



**SPC BENCHMARK 1™
FULL DISCLOSURE REPORT**

**SUN MICROSYSTEMS, INC.
SUN STORAGE J4200 ARRAY**

SPC-1 V1.10.1

**Submitted for Review: July 7, 2008
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First Edition – July 2008

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AUDIT CERTIFICATION



Leah Schoeb
Sun Microsystems, Inc.
5300 Riata Park Court AUS08
Austin, TX 78721

July 7, 2008

The SPC Benchmark 1™ results listed below for the Sun Storage J4200 Array were produced in compliance with the SPC Benchmark 1™ V1.10.1 Remote Audit requirements.

SPC Benchmark 1™ V1.10.1 Results	
Tested Storage Configuration (TSC) Name:	
Sun Storage J4200 Array	
Metric	Reported Result
SPC-1 IOPS™	3,144.63
SPC-1 Price-Performance	\$2.38/SPC-1 IOPS™
Total ASU Capacity	1,180,277 GB
Data Protection Level	Unprotected
Total TSC Price (including three-year maintenance)	\$7,432

The following SPC Benchmark 1™ Remote Audit requirements were reviewed and found compliant with V1.10.1 of the SPC Benchmark 1™ specification:

- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository storage items, based on information supplied by Sun Microsystems, Inc.:
 - ✓ 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 Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters that were changed from default values.

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

AUDIT CERTIFICATION (CONT.)

Sun Storage J4200 Array
SPC-1 Audit Certification

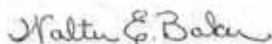
Page 2

- SPC-1 Workload Generator commands and parameters used for the audited SPC Test Runs.
- The following Host System requirements, based on information supplied by Sun Microsystems, Inc.:
 - ✓ 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 Sun Microsystems, Inc. for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4 and 5 of the SPC-1 Benchmark Specification:
 - ✓ Data Persistence Test
 - ✓ Sustainability Test Phase
 - ✓ IOPS Test Phase
 - ✓ Response Time Ramp Test Phase
 - ✓ Repeatability Test
- There were no differences between the Tested Storage Configuration (TSC) used for the benchmark 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
SPC Auditor

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LETTER OF GOOD FAITH

Sun Microsystems, Inc.
Mailstop USCA14-203
4140 Network Circle
Santa Clara, CA 95054



Date: 6/3/08

From: Ronald Melanson

To: Walter Baker

Subject: SPC-1 Letter of Good Faith for the Sun Storage J4200

Sun Microsystems Inc. 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 V1.10.1 of the SPC-1 benchmark specification.

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

Signed:

A handwritten signature in blue ink that reads "Ronald Melanson". The signature is written over a solid horizontal line.

Ronald Melanson
Vice President, System Group Quality Office

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact	Sun Microsystems, Inc. – http://www.sun.com Leah Schoeb – leah.schoeb@sun.com 5300 Riata Park Court AUS08 Austin, TX 78721 Phone: (877) 319-0457 FAX: (512) 266-2523
Test Sponsor Alternate Contact	Sun Microsystems, Inc. – http://www.sun.com Jason Schaffer – jason.schaffer@sun.com 500 Eldorado Blvd. Broomfield, CO 80021 Phone: (303) 272-4743 FAX: (512) 266-2523
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	V1.10.1
SPC-1 Workload Generator revision number	V2.00.04a
Date Results were first used publicly	July 7, 2008
Date the FDR was submitted to the SPC	July 7, 2008
Date the TSC is available for shipment to customers	July 8, 2008
Date the TSC completed audit certification	July 7, 2008

Tested Storage Product (TSP) Description

The Sun Storage J4200 Array is an easy and inexpensive way to extend your server-storage capabilities. This Array offers high-quality low-cost SAS/SATA JBOD storage that grows with your business. Plus, it comes with the groundbreaking ZFS file system. Included at no extra charge, ZFS automates common administrative tasks, protects data from corruption, and provides unlimited scalability.

Summary of Results

SPC-1 Results	
Tested Storage Configuration (TSC) Name: Sun Storage J4200 Array	
Metric	Reported Result
SPC-1 IOPS™	3,144.63
SPC-1 Price-Performance	\$2.36/SPC-1 IOPS™
Total ASU Capacity	1,180.277GB
Data Protection Level	Unprotected
Total TSC Price (including three-year maintenance)	\$7,432

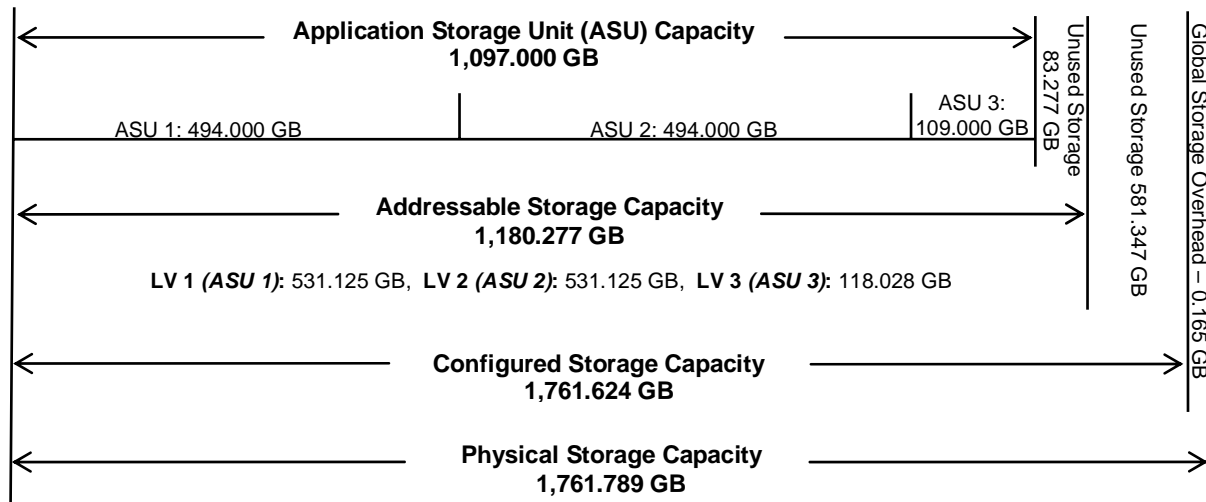
SPC-1 IOPS™ represents the maximum I/O Request Throughput at the 100% load point.

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

A **Data Protection Level** of “Unprotected” provides no data protection.

Storage Capacities and Relationships

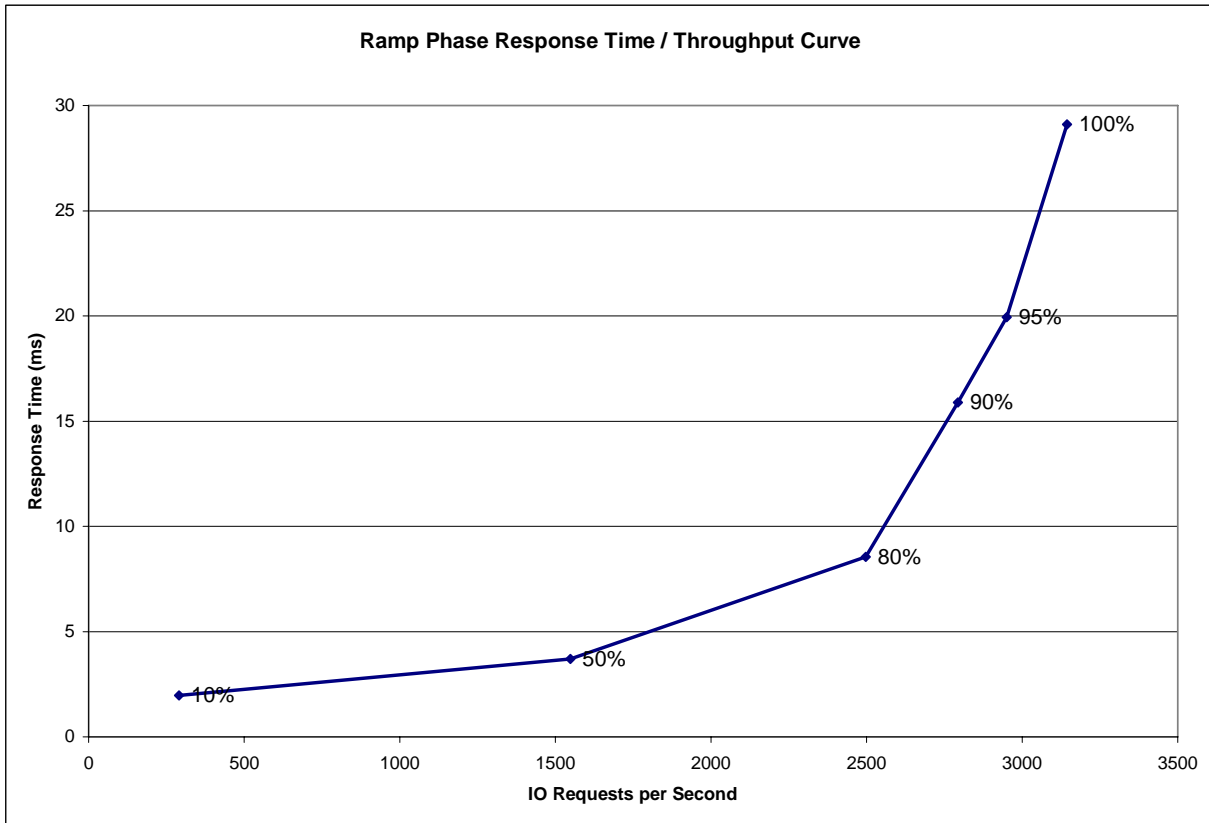
The following diagram documents the various storage capacities, used in this benchmark, and their relationships.



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	291.03	1,548.28	2,497.82	2,793.97	2,949.77	3,144.63
Average Response Time (ms):						
All ASUs	1.95	3.71	8.55	15.90	19.94	29.11
ASU-1	2.57	4.23	5.17	5.76	6.17	6.72
ASU-2	2.32	4.05	6.39	7.79	8.84	10.45
ASU-3	0.49	2.46	16.63	40.96	53.94	84.64
Reads	4.25	6.93	9.30	10.63	11.54	12.86
Writes	0.47	1.61	8.05	19.33	25.39	39.68

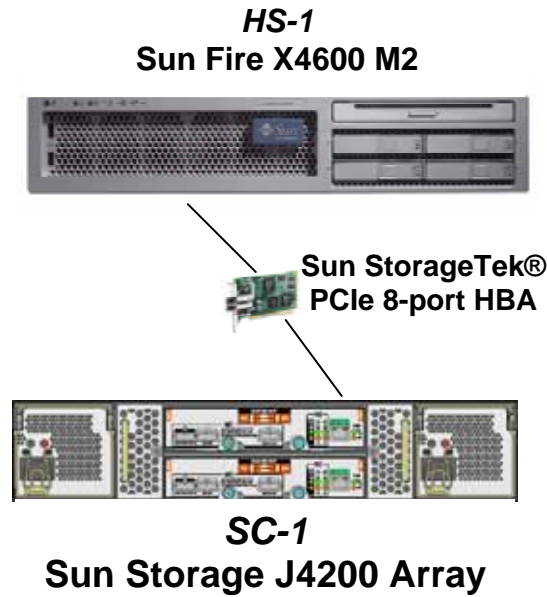
Tested Storage Configuration Pricing (*Priced Storage Configuration*)

Part Number	Description	Quantity	US List	Total	discount	Ave. Price
XTA4200R00A10DISK	Sun Storage J4200 Rack Ready JBOD Chassis, No drives, dual AC power supplies, dual fan module, rail kit, single SAS I/O module, One .5M SAS cable, RoHS-5.	1	\$2,800.00	\$2,800	22%	\$2,184
XTA-4200-IOM	One three-port SAS I/O module for Sun Storage J4200, One .5M SAS cable.	1	\$500	\$500	22%	\$390
XTA-SS1NJ-146G15K	RoHS-6. Internal 146GB 15K SAS HDD, 3.5" x 1" drive with bracket for J4200 and J4400.	12	\$399	\$4,788	22%	\$3,735
XTA-4200-2URK-19U	Sun Storage J4200 2U universal rack rail kit; RoHS-5	1	\$125	\$125	22%	\$98
SG-XPCIE8SAS-E-Z	Sun StorageTek (TM) PCIe SAS Host Bus Adapter, 8 port, RoHS 6 compliant	1	\$550	\$550	22%	\$429
IWU-STJ4200-24-3G	Controller unit upgrade 3 year Gold Service Maintenance	1	\$1,065.64	\$1,066	44%	\$597
	- 7/24 coverage					
	- 4 hr response time					
	- 4 hour resolution					
Total				\$9,829		\$7,432

Differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration

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

Benchmark Configuration/Tested Storage Configuration Diagram



Benchmark Configuration/Tested Storage Configuration Components

Host System:	Tested Storage Configuration (TSC):
UID=HS-1 Sun Fire X4600 M2	1 – Sun StorageTek PCI Express SAS 8-Channel HBA
4 – 2.6 GHz dual core AMD Opteron™ Processor 8222, 1 MB L2	UID=SC-1: Sun Storage J4200
15.5 GB main memory	3 – 3 Gb/s “x4 wide” SAS ports available 1 port used
MS Windows Server 2003 Enterprise x64 with Service Pack 2	12 – 146 GB, 15K RPM Seagate SAS disk drives
PCIe	
WG	

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 9.2.4.4.1

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

The Benchmark Configuration (BC)/Tested Storage Configuration (TSC) is illustrated on page 13 (*Benchmark Configuration/Tested Storage Configuration Diagram*).

Storage Network Configuration

Clause 9.2.4.4.1

...

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 9.2.4.4.2.*

Clause 9.2.4.4.2

If a storage network was configured as a part of the Tested Storage Configuration and the Benchmark Configuration diagram described in Clause 9.2.4.4.1 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), including the network configuration, is illustrated on page 13 (*Benchmark Configuration/Tested Storage Configuration Diagram*).

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.*

The details of the Host System configuration may be found on page 13 (*Benchmark Configuration/Tested Storage Configuration Diagram*).

Customer Tunable 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. 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 57 contains the customer tunable parameters and options that have been altered from their default values for this benchmark.

Tested Storage Configuration (TSC) Description

Clause 9.2.4.5.2

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

SPC-1 Workload Generator Storage Configuration

Clause 9.2.4.5.3

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 61.

