1 (LRT)

Repeatability Test Phase 2, Test Run 2 (IOPS)

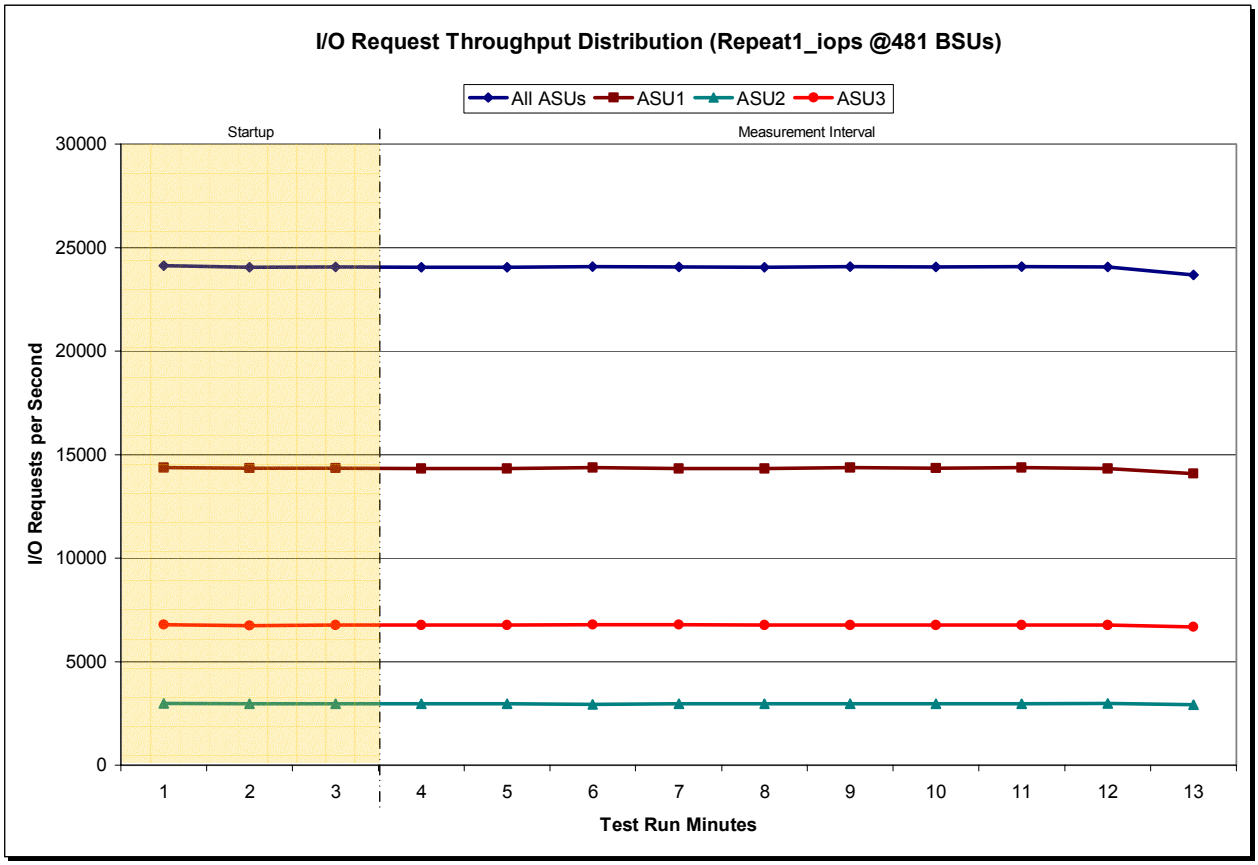
Repeatability Test Phase 2, Test Run 1 (LRT)

Repeatability 1 IOPS – I/O Request Throughput Distribution Data

481 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	3:47:31	3:50:32	0-2	0:03:01
Measurement Interval	3:50:32	4:00:32	3-12	0:10:00

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	24,120.43	14,366.05	2,974.82	6,779.57
1	24,028.73	14,335.17	2,951.23	6,742.33
2	24,061.08	14,339.27	2,956.83	6,764.98
3	24,039.75	14,312.02	2,966.77	6,760.97
4	24,042.85	14,328.17	2,963.00	6,751.68
5	24,078.43	14,355.45	2,947.18	6,775.80
6	24,054.35	14,308.97	2,966.17	6,779.22
7	24,044.32	14,329.32	2,952.37	6,762.63
8	24,085.83	14,359.77	2,969.25	6,756.82
9	24,068.37	14,339.12	2,959.15	6,770.10
10	24,084.65	14,370.45	2,957.98	6,756.22
11	24,061.13	14,326.30	2,972.45	6,762.38
12	23,665.95	14,079.50	2,921.85	6,664.60
Average	24,022.56	14,310.91	2,957.62	6,754.04

