



**SPC BENCHMARK 1™  
FULL DISCLOSURE REPORT**

**IBM CORPORATION  
IBM SYSTEM STORAGE® DS3524 EXPRESS TURBO**

**SPC-1 V1.12**

**Submitted for Review: December 31, 2010  
Submission Identifier: A00100**

**First Edition – December 2010**

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## AUDIT CERTIFICATION



Bruce McNutt  
IBM Corporation  
650 Harry Road C2 500  
San Jose, CA 95120

December 30, 2010

The SPC Benchmark 1™ results listed below for the IBM System Storage® DS3524 Express Turbo were produced in compliance with the SPC Benchmark 1™ 1.12 Remote Audit requirements.

SPC Benchmark 1™ 1.12 Results	
<b>Tested Storage Configuration (TSC) Name:</b> IBM System Storage® DS3524 Express Turbo	
Metric	Reported Result
SPC-1 IOPS™	24,449.27
SPC-1 Price-Performance	\$3.90/SPC-1 IOPS™
Total ASU Capacity	13,412.881 GB
Data Protection Level	Protected (Mirroring)
Total TSC Price (including three-year maintenance)	\$95,384.00

The following SPC Benchmark 1™ Remote Audit requirements were reviewed and found compliant with 1.12 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 IBM Corporation:
  - ✓ Physical Storage Capacity and requirements.
  - ✓ Configured Storage Capacity and requirements.
  - ✓ Addressable Storage Capacity and requirements.
  - ✓ Capacity of each Logical Volume and requirements.
  - ✓ Capacity of each Application Storage Unit (ASU) and requirements.
- An appropriate diagram of the Benchmark Configuration (BC)/Tested Storage Configuration (TSC).
- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters that were changed from default values.
- SPC-1 Workload Generator commands and parameters used for the audited SPC Test Runs.

Storage Performance Council  
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Redwood City, CA 94062  
[AuditService@storageperformance.org](mailto:AuditService@storageperformance.org)  
650.556.9384

**AUDIT CERTIFICATION (CONT.)**

IBM System Storage® DS3524 Express Turbo  
SPC-1 Audit Certification

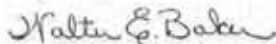
Page 2

- The following Host System requirements, based on information supplied by IBM Corporation:
  - ✓ The type of Host System including the number of processors and main memory.
  - ✓ The presence and version number of the SPC-1 Workload Generator on the Host System.
  - ✓ The TSC boundary within the Host System.
- The Test Results Files and resultant Summary Results Files received from IBM Corporation for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4 and 5 of the SPC-1 Benchmark Specification:
  - ✓ Data Persistence Test
  - ✓ Sustainability Test Phase
  - ✓ IOPS Test Phase
  - ✓ Response Time Ramp Test Phase
  - ✓ Repeatability Test
- The differences between the Tested Storage Configuration and Priced Storage Configuration were documented and, if applied to the Tested Storage Configuration, would not have an impact on the audited benchmark measurements.
- 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

Storage Performance Council  
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Redwood City, CA 94062  
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**LETTER OF GOOD FAITH**

Vice President and Disk Storage Business Line Executive

IBM Technology & Systems Group  
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Phone: 1-919-643-6345  
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October 7, 2010

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

Subject: SPC-1 Letter of Good Faith for the IBM System Storage DS3500 Express Turbo.

IBM Corporation is the SPC-1 Test Sponsor for the above listed product. To the best of our knowledge and belief, the required SPC-1 benchmark results and materials we have submitted for that product are complete, accurate, and in full compliance with Version 1.10.1 of the SPC-1 benchmark specification.

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

Sincerely,

A handwritten signature in black ink that reads "Doug Balog".

Doug Balog

## **EXECUTIVE SUMMARY**

### **Test Sponsor and Contact Information**

<b>Test Sponsor and Contact Information</b>	
<b>Test Sponsor Primary Contact</b>	IBM Corporation – <a href="http://www.ibm.com">http://www.ibm.com</a> Bruce McNutt – <a href="mailto:bmcnutt@us.ibm.com">bmcnutt@us.ibm.com</a> 650 Harry Road C2 500 San Jose, CA 95120 Phone: (408) 927-2717 FAX: 0086 28 62905793
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### **Revision Information and Key Dates**

<b>Revision Information and Key Dates</b>	
<b>SPC-1 Specification revision number</b>	V1.12
<b>SPC-1 Workload Generator revision number</b>	V2.1.0
<b>Date Results were first used publicly</b>	December 31, 2010
<b>Date the FDR was submitted to the SPC</b>	December 31, 2010
<b>Date the priced storage configuration is available for shipment to customers</b>	currently available
<b>Date the TSC completed audit certification</b>	December 30, 2010

## Tested Storage Product (TSP) Description

The IBM System Storage DS3500 Express Storage Systems and EXP3500 Express Expansion Units are the newest addition to the IBM System Storage DS3000 series family of entry disk storage systems. The DS3500 delivers affordable, entry-level configurations for small and medium businesses in compact 2U, 19-inch rack mount enclosures, with the flexibility to scale in capacity, performance, host interfaces, and functions as your business grows or requirements change.

## Summary of Results

SPC-1 Results	
Tested Storage Configuration (TSC) Name: IBM System Storage® DS3524 Express Turbo	
Metric	Reported Result
SPC-1 IOPS™	24,449.27
SPC-1 Price-Performance	\$3.90/SPC-1 IOPS™
Total ASU Capacity	13,412.881 GB
Data Protection Level	Protected ( <i>Mirroring</i> )
Total TSC Price (including three-year maintenance)	\$95,384.00

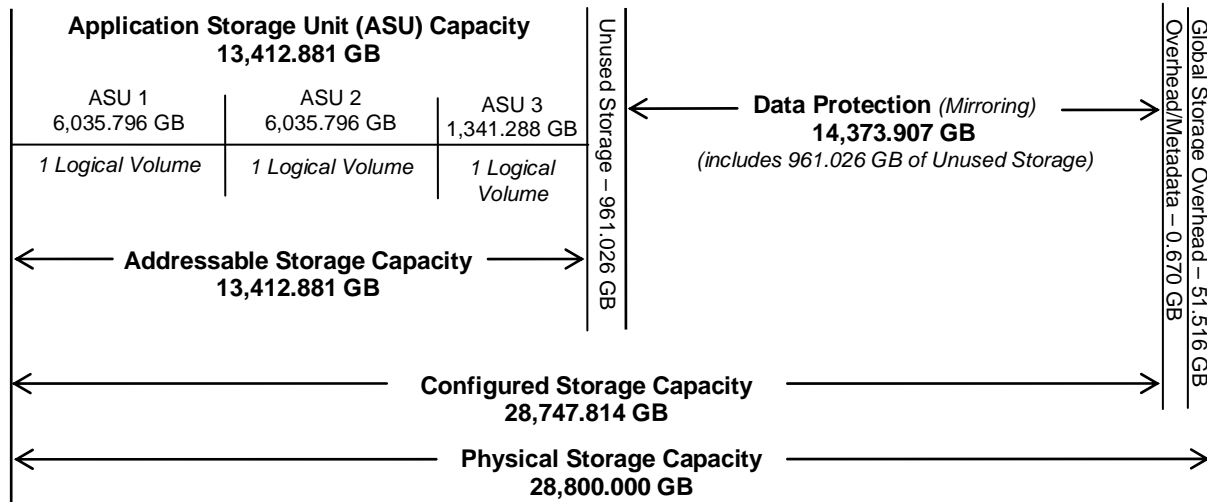
**SPC-1 IOPS™** represents the maximum I/O Request Throughput at the 100% load point.

**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 Protected** using *Mirroring* configures two or more identical copies of user data.

### Storage Capacities, Relationships, and Utilization

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



SPC-1 Storage Capacity Utilization	
Application Utilization	46.57%
Protected Application Utilization	93.15%
Unused Storage Ratio	6.68%

**Application Utilization:** Total ASU Capacity (13,412.881 GB) divided by Physical Storage Capacity (28,800.000 GB)

**Protected Application Utilization:** (Total ASU Capacity (13,412.881 GB) plus total Data Protection Capacity (14,373.907 GB) minus unused Data Protection Capacity (961.026 GB) divided by Physical Storage Capacity (28,800.000 GB)

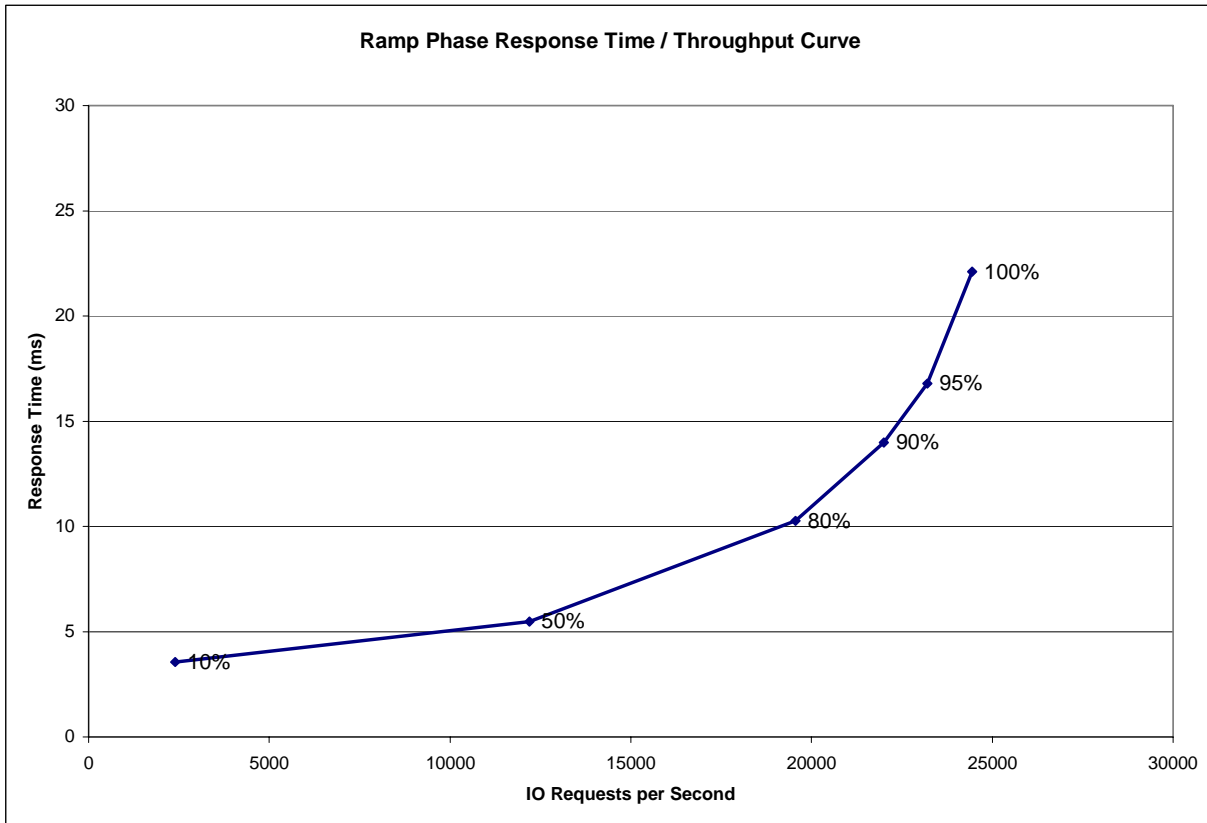
**Unused Storage Ratio:** Total Unused Capacity (1,922.722 GB) divided by Physical Storage Capacity (28,800.000 GB) and may not exceed 45%.

Detailed information for the various storage capacities and utilizations is available on pages 21-22 in the Full Disclosure Report.

### 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
<b>I/O Request Throughput</b>	2,401.15	12,192.77	19,549.62	21,996.13	23,204.87	24,449.27
<b>Average Response Time (ms):</b>						
All ASUs	3.56	5.48	10.26	13.98	16.79	22.11
ASU-1	4.85	7.56	13.37	17.30	20.13	25.18
ASU-2	3.82	5.97	11.78	15.97	18.90	24.38
ASU-3	0.72	0.86	3.01	6.08	8.78	14.60
Reads	8.07	12.64	21.54	26.42	29.56	34.46
Writes	0.62	0.82	2.92	5.88	8.47	14.06

## Priced Storage Configuration Pricing

Item	IBM Description	Feature Code (4 digits) or Part Number (7 digits)	Qty	Unit Price (usd)	Total (usd)
HBA	IBM 6Gb SAS HBA	46M0907	2	\$ 199.00	\$ 398.00
Storage System	IBM System Storage DS3524 Express Dual Controller	2812	1	\$ 9,299.00	\$ 9,299.00
HIC	6Gb SAS 2 Port Daughter Card	3610	2	\$ 1,499.00	\$ 2,998.00
Advanced Functions	Turbo Performance	4400	1	\$ 6,850.00	\$ 6,850.00
Memory	2 GB cache upgrade	3630	2	\$ 2,499.00	\$ 4,998.00
Expansion Unit	IBM System Storage EXP3524 Express	2822	3	\$ 3,999.00	\$ 11,997.00
Drives	300GB 10,000 rpm 6Gb SAS 2.5" HDD	5210	96	\$ 549.00	\$ 52,704.00
Cables	1m SAS Cable	3708	10	\$ 119.00	\$ 1,190.00
Maintenance and Warranty	DS3524 3 Year Onsite Repair 24x7 4 Hour Response	67567DT	1	\$ 1,350.00	\$ 1,350.00
Maintenance and Warranty	EXP3524 3 Year Onsite Repair 24x7 4 Hour Response	67567F3	3	\$ 1,200.00	\$ 3,600.00
<b>Total Price List (usd)</b>					<b>\$ 95,384.00</b>

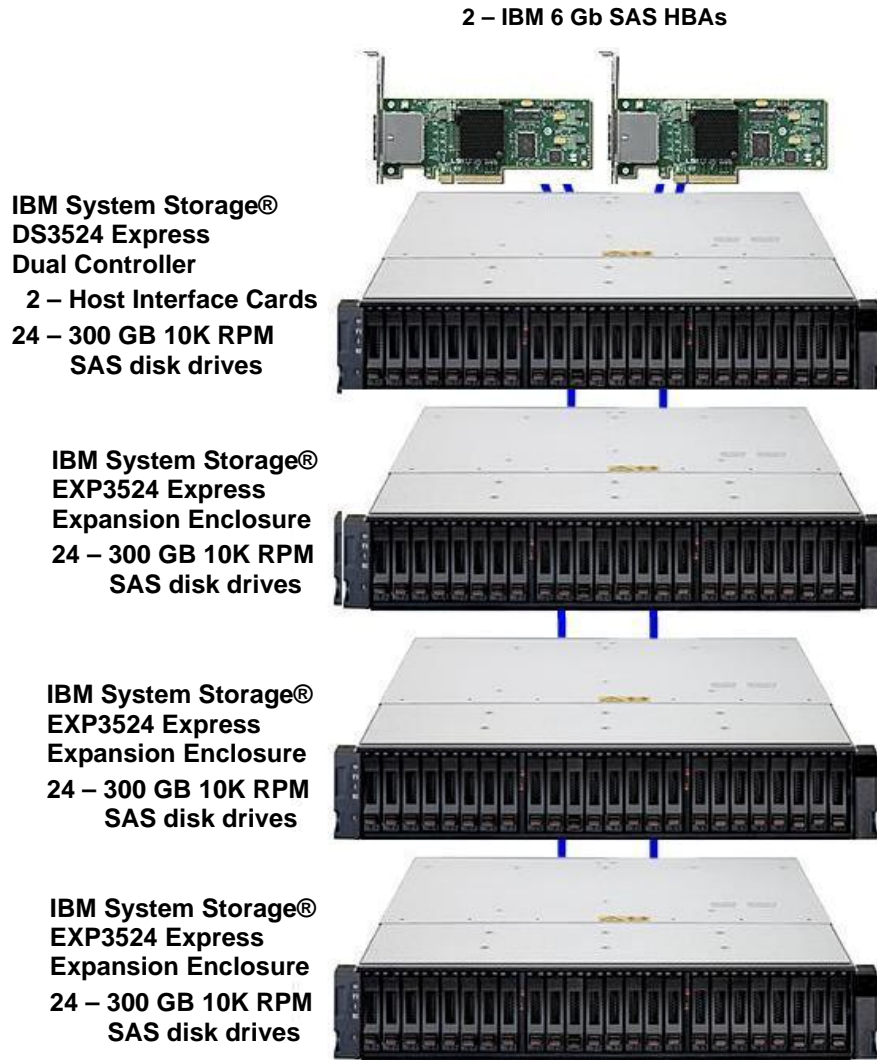
The above pricing includes hardware maintenance and software support for three years, 7 days per week, 24 hours per day. The hardware maintenance and software support provides the following:

- Acknowledgement of new and existing problems with four (4) hours.
- Onsite present of a qualified maintenance engineer or provision of a customer replaceable part within four (4) hours of the above acknowledgement for any hardware failure that results in an inoperative Priced Storage Configuration that can be remedied by the repair or replacement of a Priced Storage Configuration component.

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

The difference between the Tested Storage Configuration and Priced Storage Configuration is that the priced disk drives are mounted in an IBM drive carrier and each disk drive is configured to self-identify as a DS3000 brand. That difference, if applied to the TSC, would not have a negative impact on the reported SPC-1 performance.

### Priced Storage Configuration Diagram



## Priced Storage Configuration Components

Priced Storage Configuration
2 – IBM 6 Gb dual-ported SAS HBAs
<b>IBM System Storage® DS3524 Express Turbo</b> <b>IBM System Storage® DS3524 Express dual controller with:</b> 2 GB cache per controller ( <i>4 GB total</i> ) Turbo Performance 2 – Host Interface Cards (HIC) ( <i>1 HIC/controller</i> ) ( <i>2 – 6 GB SAS host connections per HIC,</i> <i>4 total, 4 used</i> ) 2 – 6 Gb SAS baseboard host connections per controller ( <i>4 total, 0 used</i> ) 1 – 6 Gb SAS drive connections per controller ( <i>2 total, 2 used</i> )
10 – 1m SAS cables
3 – IBM System Storage® EXP3524 Express expansion units
96 – 300 GB 10K RPM SAS disk drives 24 disk drives in the base unit 24 disk drives in each expansion unit



In each of the following sections of this document, the appropriate Full Disclosure Report requirement, from the SPC-1 benchmark specification, is stated in italics followed by the information to fulfill the stated requirement.