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

Storage Capacities and Relationships

Clause 9.2.4.6.1

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

SPC-1 Storage Capacities		
Storage Hierarchy Component	Units	Capacity
Total ASU Capacity	Gigabytes (GB)	1,097.000
Addressable Storage Capacity	Gigabytes (GB)	1,180.277
Configured Storage Capacity	Gigabytes (GB)	1,761.624
Physical Storage Capacity	Gigabytes (GB)	1,761.789
Data Protection (<i>Unprotected</i>)	Gigabytes (GB)	0.000
Required Storage (<i>spares/overhead</i>)	Gigabytes (GB)	0.000
Global Storage Overhead	Gigabytes (GB)	0.165
Total Unused Storage	Gigabytes (GB)	664.624

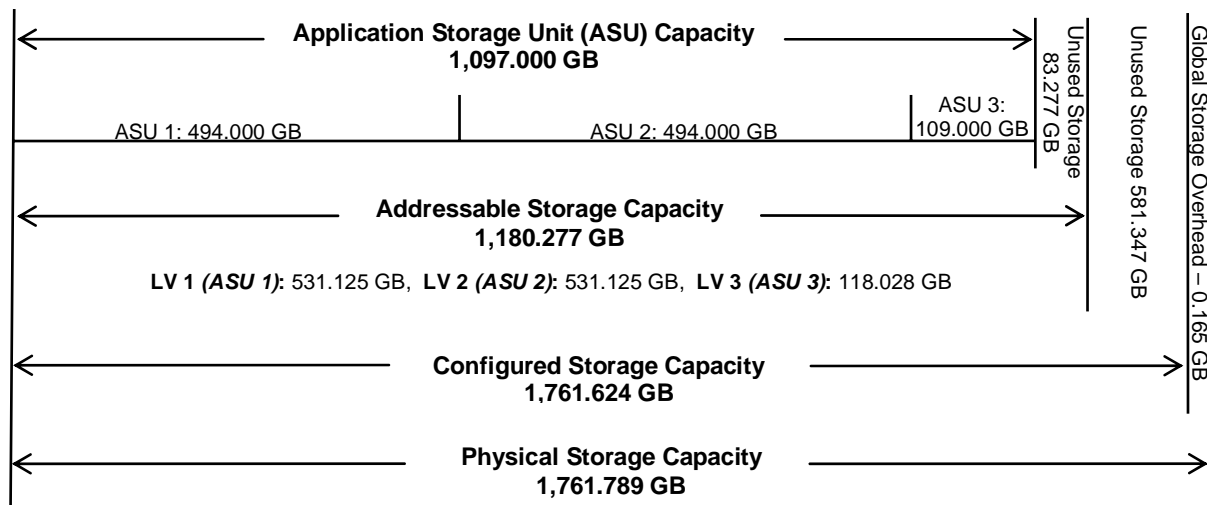
SPC-1 Storage Hierarchy Ratios

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	92.94%	62.27%	62.27%
Required for Data Protection (<i>Unprotected</i>)		0.00%	0.00%
Addressable Storage Capacity		67.00%	66.99%
Required Storage		0.00%	0.00%
Configured Storage Capacity			99.99%
Global Storage Overhead			0..01%
Unused Storage:			
Addressable	7.06%		
Configured		33.00%	
Physical			0.00%

The Physical Storage Capacity consisted of 1,761.789 GB distributed over 12 disk drives each with a formatted capacity of 146.816 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 0.165 GB (0.01%) of Physical Storage Capacity. There was 581.347 GB (33.00%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 92.94% of the Addressable Storage Capacity resulting in 83.277 GB (7.06%) of Unused Storage within the Addressable Storage Capacity.

SPC-1 Storage Capacities and Relationships Illustration

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



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 (494.000 GB)	ASU-2 (494.000 GB)	ASU-3 (109.000 GB)
1 Logical Volume 531.125 GB per Logical Volume (494.000 GB used per Logical Volume)	1 Logical Volume 531.125 GB per Logical Volume (494.000 GB used per Logical Volume)	1 Logical Volume 118.028 GB per Logical Volume (109.000 GB used per Logical Volume)

The Data Protection Level used for all Logical Volumes was “Unprotected” as described on page 10. 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. “SPC-1 Test Execution Definitions” on page 54 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.

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 three (3) 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 9.2.4.7.1

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

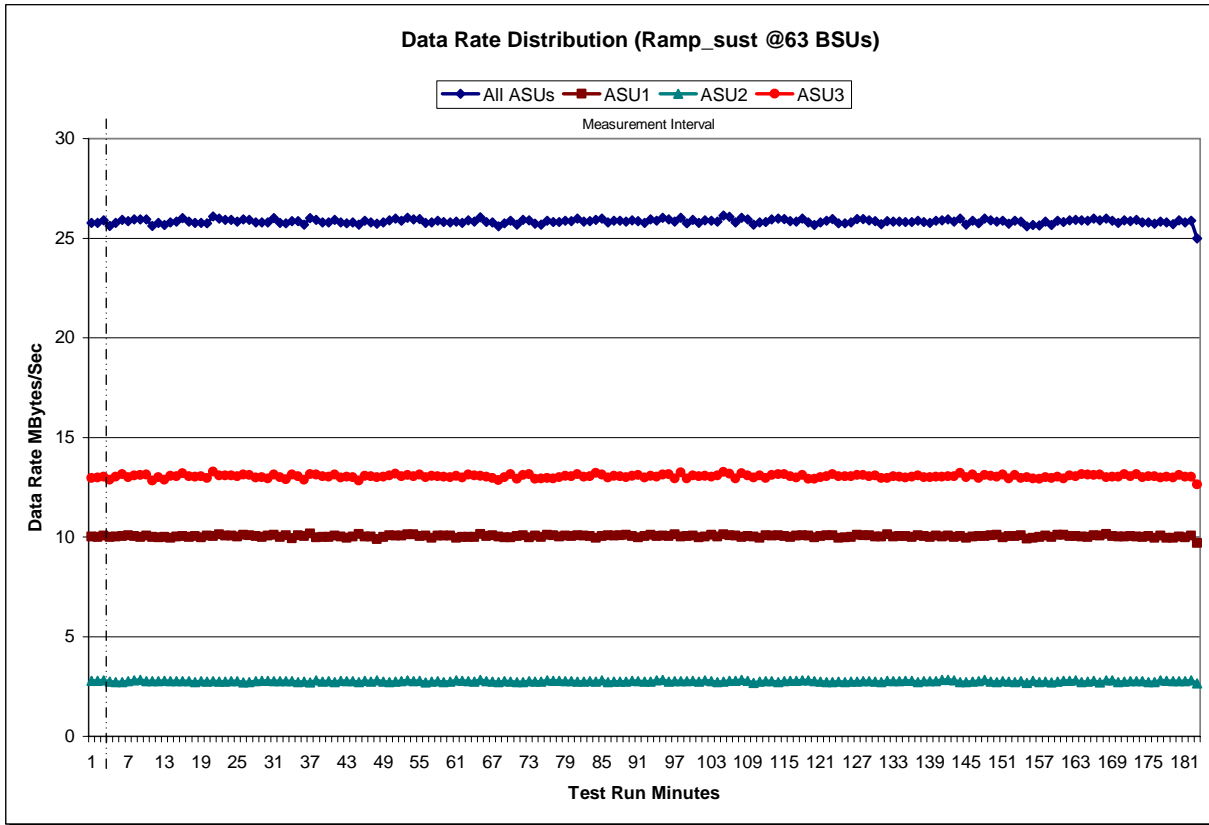
The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in “Appendix E: SPC-1 Workload Generator Input Parameters” on Page 62.

Sustainability Test Results File

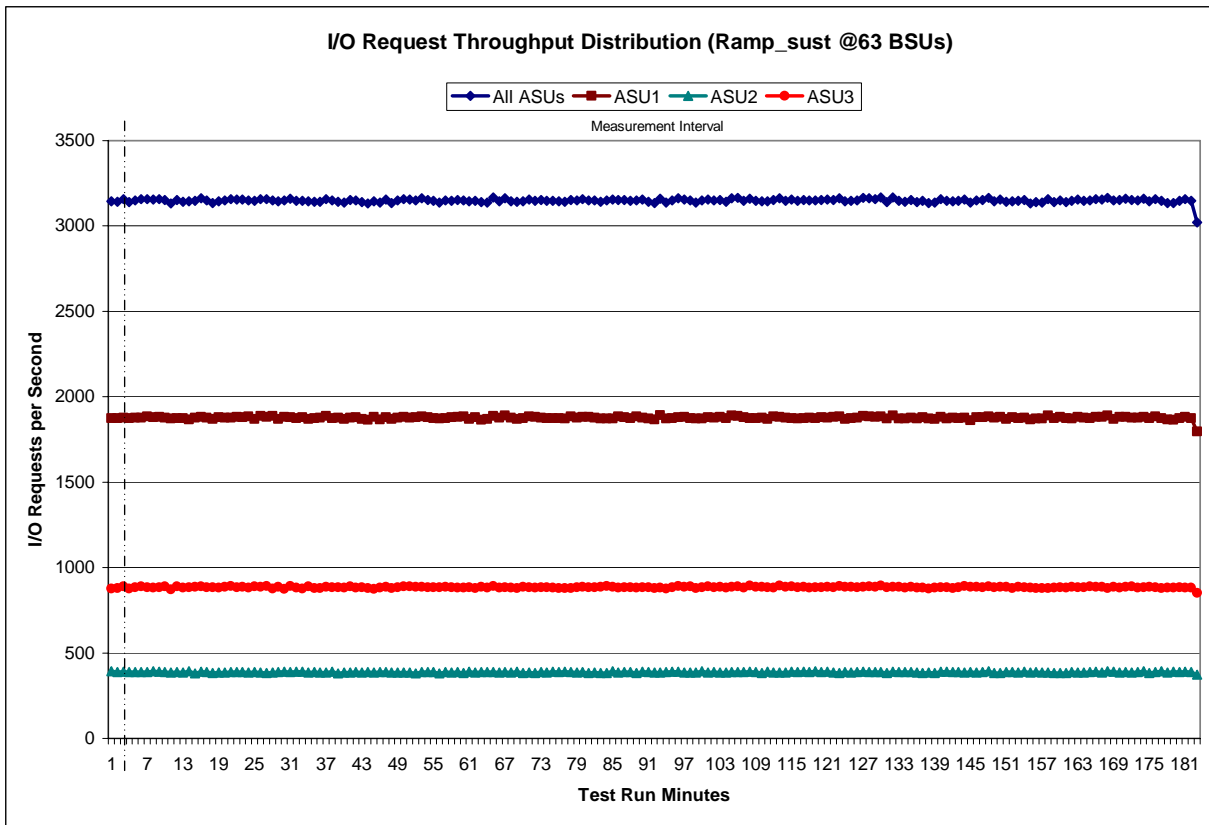
A link to the test results file generated from the Sustainability Test Run is listed below.

[Sustainability Test Results File](#)

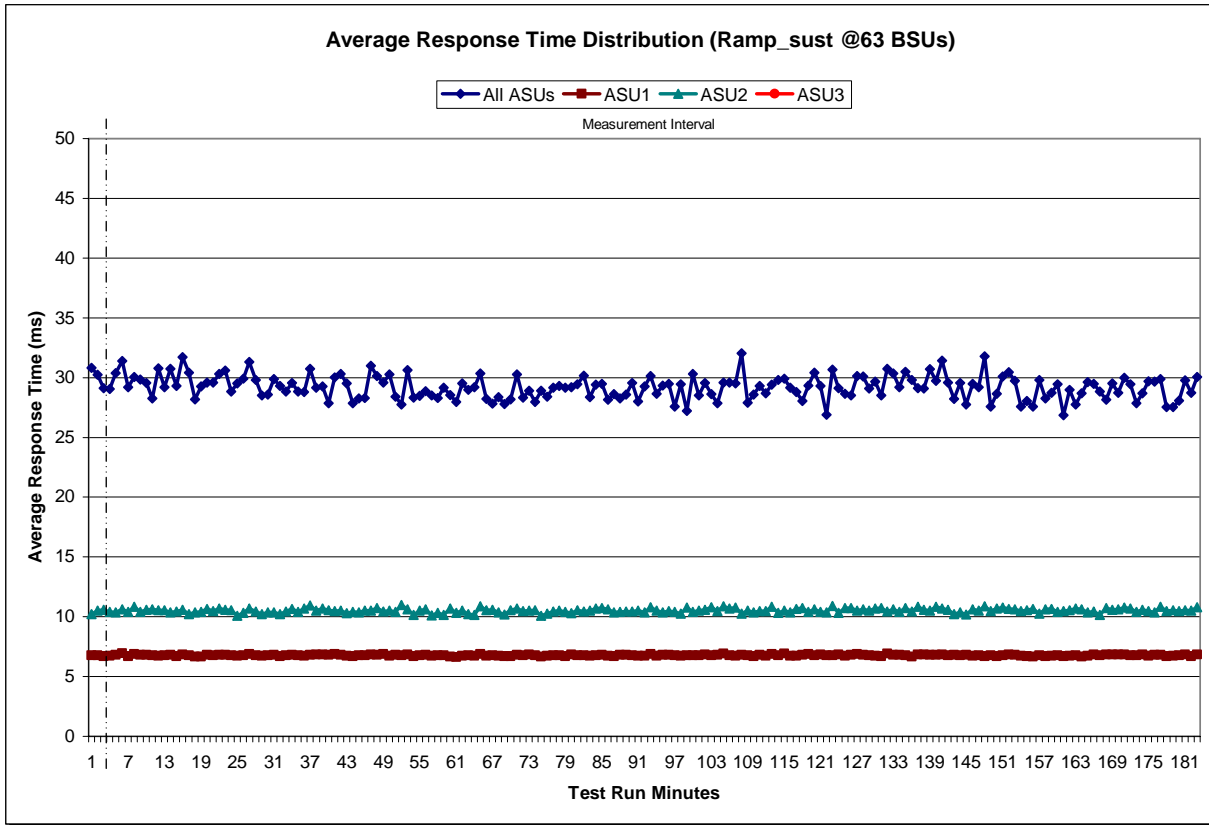
Sustainability – Data Rate Distribution Graph