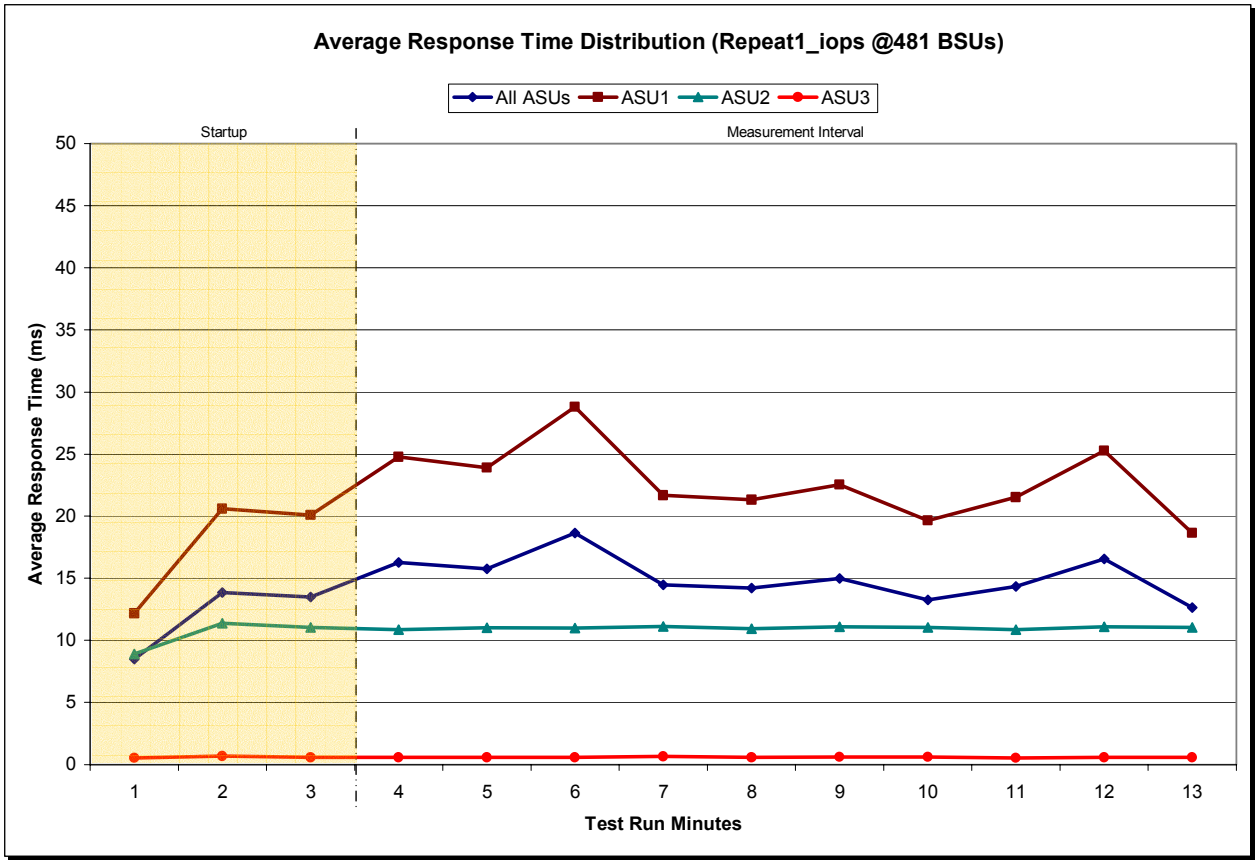
Repeatability 1 IOPS – I/O Request Throughput Distribution Graph



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

481 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	3:47:31	3:50:32	0-2	0:03:01
Measurement Interval	3:50:32	4:00:32	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	8.50	12.16	8.89	0.56
1	13.87	20.60	11.36	0.68
2	13.49	20.08	11.06	0.59
3	16.26	24.78	10.87	0.59
4	15.77	23.91	11.02	0.57
5	18.66	28.78	10.96	0.56
6	14.46	21.69	11.11	0.66
7	14.21	21.31	10.93	0.59
8	14.98	22.55	11.10	0.60
9	13.23	19.65	11.05	0.60
10	14.33	21.53	10.87	0.55
11	16.57	25.25	11.07	0.59
12	12.62	18.65	11.06	0.59
Average	15.11	22.81	11.00	0.59