## **CONFIGURATION INFORMATION**

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

#### Clause 9.4.3.4.1

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

The Benchmark Configuration (BC)/Tested Storage Configuration (TSC) is illustrated on page 18 (*Benchmark Configuration/Tested Storage Configuration Diagram*).

### **Storage Network Configuration**

#### Clause 9.4.3.4.1

...

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

#### Clause 9.4.3.4.2

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

The storage network configuration is illustrated on page 18 (*Benchmark Configuration/Tested Storage Configuration Diagram*).

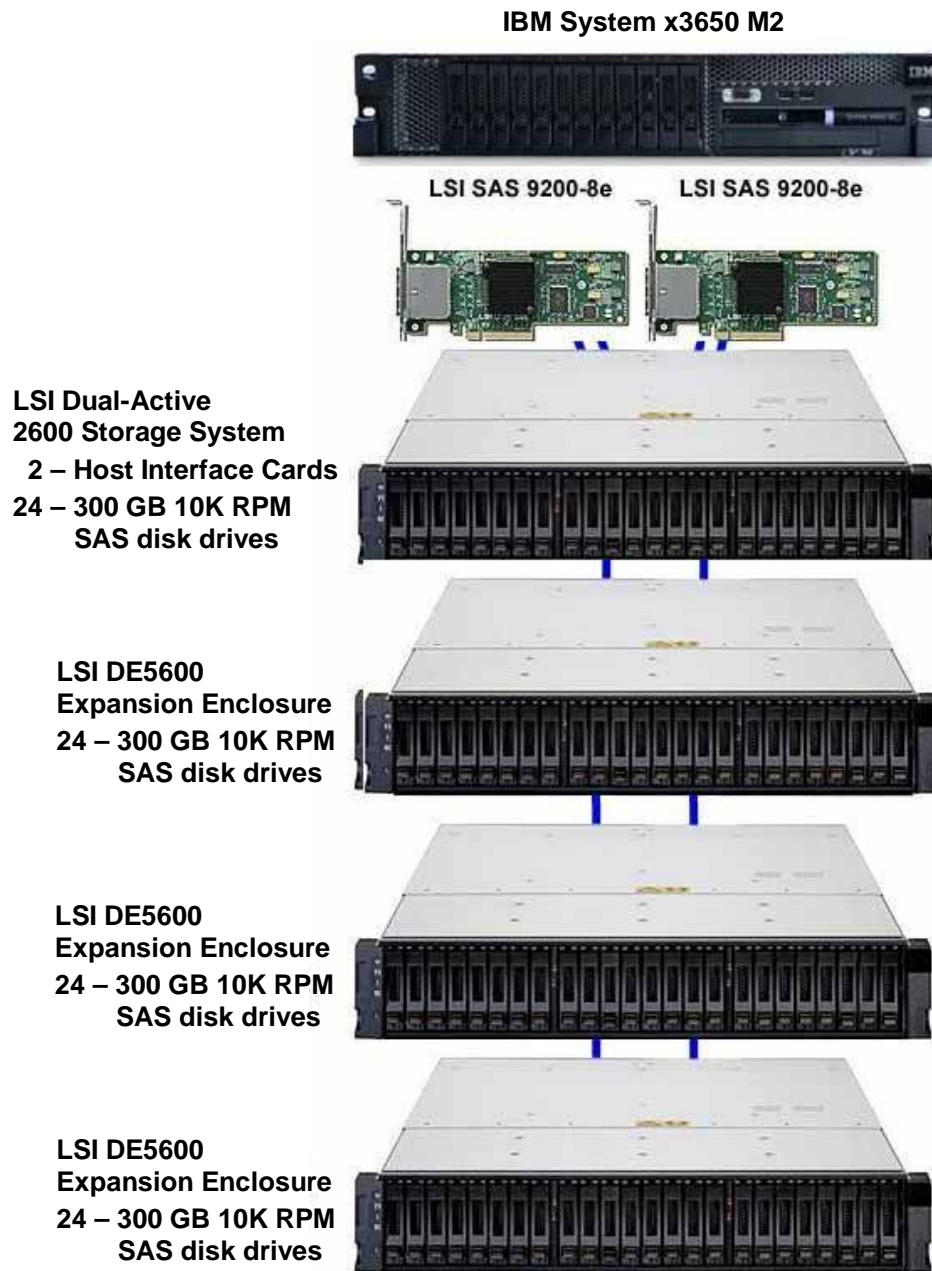
### **Host System and Tested Storage Configuration (TSC) Table of Components**

#### Clause 9.4.3.4.3

*The FDR will contain a table that lists the major components of each Host System and the Tested Storage Configuration (TSC). Table 9-10 specifies the content, format, and appearance of the table.*

The Host System and TSC table of components may be found on page 19 (*Host System(s) and Tested Storage Configuration Components*).

### Benchmark Configuration/Tested Storage Configuration Diagram



**Host System(s) and Tested Storage Configuration Components**

Host System:	Tested Storage Configuration (TSC):
<b>IBM System x3650 M2</b>	2 – LSI 9200-8e 6Gb SAS HBAs ( <i>dual-ported</i> )
2 – 2.8 GHz Dual Xeon Processors with 8 MB L2 cache/CPU	<b>LSI 26000 Storage System</b> <b>2 – LSI 2660 SAS dual-active controllers with:</b> 2 GB cache per controller ( <i>4 GB total</i> ) High Performance Tier enabled 2 – Host Interface Cards (HIC) ( <i>1 HIC/controller</i> ) ( <i>2 – 6 GB SAS host connections per HIC,</i> <i>4 total, 4 used</i> ) 2 – 6 Gb SAS baseboard host connections per controller ( <i>4 total, 0 used</i> ) 1 – 6 Gb SAS drive connections per controller ( <i>2 total, 2 used</i> )
12 GB main memory	
Windows Server 2003 Enterprise Edition with SP2	
PCIe	
	10 – 1m SAS cables
	3 – LSI DE5600 24-slot expansion units
	96 – 300 GB 10K RPM SAS disk drives 24 disk drives in the base unit 24 disk drives in each expansion unit

## Customer Tunable Parameters and Options

### Clause 9.4.3.5.1

All Benchmark Configuration (BC) components with customer tunable parameter and options that have been altered from their default values must be listed in the FDR. The FDR entry for each of those components must include both the name of the component and the altered value of the parameter or option. If the parameter name is not self-explanatory to a knowledgeable practitioner, a brief description of the parameter's use must also be included in the FDR entry.

“Appendix B: Customer Tunable Parameters and Options” on page 63 contains the customer tunable parameters and options that have been altered from their default values for this benchmark.

## Tested Storage Configuration (TSC) Description

### Clause 9.4.3.5.2

The FDR must include sufficient information to recreate the logical representation of the TSC. In addition to customer tunable parameters and options (Clause 4.2.4.5.3), that information must include, at a minimum:

- A diagram and/or description of the following:
  - All physical components that comprise the TSC. Those components are also illustrated in the BC Configuration Diagram in Clause 9.2.4.4.1 and/or the Storage Network Configuration Diagram in Clause 9.2.4.4.2.
  - The logical representation of the TSC, configured from the above components that will be presented to the Workload Generator.
- Listings of scripts used to create the logical representation of the TSC.
- If scripts were not used, a description of the process used with sufficient detail to recreate the logical representation of the TSC.

“Appendix C: Tested Storage Configuration (TSC) Creation” on page 64 contains the detailed information that describes how to create and configure the logical TSC.

## SPC-1 Workload Generator Storage Configuration

### Clause 9.4.3.5.3

The FDR must include all SPC-1 Workload Generator storage configuration commands and parameters.

The SPC-1 Workload Generator storage configuration commands and parameters for this measurement appear in “Appendix D: SPC-1 Workload Generator Storage Commands and Parameters” on page 70.

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

### Storage Capacities and Relationships

#### Clause 9.4.3.6.1

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

### SPC-1 Storage Capacities

SPC-1 Storage Capacities		
Storage Hierarchy Component	Units	Capacity
Total ASU Capacity	Gigabytes (GB)	13,412.881
Addressable Storage Capacity	Gigabytes (GB)	13,412.881
Configured Storage Capacity	Gigabytes (GB)	28,747.814
Physical Storage Capacity	Gigabytes (GB)	28,800.000
Data Protection ( <i>Mirroring</i> )	Gigabytes (GB)	14,373.907
Required Storage	Gigabytes (GB)	0.000
Global Storage Overhead	Gigabytes (GB)	51.516
Total Unused Storage	Gigabytes (GB)	1,922.722

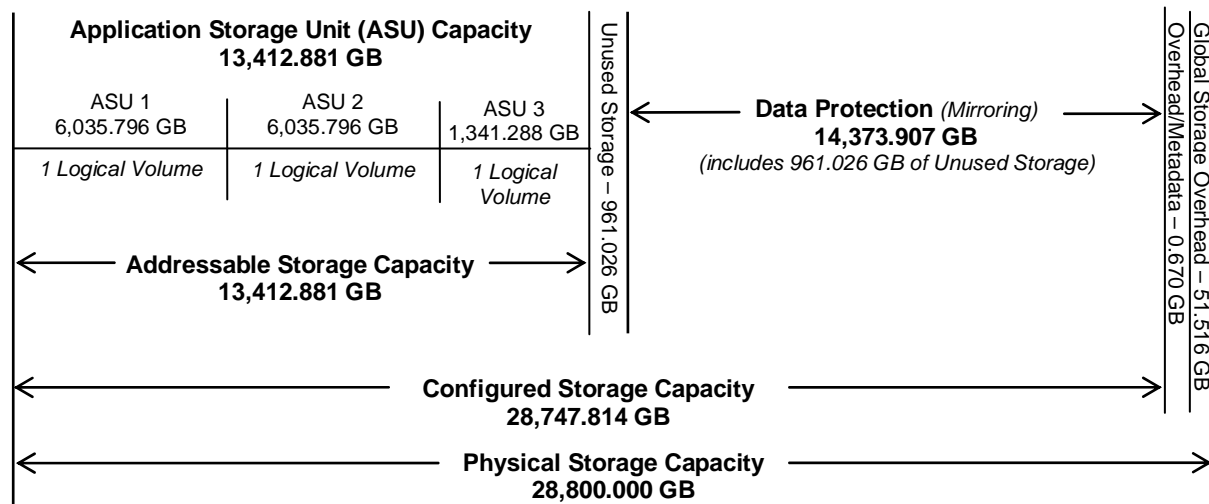
### SPC-1 Storage Hierarchy Ratios

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	46.66%	46.57%
Required for Data Protection ( <i>Mirrored</i> )		50.00%	49.91%
Addressable Storage Capacity		46.66%	46.57%
Required Storage		0.00%	0.00%
Configured Storage Capacity			99.82%
Global Storage Overhead			0.18%
Unused Storage:			
Addressable	0.00%		
Configured		6.69%	
Physical			0.00%

The Physical Storage Capacity consisted of 28,800.000 GB distributed over 96 disk drives each with a formatted capacity of 300.00 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 51.516 GB (0.18%) of Physical Storage Capacity. There was 1,922.052 GB (6.69%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 100.00% of the Addressable Storage Capacity resulting in 0.000 GB (0.00%) of Unused Storage within the Addressable Storage Capacity. The Data Protection (*mirroring*) capacity was 14,373.907 GB of which 13,412.881 GB was utilized. The total Unused Storage was 1,922.722 GB.

### 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 9.4.3.6.3

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

Logical Volume Capacity and Mapping		
ASU-1 (6,035.796 GB)	ASU-2 (6,035.796 GB)	ASU-3 (1,341.288 GB)
1 Logical Volume 6,035.696 GB per Logical Volume (6,035.696 GB used per Logical Volume)	1 Logical Volume 6,035.696 GB per Logical Volume (6,035.696 GB used per Logical Volume)	1 Logical Volume 1,342.288 GB per Logical Volume (1,342.288 GB used per Logical Volume)

The Data Protection Level used for all Logical Volumes was “Mirrored” as described on page 11. See “ASU Configuration” in the [IOPS Test Results File](#) for more detailed configuration information.

## Storage Capacity Utilization

### Clause 9.4.3.6.2

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

### Clause 2.8.1

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

### Clause 2.8.2

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

### Clause 2.8.3

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

SPC-1 Storage Capacity Utilization	
Application Utilization	46.57%
Protected Application Utilization	93.15%
Unused Storage Ratio	6.68%

## **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 60 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 9.4.3.7.1

*For the Sustainability Test Phase the FDR shall contain:*

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

## SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in “Appendix E: SPC-1 Workload Generator Input Parameters” on Page 71.

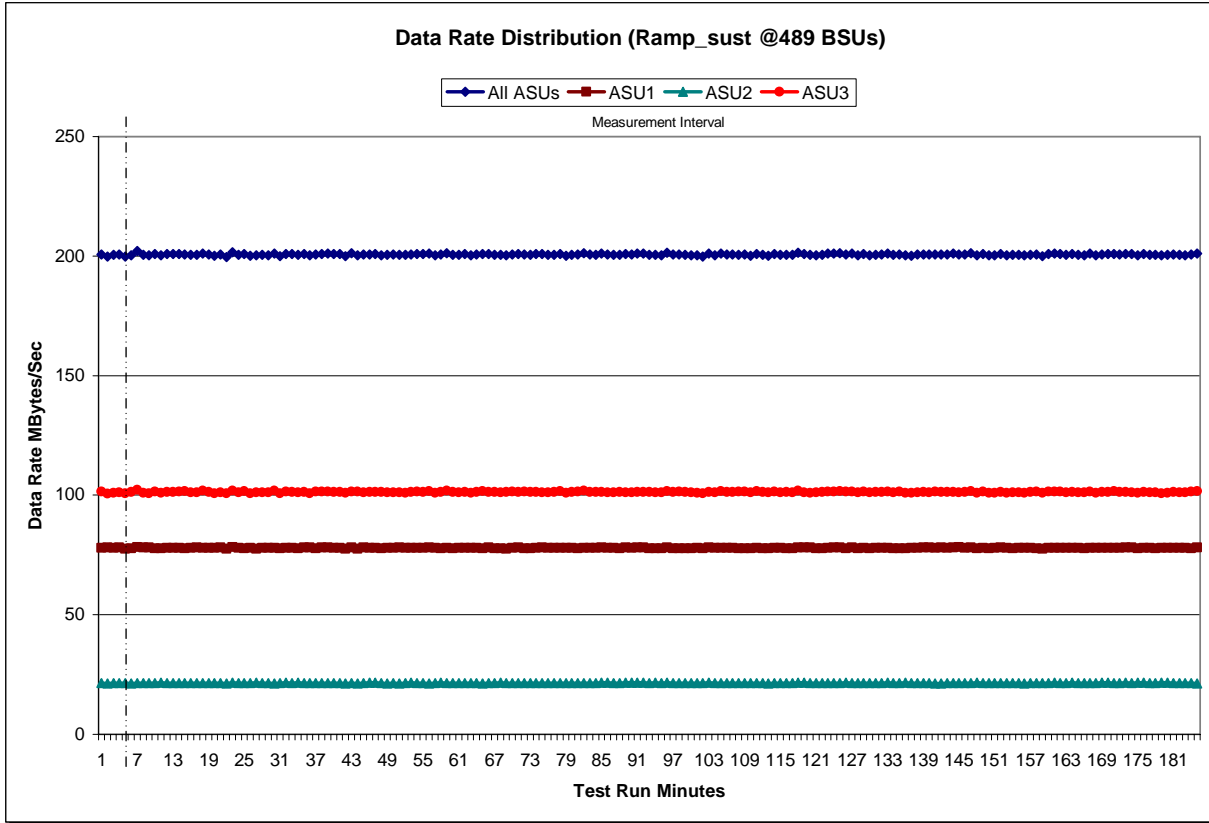
## Sustainability Test Results File

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

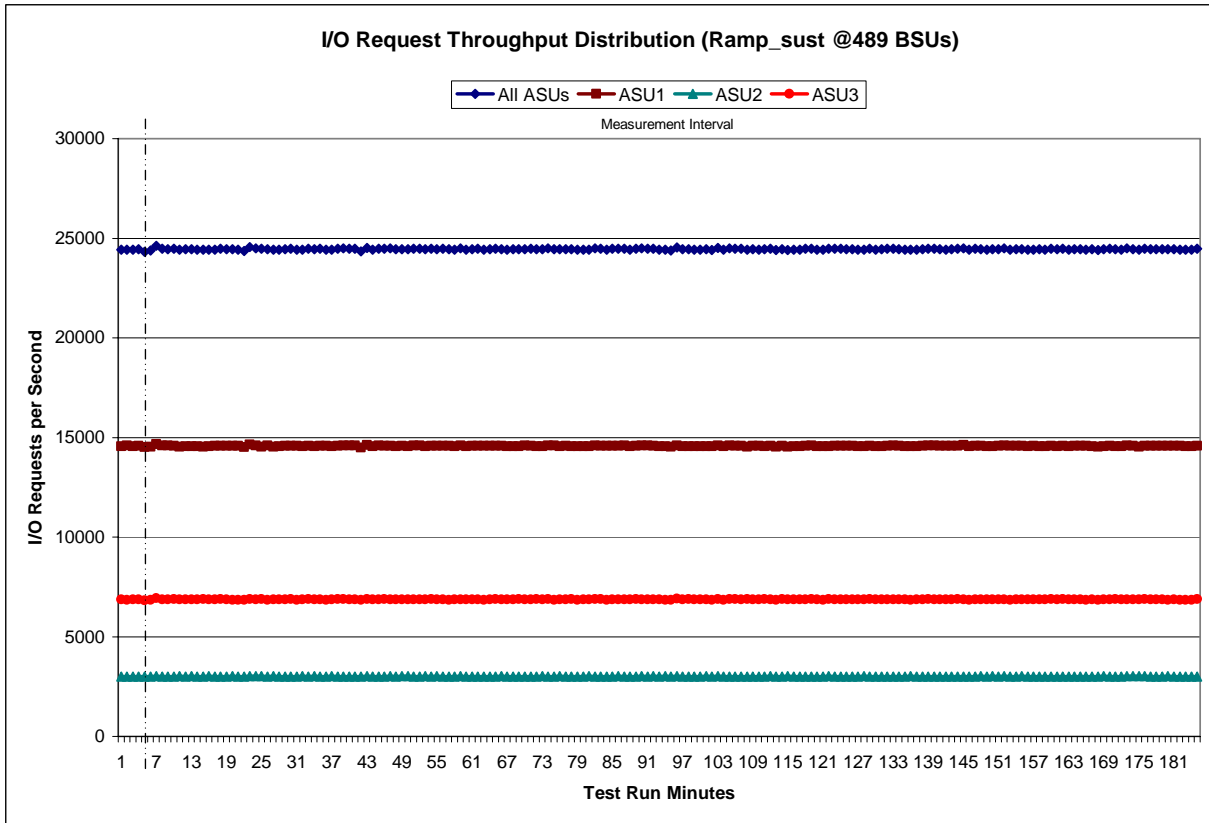


Sustainability – I/O Request Throughput Distribution Data

Ramp-Up/Start-Up Measurement Interval Start Stop Interval Duration  
6:00:56 6:05:56 0-4 0:05:00  
6:05:56 9:05:56 5-184 3:00:00

Table with 15 columns: Interval, All ASUs, ASU1, ASU2, ASU3. It contains 184 rows of data representing throughput distribution over time, including an average row at the bottom.