Sustainability – I/O Request Throughput Distribution Graph



Sustainability – Average Response Time (ms) Distribution Graph



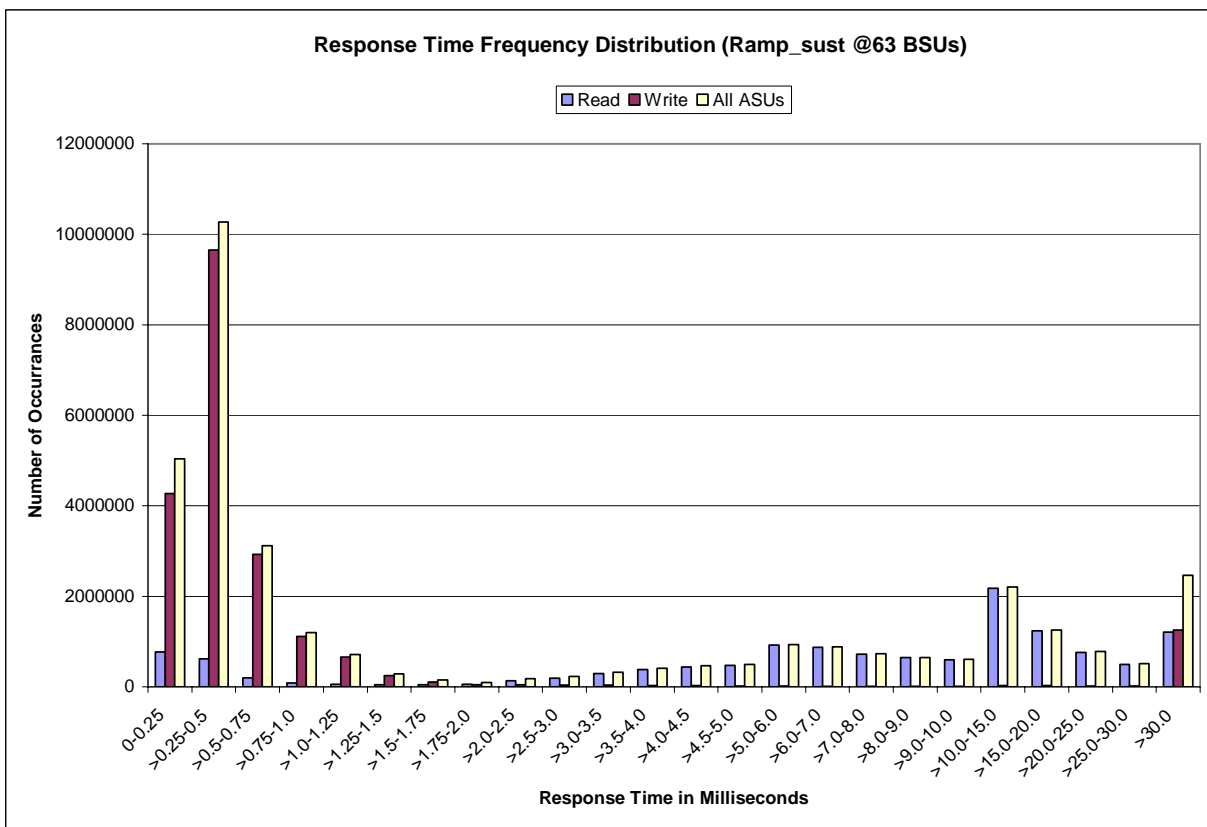
Sustainability – Response Time Frequency Distribution Data

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	770,224	619,952	197,447	82,976	57,516	43,119	46,757	52,972
Write	4,265,558	9,652,118	2,924,824	1,116,314	653,253	244,053	103,072	44,954
All ASUs	5,035,782	10,272,070	3,122,271	1,199,290	710,769	287,172	149,829	97,926
ASU1	3,122,718	4,678,183	1,339,139	518,776	316,497	131,028	83,701	68,073
ASU2	798,905	1,148,827	330,275	128,714	77,334	27,763	12,753	6,794
ASU3	1,114,159	4,445,060	1,452,857	551,800	316,938	128,381	53,375	23,059

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	133,161	192,699	290,901	377,381	440,140	471,245	919,502	871,477
Write	46,721	35,615	33,652	31,969	28,837	19,803	16,297	8,599
All ASUs	179,882	228,314	324,553	409,350	468,977	491,048	935,799	880,076
ASU1	146,323	198,855	293,272	372,156	425,053	444,834	851,646	800,278
ASU2	10,584	12,234	14,826	21,659	29,580	35,436	73,416	72,644
ASU3	22,975	17,225	16,455	15,535	14,344	10,778	10,737	7,154

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	725,171	643,728	598,708	2,177,536	1,232,550	760,922	494,441	1,210,912
Write	7,474	7,179	6,898	29,522	24,149	19,835	17,058	1,256,252
All ASUs	732,645	650,907	605,606	2,207,058	1,256,699	780,757	511,499	2,467,164
ASU1	655,311	579,313	537,338	1,908,986	1,043,020	620,577	385,674	752,001
ASU2	70,637	65,002	61,780	270,271	191,822	142,087	110,026	467,374
ASU3	6,697	6,592	6,488	27,801	21,857	18,093	15,799	1,247,789

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 5.1.0 and 5.3.13.2

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 5.3.13.3

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	0.1406	0.0700	0.2100	0.0180	0.0701	0.0349	0.2809
COV	0.012	0.004	0.007	0.005	0.017	0.008	0.012	0.004

Primary Metrics Test – 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 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 62.

IOPS Test Results File

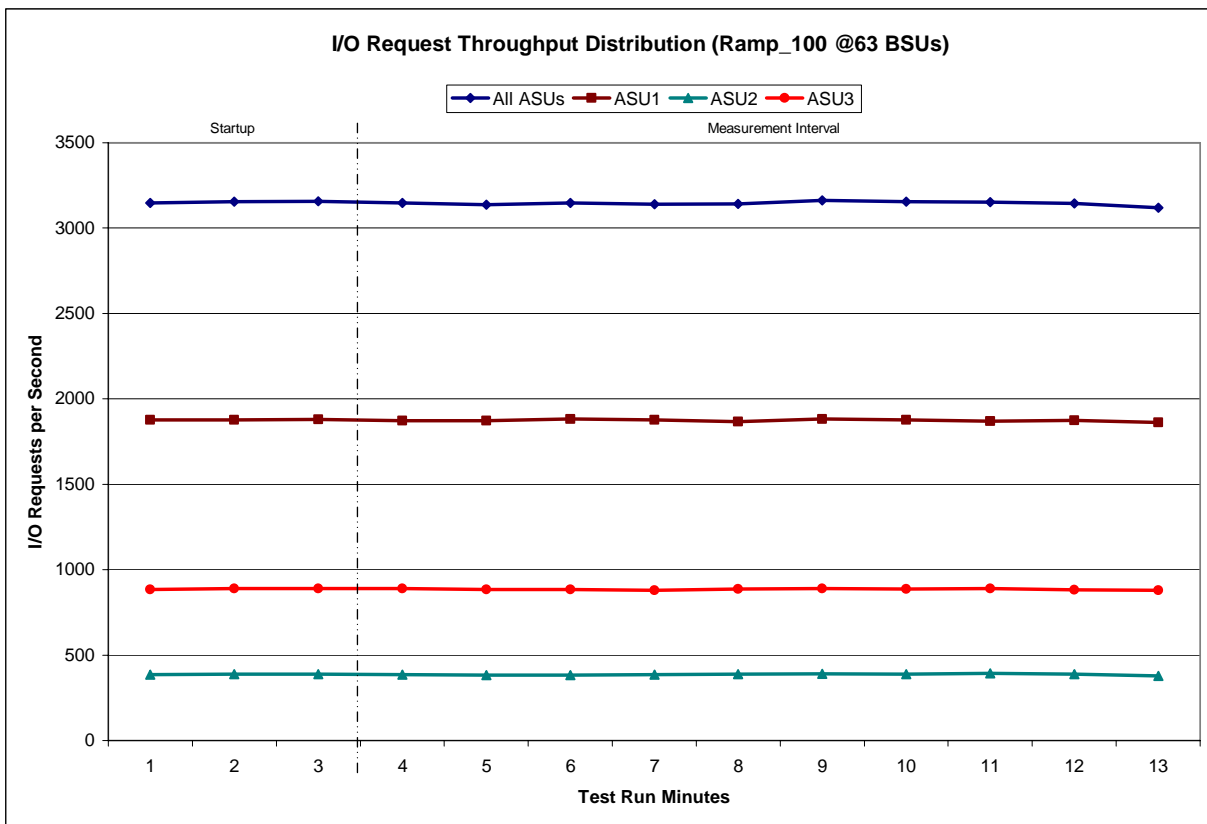
A link to the test results file generated from the IOPS Test Run is listed below.

[IOPS Test Results File](#)

IOPS Test Run – I/O Request Throughput Distribution Data

63 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	20:39:20	20:42:20	0-2	0:03:00
<i>Measurement Interval</i>	20:42:20	20:52:20	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	3,148.12	1,878.20	386.18	883.73
1	3,154.98	1,878.33	387.60	889.05
2	3,157.03	1,878.77	388.22	890.05
3	3,146.88	1,873.35	384.62	888.92
4	3,138.18	1,871.15	383.77	883.27
5	3,148.15	1,881.60	382.93	883.62
6	3,139.95	1,876.45	384.40	879.10
7	3,142.12	1,867.80	387.03	887.28
8	3,161.40	1,882.90	389.93	888.57
9	3,153.55	1,878.47	388.22	886.87
10	3,151.63	1,869.42	392.57	889.65
11	3,143.80	1,873.88	387.03	882.88
12	3,120.65	1,863.08	378.57	879.00
Average	3,144.63	1,873.81	385.91	884.92

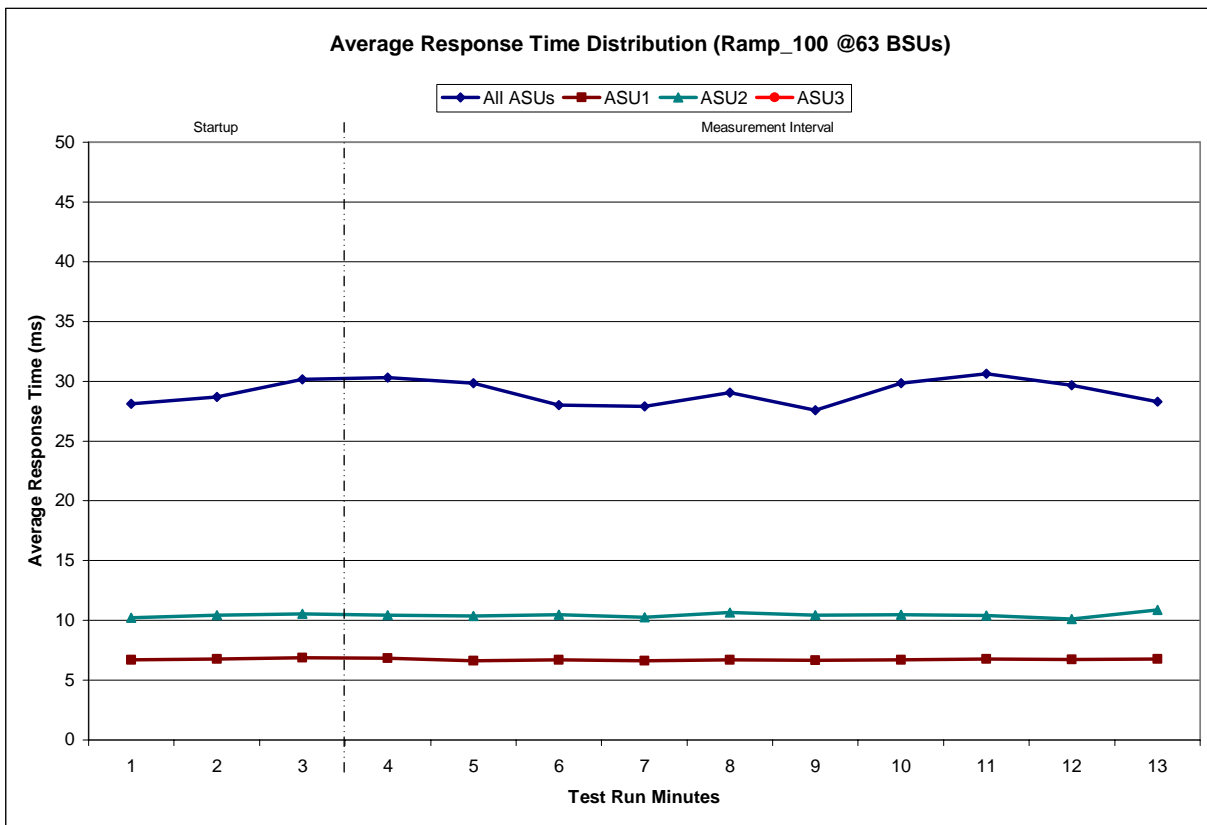
IOPS Test Run – I/O Request Throughput Distribution Graph



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

63 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	20:39:20	20:42:20	0-2	0:03:00
<i>Measurement Interval</i>	20:42:20	20:52:20	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	28.12	6.71	10.23	81.44
1	28.68	6.77	10.43	82.95
2	30.15	6.87	10.56	87.83
3	30.29	6.83	10.45	88.34
4	29.85	6.64	10.36	87.49
5	28.01	6.71	10.49	80.96
6	27.88	6.64	10.28	80.92
7	29.04	6.71	10.65	84.05
8	27.57	6.66	10.43	79.41
9	29.82	6.70	10.49	87.27
10	30.64	6.77	10.41	89.73
11	29.66	6.73	10.10	86.88
12	28.29	6.77	10.86	81.40
Average	29.11	6.72	10.45	84.64