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

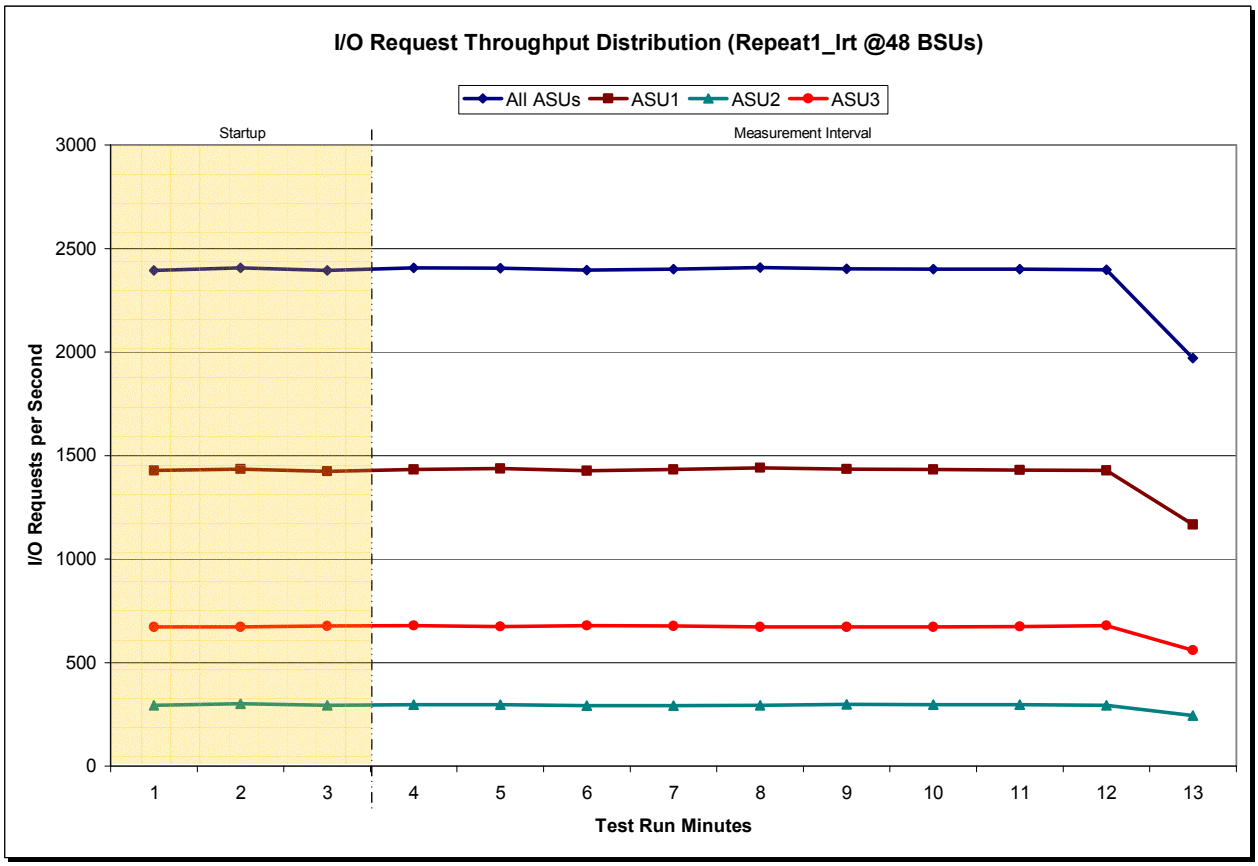


Repeatability 1 LRT – I/O Request Throughput Distribution Data

48 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	3:34:11	3:37:11	0-2	0:03:00
Measurement Interval	3:37:11	3:47:11	3-12	0:10:00

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	2,392.70	1,427.15	292.90	672.65
1	2,406.00	1,433.92	300.58	671.50
2	2,393.07	1,424.23	293.85	674.98
3	2,405.60	1,431.93	295.98	677.68
4	2,404.58	1,435.93	295.85	672.80
5	2,395.92	1,426.22	292.13	677.57
6	2,400.52	1,432.47	291.77	676.28
7	2,407.53	1,440.60	294.45	672.48
8	2,402.32	1,433.50	298.10	670.72
9	2,400.30	1,432.53	296.63	671.13
10	2,400.13	1,429.37	296.73	674.03
11	2,398.48	1,426.65	293.25	678.58
12	1,968.75	1,165.78	244.50	558.47
Average	2,358.41	1,405.50	289.94	662.98