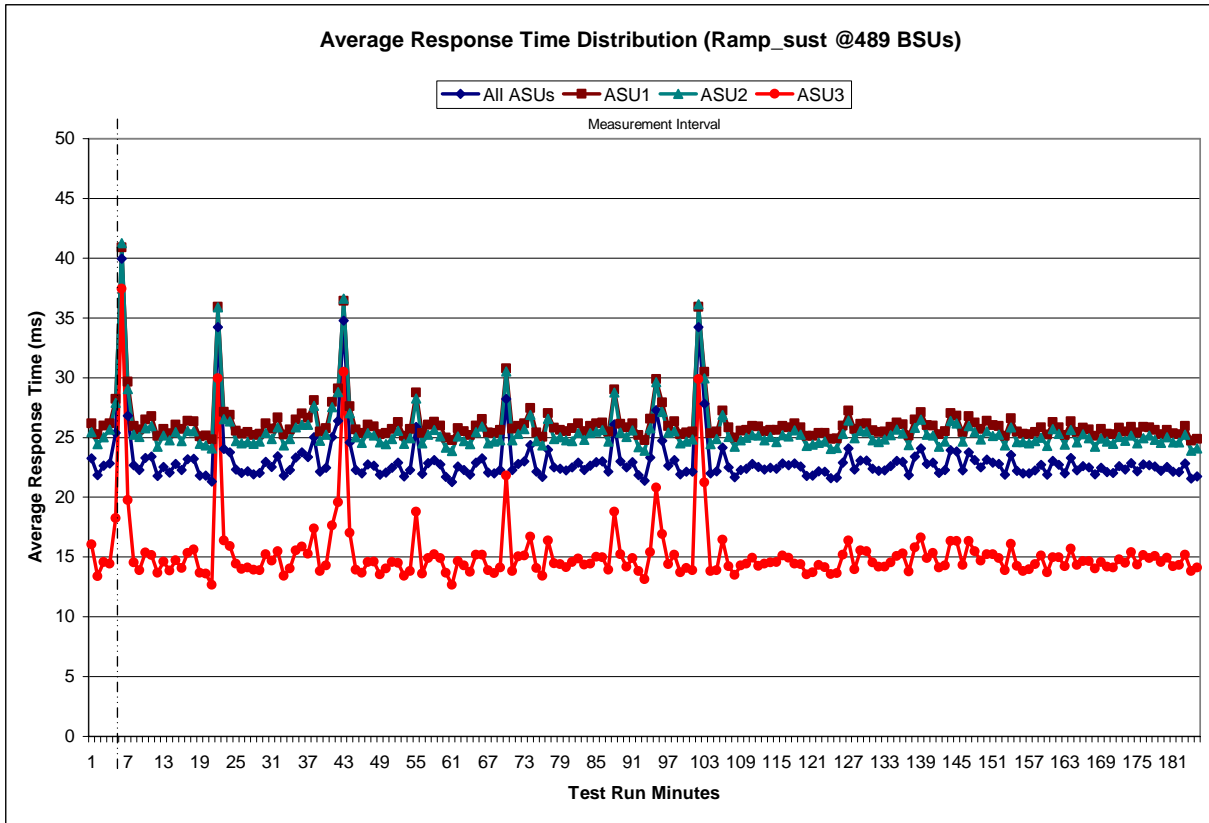
### Sustainability – I/O Request Throughput Distribution Graph



Sustainability – Average Response Time (ms) Distribution Data

		Start	Stop	Interval	Duration										
Ramp-Up/Start-Up		6:00:56	6:05:56	0-4	0:05:00										
Measurement Interval		6:05:56	9:05:56	4-184	3:00:00										
Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	Interval	All ASUs	ASU1	ASU2	ASU3	
0	23.25	26.18	25.46	16.06	63	21.90	25.20	24.46	13.75	126	24.09	27.24	26.43	16.38	
1	21.85	25.28	24.44	13.40	64	22.89	26.00	25.45	15.19	127	22.32	25.72	24.96	13.97	
2	22.66	25.98	25.02	14.58	65	23.26	26.51	25.90	15.19	128	23.08	26.12	25.57	15.56	
3	22.81	26.17	25.67	14.44	66	22.05	25.40	24.52	13.88	129	23.07	26.17	25.47	15.47	
4	25.39	28.23	27.91	18.25	67	22.00	25.39	24.66	13.65	130	22.38	25.59	24.76	14.55	
5	39.96	40.88	41.25	37.44	68	22.27	25.62	24.75	14.11	131	22.19	25.45	24.63	14.20	
6	26.81	29.68	29.03	19.77	69	28.22	30.77	30.53	21.80	132	22.24	25.50	24.85	14.18	
7	22.67	25.96	25.23	14.54	70	22.28	25.74	24.75	13.83	133	22.62	25.89	25.19	14.54	
8	22.30	25.68	25.07	13.90	71	22.80	25.96	25.30	15.04	134	23.04	26.25	25.67	15.09	
9	23.29	26.51	25.77	15.38	72	23.01	26.17	25.70	15.13	135	22.97	26.10	25.33	15.31	
10	23.41	26.78	25.95	15.16	73	24.36	27.45	26.90	16.69	136	21.86	25.15	24.37	13.77	
11	21.79	25.12	24.21	13.69	74	22.14	25.40	24.69	14.09	137	23.40	26.48	25.82	15.79	
12	22.52	25.72	25.14	14.60	75	21.69	25.06	24.33	13.41	138	24.09	27.12	26.50	16.63	
13	22.05	25.35	24.78	13.87	76	23.97	27.03	26.55	16.36	139	22.80	26.01	25.25	14.89	
14	22.79	26.06	25.45	14.72	77	22.50	25.81	24.86	14.46	140	22.90	26.00	25.17	15.33	
15	22.30	25.69	24.71	14.07	78	22.40	25.63	25.02	14.39	141	22.02	25.28	24.24	14.13	
16	23.19	26.39	25.54	15.35	79	22.23	25.51	24.77	14.16	142	22.27	25.53	24.67	14.29	
17	23.22	26.33	25.53	15.62	80	22.49	25.76	24.71	14.59	143	23.95	27.04	26.39	16.32	
18	21.80	25.08	24.47	13.69	81	22.89	26.18	25.36	14.86	144	23.81	26.84	26.16	16.35	
19	21.82	25.16	24.32	13.61	82	22.29	25.52	24.79	14.36	145	22.24	25.46	24.67	14.34	
20	21.33	24.84	24.07	12.65	83	22.65	25.95	25.37	14.44	146	23.76	26.80	25.96	16.35	
21	34.24	35.92	35.87	29.96	84	22.94	26.16	25.50	15.00	147	23.13	26.25	25.46	15.47	
22	24.05	27.15	26.53	16.38	85	23.00	26.24	25.62	14.97	148	22.49	25.69	24.84	14.69	
23	23.75	26.90	26.37	15.89	86	22.13	25.47	24.67	13.93	149	23.14	26.37	25.52	15.24	
24	22.31	25.55	24.69	14.44	87	26.10	29.01	28.76	18.78	150	22.89	26.03	25.13	15.24	
25	22.04	25.31	24.50	14.01	88	22.99	26.15	25.43	15.22	151	22.77	25.97	25.24	14.89	
26	22.16	25.45	24.64	14.12	89	22.49	25.86	25.07	14.20	152	21.87	25.11	24.35	13.90	
27	21.93	25.18	24.48	13.94	90	22.95	26.19	25.60	14.90	153	23.55	26.60	25.83	16.08	
28	22.03	25.32	24.65	13.90	91	21.87	25.19	24.19	13.81	154	22.22	25.47	24.63	14.25	
29	22.98	26.16	25.39	15.23	92	21.39	24.75	23.91	13.15	155	21.99	25.30	24.63	13.83	
30	22.53	25.73	24.89	14.68	93	23.34	26.57	25.77	15.41	156	22.01	25.29	24.50	13.97	
31	23.42	26.66	25.84	15.48	94	27.29	29.86	29.61	20.81	157	22.25	25.46	24.70	14.39	
32	21.80	25.24	24.32	13.41	95	24.74	27.93	27.15	16.92	158	22.72	25.84	24.98	15.12	
33	22.30	25.66	24.88	14.03	96	22.64	25.96	25.43	14.38	159	21.89	25.25	24.32	13.73	
34	23.34	26.50	25.83	15.54	97	23.10	26.34	25.51	15.21	160	23.03	26.27	25.71	14.96	
35	23.76	26.98	26.08	15.89	98	21.92	25.26	24.50	13.71	161	22.72	25.85	25.31	14.98	
36	23.36	26.64	26.07	15.25	99	22.13	25.40	24.66	14.08	162	22.00	25.19	24.41	14.21	
37	25.03	28.10	27.64	17.38	100	22.14	25.47	24.83	13.91	163	23.28	26.37	25.64	15.70	
38	22.12	25.50	24.71	13.84	101	34.24	35.91	36.13	29.87	164	22.23	25.45	24.60	14.34	
39	22.48	25.77	25.24	14.27	102	27.82	30.48	29.96	21.23	165	22.61	25.81	25.26	14.66	
40	25.02	27.97	27.53	17.65	103	22.00	25.34	24.44	13.83	166	22.49	25.67	24.93	14.67	
41	26.39	29.10	28.79	19.59	104	22.16	25.50	24.87	13.91	167	21.90	25.13	24.23	14.04	
42	34.78	36.42	36.62	30.50	105	24.16	27.24	26.88	16.45	168	22.47	25.69	24.93	14.58	
43	24.57	27.63	27.03	17.03	106	22.49	25.85	25.05	14.22	169	22.10	25.31	24.67	14.17	
44	22.29	25.66	25.03	13.92	107	21.66	25.00	24.21	13.51	170	22.02	25.26	24.47	14.12	
45	21.99	25.38	24.57	13.69	108	22.29	25.55	24.77	14.30	171	22.62	25.81	25.07	14.80	
46	22.75	26.07	25.39	14.57	109	22.41	25.62	25.00	14.45	172	22.30	25.47	24.74	14.49	
47	22.65	25.92	25.17	14.60	110	22.77	25.97	25.21	14.95	173	22.86	25.90	25.15	15.42	
48	21.90	25.27	24.59	13.55	111	22.54	25.91	25.17	14.25	174	22.19	25.41	24.51	14.35	
49	22.06	25.36	24.45	14.02	112	22.32	25.52	24.78	14.44	175	22.75	25.87	24.95	15.17	
50	22.47	25.69	24.86	14.59	113	22.45	25.65	25.06	14.55	176	22.69	25.84	25.17	14.91	
51	22.89	26.29	25.56	14.51	114	22.40	25.63	24.63	14.59	177	22.57	25.64	24.82	15.07	
52	21.75	25.13	24.47	13.43	115	22.81	25.95	25.19	15.13	178	22.19	25.29	24.56	14.59	
53	22.28	25.72	24.95	13.83	116	22.68	25.84	25.09	14.92	179	22.55	25.63	25.01	14.92	
54	25.90	28.75	28.27	18.78	117	22.82	26.19	25.60	14.44	180	22.13	25.35	24.57	14.21	
55	21.96	25.38	24.52	13.60	118	22.56	25.85	25.23	14.39	181	22.11	25.27	24.58	14.31	
56	22.84	26.08	25.23	14.91	119	21.76	25.12	24.29	13.53	182	22.83	25.94	25.22	15.18	
57	23.12	26.33	25.61	15.23	120	21.83	25.13	24.40	13.70	183	21.56	24.71	23.91	13.82	
58	22.76	25.99	25.09	14.89	121	22.17	25.38	24.54	14.32	184	21.74	24.86	24.09	14.10	
59	21.71	24.99	24.14	13.70	122	22.13	25.38	24.66	14.14	<b>Average</b> <b>23.05</b> <b>26.23</b> <b>25.52</b> <b>15.23</b>					
60	21.26	24.77	23.86	12.69	123	21.59	24.87	24.03	13.57						
61	22.57	25.79	25.10	14.65	124	21.64	24.89	24.14	13.65						
62	22.27	25.52	24.70	14.30	125	22.88	26.00	25.32	15.20						

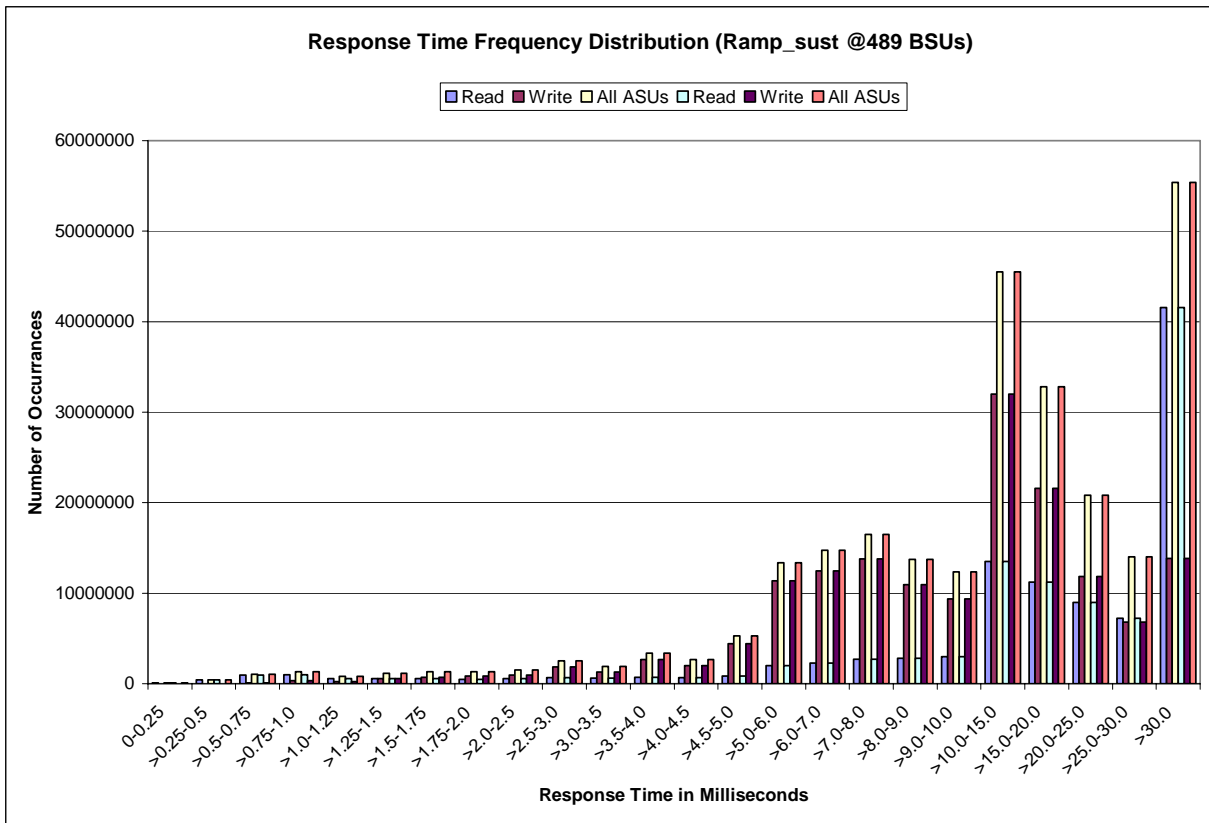
### Sustainability – Average Response Time (ms) Distribution Graph



**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	111,740	435,248	944,130	1,008,242	569,854	558,755	585,602	490,300
Write	109	8,707	78,876	316,282	217,030	585,483	725,355	848,497
All ASUs	111,849	443,955	1,023,006	1,324,524	786,884	1,144,238	1,310,957	1,338,797
ASU1	103,405	356,504	741,163	894,139	523,526	691,006	759,319	737,890
ASU2	8,435	84,546	253,475	305,667	174,473	211,611	231,462	214,956
ASU3	9	2,905	28,368	124,718	88,885	241,621	320,176	385,951
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	574,083	654,360	622,895	720,412	664,502	874,111	2,002,039	2,284,371
Write	932,387	1,856,583	1,288,024	2,676,830	1,990,978	4,424,953	11,372,299	12,463,940
All ASUs	1,506,470	2,510,943	1,910,919	3,397,242	2,655,480	5,299,064	13,374,338	14,748,311
ASU1	838,488	1,330,759	1,058,775	1,784,641	1,432,370	2,757,545	6,913,197	7,629,198
ASU2	239,814	352,069	281,053	437,467	356,527	639,094	1,581,010	1,725,622
ASU3	428,168	828,115	571,091	1,175,134	866,583	1,902,425	4,880,131	5,393,491
Response Time (ms)	>7.0-8.0	>8.0-9.0	>9.0-10.0	>10.0-15.0	>15.0-20.0	>20.0-25.0	>25.0-30.0	>30.0
Read	2,732,923	2,813,835	3,002,125	13,504,781	11,219,642	8,985,167	7,243,427	41,550,060
Write	13,776,229	10,931,373	9,344,537	32,006,259	21,582,653	11,860,041	6,789,165	13,837,312
All ASUs	16,509,152	13,745,208	12,346,662	45,511,040	32,802,295	20,845,208	14,032,592	55,387,372
ASU1	8,551,019	7,288,022	6,654,854	25,342,853	18,756,272	12,617,836	8,940,158	40,676,020
ASU2	1,895,738	1,585,047	1,412,390	5,128,733	3,668,314	2,386,081	1,649,287	7,669,265
ASU3	6,062,395	4,872,139	4,279,418	15,039,454	10,377,709	5,841,291	3,443,147	7,042,087

**Sustainability – Response Time Frequency Distribution Graph**





**Sustainability – Measured Intensity Multiplier and Coefficient of Variation**

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.13.2

**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	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.005	0.001	0.002	0.002	0.006	0.003	0.005	0.001

## Primary Metrics Test – IOPS Test Phase

### Clause 5.4.4.2

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

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

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

### Clause 9.4.3.7.2

*For the IOPS Test Phase the FDR shall contain:*

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

## SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in “Appendix E: SPC-1 Workload Generator Input Parameters” on Page 71.