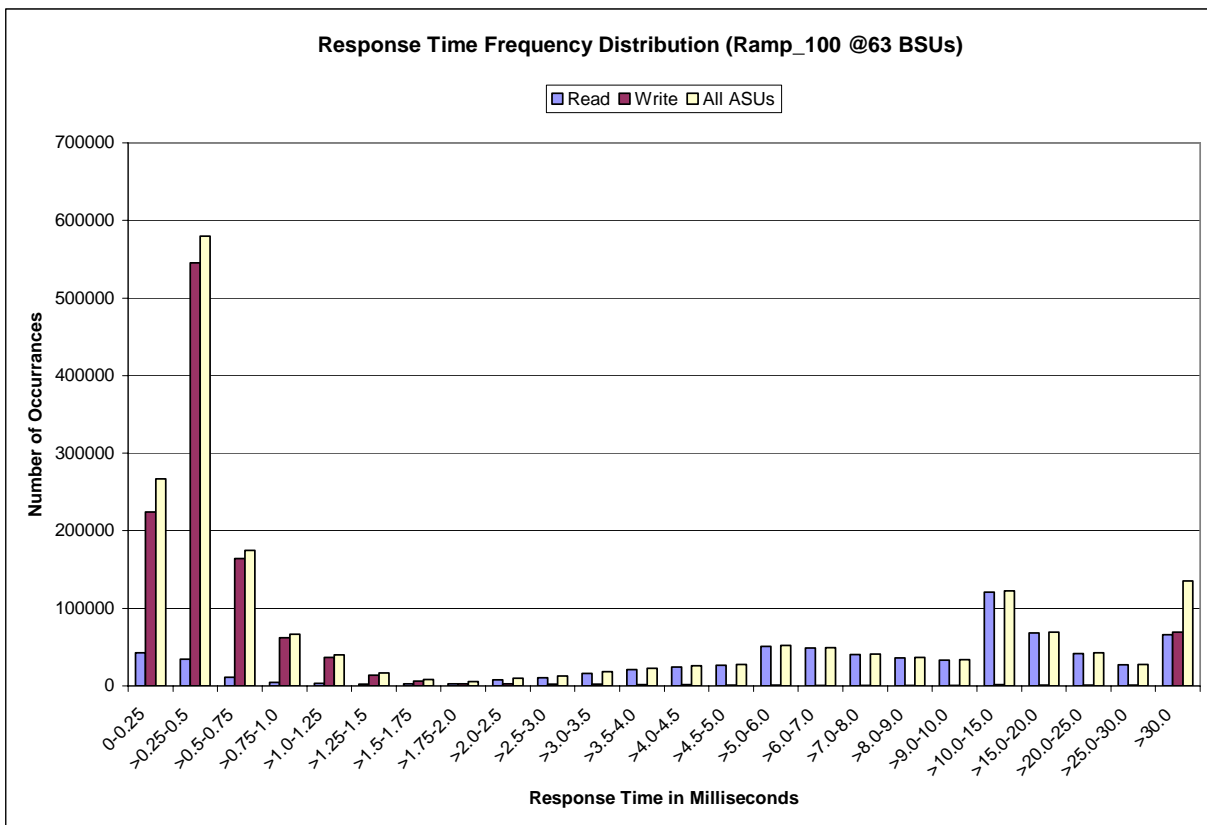
IOPS Test Run – Average Response Time (ms) Distribution Graph



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	42,680	34,634	10,967	4,581	3,069	2,480	2,614	2,912
Write	224,295	545,067	163,925	61,911	36,695	13,988	5,850	2,692
All ASUs	266,975	579,701	174,892	66,492	39,764	16,468	8,464	5,604
ASU1	166,014	265,729	74,894	28,554	17,551	7,558	4,795	3,830
ASU2	42,634	64,935	18,359	7,021	4,320	1,583	708	422
ASU3	58,327	249,037	81,639	30,917	17,893	7,327	2,961	1,352
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	7,567	10,712	16,242	21,010	24,360	26,408	50,949	48,920
Write	2,690	2,014	2,011	1,879	1,685	1,151	950	481
All ASUs	10,257	12,726	18,253	22,889	26,045	27,559	51,899	49,401
ASU1	8,336	11,038	16,410	20,770	23,566	24,923	47,089	44,858
ASU2	630	696	815	1,217	1,632	2,008	4,154	4,148
ASU3	1,291	992	1,028	902	847	628	656	395
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	40,675	35,957	33,365	120,949	67,966	41,735	27,045	66,050
Write	404	410	396	1,616	1,267	1,122	960	69,473
All ASUs	41,079	36,367	33,761	122,565	69,233	42,857	28,005	135,523
ASU1	36,676	32,231	30,024	105,991	57,383	34,060	21,108	40,898
ASU2	4,027	3,761	3,368	15,035	10,712	7,772	5,993	25,594
ASU3	376	375	369	1,539	1,138	1,025	904	69,031

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
1,886,779	1,751,256	135,523

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 5.1.0 and 5.3.13.2

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 5.3.13.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
MIM	0.0351	0.2807	0.0701	0.2099	0.0182	0.0698	0.0347	0.2814
COV	0.01	0.004	0.012	0.006	0.014	0.007	0.014	0.003

Primary Metrics Test – 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™ 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, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in “Appendix E: SPC-1 Workload Generator Input Parameters” on Page 62.

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](#)

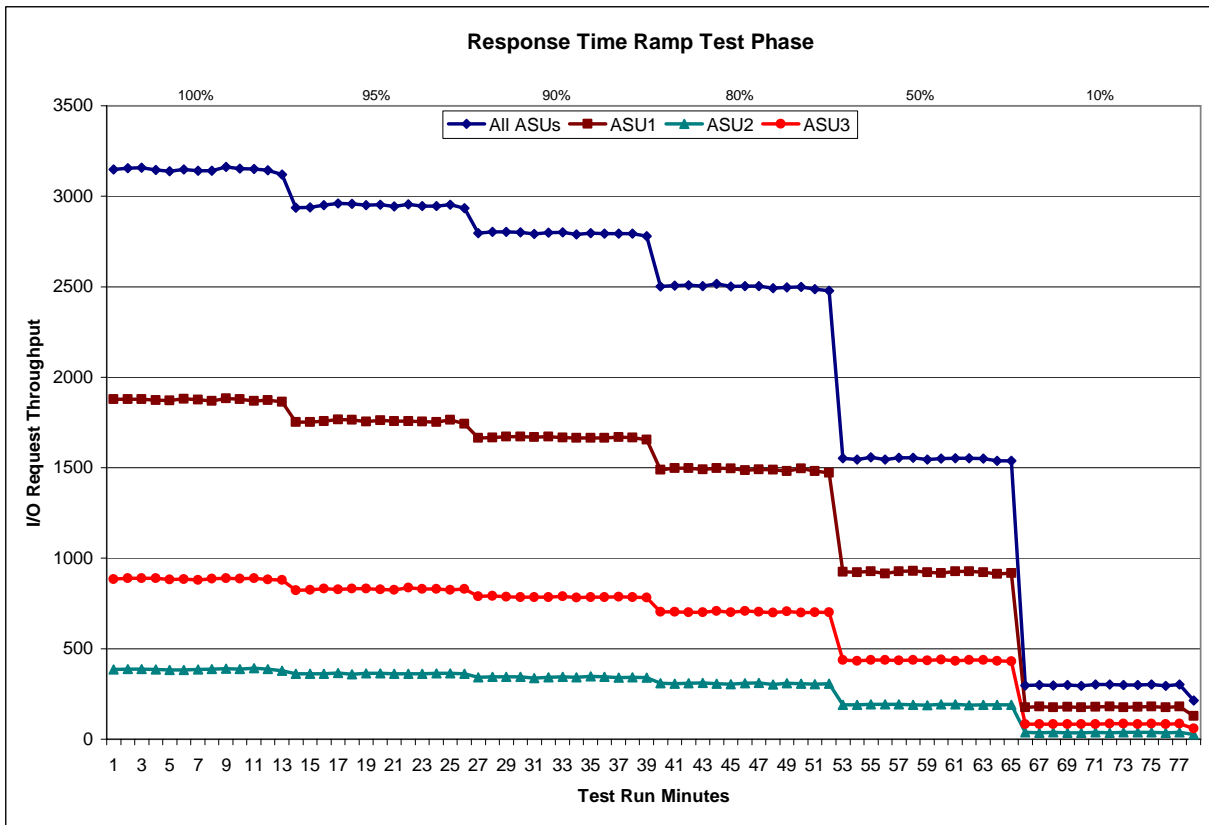
[10% Load Level](#)

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 - 63 BSUs					95% Load Level - 59 BSUs				
Start	Stop	Interval	Duration		Start	Stop	Interval	Duration	
20:39:20	20:42:20	0-2	0:03:00	Start-Up/Ramp-Up	20:52:23	20:55:23	0-2	0:03:00	Start-Up/Ramp-Up
20:42:20	20:52:20	3-12	0:10:00	Measurement Interval	20:55:23	21:05:23	3-12	0:10:00	Measurement Interval
<i>(60 second intervals)</i>					<i>(60 second intervals)</i>				
All ASUs	ASU-1	ASU-2	ASU-3		All ASUs	ASU-1	ASU-2	ASU-3	
0	3,148.12	1,878.20	386.18	883.73	0	2,935.42	1,751.67	361.02	822.73
1	3,154.98	1,878.33	387.60	889.05	1	2,938.00	1,751.33	360.92	825.75
2	3,157.03	1,878.77	388.22	890.05	2	2,951.78	1,757.97	362.00	831.82
3	3,146.88	1,873.35	384.62	888.92	3	2,959.62	1,766.00	367.30	826.32
4	3,138.18	1,871.15	383.77	883.27	4	2,956.83	1,763.90	359.60	833.33
5	3,148.15	1,881.60	382.93	883.62	5	2,950.32	1,755.37	362.85	832.10
6	3,139.95	1,876.45	384.40	879.10	6	2,953.05	1,762.63	363.73	826.68
7	3,142.12	1,867.80	387.03	887.28	7	2,942.55	1,755.95	360.83	825.77
8	3,161.40	1,882.90	389.93	888.57	8	2,954.32	1,757.92	360.27	836.13
9	3,153.55	1,878.47	388.22	886.87	9	2,946.60	1,755.00	361.80	829.80
10	3,151.63	1,869.42	392.57	889.65	10	2,945.65	1,752.10	363.03	830.52
11	3,143.80	1,873.88	387.03	882.88	11	2,953.77	1,764.03	363.95	825.78
12	3,120.65	1,863.08	378.57	879.00	12	2,934.95	1,743.63	360.47	830.85
Average	3,144.63	1,873.81	385.91	884.92	Average	2,949.77	1,757.65	362.38	829.73
90% Load Level - 56 BSUs					80% Load Level - 50 BSUs				
Start	Stop	Interval	Duration		Start	Stop	Interval	Duration	
21:05:26	21:08:26	0-2	0:03:00	Start-Up/Ramp-Up	21:18:29	21:21:29	0-2	0:03:00	Start-Up/Ramp-Up
21:08:26	21:18:26	3-12	0:10:00	Measurement Interval	21:21:29	21:31:29	3-12	0:10:00	Measurement Interval
<i>(60 second intervals)</i>					<i>(60 second intervals)</i>				
All ASUs	ASU-1	ASU-2	ASU-3		All ASUs	ASU-1	ASU-2	ASU-3	
0	2,796.98	1,663.52	343.30	790.17	0	2,501.05	1,489.33	308.32	703.40
1	2,803.33	1,667.70	343.88	791.75	1	2,506.95	1,496.98	307.23	702.73
2	2,803.03	1,671.72	344.33	786.98	2	2,509.23	1,497.83	309.42	701.98
3	2,800.63	1,670.77	345.67	784.20	3	2,502.63	1,491.48	310.42	700.73
4	2,791.58	1,669.77	337.00	784.82	4	2,514.82	1,499.00	306.90	708.92
5	2,799.08	1,672.52	342.92	783.65	5	2,500.95	1,495.05	304.70	701.20
6	2,800.80	1,666.93	344.43	789.43	6	2,503.30	1,486.07	309.28	707.95
7	2,788.52	1,664.55	342.87	781.10	7	2,504.52	1,490.05	310.55	703.92
8	2,796.45	1,663.70	347.22	785.53	8	2,491.02	1,488.25	303.02	699.75
9	2,794.03	1,665.28	344.20	784.55	9	2,496.28	1,481.30	309.65	705.33
10	2,794.93	1,668.75	339.82	786.37	10	2,499.63	1,494.73	305.87	699.03
11	2,794.50	1,666.30	343.08	785.12	11	2,487.23	1,481.98	303.82	701.43
12	2,779.15	1,655.35	340.87	782.93	12	2,477.85	1,471.67	305.92	700.27
Average	2,793.97	1,666.39	342.81	784.77	Average	2,497.82	1,487.96	307.01	702.85
50% Load Level - 31 BSUs					10% Load Level - 6 BSUs				
Start	Stop	Interval	Duration		Start	Stop	Interval	Duration	
21:31:32	21:34:32	0-2	0:03:00	Start-Up/Ramp-Up	21:44:35	21:47:35	0-2	0:03:00	Start-Up/Ramp-Up
21:34:32	21:44:32	3-12	0:10:00	Measurement Interval	21:47:35	21:57:35	3-12	0:10:00	Measurement Interval
<i>(60 second intervals)</i>					<i>(60 second intervals)</i>				
All ASUs	ASU-1	ASU-2	ASU-3		All ASUs	ASU-1	ASU-2	ASU-3	
0	1,553.22	925.70	190.58	436.93	0	297.97	176.58	37.22	84.17
1	1,544.60	921.40	190.35	432.85	1	299.98	180.32	36.15	83.52
2	1,556.27	926.88	191.42	437.97	2	296.33	175.28	37.42	83.63
3	1,546.33	915.90	192.98	437.45	3	298.50	178.78	36.75	82.97
4	1,555.43	926.83	192.73	435.87	4	295.55	175.55	36.30	83.70
5	1,555.57	928.63	189.28	437.65	5	301.32	178.83	38.90	83.58
6	1,545.98	922.02	188.70	435.27	6	301.48	180.28	36.63	84.57
7	1,549.42	917.92	192.38	439.12	7	299.62	177.08	37.15	85.38
8	1,551.97	926.40	192.78	432.78	8	300.42	177.60	38.43	84.38
9	1,552.37	926.67	188.67	437.03	9	302.02	179.73	37.27	85.02
10	1,549.83	922.03	189.93	437.87	10	295.52	176.38	34.85	84.28
11	1,537.50	913.65	189.97	433.88	11	301.83	179.57	37.23	85.03
12	1,538.37	917.43	190.42	430.52	12	214.02	127.80	25.73	60.48
Average	1,548.28	921.75	190.79	435.74	Average	291.03	173.16	35.93	81.94