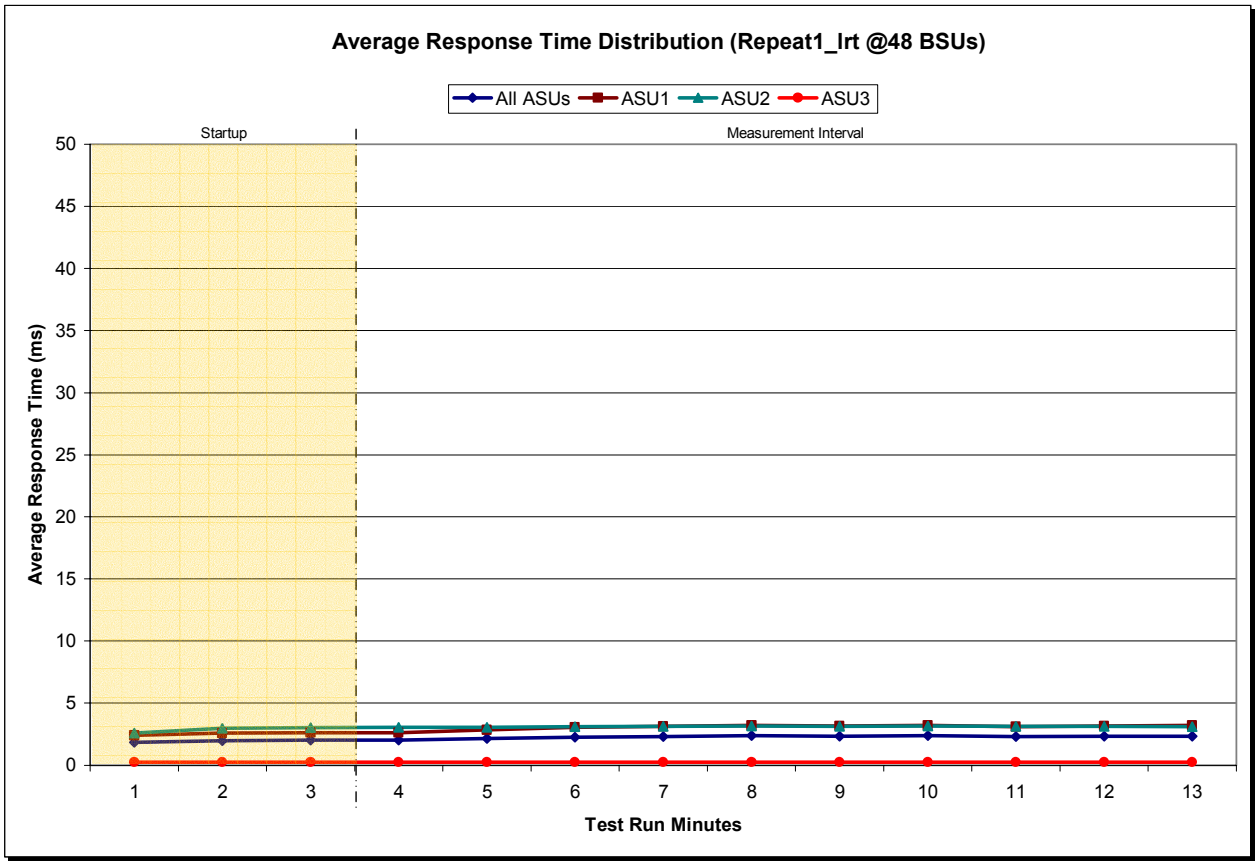
Repeatability 1 LRT – I/O Request Throughput Distribution Graph



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

48 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	3:34:11	3:37:11	0-2	0:03:01
Measurement Interval	3:37:11	3:47:11	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	1.83	2.41	2.61	0.27
1	1.99	2.59	2.97	0.27
2	2.01	2.62	3.03	0.27
3	2.02	2.64	3.06	0.27
4	2.15	2.85	3.05	0.27
5	2.27	3.05	3.11	0.26
6	2.32	3.12	3.14	0.26
7	2.37	3.19	3.15	0.27
8	2.35	3.16	3.14	0.27
9	2.37	3.19	3.16	0.27
10	2.32	3.11	3.14	0.27
11	2.35	3.17	3.14	0.27
12	2.35	3.20	3.08	0.27
Average	2.29	3.07	3.12	0.27