## IOPS Test Results File

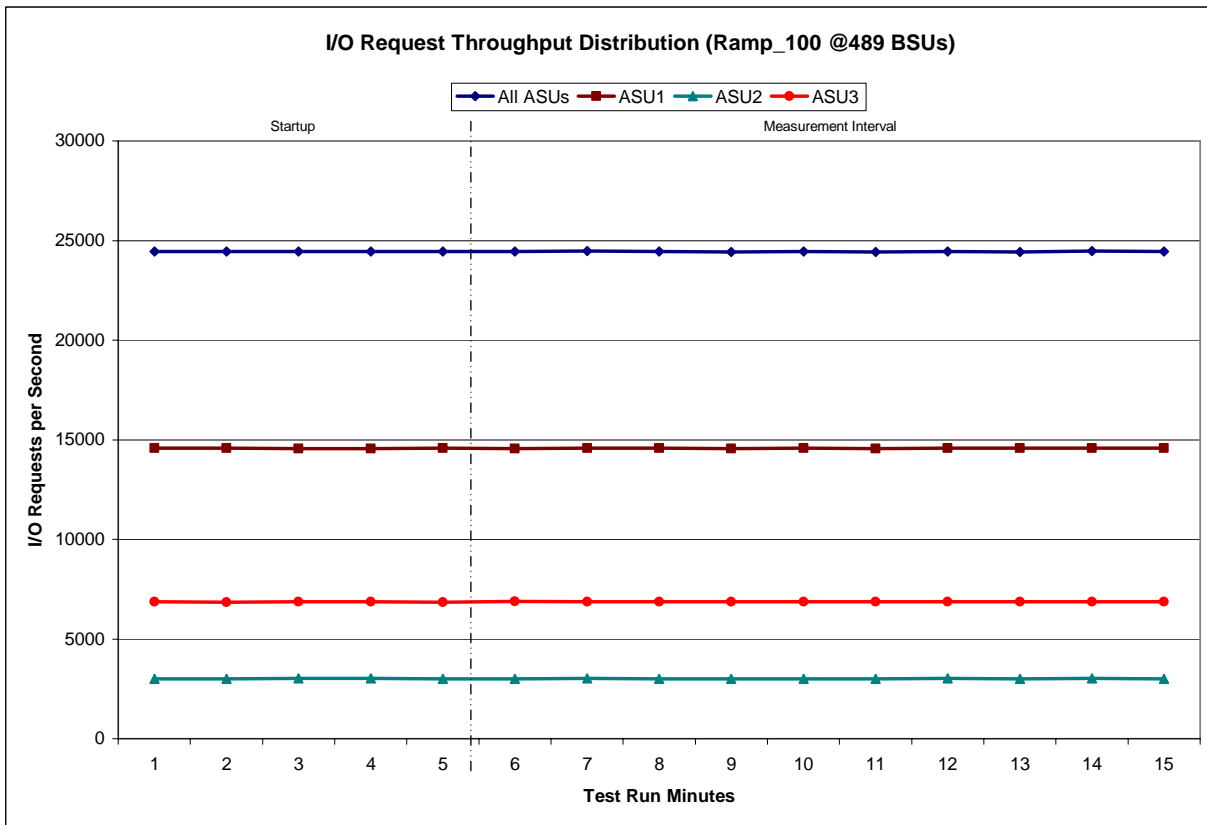
A link to the test results file generated from the IOPS Test Run is listed below.

[IOPS Test Results File](#)

**IOPS Test Run – I/O Request Throughput Distribution Data**

489 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	9:05:59	9:11:00	0-4	0:05:01
<i>Measurement Interval</i>	9:11:00	9:21:00	3-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	24,451.03	14,587.95	2,994.50	6,868.58
1	24,448.62	14,584.03	3,008.33	6,856.25
2	24,445.30	14,566.50	3,012.98	6,865.82
3	24,458.38	14,565.88	3,014.82	6,877.68
4	24,439.17	14,585.53	3,004.87	6,848.77
5	24,443.17	14,553.40	3,001.37	6,888.40
6	24,469.55	14,585.92	3,014.05	6,869.58
7	24,453.65	14,574.30	3,003.00	6,876.35
8	24,435.07	14,548.58	3,011.97	6,874.52
9	24,459.38	14,586.62	3,003.45	6,869.32
10	24,437.63	14,567.85	3,006.15	6,863.63
11	24,454.87	14,569.25	3,016.55	6,869.07
12	24,436.37	14,579.43	2,999.25	6,857.68
13	24,460.87	14,570.10	3,014.27	6,876.50
14	24,442.12	14,573.28	3,006.85	6,861.98
<b>Average</b>	<b>24,449.27</b>	<b>14,570.87</b>	<b>3,007.69</b>	<b>6,870.70</b>

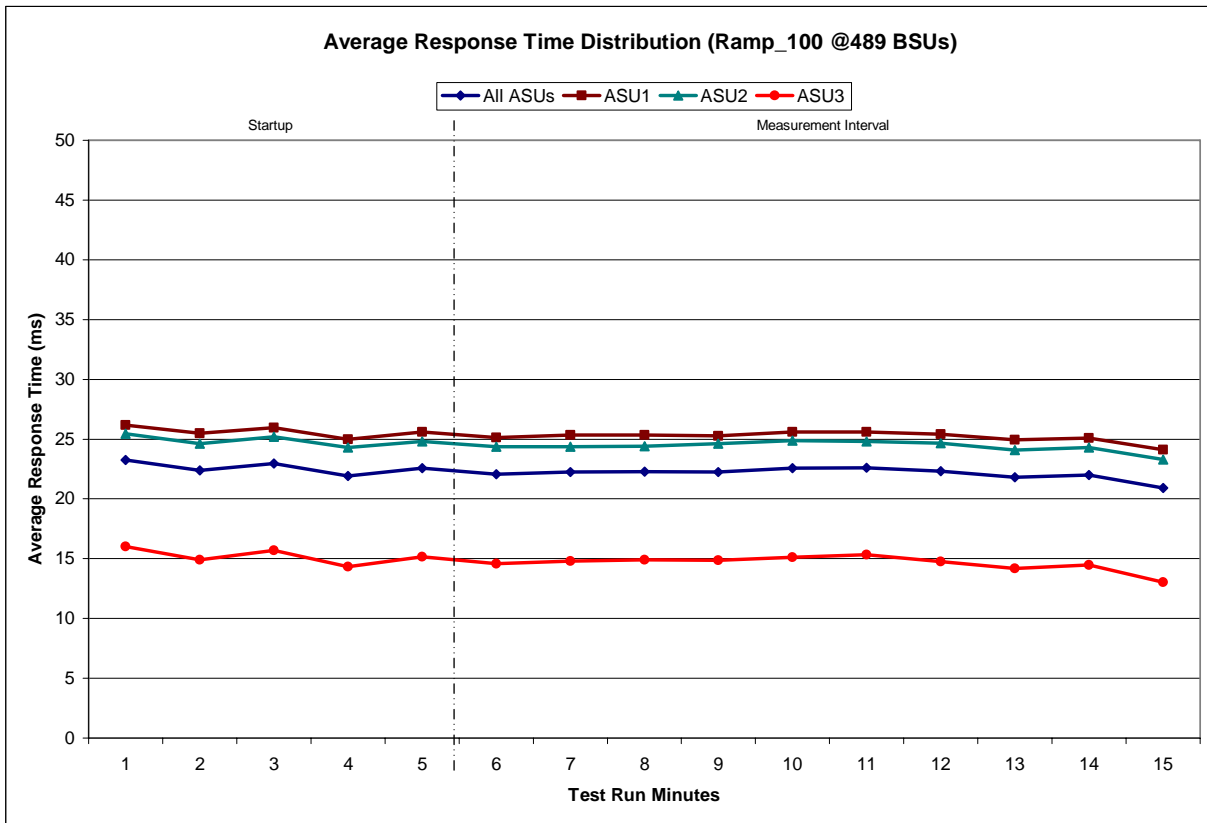
**IOPS Test Run – I/O Request Throughput Distribution Graph**



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

489 BSUs Start-Up/Ramp-Up Measurement Interval	Start 9:05:59 9:11:00	Stop 9:11:00 9:21:00	Interval 0-4 3-14	Duration 0:05:01 0:10:00
<b>60 second intervals</b>	<b>All ASUs</b>	<b>ASU1</b>	<b>ASU2</b>	<b>ASU3</b>
0	23.24	26.18	25.47	16.01
1	22.40	25.47	24.62	14.90
2	22.98	25.96	25.20	15.71
3	21.91	25.00	24.30	14.33
4	22.57	25.60	24.81	15.16
5	22.06	25.13	24.36	14.59
6	22.25	25.33	24.38	14.78
7	22.28	25.32	24.40	14.90
8	22.25	25.26	24.63	14.85
9	22.56	25.59	24.86	15.12
10	22.61	25.58	24.81	15.34
11	22.32	25.40	24.66	14.74
12	21.81	24.93	24.08	14.18
13	22.01	25.10	24.30	14.47
14	20.91	24.13	23.28	13.05
<b>Average</b>	<b>22.11</b>	<b>25.18</b>	<b>24.38</b>	<b>14.60</b>

**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	6515	25,012	54,677	56,978	31,181	30,302	31,532	25,845
Write	0	385	5,731	23,807	17,445	43,545	53,151	58,314
All ASUs	6515	25,397	60,408	80,785	48,626	73,847	84,683	84,159
ASU1	6028	20,358	43,534	53,455	31,410	42,940	47,023	44,244
ASU2	487	4,932	14,793	17,954	10,127	12,815	13,881	12,588
ASU3	0	107	2,081	9,376	7,089	18,092	23,779	27,327

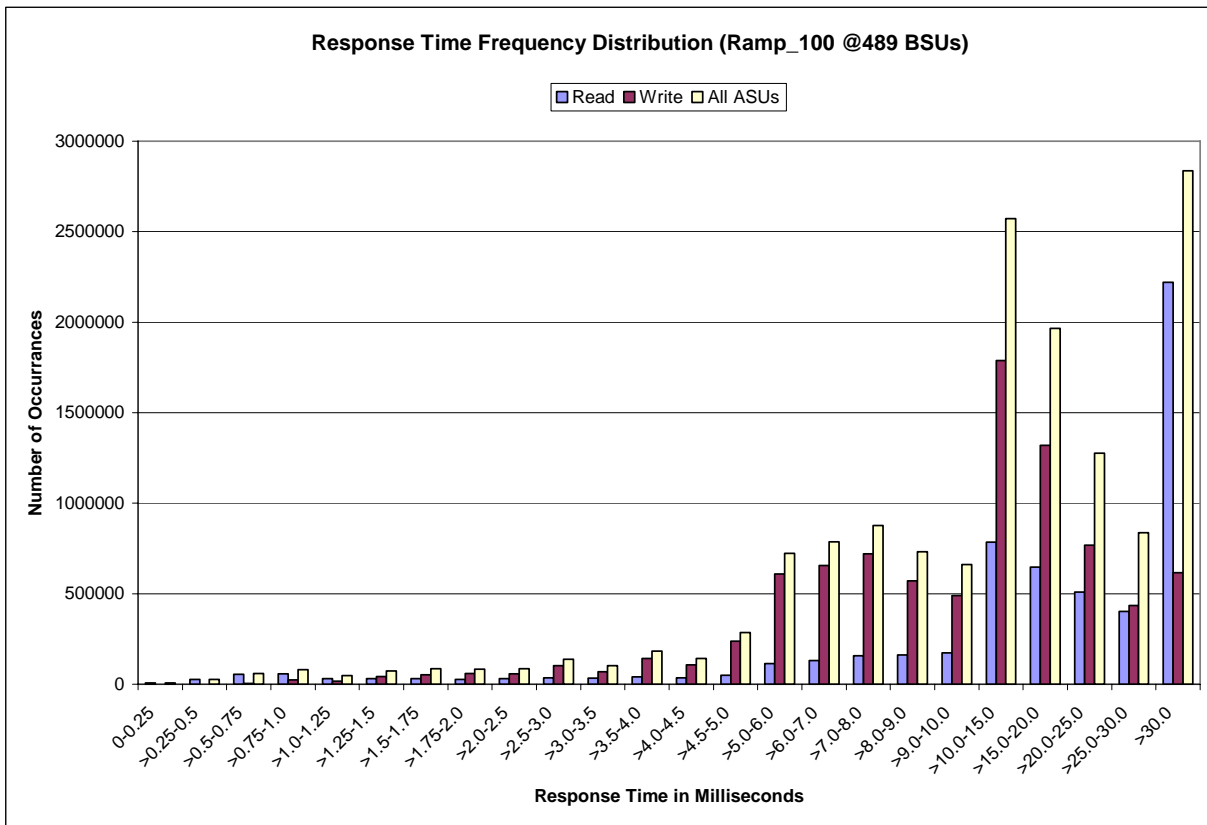
  

Response Time (ms)	>2.0-2.5	>2.5-3.0	>3.0-3.5	>3.5-4.0	>4.0-4.5	>4.5-5.0	>5.0-6.0	>6.0-7.0
Read	30,402	34,675	33,011	39,993	36,630	49,251	114,201	130,984
Write	56,190	103,205	68,598	142,618	106,213	236,752	608,185	655,797
All ASUs	86,592	137,880	101,609	182,611	142,843	286,003	722,386	786,781
ASU1	46,933	72,307	55,941	96,139	77,067	149,617	374,950	409,822
ASU2	13,376	19,170	14,959	23,742	19,157	34,864	85,720	92,228
ASU3	26,283	46,403	30,709	62,730	46,619	101,522	261,716	284,731

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	156,918	162,040	173,268	783,758	646,760	508,987	401,966	2,219,759
Write	721,092	570,789	488,581	1,788,720	1,318,343	767,152	434,215	615,517
All ASUs	878,010	732,829	661,849	2,572,478	1,965,103	1,276,139	836,181	2,835,276
ASU1	459,448	393,410	361,363	1,445,523	1,117,067	757,375	519,588	2,116,568
ASU2	101,594	85,280	76,227	293,313	219,592	144,917	96,771	396,051
ASU3	316,968	254,139	224,259	833,642	628,444	373,847	219,822	322,657

**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
14,668,990	11,833,714	2,835,276

**IOPS Test Run – Measured Intensity Multiplier and Coefficient of Variation**

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.13.2

**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
<b>IM</b>	<b>0.0350</b>	<b>0.2810</b>	<b>0.0700</b>	<b>0.2100</b>	<b>0.0180</b>	<b>0.0700</b>	<b>0.0350</b>	<b>0.2810</b>
MIM	0.0350	0.2812	0.0700	0.2098	0.0180	0.0700	0.0350	0.2810
COV	0.002	0.002	0.002	0.001	0.006	0.002	0.004	0.001

## Primary Metrics Test – Response Time Ramp Test Phase

### Clause 5.4.4.3

*The Response Time Ramp Test Phase consists of five Test Runs, one each at 95%, 90%, 80%, 50%, and 10% of the load point (100%) used to generate the SPC-1 IOPS™ primary metric. Each of the five Test Runs has a Measurement Interval of ten (10) minutes. The Response Time Ramp Test Phase immediately follows the IOPS Test Phase without any interruption or manual intervention.*

*The five Response Time Ramp Test Runs, in conjunction with the IOPS Test Run (100%), demonstrate the relationship between Average Response Time and I/O Request Throughput for the Tested Storage Configuration (TSC) as illustrated in the response time/throughput curve on page 13.*

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

### Clause 9.4.3.7.3

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

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

## SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in “Appendix E: SPC-1 Workload Generator Input Parameters” on Page 71.