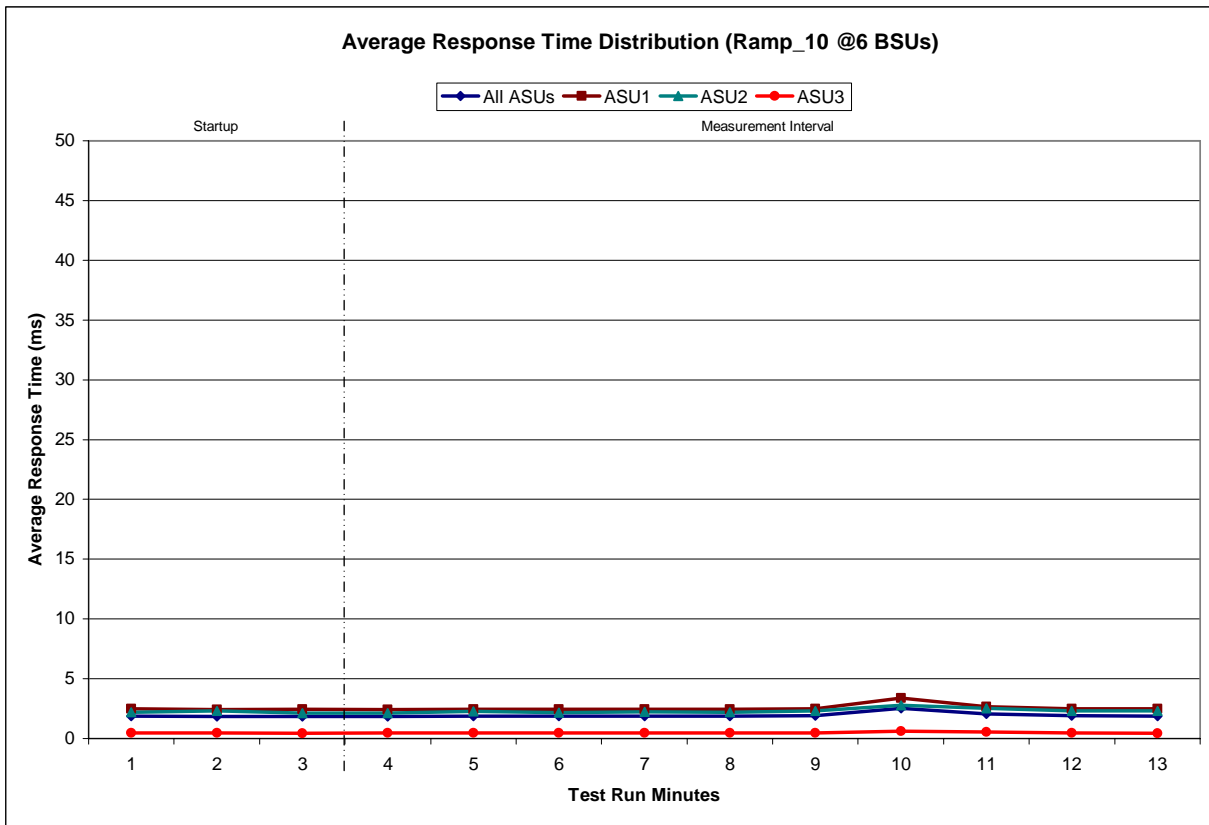
Response Time Ramp Distribution (IOPS) Graph



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

6 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	21:44:35	21:47:35	0-2	0:03:00
<i>Measurement Interval</i>	21:47:35	21:57:35	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	1.87	2.48	2.20	0.47
1	1.85	2.41	2.29	0.46
2	1.83	2.43	2.12	0.45
3	1.84	2.42	2.12	0.48
4	1.86	2.45	2.28	0.46
5	1.86	2.46	2.15	0.46
6	1.87	2.46	2.23	0.46
7	1.86	2.46	2.19	0.47
8	1.89	2.49	2.29	0.46
9	2.53	3.38	2.78	0.62
10	2.04	2.66	2.52	0.55
11	1.89	2.48	2.29	0.47
12	1.87	2.47	2.31	0.44
Average	1.95	2.57	2.32	0.49

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 5.1.0 and 5.3.13.2

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 5.3.13.3

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	0.2803	0.0701	0.2095	0.0181	0.0703	0.0351	0.2816
COV	0.30	0.008	0.030	0.014	0.050	0.030	0.039	0.009

Repeatability Test

Clause 5.4.5

The Repeatability Test demonstrates the repeatability and reproducibility of the SPC-1 IOPS™ primary metric and 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%.

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 9.2.4.7.4

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 62.

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™
<i>Primary Metrics</i>	3,144.63	1.95 ms
Repeatability Test Phase 1	3,145.27	1.99 ms
Repeatability Test Phase 2	3,146.62	1.97 ms

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 be greater than 95% of the reported SPC-1 IOPS™ Primary Metric.

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.

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 \(IOPS\)](#)

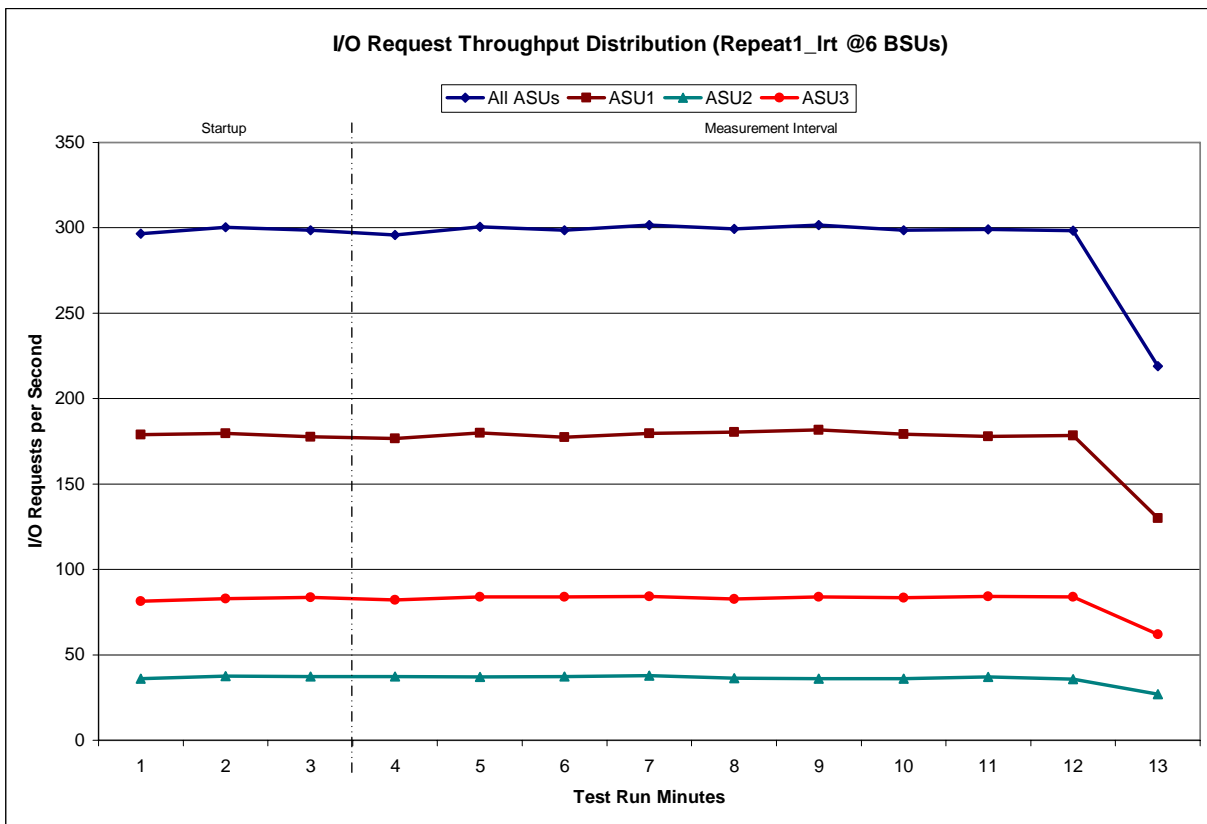
[Repeatability Test Phase 2, Test Run 1 \(LRT\)](#)

[Repeatability Test Phase 2, Test Run 2 \(IOPS\)](#)

Repeatability 1 LRT - I/O Request Throughput Distribution Data

6 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	21:57:39	22:00:39	0-2	0:03:00
<i>Measurement Interval</i>	22:00:39	22:10:39	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	296.57	178.95	36.13	81.48
1	300.38	179.77	37.67	82.95
2	298.68	177.62	37.30	83.77
3	295.92	176.62	37.25	82.05
4	300.73	179.98	36.93	83.82
5	298.48	177.40	37.23	83.85
6	301.63	179.60	37.85	84.18
7	299.25	180.45	36.22	82.58
8	301.58	181.57	36.13	83.88
9	298.70	179.03	36.15	83.52
10	299.15	177.93	36.97	84.25
11	298.23	178.52	35.88	83.83
12	218.92	129.93	26.93	62.05
Average	291.26	174.10	35.76	81.40

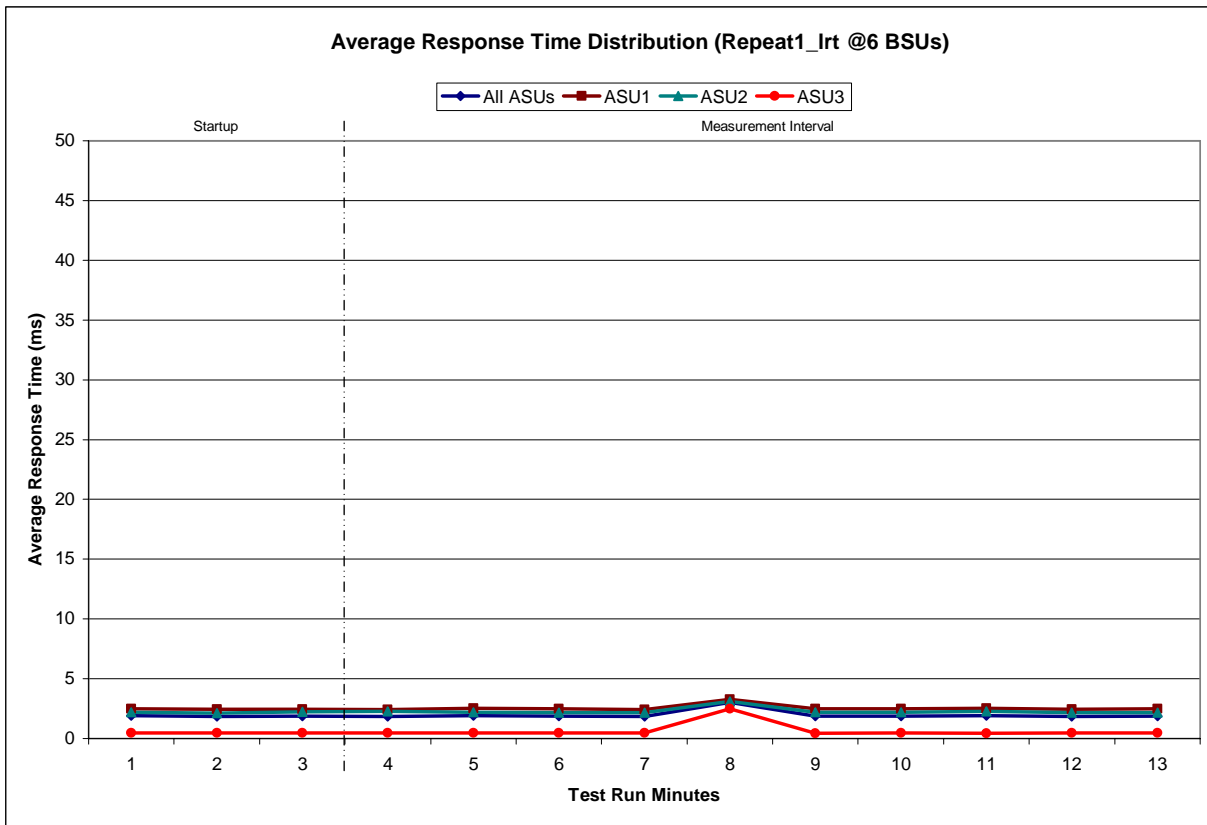
Repeatability 1 LRT - I/O Request Throughput Distribution Graph



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

6 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	21:57:39	22:00:39	0-2	0:03:00
<i>Measurement Interval</i>	22:00:39	22:10:39	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	1.89	2.48	2.20	0.45
1	1.85	2.44	2.13	0.46
2	1.86	2.44	2.23	0.45
3	1.85	2.42	2.25	0.45
4	1.90	2.50	2.18	0.48
5	1.87	2.48	2.17	0.46
6	1.84	2.41	2.17	0.48
7	3.04	3.28	3.08	2.49
8	1.89	2.49	2.21	0.44
9	1.88	2.48	2.19	0.46
10	1.90	2.51	2.26	0.45
11	1.85	2.45	2.15	0.46
12	1.86	2.47	2.15	0.46
Average	1.99	2.55	2.28	0.66

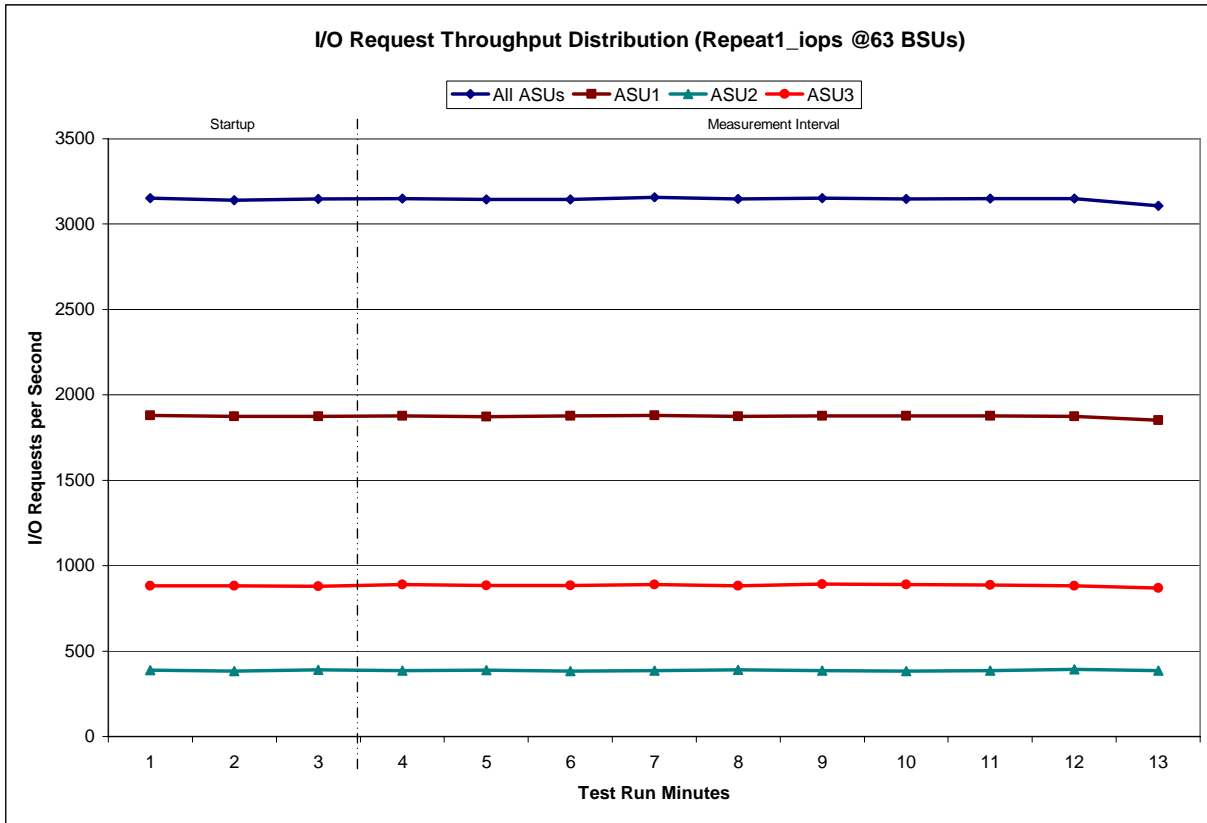
Repeatability 1 LRT –Average Response Time (ms) Distribution Graph