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

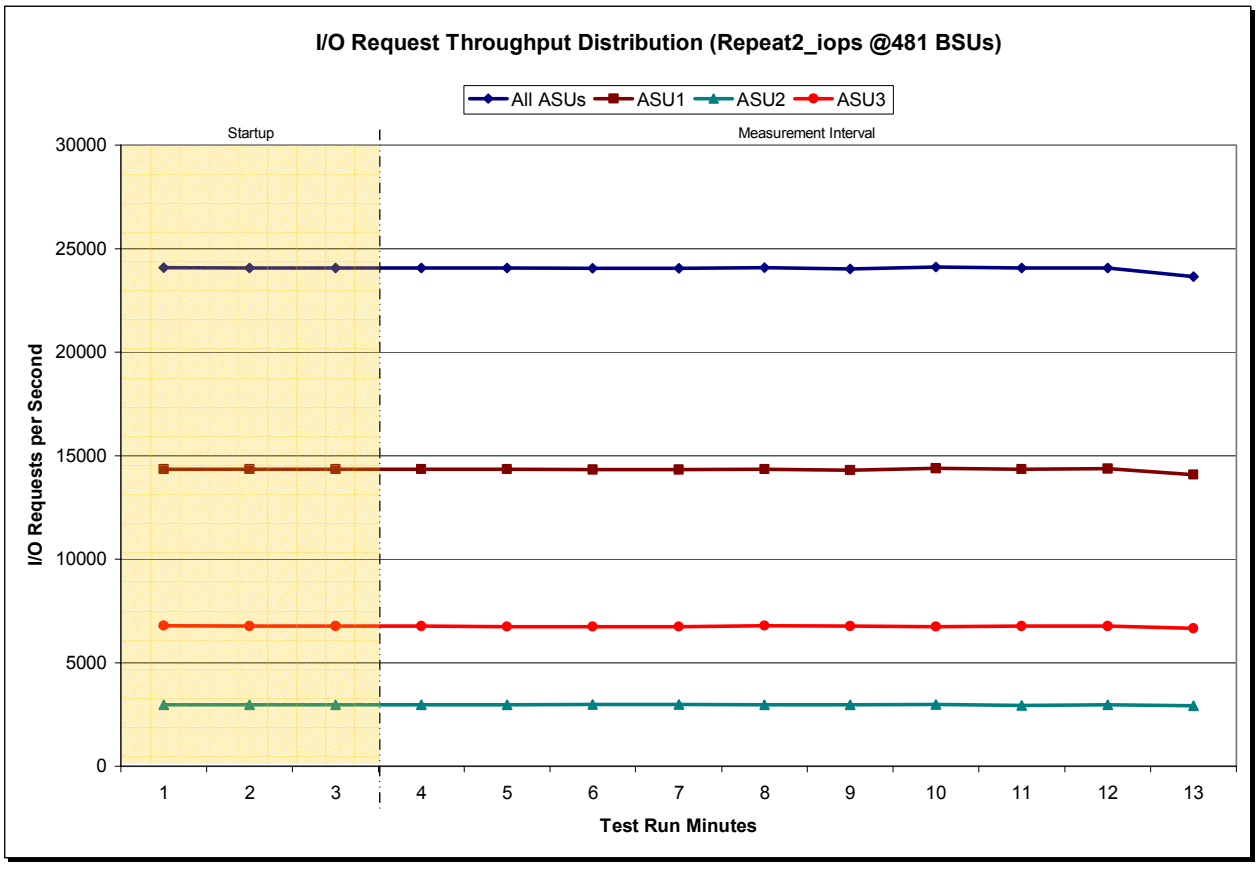


Repeatability 2 IOPS – I/O Request Throughput Distribution Data

481 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	4:14:16	4:17:17	0-2	0:03:01
Measurement Interval	4:17:17	4:27:17	3-12	0:10:00

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	24,089.87	14,350.82	2,960.65	6,778.40
1	24,062.15	14,334.93	2,962.53	6,764.68
2	24,062.03	14,334.75	2,966.32	6,760.97
3	24,059.63	14,345.32	2,954.98	6,759.33
4	24,057.92	14,348.05	2,960.50	6,749.37
5	24,040.77	14,325.07	2,972.02	6,743.68
6	24,045.48	14,326.65	2,971.05	6,747.78
7	24,075.35	14,333.73	2,961.67	6,779.95
8	24,009.72	14,289.00	2,961.68	6,759.03
9	24,103.28	14,385.02	2,971.88	6,746.38
10	24,054.03	14,351.38	2,943.25	6,759.40
11	24,070.23	14,357.48	2,959.47	6,753.28
12	23,646.40	14,083.68	2,916.45	6,646.27
Average	24,016.28	14,314.54	2,957.30	6,744.45