## 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](#)

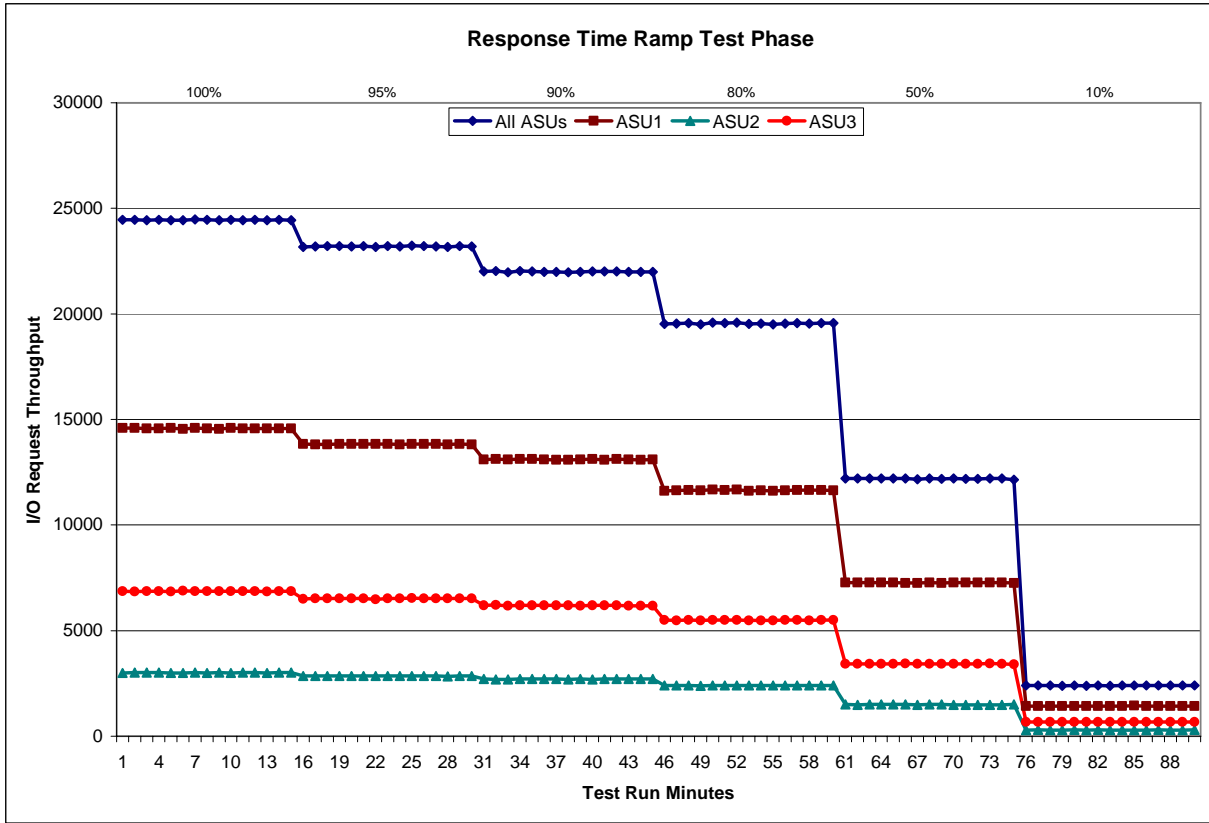
**Response Time Ramp Distribution (IOPS) Data**

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 - 489 BSUs					95% Load Level - 464 BSUs				
Start	Stop	Interval	Duration		Start	Stop	Interval	Duration	
<b>Start-Up/Ramp-Up</b>					<b>Start-Up/Ramp-Up</b>				
9:05:59 9:11:00 0-4 0:05:01					9:21:02 9:26:03 0-4 0:05:01				
<b>Measurement Interval</b>					<b>Measurement Interval</b>				
9:11:00 9:21:00 5-14 0:10:00					9:26:03 9:36:03 5-14 0:10:00				
<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	24,451.03	14,587.95	2,994.50	6,868.58	0	23,182.08	13,837.67	2,847.92	6,496.50
1	24,448.62	14,584.03	3,008.33	6,856.25	1	23,197.33	13,811.35	2,856.48	6,529.50
2	24,445.30	14,566.50	3,012.98	6,865.82	2	23,206.80	13,824.98	2,850.75	6,531.07
3	24,458.38	14,565.88	3,014.82	6,877.68	3	23,215.00	13,844.33	2,854.85	6,515.82
4	24,439.17	14,585.53	3,004.87	6,848.77	4	23,195.65	13,834.07	2,843.48	6,518.10
5	24,443.17	14,553.40	3,001.37	6,888.40	5	23,215.80	13,841.80	2,854.05	6,519.95
6	24,469.55	14,585.92	3,014.05	6,869.58	6	23,180.63	13,840.08	2,850.45	6,490.10
7	24,453.65	14,574.30	3,003.00	6,876.35	7	23,211.58	13,847.32	2,848.62	6,515.65
8	24,435.07	14,548.58	3,011.97	6,874.52	8	23,194.35	13,814.27	2,852.15	6,527.93
9	24,459.38	14,586.62	3,003.45	6,869.32	9	23,230.93	13,830.72	2,863.02	6,537.20
10	24,437.63	14,567.85	3,006.15	6,863.63	10	23,210.68	13,831.93	2,856.40	6,522.35
11	24,454.87	14,569.25	3,016.55	6,869.07	11	23,201.65	13,833.52	2,849.12	6,519.02
12	24,436.37	14,579.43	2,999.25	6,857.68	12	23,182.55	13,827.82	2,835.53	6,519.20
13	24,460.87	14,570.10	3,014.27	6,876.50	13	23,218.75	13,840.45	2,848.45	6,529.85
14	24,442.12	14,573.28	3,006.85	6,861.98	14	23,201.72	13,825.12	2,860.80	6,515.80
Average	24,449.27	14,570.87	3,007.69	6,870.70	Average	23,204.87	13,833.30	2,851.86	6,519.71
90% Load Level - 440 BSUs					80% Load Level - 391 BSUs				
Start	Stop	Interval	Duration		Start	Stop	Interval	Duration	
<b>Start-Up/Ramp-Up</b>					<b>Start-Up/Ramp-Up</b>				
9:36:05 9:41:06 0-4 0:05:01					9:51:08 9:56:09 0-4 0:05:01				
<b>Measurement Interval</b>					<b>Measurement Interval</b>				
9:41:06 9:51:06 5-14 0:10:00					9:56:09 10:06:09 5-14 0:10:00				
<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	22,010.33	13,104.28	2,716.07	6,189.98	0	19,519.20	11,625.35	2,397.83	5,496.02
1	22,038.13	13,117.17	2,699.75	6,221.22	1	19,540.32	11,638.75	2,411.55	5,490.02
2	21,969.08	13,100.25	2,698.80	6,170.03	2	19,559.57	11,651.83	2,408.17	5,499.57
3	22,030.50	13,121.78	2,703.85	6,204.87	3	19,511.58	11,641.45	2,392.20	5,477.93
4	22,007.10	13,115.35	2,701.48	6,190.27	4	19,578.65	11,673.08	2,402.90	5,502.67
5	21,990.90	13,101.92	2,703.05	6,185.93	5	19,570.73	11,661.20	2,409.70	5,499.83
6	21,996.87	13,086.50	2,717.15	6,193.22	6	19,585.33	11,673.98	2,411.88	5,499.47
7	21,976.48	13,087.37	2,696.75	6,192.37	7	19,517.45	11,621.75	2,405.03	5,490.67
8	21,986.63	13,109.68	2,704.67	6,172.28	8	19,544.93	11,647.32	2,407.13	5,490.48
9	22,013.48	13,124.32	2,696.65	6,192.52	9	19,496.93	11,614.95	2,399.12	5,482.87
10	22,005.50	13,092.07	2,708.92	6,204.52	10	19,547.30	11,638.98	2,415.03	5,493.28
11	22,019.10	13,124.23	2,705.23	6,189.63	11	19,555.73	11,649.02	2,403.82	5,502.90
12	21,999.67	13,105.88	2,711.78	6,182.00	12	19,546.15	11,659.82	2,396.17	5,490.17
13	21,981.40	13,092.03	2,707.70	6,181.67	13	19,569.73	11,658.85	2,411.40	5,499.48
14	21,991.30	13,109.00	2,710.72	6,171.58	14	19,561.87	11,646.25	2,412.95	5,502.67
Average	21,996.13	13,103.30	2,706.26	6,186.57	Average	19,549.62	11,647.21	2,407.22	5,495.18
50% Load Level - 244 BSUs					10% Load Level - 48 BSUs				
Start	Stop	Interval	Duration		Start	Stop	Interval	Duration	
<b>Start-Up/Ramp-Up</b>					<b>Start-Up/Ramp-Up</b>				
10:06:11 10:11:12 0-4 0:05:01					10:21:14 10:26:15 0-4 0:05:01				
<b>Measurement Interval</b>					<b>Measurement Interval</b>				
10:11:12 10:21:12 5-14 0:10:00					10:26:15 10:36:15 5-14 0:10:00				
<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	12,197.82	7,277.32	1,503.45	3,417.05	0	2,395.70	1,427.45	294.82	673.43
1	12,198.38	7,272.58	1,493.58	3,432.22	1	2,409.05	1,434.22	297.02	677.82
2	12,207.58	7,283.88	1,502.57	3,421.13	2	2,403.20	1,430.48	294.28	678.43
3	12,205.88	7,280.50	1,505.05	3,420.33	3	2,391.88	1,427.97	293.87	670.05
4	12,198.12	7,267.22	1,500.73	3,430.17	4	2,402.00	1,434.03	297.47	670.50
5	12,197.80	7,260.77	1,502.45	3,434.58	5	2,394.53	1,425.22	291.97	677.35
6	12,175.92	7,261.40	1,495.98	3,418.53	6	2,399.60	1,431.55	296.27	671.78
7	12,209.07	7,276.23	1,500.33	3,432.50	7	2,392.42	1,422.05	294.70	675.67
8	12,188.42	7,259.95	1,500.03	3,428.43	8	2,403.60	1,435.88	294.75	672.97
9	12,206.55	7,278.15	1,497.70	3,430.70	9	2,412.63	1,437.67	295.45	679.52
10	12,192.55	7,271.12	1,494.47	3,426.97	10	2,407.25	1,431.53	295.25	680.47
11	12,190.75	7,266.40	1,496.65	3,427.70	11	2,396.35	1,427.23	296.28	672.83
12	12,205.15	7,273.12	1,497.25	3,434.78	12	2,402.43	1,435.57	292.83	674.03
13	12,212.25	7,285.57	1,494.03	3,432.65	13	2,400.92	1,432.55	292.55	675.82
14	12,149.25	7,250.83	1,503.33	3,395.08	14	2,401.78	1,432.72	300.60	668.47
Average	12,192.77	7,268.35	1,498.22	3,426.19	Average	2,401.15	1,431.20	295.07	674.89



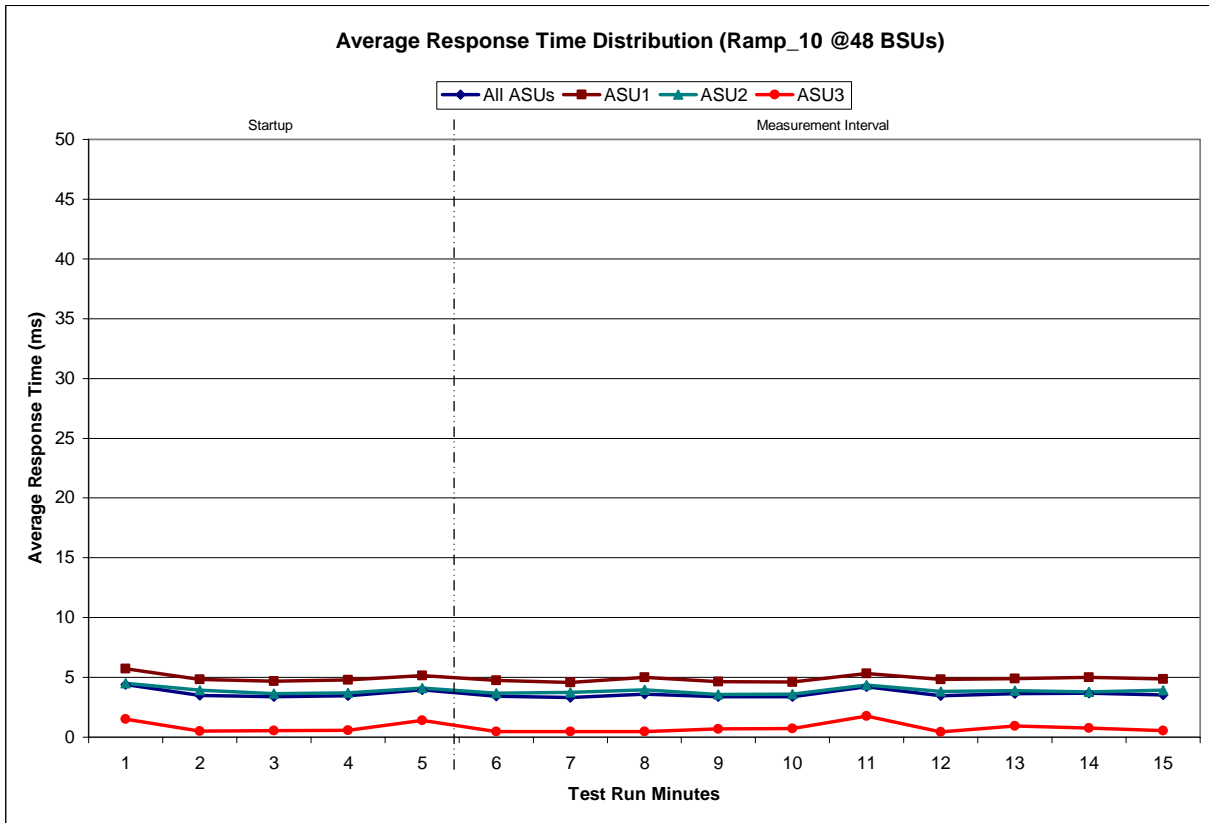
### Response Time Ramp Distribution (IOPS) Graph



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

48 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	10:21:14	10:26:15	0-4	0:05:01
<i>Measurement Interval</i>	10:26:15	10:36:15	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	4.39	5.72	4.49	1.51
1	3.49	4.82	3.91	0.50
2	3.38	4.67	3.64	0.55
3	3.47	4.78	3.72	0.57
4	3.97	5.14	4.12	1.41
5	3.42	4.77	3.67	0.47
6	3.32	4.57	3.74	0.48
7	3.59	5.00	3.96	0.47
8	3.40	4.64	3.56	0.68
9	3.38	4.61	3.59	0.71
10	4.21	5.34	4.35	1.76
11	3.46	4.81	3.82	0.45
12	3.65	4.88	3.90	0.92
13	3.66	5.01	3.76	0.75
14	3.53	4.85	3.91	0.53
<i>Average</i>	<i>3.56</i>	<i>4.85</i>	<i>3.82</i>	<i>0.72</i>

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



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

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.13.2

**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	0.0353	0.2809	0.0702	0.2096	0.0181	0.0698	0.0350	0.2811
COV	0.011	0.004	0.006	0.004	0.016	0.009	0.015	0.005

## 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% or less than the SPC-1 LRT™ metric plus one (1) millisecond (ms).*

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

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

### Clause 9.4.3.7.4

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

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

## SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in “Appendix E: SPC-1 Workload Generator Input Parameters” on Page 71.

**Repeatability Test Results File**

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

	SPC-1 IOPS™
<i>Primary Metrics</i>	<b>24,449.27</b>
Repeatability Test Phase 1	24,450.60
Repeatability Test Phase 2	24,448.47

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.

	SPC-1 LRT™
<i>Primary Metrics</i>	<b>3.56 ms</b>
Repeatability Test Phase 1	3.43 ms
Repeatability Test Phase 2	3.43 ms

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

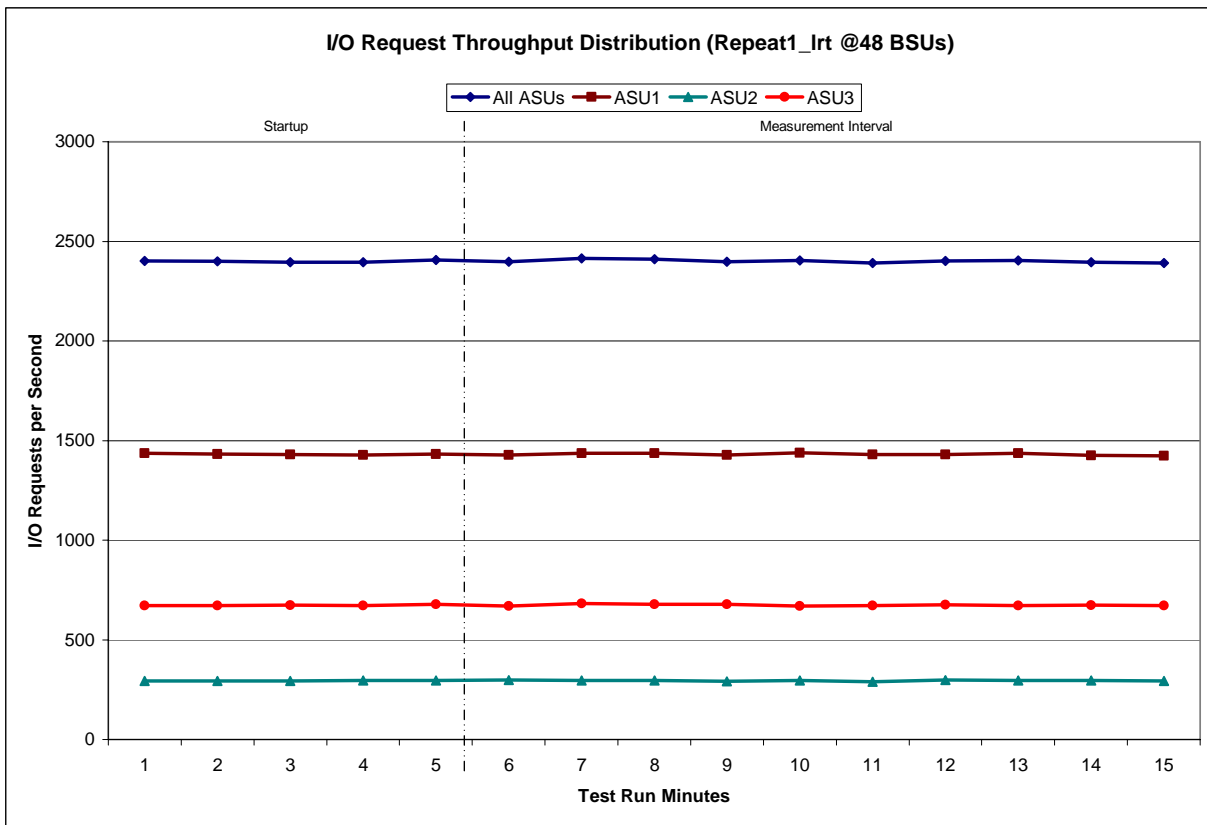
A link to the test result file generated from each Repeatability Test Run is listed below.