Repeatability 1 IOPS - I/O Request Throughput Distribution Data

63 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	22:10:41	22:13:41	0-2	0:03:00
<i>Measurement Interval</i>	22:13:41	22:23:41	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	3,151.83	1,880.10	389.20	882.53
1	3,139.73	1,874.65	383.93	881.15
2	3,147.07	1,875.25	391.73	880.08
3	3,150.32	1,877.17	384.72	888.43
4	3,144.58	1,872.92	388.43	883.23
5	3,145.50	1,877.75	383.70	884.05
6	3,156.23	1,879.20	386.62	890.42
7	3,146.85	1,874.53	390.37	881.95
8	3,153.17	1,876.60	385.52	891.05
9	3,147.65	1,876.43	382.73	888.48
10	3,150.83	1,877.75	386.40	886.68
11	3,150.05	1,874.15	393.08	882.82
12	3,107.53	1,852.93	385.35	869.25
Average	3,145.27	1,873.94	386.69	884.64

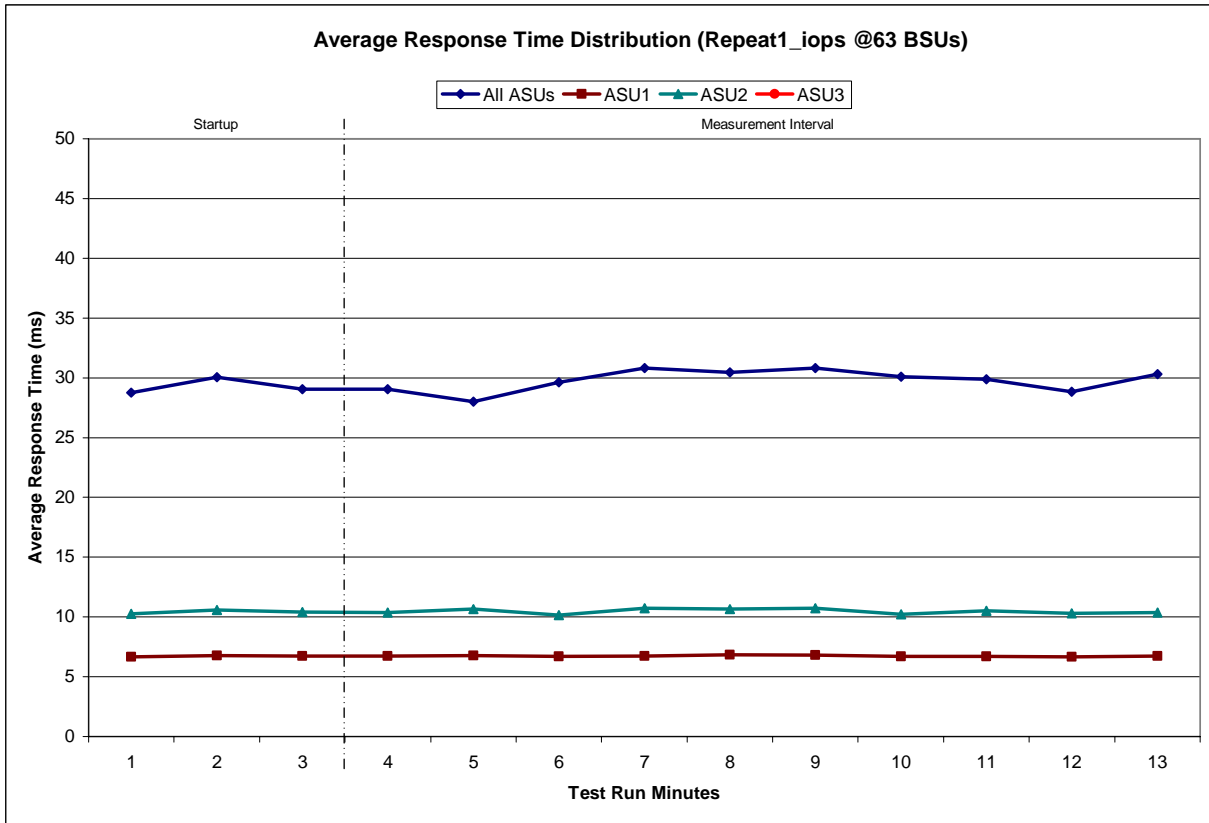
Repeatability 1 IOPS - I/O Request Throughput Distribution Graph



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

63 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	22:10:41	22:13:41	0-2	0:03:00
<i>Measurement Interval</i>	22:13:41	22:23:41	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	28.75	6.66	10.26	83.96
1	30.07	6.77	10.58	88.14
2	29.05	6.74	10.40	84.89
3	29.04	6.74	10.36	84.26
4	28.01	6.75	10.67	80.71
5	29.62	6.68	10.16	86.80
6	30.82	6.73	10.74	90.39
7	30.44	6.84	10.66	89.33
8	30.82	6.80	10.74	90.11
9	30.10	6.68	10.23	88.09
10	29.88	6.70	10.52	87.42
11	28.84	6.66	10.30	84.17
12	30.31	6.72	10.38	89.41
Average	29.79	6.73	10.48	87.07

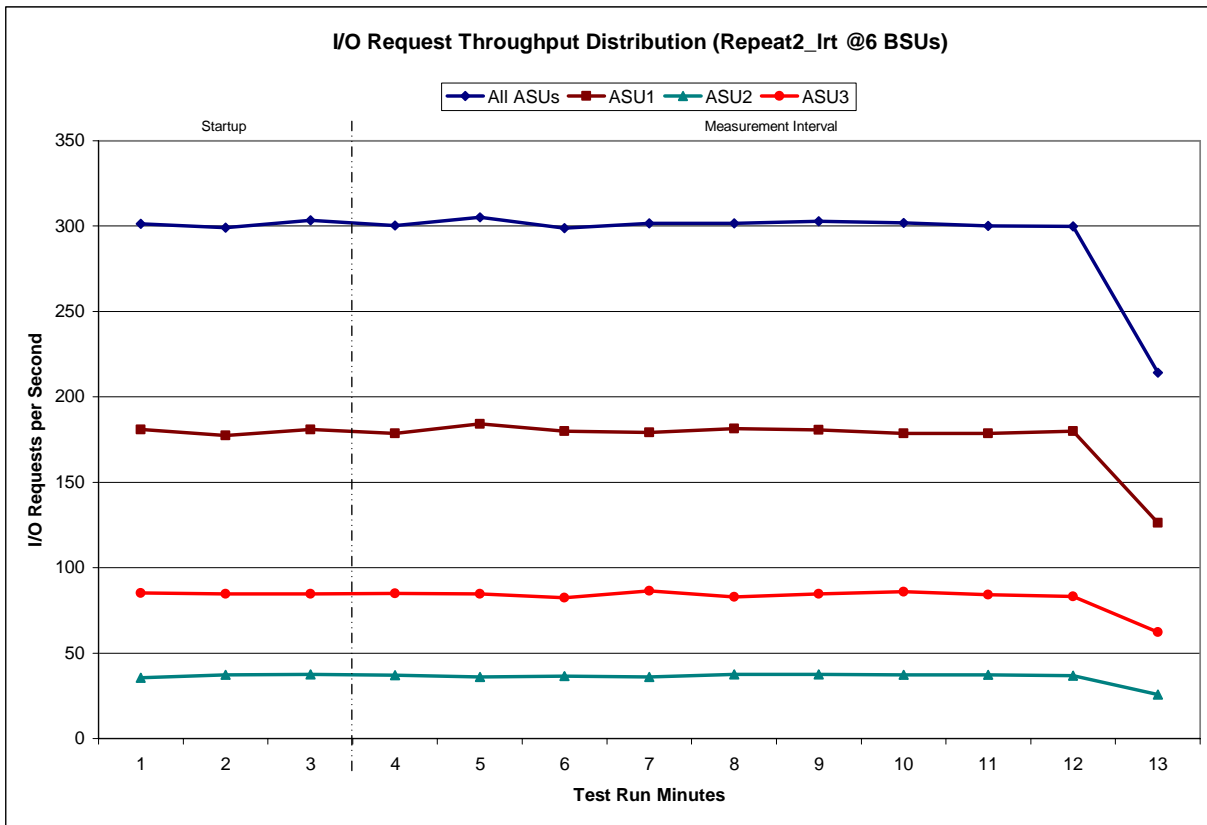
Repeatability 1 IOPS -Average Response Time (ms) Distribution Graph



Repeatability 2 LRT - I/O Request Throughput Distribution Data

6 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	22:23:45	22:26:45	0-2	0:03:00
Measurement Interval	22:26:45	22:36:45	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	301.43	180.88	35.45	85.10
1	299.12	177.30	37.22	84.60
2	303.37	180.98	37.62	84.77
3	300.40	178.55	37.03	84.82
4	305.12	184.25	36.15	84.72
5	298.83	179.87	36.53	82.43
6	301.68	179.20	36.12	86.37
7	301.63	181.33	37.45	82.85
8	302.85	180.63	37.52	84.70
9	301.90	178.72	37.27	85.92
10	300.02	178.60	37.23	84.18
11	299.92	179.93	36.88	83.10
12	214.18	126.12	25.72	62.35
Average	292.65	174.72	35.79	82.14

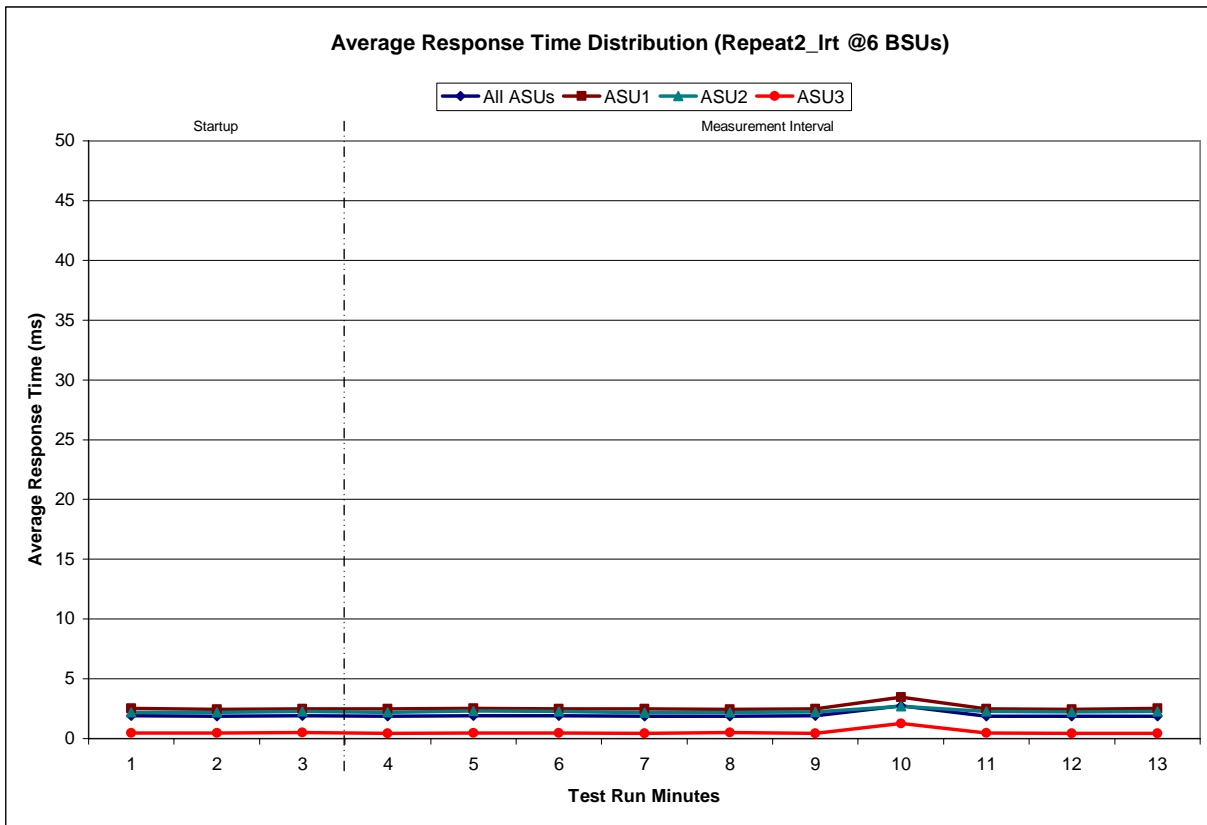
Repeatability 2 LRT - I/O Request Throughput Distribution Graph



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

6 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	22:23:45	22:26:45	0-2	0:03:00
<i>Measurement Interval</i>	22:26:45	22:36:45	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	1.90	2.51	2.20	0.47
1	1.86	2.46	2.19	0.46
2	1.91	2.49	2.25	0.50
3	1.87	2.48	2.18	0.45
4	1.92	2.51	2.30	0.47
5	1.89	2.47	2.28	0.45
6	1.86	2.49	2.17	0.43
7	1.89	2.46	2.21	0.49
8	1.89	2.50	2.25	0.44
9	2.72	3.44	2.70	1.25
10	1.89	2.48	2.26	0.47
11	1.86	2.44	2.22	0.44
12	1.88	2.52	2.27	0.44
Average	1.97	2.58	2.28	0.53