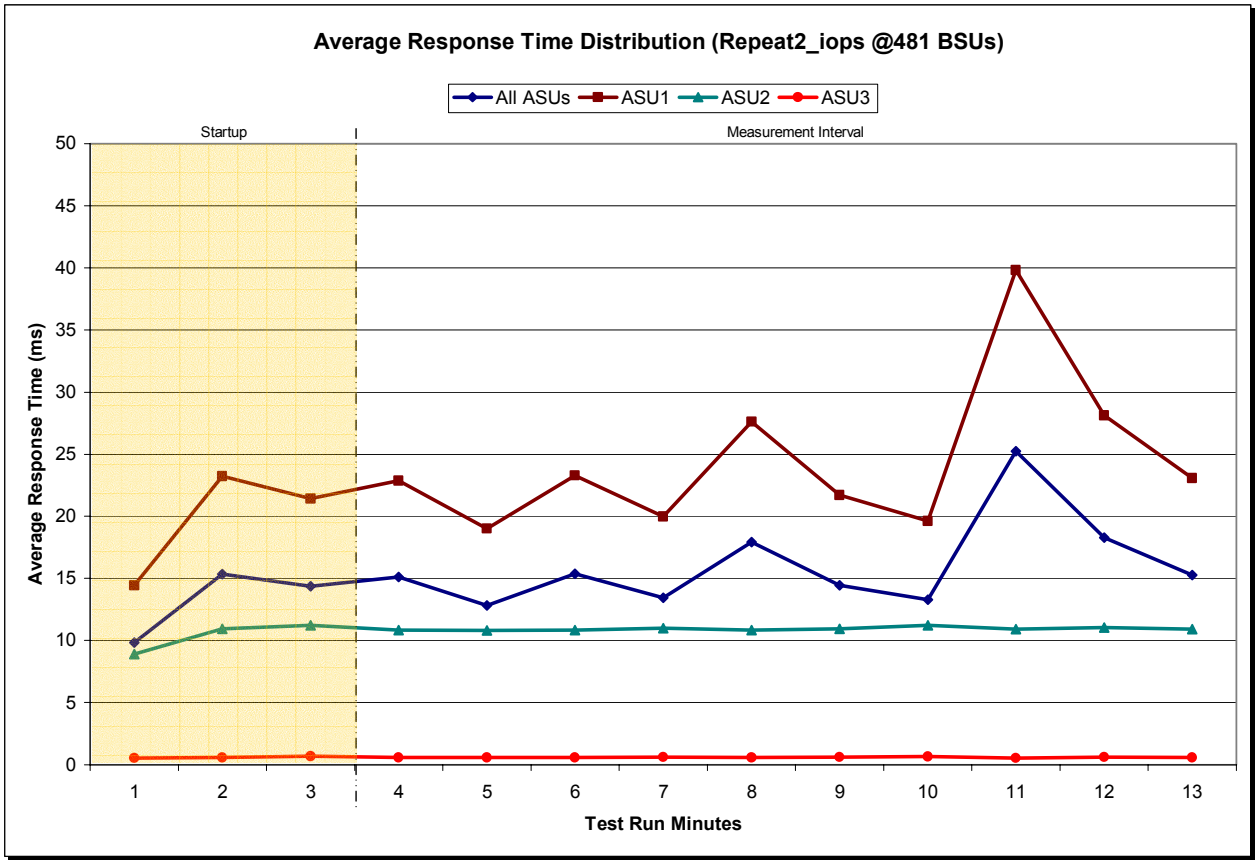
Repeatability 2 IOPS – I/O Request Throughput Distribution Graph



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

481 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	4:14:16	4:17:17	0-2	0:03:01
Measurement Interval	4:17:17	4:27:17	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	9.84	14.43	8.91	0.53
1	15.34	23.21	10.96	0.59
2	14.35	21.43	11.21	0.70
3	15.13	22.87	10.82	0.59
4	12.83	19.02	10.80	0.56
5	15.38	23.29	10.85	0.58
6	13.43	19.98	10.96	0.60
7	17.94	27.60	10.85	0.59
8	14.43	21.70	10.96	0.60
9	13.28	19.63	11.23	0.65
10	25.24	39.81	10.91	0.55
11	18.30	28.12	11.04	0.60
12	15.26	23.08	10.90	0.59
Average	16.12	24.51	10.93	0.59