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

**Repeatability 1 LRT - I/O Request Throughput Distribution Data**

48 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	10:36:19	10:41:19	0-4	0:05:00
<i>Measurement Interval</i>	10:41:19	10:51:19	3-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	2,400.98	1,435.65	294.08	671.25
1	2,399.73	1,432.27	294.72	672.75
2	2,394.72	1,428.78	292.72	673.22
3	2,395.18	1,426.85	296.95	671.38
4	2,405.65	1,431.53	296.60	677.52
5	2,396.63	1,428.28	298.47	669.88
6	2,413.77	1,436.77	295.10	681.90
7	2,411.20	1,435.93	296.90	678.37
8	2,398.32	1,428.70	291.53	678.08
9	2,404.53	1,438.00	296.18	670.35
10	2,391.57	1,430.15	290.05	671.37
11	2,402.72	1,429.63	297.85	675.23
12	2,403.17	1,435.87	295.42	671.88
13	2,395.82	1,424.43	296.73	674.65
14	2,389.90	1,423.47	294.13	672.30
<b>Average</b>	<b>2,400.76</b>	<b>1,431.12</b>	<b>295.24</b>	<b>674.40</b>

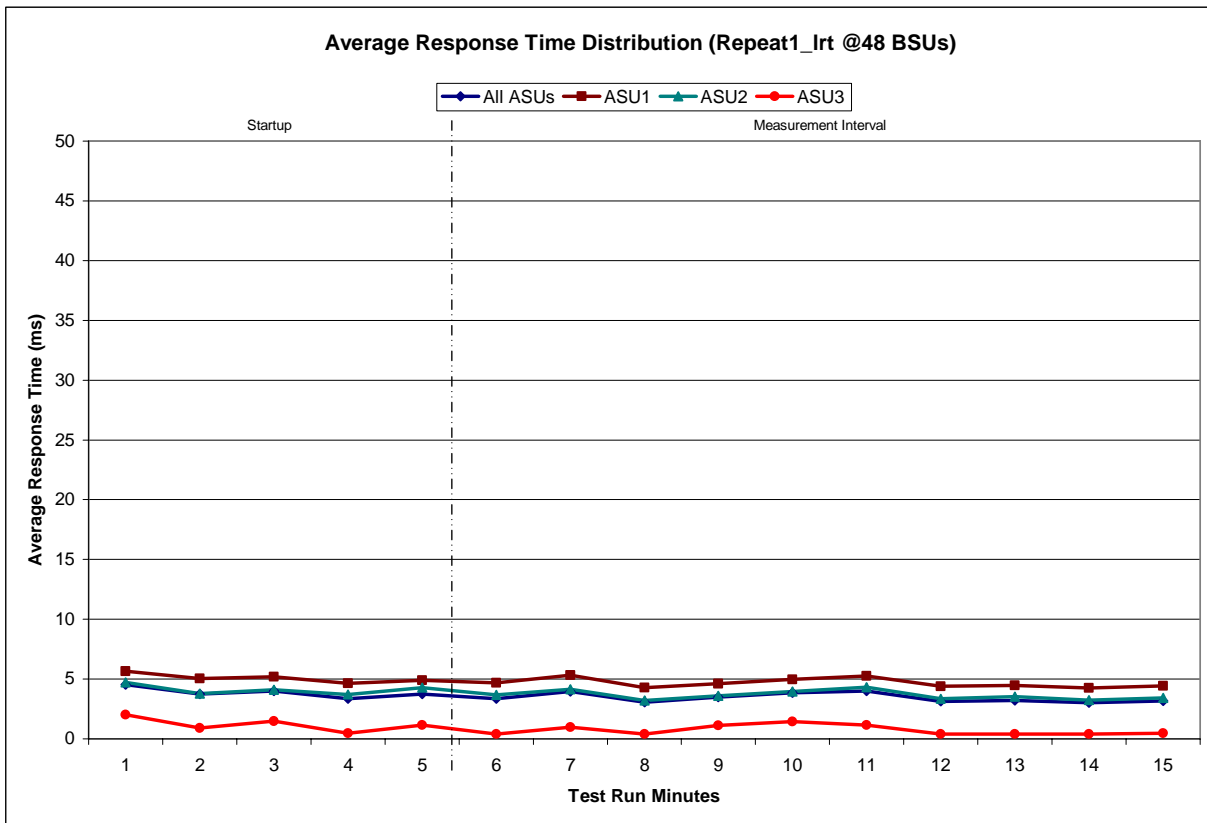
**Repeatability 1 LRT - I/O Request Throughput Distribution Graph**



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

48 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	10:36:19	10:41:19	0-4	0:05:00
<i>Measurement Interval</i>	10:41:19	10:51:19	3-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	4.52	5.65	4.71	2.02
1	3.74	5.06	3.77	0.92
2	4.00	5.17	4.12	1.47
3	3.35	4.63	3.71	0.48
4	3.76	4.88	4.30	1.15
5	3.35	4.67	3.68	0.39
6	3.95	5.33	4.15	0.97
7	3.06	4.29	3.19	0.39
8	3.51	4.62	3.60	1.13
9	3.87	4.97	3.97	1.45
10	4.00	5.26	4.33	1.17
11	3.13	4.38	3.36	0.38
12	3.21	4.46	3.51	0.41
13	3.03	4.23	3.24	0.40
14	3.18	4.42	3.43	0.45
<b>Average</b>	<b>3.43</b>	<b>4.66</b>	<b>3.65</b>	<b>0.71</b>

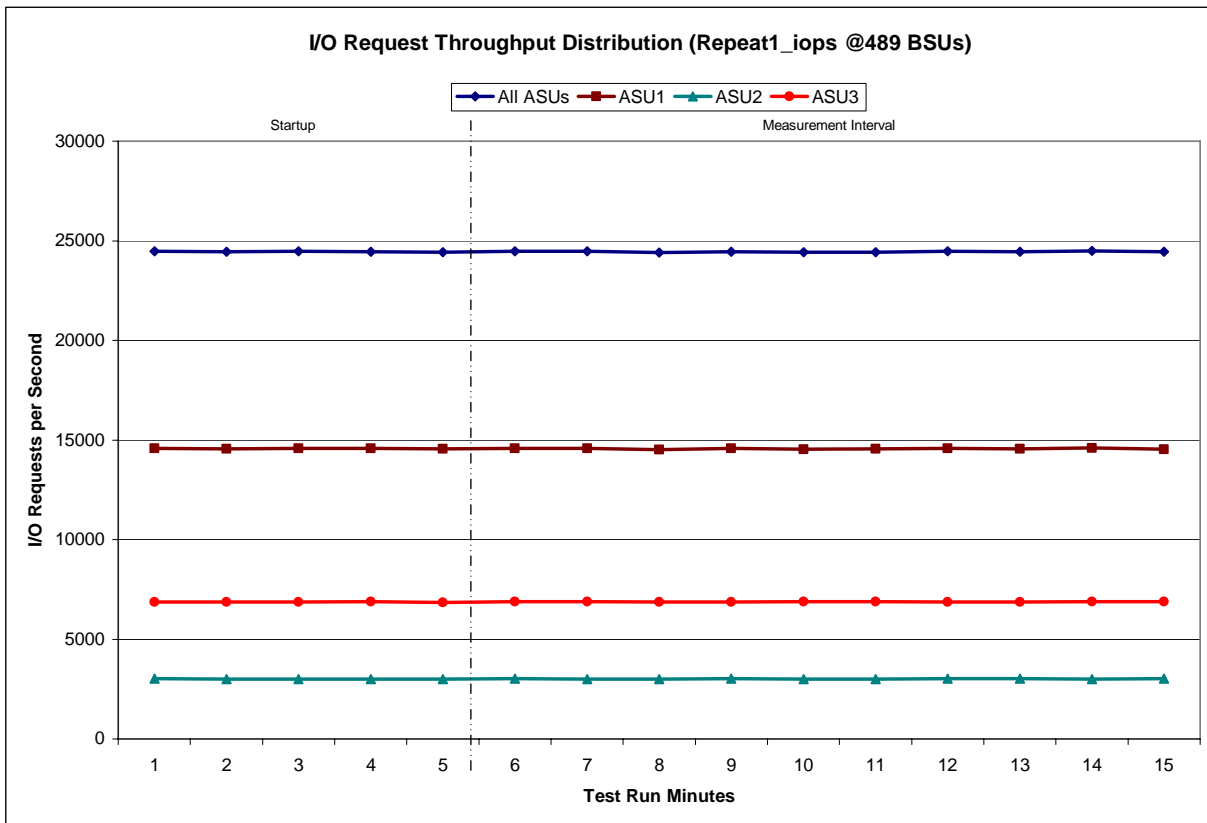
**Repeatability 1 LRT –Average Response Time (ms) Distribution Graph**



**Repeatability 1 IOPS - I/O Request Throughput Distribution Data**

489 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	10:51:21	10:56:22	0-4	0:05:01
<i>Measurement Interval</i>	10:56:22	11:06:22	3-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	24,475.42	14,589.43	3,020.73	6,865.25
1	24,438.77	14,561.88	3,003.90	6,872.98
2	24,473.07	14,585.37	3,009.68	6,878.02
3	24,459.55	14,574.80	2,999.73	6,885.02
4	24,422.42	14,559.00	3,010.13	6,853.28
5	24,476.60	14,573.45	3,017.85	6,885.30
6	24,476.27	14,569.18	3,012.47	6,894.62
7	24,397.18	14,523.70	2,998.38	6,875.10
8	24,452.48	14,569.10	3,019.33	6,864.05
9	24,423.67	14,540.72	3,003.78	6,879.17
10	24,436.15	14,547.42	3,006.47	6,882.27
11	24,466.52	14,576.13	3,018.07	6,872.32
12	24,447.72	14,562.32	3,014.60	6,870.80
13	24,485.30	14,589.88	3,009.90	6,885.52
14	24,444.13	14,544.55	3,020.03	6,879.55
<b>Average</b>	<b>24,450.60</b>	<b>14,559.65</b>	<b>3,012.09</b>	<b>6,878.87</b>

**Repeatability 1 IOPS - I/O Request Throughput Distribution Graph**

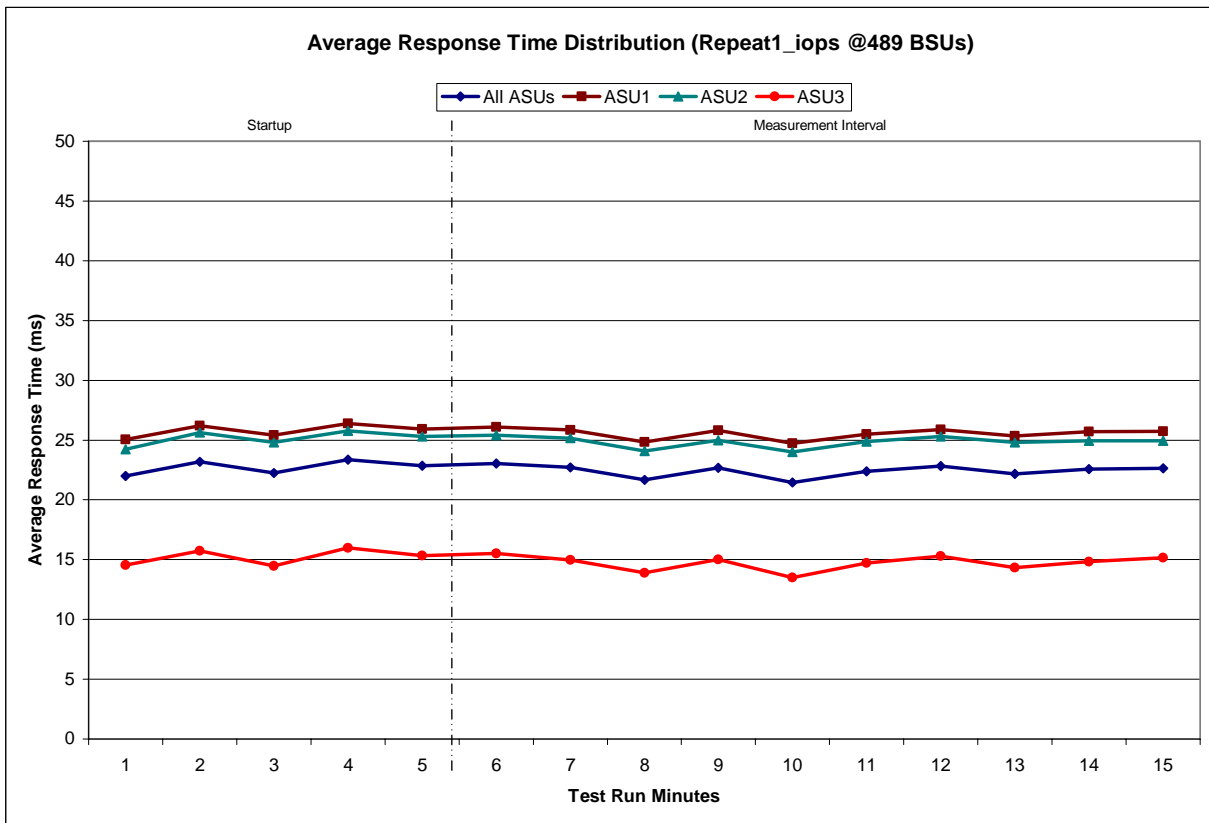




**Repeatability 1 IOPS –Average Response Time (ms) Distribution Data**

489 BSUs Start-Up/Ramp-Up Measurement Interval	Start 10:51:21	Stop 10:56:22	Interval 0-4	Duration 0:05:01
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	22.01	25.06	24.24	14.53
1	23.18	26.19	25.62	15.73
2	22.25	25.40	24.80	14.46
3	23.37	26.37	25.77	15.98
4	22.87	25.92	25.29	15.33
5	23.04	26.10	25.41	15.53
6	22.70	25.86	25.16	14.96
7	21.65	24.83	24.10	13.88
8	22.67	25.80	24.99	15.01
9	21.47	24.71	24.02	13.51
10	22.38	25.48	24.88	14.74
11	22.84	25.88	25.30	15.30
12	22.17	25.33	24.79	14.32
13	22.56	25.71	24.96	14.82
14	22.65	25.73	24.96	15.14
<b>Average</b>	<b>22.41</b>	<b>25.54</b>	<b>24.86</b>	<b>14.72</b>

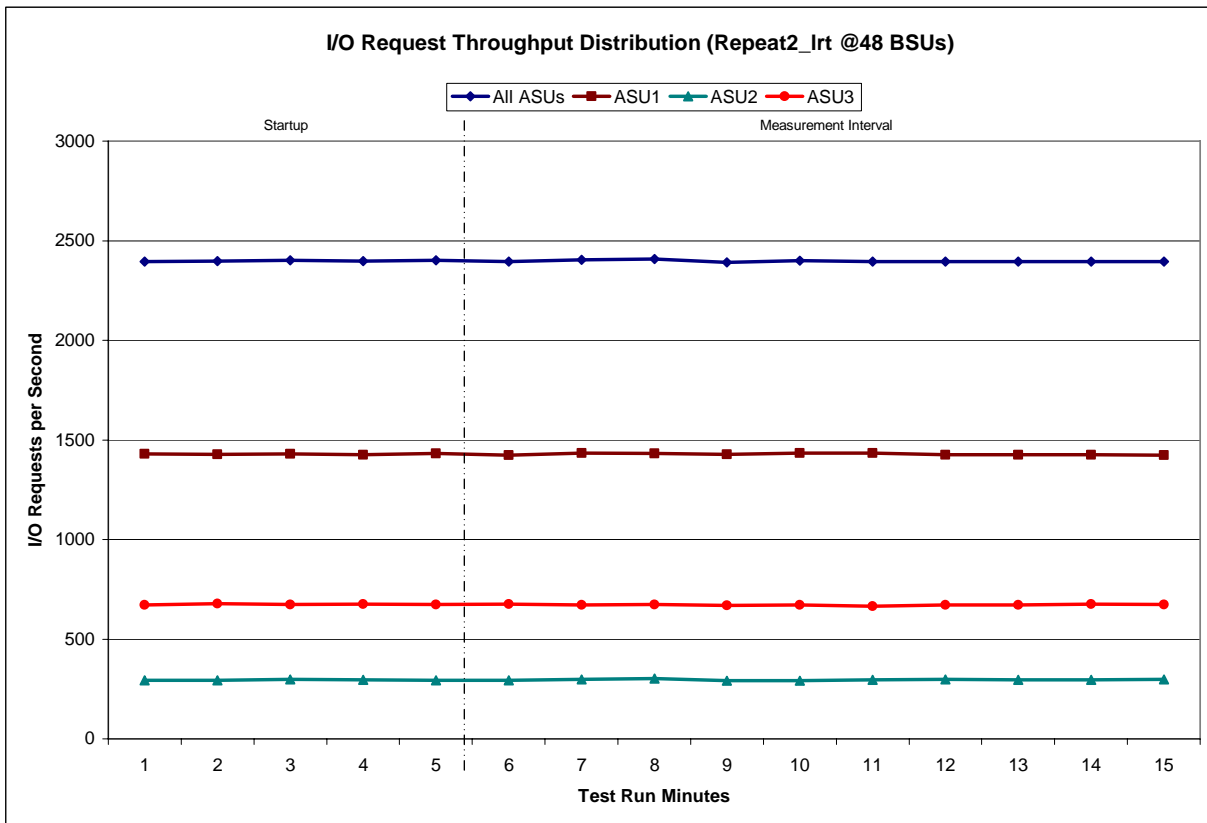
**Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph**



**Repeatability 2 LRT - I/O Request Throughput Distribution Data**

48 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	11:06:26	11:11:26	0-4	0:05:00
<i>Measurement Interval</i>	11:11:26	11:21:26	3-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	2,394.72	1,429.68	293.33	671.70
1	2,397.68	1,426.83	293.45	677.40
2	2,400.98	1,429.15	298.12	673.72
3	2,397.48	1,424.65	296.17	676.67
4	2,400.85	1,432.52	294.08	674.25
5	2,395.07	1,423.58	294.77	676.72
6	2,404.25	1,434.73	297.35	672.17
7	2,408.23	1,432.33	301.57	674.33
8	2,390.92	1,428.58	291.83	670.50
9	2,398.52	1,435.08	292.62	670.82
10	2,396.02	1,434.73	295.98	665.30
11	2,395.00	1,426.02	297.45	671.53
12	2,394.67	1,425.83	296.08	672.75
13	2,395.43	1,424.48	295.55	675.40
14	2,394.95	1,422.62	298.35	673.98
<b>Average</b>	<b>2,397.31</b>	<b>1,428.80</b>	<b>296.16</b>	<b>672.35</b>