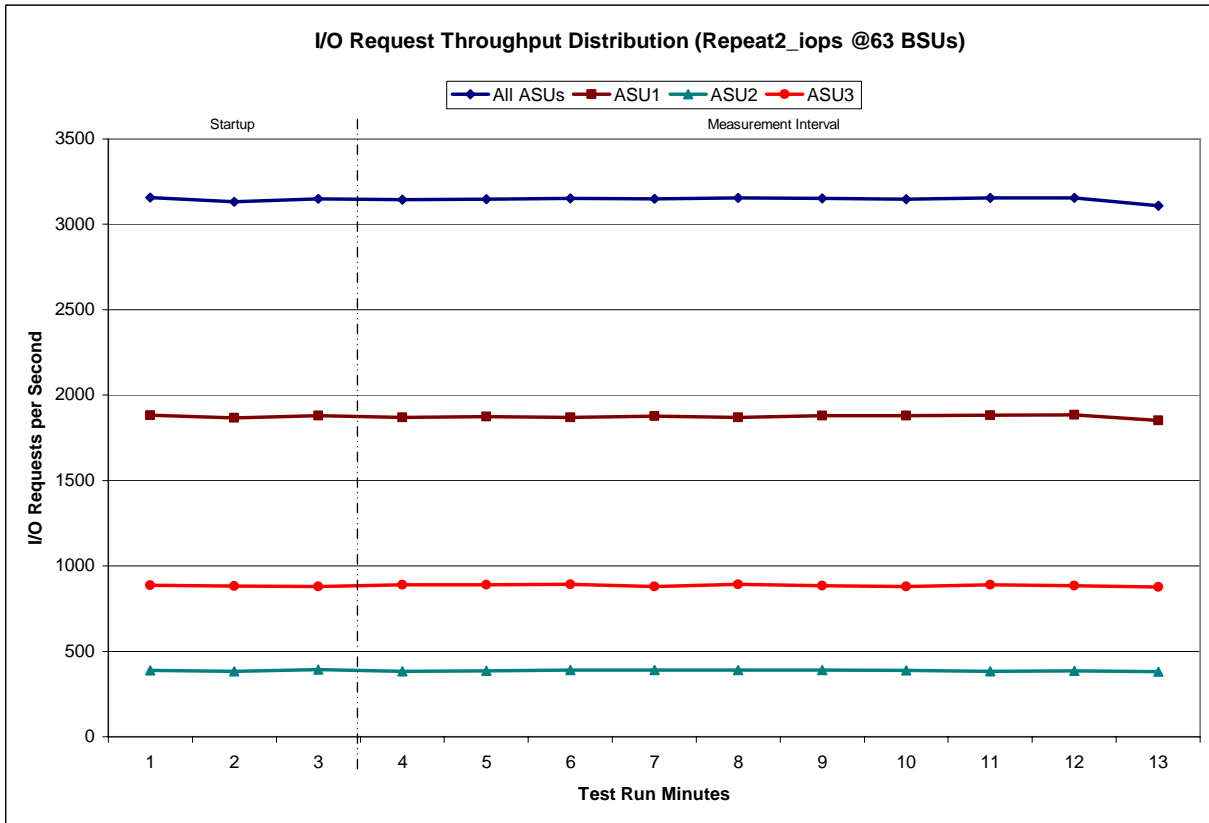
Repeatability 2 LRT –Average Response Time (ms) Distribution Graph



Repeatability 2 IOPS - I/O Request Throughput Distribution Data

63 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	22:36:47	22:39:47	0-2	0:03:00
<i>Measurement Interval</i>	22:39:47	22:49:47	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	3,158.18	1,882.93	388.55	886.70
1	3,132.37	1,868.07	382.35	881.95
2	3,150.00	1,879.35	391.92	878.73
3	3,144.07	1,870.87	383.53	889.67
4	3,146.78	1,873.70	384.28	888.80
5	3,152.35	1,870.68	390.68	890.98
6	3,148.63	1,877.72	390.72	880.20
7	3,155.62	1,870.73	391.77	893.12
8	3,153.40	1,879.10	389.60	884.70
9	3,146.32	1,880.92	386.88	878.52
10	3,154.07	1,881.18	383.98	888.90
11	3,154.43	1,883.70	385.10	885.63
12	3,110.52	1,852.17	381.37	876.98
Average	3,146.62	1,874.08	386.79	885.75

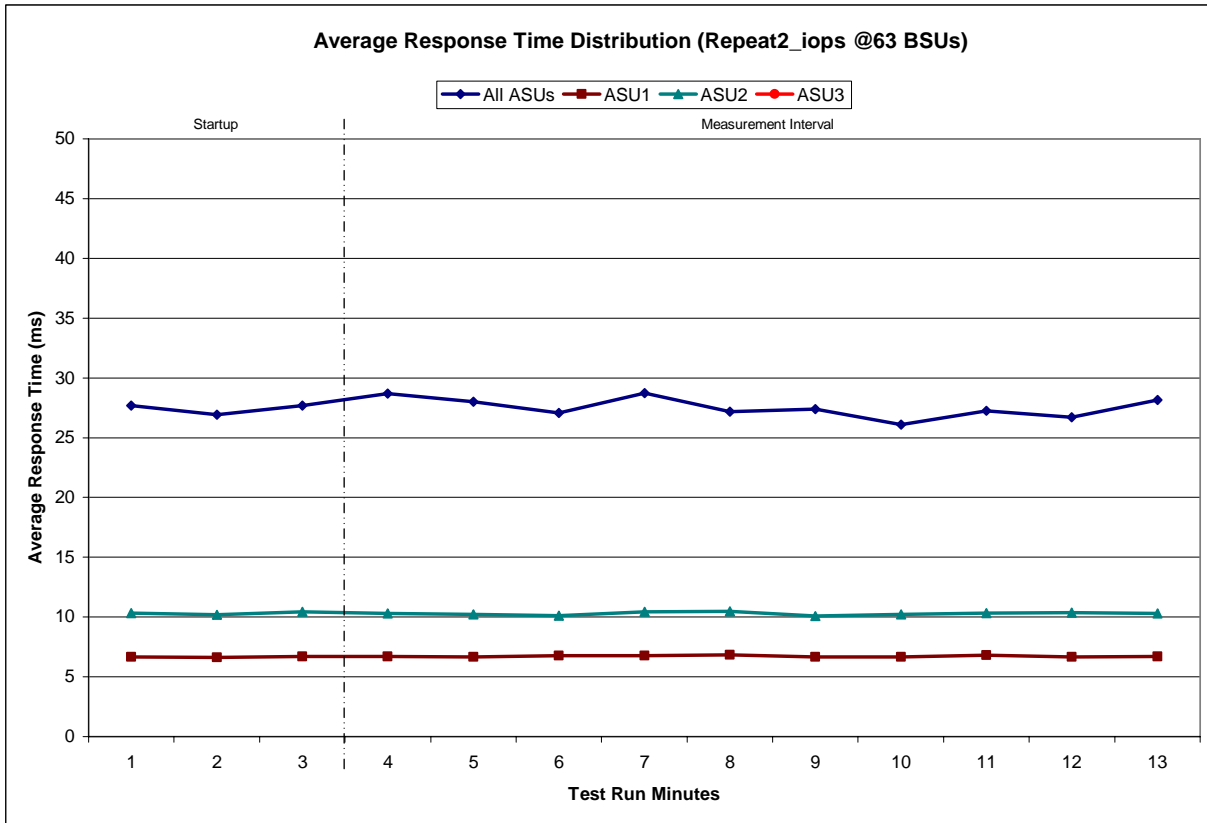
Repeatability 2 IOPS - I/O Request Throughput Distribution Graph



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

63 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	22:36:47	22:39:47	0-2	0:03:00
<i>Measurement Interval</i>	22:39:47	22:49:47	3-12	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	27.67	6.66	10.32	79.87
1	26.93	6.63	10.17	77.18
2	27.69	6.68	10.44	80.31
3	28.68	6.70	10.28	82.85
4	28.02	6.65	10.21	80.78
5	27.07	6.75	10.10	77.18
6	28.71	6.77	10.45	83.61
7	27.18	6.82	10.49	77.14
8	27.39	6.65	10.10	79.08
9	26.10	6.67	10.24	74.69
10	27.27	6.80	10.34	77.89
11	26.71	6.66	10.36	76.45
12	28.14	6.71	10.29	81.14
Average	27.53	6.72	10.29	79.08

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.

Clauses 5.1.0 and 5.3.13.2

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 5.3.13.3

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	0.0362	0.2825	0.0702	0.2088	0.0178	0.0705	0.0345	0.2795
COV	0.035	0.012	0.020	0.013	0.054	0.023	0.025	0.008

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	0.0349	0.2805	0.0701	0.2104	0.0180	0.0698	0.0351	0.2813
COV	0.013	0.003	0.009	0.004	0.021	0.009	0.011	0.003

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	0.2812	0.0706	0.2102	0.0182	0.0690	0.0350	0.2807
COV	0.046	0.014	0.027	0.013	0.051	0.022	0.038	0.018

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
<i>IM</i>	<i>0.0350</i>	<i>0.2810</i>	<i>0.0700</i>	<i>0.2100</i>	<i>0.0180</i>	<i>0.0700</i>	<i>0.0350</i>	<i>0.2810</i>
MIM	0.0350	0.2810	0.0701	0.2095	0.0180	0.0698	0.0352	0.2815
COV	0.010	0.004	0.005	0.004	0.017	0.011	0.007	0.005

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, 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.*

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 62.

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	7,186,624
Total Number of Logical Blocks Verified	6,999,280
Total Number of Logical Blocks that Failed Verification	0
Time Duration for Writing Test Logical Blocks	10 minutes
Size in Bytes of each Logical Block	512
Number of Failed I/O Requests in the process of the Test	0

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

PRICED STORAGE CONFIGURATION AVAILABILITY DATE

Clause 9.2.4.9

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 must be the date at which all components are committed to be available.

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

The Sun Storage J4200 Array as documented in this Full Disclosure Report will become available for customer purchase and shipment on July 8, 2008.

PRICING INFORMATION

Clause 9.2.4.11

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

Clause 9.2.4.11.3

A list of all differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration must be included.

Pricing information may found in the Tested Storage Configuration Pricing section on page 12. 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 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 encountered during the SPC-1 Remote Audit of the Sun Storage J4200 Array.

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 gibibyte (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

RAID5: User data is distributed across the disks in the array. Check data corresponding to user data is distributed across multiple disks in the form of bit-by-bit parity.

Mirroring: Two or more identical copies of user data are maintained on separate disks.

Other Protection Level: Any data protection other than **RAID5** or **Mirroring**.

Unprotected: There is no data protection provided.

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.

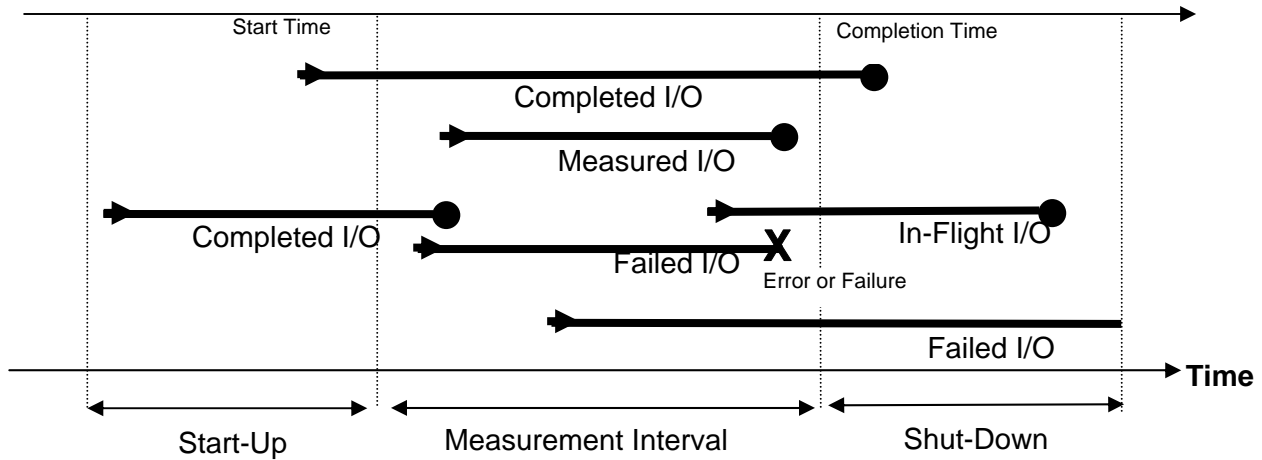
Test: A collection of Test Phases and or Test Runs sharing a common objective.

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

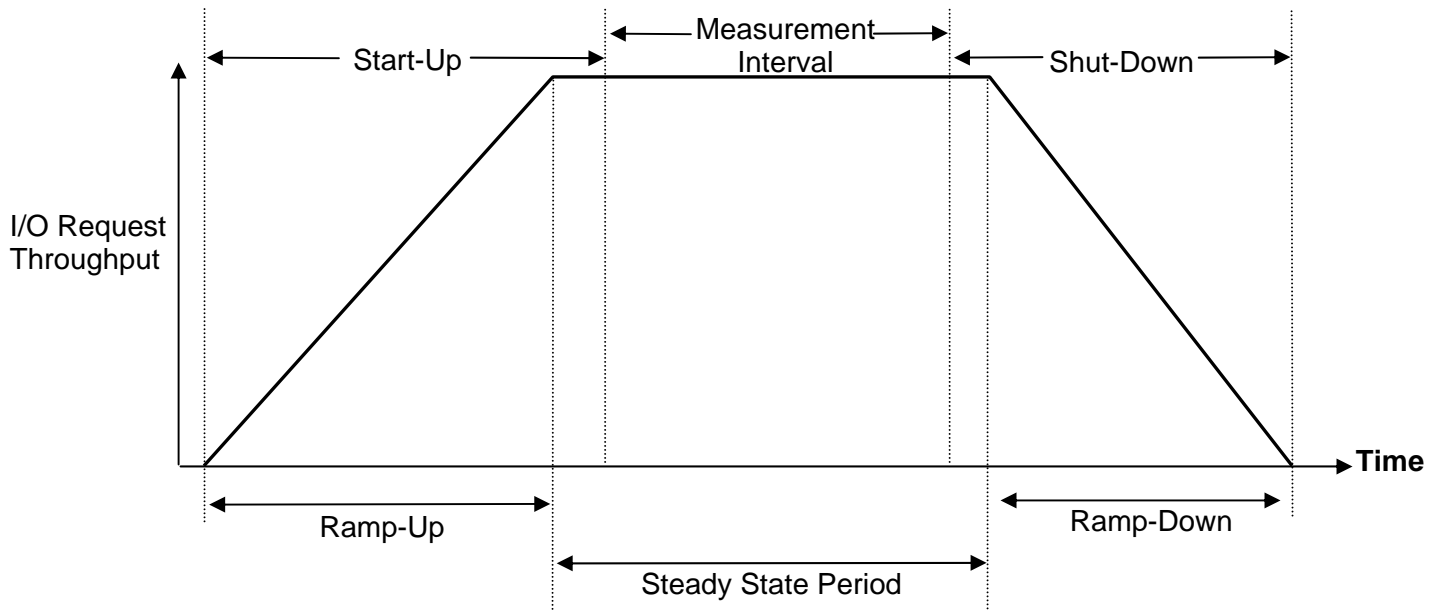
period, Shut-Down period, and Ramp-Down period as illustrated in the “SPC-1 Test Run Components” below. All SPC-1 Test Runs shall have a Steady State period and a Measurement Interval.