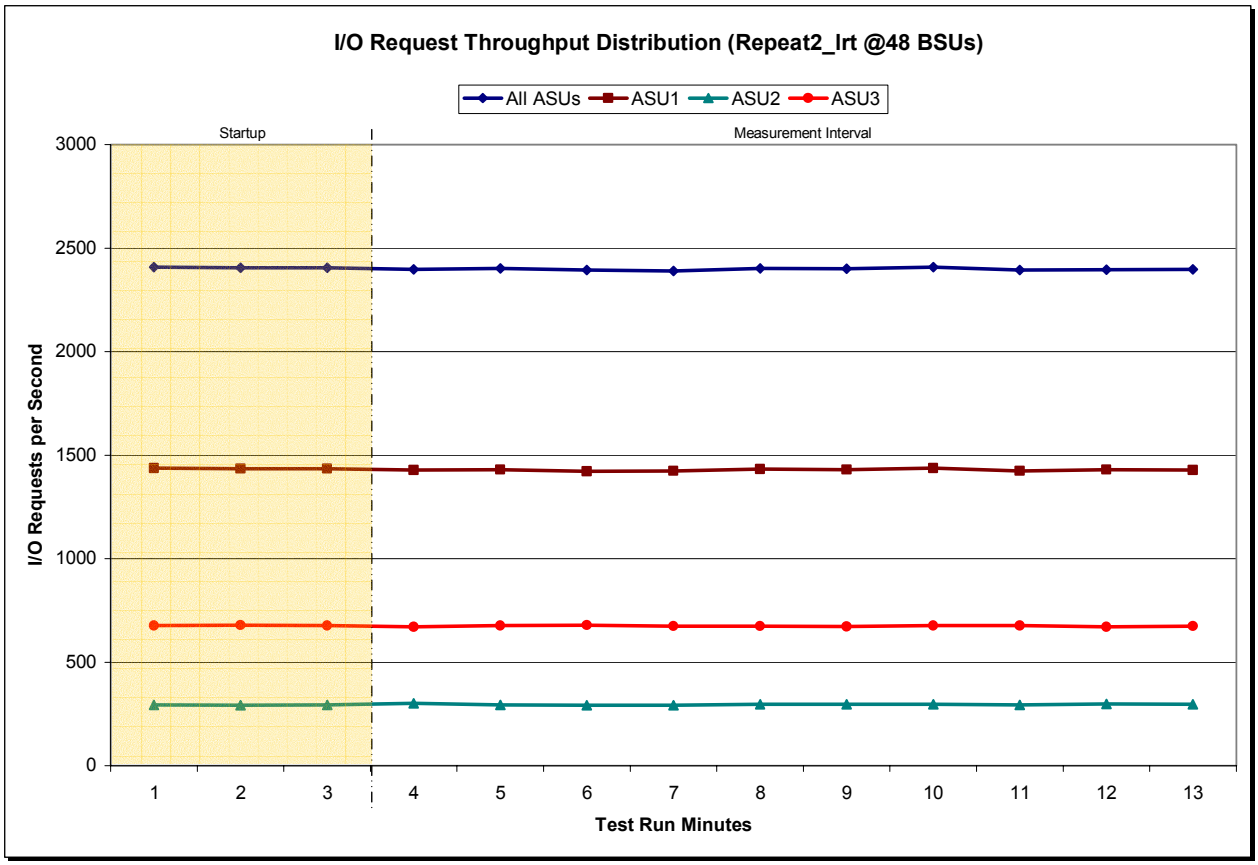
Repeatability 2 IOPS –Average Response Time (ms) Distribution Graph



Repeatability 2 LRT – I/O Request Throughput Distribution Data

48 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	4:00:56	4:03:56	0-2	0:03:00
Measurement Interval	4:03:56	4:13:56	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	2,407.48	1,436.27	294.75	676.47
1	2,403.72	1,433.67	292.08	677.97
2	2,402.83	1,433.23	293.68	675.92
3	2,397.90	1,428.28	299.37	670.25
4	2,400.95	1,429.93	293.92	677.10
5	2,392.40	1,421.43	292.60	678.37
6	2,389.20	1,423.92	290.97	674.32
7	2,401.60	1,431.48	296.30	673.82
8	2,398.58	1,430.05	296.17	672.37
9	2,407.62	1,437.12	295.25	675.25
10	2,393.10	1,424.20	293.83	675.07
11	2,396.18	1,429.40	297.25	669.53
12	2,397.25	1,427.97	295.02	674.27
Average	2,397.48	1,428.38	295.07	674.03