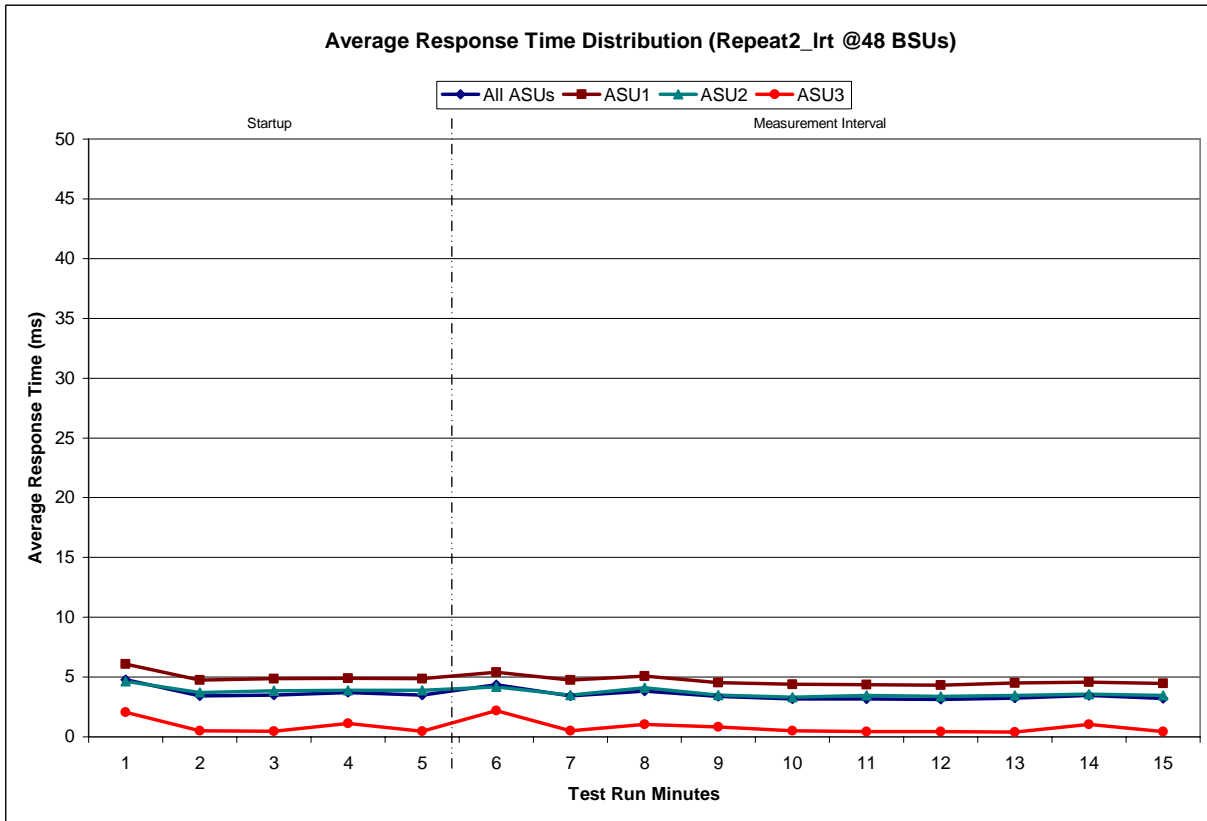
**Repeatability 2 LRT - I/O Request Throughput Distribution Graph**



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

48 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	11:06:26	11:11:26	0-4	0:05:00
Measurement Interval	11:11:26	11:21:26	3-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	4.77	6.08	4.66	2.04
1	3.43	4.76	3.71	0.50
2	3.51	4.86	3.86	0.48
3	3.71	4.90	3.89	1.12
4	3.51	4.86	3.90	0.47
5	4.35	5.41	4.19	2.21
6	3.41	4.75	3.51	0.50
7	3.83	5.08	4.12	1.04
8	3.38	4.55	3.50	0.85
9	3.18	4.40	3.30	0.50
10	3.16	4.36	3.46	0.44
11	3.12	4.34	3.38	0.43
12	3.22	4.50	3.46	0.41
13	3.46	4.59	3.58	1.04
14	3.20	4.45	3.46	0.42
<b>Average</b>	<b>3.43</b>	<b>4.64</b>	<b>3.60</b>	<b>0.78</b>

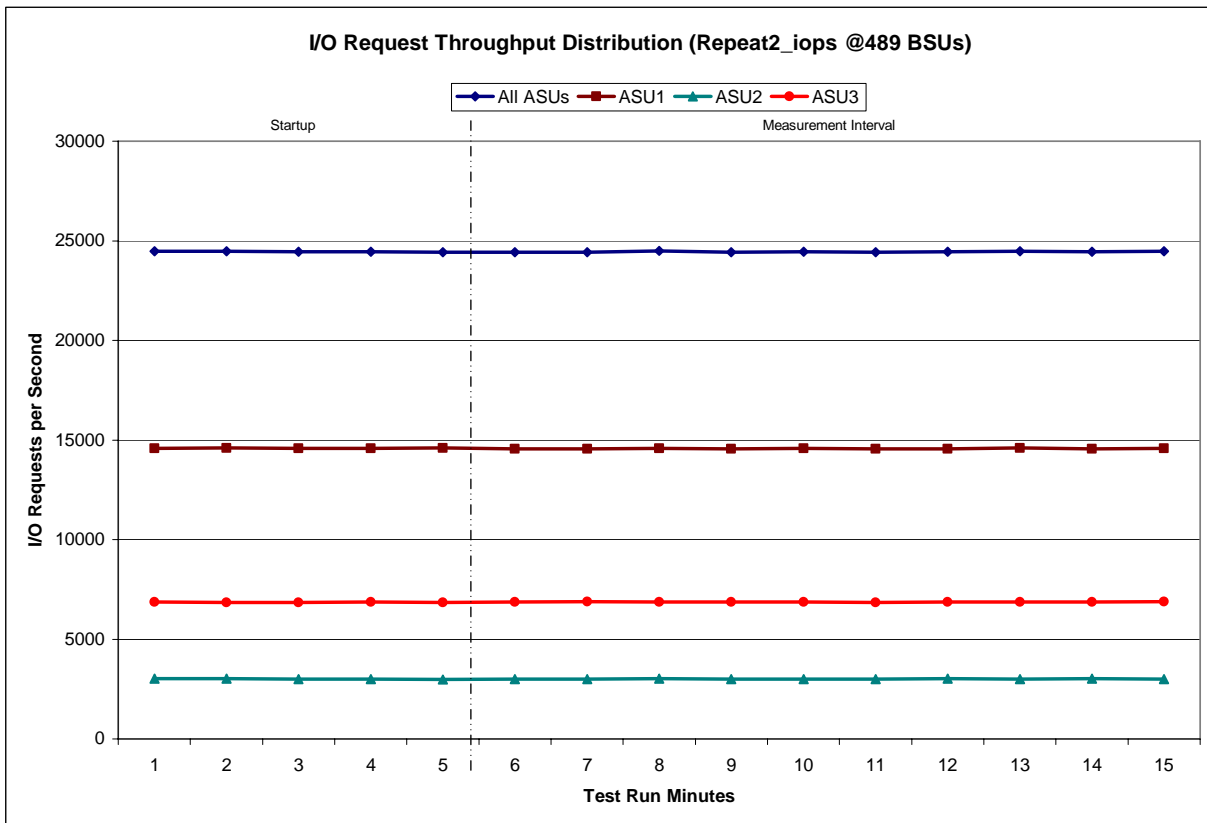
**Repeatability 2 LRT –Average Response Time (ms) Distribution Graph**



**Repeatability 2 IOPS - I/O Request Throughput Distribution Data**

489 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	11:21:28	11:26:29	0-4	0:05:01
<i>Measurement Interval</i>	11:26:29	11:36:29	3-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	24,462.25	14,576.93	3,014.85	6,870.47
1	24,464.15	14,593.95	3,017.17	6,853.03
2	24,446.13	14,580.77	3,010.77	6,854.60
3	24,450.83	14,575.67	2,998.58	6,876.58
4	24,435.18	14,591.37	2,988.70	6,855.12
5	24,431.15	14,561.72	3,000.17	6,869.27
6	24,436.28	14,550.22	3,006.22	6,879.85
7	24,483.02	14,582.72	3,027.35	6,872.95
8	24,426.70	14,563.80	2,994.27	6,868.63
9	24,445.52	14,571.63	3,007.00	6,866.88
10	24,425.47	14,564.03	3,008.27	6,853.17
11	24,440.33	14,562.98	3,013.77	6,863.58
12	24,478.72	14,591.17	3,008.70	6,878.85
13	24,449.63	14,552.22	3,027.75	6,869.67
14	24,467.92	14,581.65	3,006.07	6,880.20
<b>Average</b>	<b>24,448.47</b>	<b>14,568.21</b>	<b>3,009.96</b>	<b>6,870.31</b>

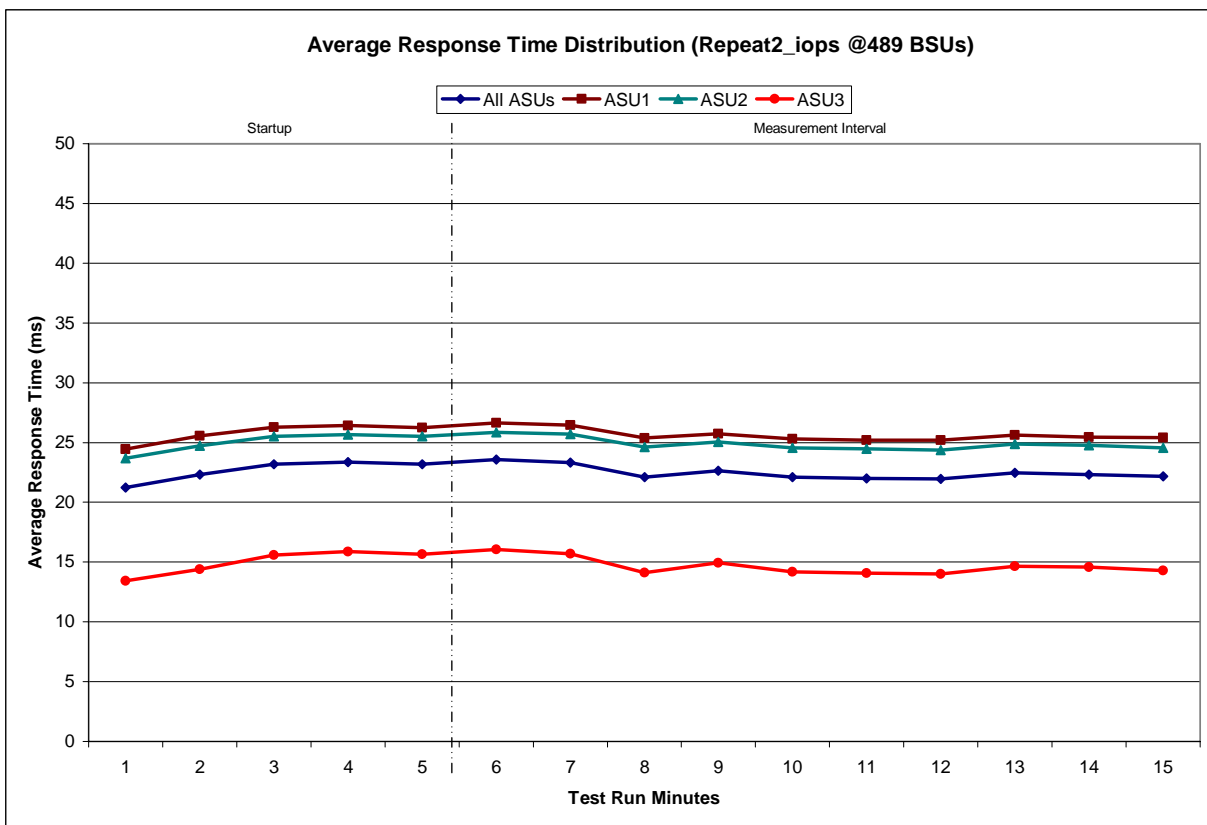
**Repeatability 2 IOPS - I/O Request Throughput Distribution Graph**



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

489 BSUs Start-Up/Ramp-Up Measurement Interval	Start	Stop	Interval	Duration
	11:21:28	11:26:29	0-4	0:05:01
	11:26:29	11:36:29	3-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	21.25	24.44	23.68	13.43
1	22.32	25.55	24.75	14.39
2	23.18	26.27	25.53	15.59
3	23.36	26.41	25.68	15.88
4	23.19	26.24	25.53	15.67
5	23.56	26.63	25.83	16.06
6	23.33	26.45	25.71	15.68
7	22.12	25.38	24.62	14.10
8	22.63	25.75	25.04	14.94
9	22.09	25.31	24.55	14.18
10	22.00	25.21	24.49	14.08
11	21.96	25.21	24.36	14.01
12	22.46	25.63	24.86	14.67
13	22.30	25.44	24.78	14.57
14	22.17	25.40	24.56	14.28
<b>Average</b>	<b>22.46</b>	<b>25.64</b>	<b>24.88</b>	<b>14.66</b>

**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 5.1.10 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
<b>IM</b>	<b>0.0350</b>	<b>0.2810</b>	<b>0.0700</b>	<b>0.2100</b>	<b>0.0180</b>	<b>0.0700</b>	<b>0.0350</b>	<b>0.2810</b>
MIM	0.0350	0.2813	0.0698	0.2101	0.0179	0.0702	0.0349	0.2809
COV	0.020	0.003	0.005	0.003	0.025	0.010	0.015	0.005

**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
<b>IM</b>	<b>0.0350</b>	<b>0.2810</b>	<b>0.0700</b>	<b>0.2100</b>	<b>0.0180</b>	<b>0.0700</b>	<b>0.0350</b>	<b>0.2810</b>
MIM	0.0350	0.2807	0.0699	0.2098	0.0181	0.0701	0.0350	0.2813
COV	0.005	0.001	0.002	0.001	0.007	0.002	0.004	0.001

**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
<b>IM</b>	<b>0.0350</b>	<b>0.2810</b>	<b>0.0700</b>	<b>0.2100</b>	<b>0.0180</b>	<b>0.0700</b>	<b>0.0350</b>	<b>0.2810</b>
MIM	0.0349	0.2808	0.0700	0.2102	0.0180	0.0703	0.0351	0.2805
COV	0.017	0.004	0.008	0.005	0.012	0.010	0.018	0.005

**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	0.2811	0.0700	0.2098	0.0180	0.0701	0.0350	0.2810
COV	0.003	0.002	0.003	0.002	0.005	0.004	0.005	0.001

## Data Persistence Test

### Clause 6

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

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

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

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

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

### Clause 9.4.3.8

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

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

## 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 71.

## 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

<b>Data Persistence Test Results</b>	
Data Persistence Test Run Number: 1	
Total Number of Logical Blocks Written	58,471,008
Total Number of Logical Blocks Verified	51,708,608
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 for the Priced Storage Configuration must be the date at which all components are committed to be available.*

The IBM System Storage® DS3524 Express Turbo as documented in this Full Disclosure Report is currently available for customer purchase and shipment.

## **PRICING INFORMATION**

### *Clause 9.4.3.3.6*

*The Executive Summary shall contain a pricing spreadsheet as documented in Clause 8.3.1.*

Pricing information may found in the Priced Storage Configuration Pricing section on page 14.

## **TESTED STORAGE CONFIGURATION (TSC) AND PRICED STORAGE CONFIGURATION DIFFERENCES**

### *Clause 9.4.3.3.7*

*The Executive Summary shall contain a pricing a list of all differenced between the Tested Storage Configuration (TSC) and the Priced Storage Configuration.*

A list of all differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration may be found in the Executive Summary portion of this document on page 14.

## **ANOMALIES OR IRREGULARITIES**

### *Clause 9.4.3.10*

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

There were no anomalies or irregularities encountered during the SPC-1 Remote Audit of the IBM System Storage® DS3524 Express Turbo .

## **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**

**Protected:** This level will ensure data protection in the event of a single point of failure of any configured storage device. A brief description of the data protection utilized is included in the Executive Summary.

**Unprotected:** No claim of data protection is asserted in the event of a single point of failure.

## **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.

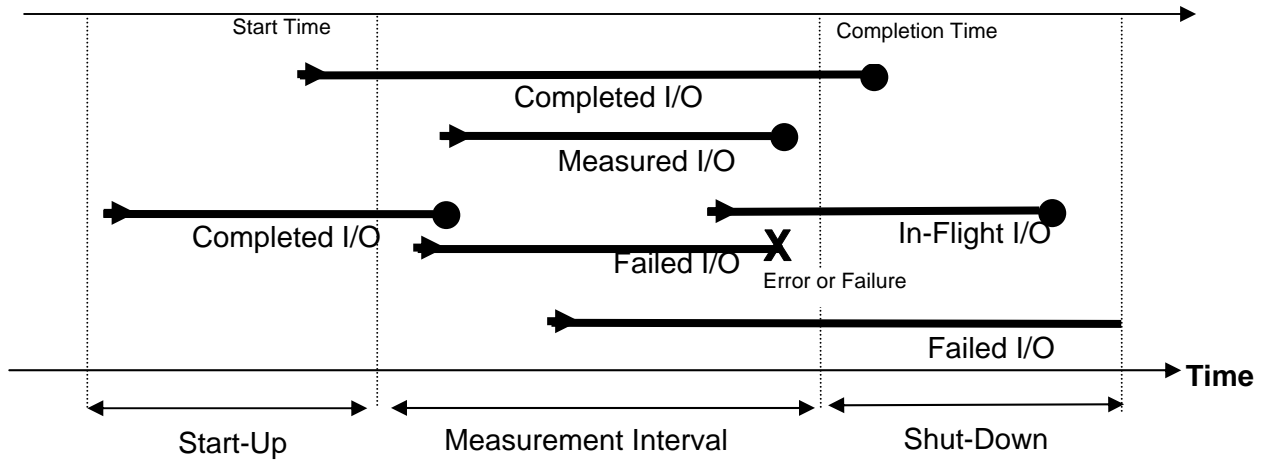
**Test:** A collection of Test Phases and or Test Runs sharing a common objective.