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

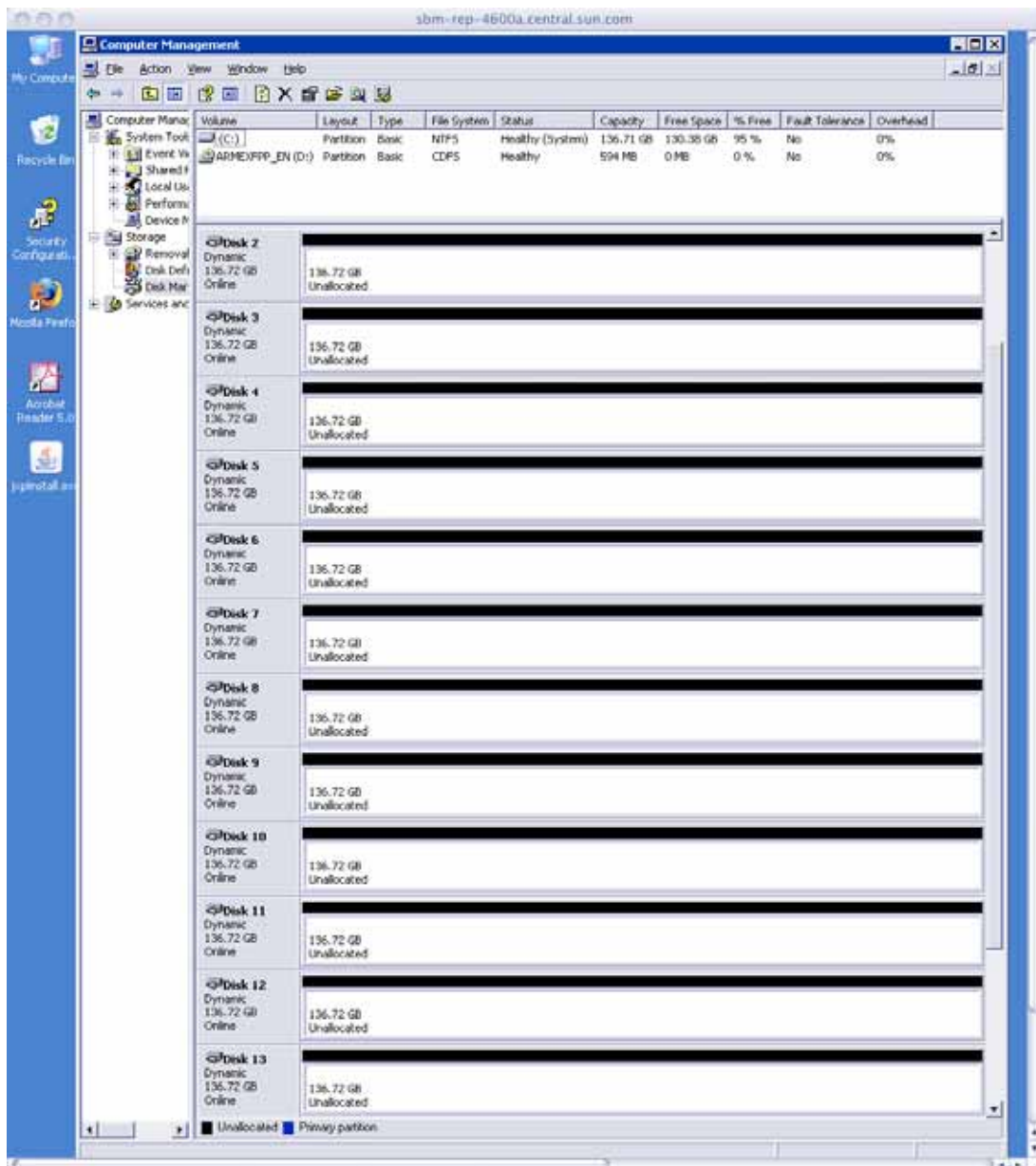


APPENDIX B: CUSTOMER TUNABLE PARAMETERS AND OPTIONS

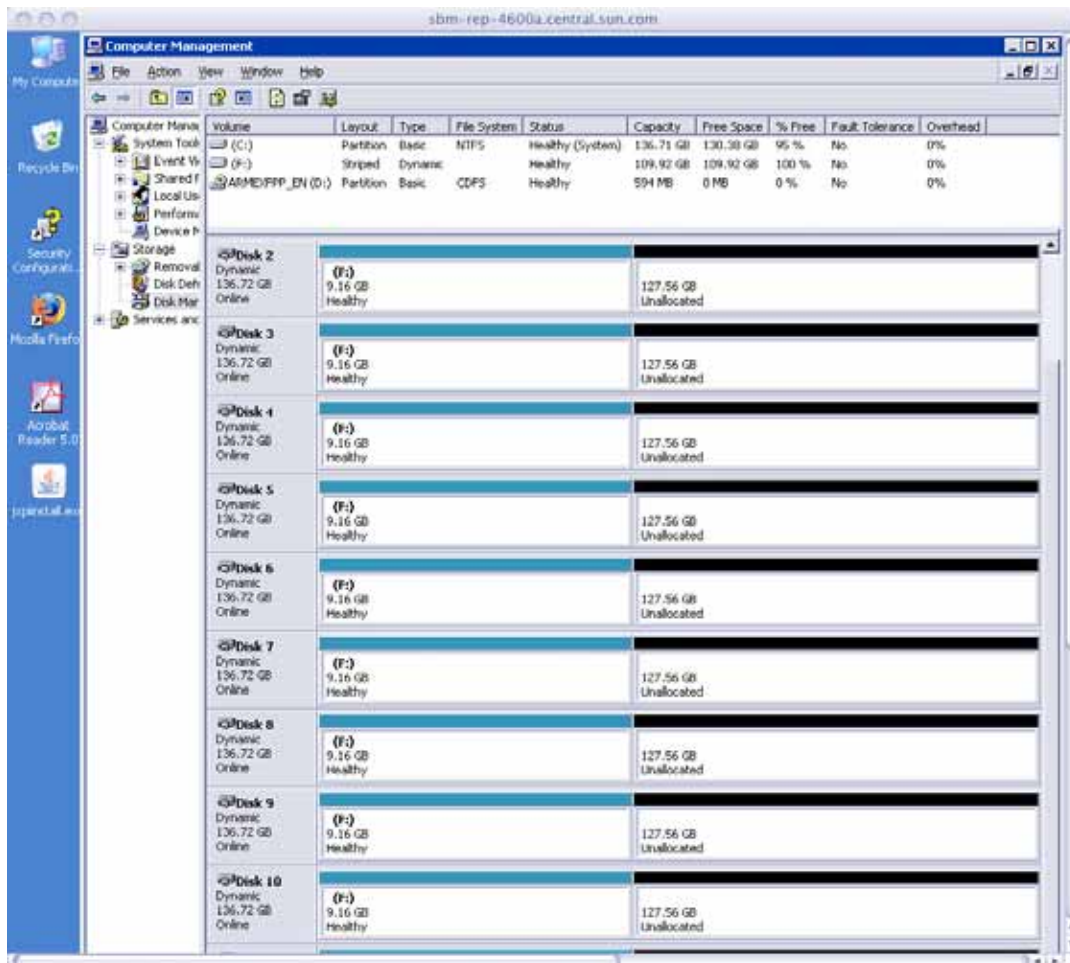
There were no customer tunable parameters or options changed from their default values.

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

1. Install the SAS HBA in the SF4600
2. Boot the SF4600.
3. Launch the Computer Management console from the Administrative Tools found in the Control Panel and select Disk Management. Select Next to the Initialize and Convert Disk Wizard pop-up dialog box. Then select Next to the following Initialize dialog box to initialize the twelve new volumes. Verify your twelve disks are selected and convert to dynamic disks by selecting Next then Finish.
4. The Computer Management Dialog box should resemble the one below.

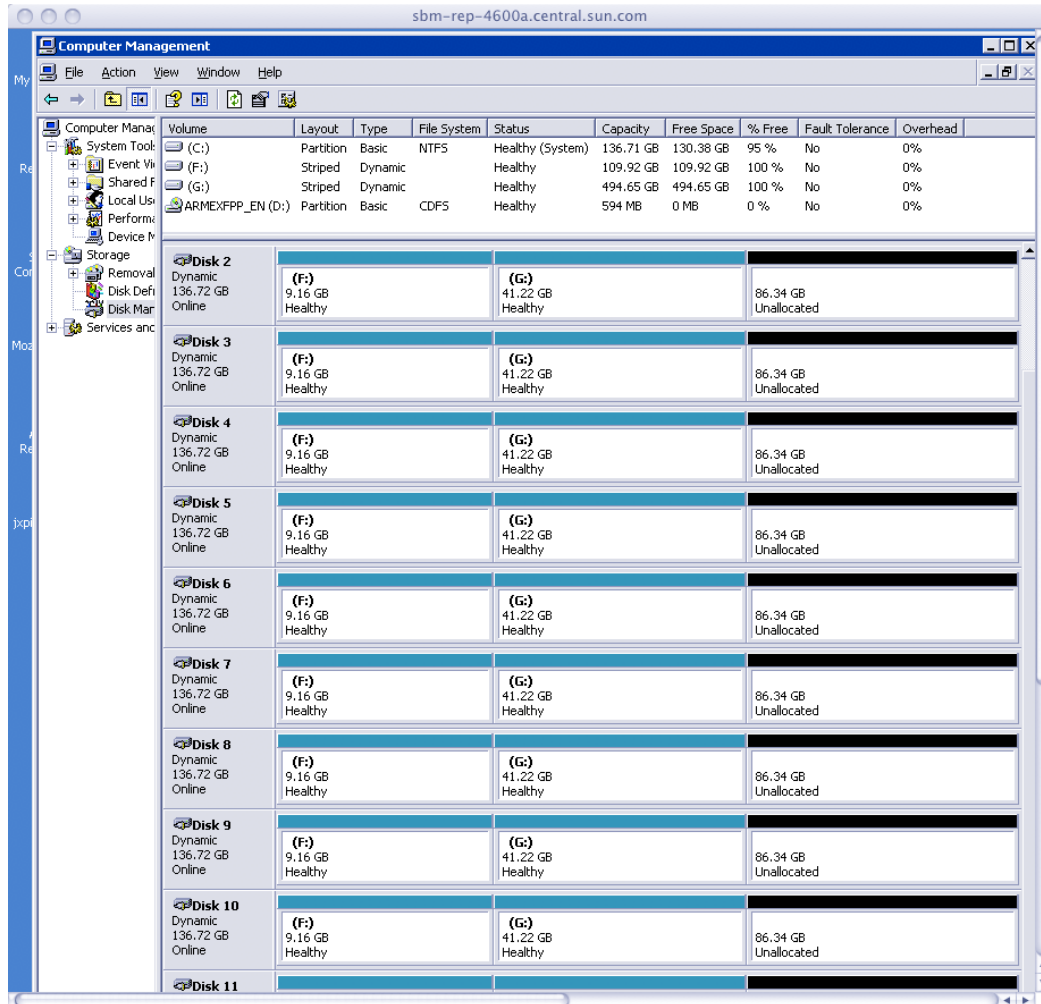


5. Select one of the twelve Unallocated Dynamic disks then Right mouse click and select the New Volume option. Select Next on the Welcome to the New Volume Wizard dialog window. Select Striped in the Select Volume Type dialog box, then Next. Add all Dynamic disks in the Select Disks dialog window and change the Select the amount of space in Mb: tab to 9380 and select Next. Select Next to the Assign Drive Letter or Path dialog box. Select Do not format this volume in the Format Volume dialog box then select Next. Select Finish in the Completing the New Volume Wizard dialog box to finish creating ASU3. Your Display should now look like the picture below.



6. For the next volume “ASU1” follow step 5 and set the size to 42210 . The Computer Management dialog box should now look like the one below.

- Follow step 5 and set the size to 42210 to create ASU2. The Computer Management dialog box should now look like the one below.



APPENDIX D: SPC-1 WORKLOAD GENERATOR STORAGE COMMANDS AND PARAMETERS

The content of SPC-1 Workload Generator command and parameter file, used in this benchmark, is listed below.

```
sd=asu1_1,lun=\\.G:,size=494g  
sd=asu2_1,lun=\\.H:,size=494g  
sd=asu3_1,lun=\\.F:,size=109g
```

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

Primary Metrics Test, Repeatability Test, and Persistence Test Run 1

The following script was used to execute the Primary Metrics Test (*Sustainability Test Phase, IOPS Test Phase, and Response Time Ramp Test Phase*), Repeatability Test (*Repeatability Test Phase 1 and Repeatability Test Phase 2*), and Persistence Test Run 1 in an uninterrupted sequence.

```
@ECHO off
*
*
* Raid 0 one big stripe then sliced at the host 67% of storage
*
*
:BEGIN

cls

"C:\Program Files (x86)\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -Xss64k
metrics -b 63
*
"C:\Program Files (x86)\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -Xss64k
repeat1 -b 63
*
"C:\Program Files (x86)\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -Xss64k
repeat2 -b 63

*
"C:\Program Files (x86)\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -Xss64k
persist1 -b 63

*"C:\Program Files (x86)\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -
Xss64k persist2

:end
```

Persistence Test Run 2

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

```
@ECHO off
*
*
* Raid 0 one big stripe then sliced at the host 67% of storage
*
*
:BEGIN

cls
```

```
*"C:\Program Files (x86)\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -  
Xss64k metrics -b 63  
*  
*"C:\Program Files (x86)\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -  
Xss64k repeat1 -b 63  
*  
*"C:\Program Files (x86)\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -  
Xss64k repeat2 -b 63  
  
*  
*"C:\Program Files (x86)\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -  
Xss64k persist1 -b 63  
  
"C:\Program Files (x86)\Java\jre1.6.0_05\bin\java" -Xmx512m -Xss512m -Xss64k  
persist2  
  
:end
```