Repeatability 2 LRT – I/O Request Throughput Distribution Graph

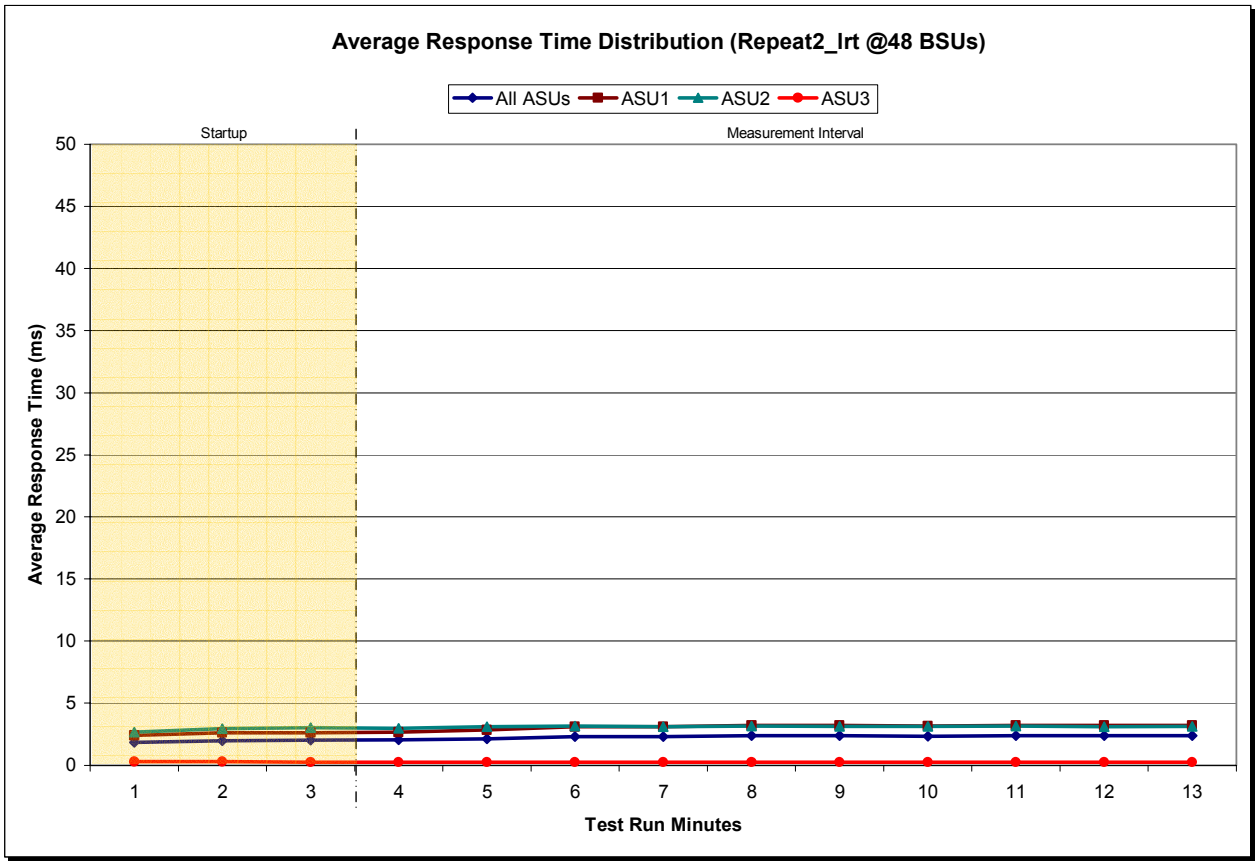


Repeatability 2 LRT –Average Response Time (ms) Distribution Data

48 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	4:00:56	4:03:56	0-2	0:03:01
Measurement Interval	4:03:56	4:13:56	3-12	0:10:00

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	1.84	2.41	2.67	0.27
1	2.00	2.62	2.96	0.27
2	2.02	2.64	3.03	0.27
3	2.04	2.68	2.99	0.27
4	2.14	2.83	3.09	0.27
5	2.30	3.09	3.15	0.27
6	2.31	3.11	3.11	0.27
7	2.37	3.19	3.16	0.27
8	2.37	3.20	3.13	0.27
9	2.35	3.17	3.14	0.27
10	2.36	3.19	3.16	0.27
11	2.37	3.21	3.10	0.27
12	2.37	3.20	3.11	0.27
Average	2.30	3.09	3.12	0.27

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



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	0.0351	0.2808	0.0699	0.2099	0.0180	0.0210	0.0351	0.2812
COV	0.0036	0.0010	0.0041	0.0014	0.0077	0.0039	0.0053	0.0015

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.*

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%.*

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

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0349	0.2808	0.0703	0.2101	0.0180	0.0700	0.0349	0.2811
COV	0.0154	0.0056	0.0101	0.0057	0.0169	0.0103	0.0123	0.0058

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	02811	0.0701	0.2099	0.0180	0.0701	0.0350	0.2808
COV	0.0023	0.0014	0.0023	0.0017	0.0064	0.0040	0.0052	0.0018

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0351	0.2811	0.0699	0.2096	0.0179	0.0703	0.0349	0.2811
COV	0.0152	0.0057	0.0083	0.0053	0.0144	0.0106	0.0153	0.0047

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 IOP™ 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 Benchmark Configuration 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 9.2.4.8

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, able 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.*

SPC-1 Workload Generator Input Parameters

A link to the SPC-1 Workload Generator input parameters for the Data Persistence Test is listed below.

java –Xmx512m persist1 -b 481

java persist2

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	54,114,128
Total Number of Logical Blocks Verified	48,433,920
Total Number of Logical Blocks that Failed Verification	0
Time Duration for Writing Test Logical Blocks	10 minutes
Size in Bytes of each Logical Block	512
Number of Failed I/O Requests in the process of the Test	0

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

TESTED STORAGE CONFIGURATION (TSC) AVAILABILITY DATE

Clause 9.2.4.9

The FDR shall state: "The Tested Storage Configuration, as documented in this Full Disclosure Report will be available for shipment to customers on MM DD YY." Where Tested Storage Configuration is the TSC Configuration Name as described in Clause 9.2.4.3.3 and MM is month, DD is the day, and YY is the year of the date that the configuration, as documented, is available for shipment to customers.

The hp StorageWorks Enterprise Virtual Array Model 2C12D, as documented in this Full Disclosure Report became available for customer purchase and shipment on July 30, 2002.

PRICING INFORMATION

Clause 9.2.4.11

A statement of the respective calculations for pricing must be included.

Pricing information may found in the Tested Storage Configuration Pricing section on page 12.

ANOMALIES OR IRREGULARITIES

Clause 9.2.4.10

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 observed during the SPC-1 remote audit of the hp StorageWorks Enterprise Virtual Array Model 2C12D.