**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

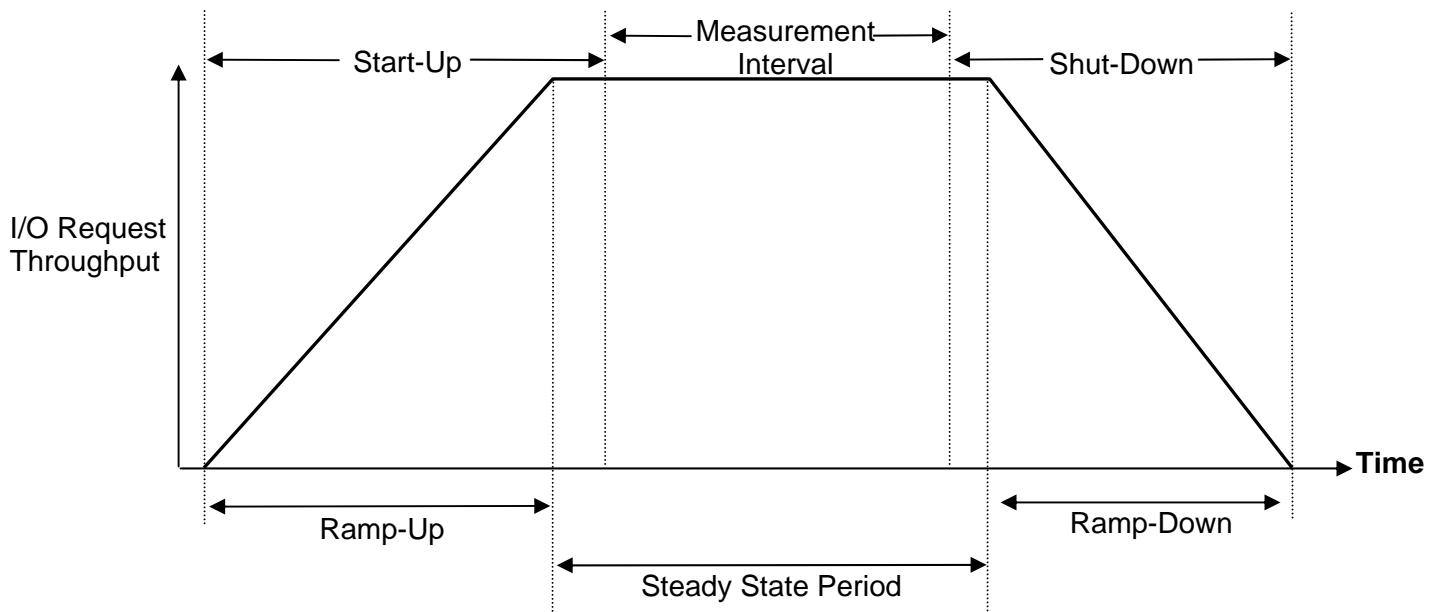
period, Shut-Down period, and Ramp-Down period as illustrated in the “SPC-1 Test Run Components” below. All SPC-1 Test Runs shall have a Steady State period and a Measurement Interval.

**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**

### **Windows Server 2003 Registry Changes**

Registry Parameter	Name	Type	Default Value	New Value
\HKEY_LOCAL_MACHINE\CurrentControlSe t\Services\Lsi_sas2\Parameters\Device	DriverParameter	REG_SZ	32	MaximumTargetQue ueDepth=254;
\HKEY_LOCAL_MACHINE\CurrentControlSe t\Services\Disk	TimeOutValue	REG_DWORD	0x3C	0xa0

**MaximumTargetQueueDepth** - Change the SAS HBA driver maximum queue depth per device from 32 to 254.

**TimeOutValue** - Change the time that Windows will wait for a response to an IO command from 60 to 160 seconds.

### **LSI HBA BIOS Modifications**

Configurable via lsiutil utility (*option 10 – Change IOC settings (interrupt coalescing)*):

#### **Disable Interrupt Coalescing**

**Interrupt Coalescing** - Disable the HBA feature to send multiple messages to the host processor during a single interrupt.

Configurable via lsiutil utility (*option 13 – Change SAS IO Unit settings*):

Driver Parameter	Default Value	New Value
SAS Max Queue Depth, Narrow	0	65535
SAS Max Queue Depth, Wide	0	65535
Device Missing Report Delay	0	144
Device Missing I/O Delay	0	8

**SAS Max Queue Depth, Narrow** - Change the queue depth allowed for IO's to each narrow SAS device from 0 (device maximum) to 255.

**SAS Max Queue Depth, Wide** - Change the queue depth allowed for IO's to each wide SAS device from 0 (device maximum) to 255.

**Device Missing Report Delay** - Change the number of seconds that the HBA will delay reporting a target or expander as missing after it becomes unavailable from 10 to 144 seconds.

**Device Missing I/O Delay** - Change the number of seconds the HBA will delay replying to SCSI initiator messages when the addressed device is missing due to the inability to access the target device from 5 to 8 seconds.

## **APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION**

Before creating volumes on the storage array, please refer to Appendix B (*page 63*) for a listing of the required Windows Server 2003 registry and HBA BIOS modifications.

### **Storage Array Volume Creation**

The storage management utility, **SANtricity**, was used to create 2 volume groups on the storage subsystem. Each volume group contains 4 RAID1 (mirrored) volumes. All eight RAID1 volumes are visible by the attached host.

The physical storage volumes are created on the storage array using the SANtricity Storage Manger script editor. Launch SANtricity Storage Manager. From the Enterprise Management window, right-click the name of the storage array that you will be creating volumes on and select **Execute Script** from the pop-up menu. In the Script Editor window load the **SPC1\_96drive\_HIC\_turbo.cfg** script (*listed below*). Once the script is loaded, select **Execute** from the Tools menu. The **SPC1\_96drive\_HIC\_turbo.cfg** script appears at the end of the appendix.

### **SPC-1 Logical Volume Creation**

The steps that follow are required to define the Windows partitions, volumes, and stripe sets that will be used by the SPC-1 benchmark and are executed on the host.

1. Use `diskpar.exe` to set the starting offset for each of the storage system volumes. Starting offset is 65536. Use all of the remaining capacity in the partition.
2. Start the Disk Management utility under Computer Management.
3. Convert all of the storage system volumes to Dynamic Disks.
4. Create a Windows Striped (RAID 0) volume using all eight 32MB partitions.
5. Delete the remaining large volume on each of the Dynamic Disks.
6. Create a Windows Striped (RAID 0) volume for ASU 3.
  - a. Select all eight volumes.
  - b. Set capacity to 159894 MB.
  - c. Assign drive letter "N" to the volume. Do not format the volume.
7. Create a Windows Striped (RAID 0) volume for ASU 1.
  - a. Select all eight volumes.
  - b. Set capacity to 719523 MB.
  - c. Assign drive letter "L" to the volume. Do not format the volume.
8. Create a Windows Striped (RAID 0) volume for ASU 2.
  - a. Select all eight volumes.
  - b. Set capacity to 719523 MB.
  - c. Assign drive letter "M" to the volume. Do not format the volume.
9. Reboot the Host System.



## SPC1\_96drive\_HIC\_turbo.cfg

Using the SANtricity scripting utility and the following SMCLI script, configure the array as defined:

```
// Logical configuration information from Storage Array bmsmclab.
// Firmware package version for Storage Array bmsmclab = 07.70.16.00
// NVSRAM package version for Storage Array bmsmclab = N26X0-770834-407

//on error stop;

// Uncomment the two lines below to delete the existing configuration.
show "Deleting the existing configuration.";
clear storageArray configuration;

// Storage Array global logical configuration script commands
show "Setting the Storage Array user label to bmsmclab.";
set storageArray userLabel="bmsmclab";

show "Setting the Storage Array media scan rate to disabled.";
set storageArray mediaScanRate=disabled;

// Uncomment the three lines below to remove the default volume (if exists). NOTE:
Default volume name is always = "Unnamed".
//on error continue;
show "Deleting the default volume created during the removal of the existing
configuration.";
delete volume["Unnamed"] removeVolumeGroup=true;
on error stop;

// Copies the hot spare settings
// NOTE: These statements are wrapped in on-error continue and on-error stop
statements to
// account for minor differences in capacity from the drive of the Storage Array on
which the
// configuration was saved to that of the drives on which the configuration will be
copied.
show "Setting the Storage Array cache block size to 16.";
set storageArray cacheBlockSize=16;

show "Setting the Storage Array to begin cache flush at 80% full.";
set storageArray cacheFlushStart=80;

show "Setting the Storage Array to end cache flush at 80% full.";
set storageArray cacheFlushStop=80;

// Creating Host Topology
show "Creating Host BM3650W with Host Type Index 1.";
// This Host Type Index corresponds to Type Windows 2000/Server 2003/Server 2008
Non-Clustered
create host userLabel="BM3650W" hostType=1;

show "Creating Host Port BM3650WP0 on Host BM3650W with WWN 500605b0006c18d0 and
with interfaceType SAS.";
create hostPort host="BM3650W" userLabel="BM3650WP0" identifier="500605b0006c18d0"
interfaceType=SAS;

show "Creating Host Port BM3650WP1 on Host BM3650W with WWN 500605b0006c1920 and
with interfaceType SAS.";
```

```
create hostPort host="BM3650W" userLabel="BM3650WP1" identifier="500605b0006c1920"
interfaceType=SAS;

show "Creating RAID 1 Volume "LUN_0"0001 on new Volume Group g0001.";
//This command creates volume group <g0001> and the initial volume <"LUN_0"0001>
with offset 0 on the volume group.
// NOTE: For Volume Groups that use all available capacity, the last Volume on this
group is
// created using all remaining capacity by omitting the capacity= volume creation
parameter.
create volume drives=(0,1 0,2 0,3 0,4 0,5 0,6 0,7 0,8 0,9 0,10 0,11 0,12 1,1 1,2 1,3
1,4 1,5 1,6 1,7 1,8 1,9 1,10 1,11 1,12 2,1 2,2 2,3 2,4 2,5 2,6 2,7 2,8 2,9 2,10 2,11
2,12 3,1 3,2 3,3 3,4 3,5 3,6 3,7 3,8 3,9 3,10 3,11 3,12) raidLevel=1
userLabel="LUN_0"0001" volumeGroupUserLabel="g0001" owner=A segmentSize=128
capacity=1796738364928 Bytes dssPreAllocate=true securityType=none;
show "Setting additional attributes for Volume "LUN_0"0001.";
// Configuration settings that can not be set during Volume creation.
set volume["LUN_0"0001"] cacheFlushModifier=10;
set volume["LUN_0"0001"] cacheWithoutBatteryEnabled=false;
set volume["LUN_0"0001"] mirrorEnabled=true;
set volume["LUN_0"0001"] readCacheEnabled=true;
set volume["LUN_0"0001"] writeCacheEnabled=true;
set volume["LUN_0"0001"] mediaScanEnabled=false;
set volume["LUN_0"0001"] redundancyCheckEnabled=false;
set volume["LUN_0"0001"] readAheadMultiplier=0;
set volume["LUN_0"0001"] modificationPriority=high;
set volume["LUN_0"0001"] preReadRedundancyCheck=false;
show "Creating Volume-to-LUN Mapping for Volume "LUN_0"0001 to LUN 0.";
set volume ["LUN_0"0001"] logicalUnitNumber=0 hostGroup=defaultGroup;

show "Creating RAID 1 Volume "LUN_0"0002 on existing Volume Group g0001.";
//This command creates volume <"LUN_0"0002> with offset 146219008 on volume group
<g0001>.
// NOTE: For Volume Groups that use all available capacity, the last Volume on this
group is
// created using all remaining capacity by omitting the capacity= volume creation
parameter.
create volume volumeGroup["g0001"] raidLevel=1 userLabel="LUN_0"0002" owner=A
segmentSize=128 capacity=1796738364928 Bytes dssPreAllocate=true;
show "Setting additional attributes for Volume "LUN_0"0002.";
// Configuration settings that can not be set during Volume creation.
set volume["LUN_0"0002"] cacheFlushModifier=10;
set volume["LUN_0"0002"] cacheWithoutBatteryEnabled=false;
set volume["LUN_0"0002"] mirrorEnabled=true;
set volume["LUN_0"0002"] readCacheEnabled=true;
set volume["LUN_0"0002"] writeCacheEnabled=true;
set volume["LUN_0"0002"] mediaScanEnabled=false;
set volume["LUN_0"0002"] redundancyCheckEnabled=false;
set volume["LUN_0"0002"] readAheadMultiplier=0;
set volume["LUN_0"0002"] modificationPriority=high;
set volume["LUN_0"0002"] preReadRedundancyCheck=false;
show "Creating Volume-to-LUN Mapping for Volume "LUN_0"0002 to LUN 1.";
set volume ["LUN_0"0002"] logicalUnitNumber=1 hostGroup=defaultGroup;

show "Creating RAID 1 Volume "LUN_0"0003 on existing Volume Group g0001.";
//This command creates volume <"LUN_0"0003> with offset 292438016 on volume group
<g0001>.
// NOTE: For Volume Groups that use all available capacity, the last Volume on this
group is
// created using all remaining capacity by omitting the capacity= volume creation
parameter.
```

```
create volume volumeGroup["g0001"] raidLevel=1 userLabel="LUN_0"0003" owner=A
segmentSize=128 capacity=1796738364928 Bytes dssPreAllocate=true;
show "Setting additional attributes for Volume "LUN_0"0003.";
// Configuration settings that can not be set during Volume creation.
set volume["LUN_0"0003] cacheFlushModifier=10;
set volume["LUN_0"0003] cacheWithoutBatteryEnabled=false;
set volume["LUN_0"0003] mirrorEnabled=true;
set volume["LUN_0"0003] readCacheEnabled=true;
set volume["LUN_0"0003] writeCacheEnabled=true;
set volume["LUN_0"0003] mediaScanEnabled=false;
set volume["LUN_0"0003] redundancyCheckEnabled=false;
set volume["LUN_0"0003] readAheadMultiplier=0;
set volume["LUN_0"0003] modificationPriority=high;
set volume["LUN_0"0003] preReadRedundancyCheck=false;
show "Creating Volume-to-LUN Mapping for Volume "LUN_0"0003 to LUN 2.";
set volume ["LUN_0"0003] logicalUnitNumber=2 hostGroup=defaultGroup;

show "Creating RAID 1 Volume "LUN_0"0004 on existing Volume Group g0001.";
//This command creates volume <"LUN_0"0004> with offset 438657024 on volume group
<g0001>.
// NOTE: For Volume Groups that use all available capacity, the last Volume on this
group is
// created using all remaining capacity by omitting the capacity= volume creation
parameter.
create volume volumeGroup["g0001"] raidLevel=1 userLabel="LUN_0"0004" owner=A
segmentSize=128 capacity=1796738364928 Bytes dssPreAllocate=true;
show "Setting additional attributes for Volume "LUN_0"0004.";
// Configuration settings that can not be set during Volume creation.
set volume["LUN_0"0004] cacheFlushModifier=10;
set volume["LUN_0"0004] cacheWithoutBatteryEnabled=false;
set volume["LUN_0"0004] mirrorEnabled=true;
set volume["LUN_0"0004] readCacheEnabled=true;
set volume["LUN_0"0004] writeCacheEnabled=true;
set volume["LUN_0"0004] mediaScanEnabled=false;
set volume["LUN_0"0004] redundancyCheckEnabled=false;
set volume["LUN_0"0004] readAheadMultiplier=0;
set volume["LUN_0"0004] modificationPriority=high;
set volume["LUN_0"0004] preReadRedundancyCheck=false;
show "Creating Volume-to-LUN Mapping for Volume "LUN_0"0004 to LUN 3.";
set volume ["LUN_0"0004] logicalUnitNumber=3 hostGroup=defaultGroup;

show "Creating RAID 1 Volume "LUN_1"0001 on new Volume Group g0002.";
//This command creates volume group <g0002> and the initial volume <"LUN_1"0001>
with offset 0 on the volume group.
// NOTE: For Volume Groups that use all available capacity, the last Volume on this
group is
// created using all remaining capacity by omitting the capacity= volume creation
parameter.
create volume drives=(0,13 0,14 0,15 0,16 0,17 0,18 0,19 0,20 0,21 0,22 0,23 0,24
1,13 1,14 1,15 1,16 1,17 1,18 1,19 1,20 1,21 1,22 1,23 1,24 2,13 2,14 2,15 2,16 2,17
2,18 2,19 2,20 2,21 2,22 2,23 2,24 3,13 3,14 3,15 3,16 3,17 3,18 3,19 3,20 3,21 3,22
3,23 3,24) raidLevel=1 userLabel="LUN_1"0001" volumeGroupUserLabel="g0002" owner=B
segmentSize=128 capacity=1796738364928 Bytes dssPreAllocate=true securityType=none;
show "Setting additional attributes for Volume "LUN_1"0001.";
// Configuration settings that can not be set during Volume creation.
set volume["LUN_1"0001] cacheFlushModifier=10;
set volume["LUN_1"0001] cacheWithoutBatteryEnabled=false;
set volume["LUN_1"0001] mirrorEnabled=true;
set volume["LUN_1"0001] readCacheEnabled=true;
set volume["LUN_1"0001] writeCacheEnabled=true;
set volume["LUN_1"0001] mediaScanEnabled=false;
set volume["LUN_1"0001] redundancyCheckEnabled=false;
set volume["LUN_1"0001] readAheadMultiplier=0;
```

```
set volume["LUN_1"0001"] modificationPriority=high;
set volume["LUN_1"0001"] preReadRedundancyCheck=false;
show "Creating Volume-to-LUN Mapping for Volume "LUN_1"0001 to LUN 4.";
set volume ["LUN_1"0001"] logicalUnitNumber=4 hostGroup=defaultGroup;

show "Creating RAID 1 Volume "LUN_1"0002 on existing Volume Group g0002.";
//This command creates volume <"LUN_1"0002> with offset 146219008 on volume group
<g0002>.
// NOTE: For Volume Groups that use all available capacity, the last Volume on this
group is
// created using all remaining capacity by omitting the capacity= volume creation
parameter.
create volume volumeGroup["g0002"] raidLevel=1 userLabel="LUN_1"0002" owner=B
segmentSize=128 capacity=1796738364928 Bytes dssPreAllocate=true;
show "Setting additional attributes for Volume "LUN_1"0002.";
// Configuration settings that can not be set during Volume creation.
set volume["LUN_1"0002"] cacheFlushModifier=10;
set volume["LUN_1"0002"] cacheWithoutBatteryEnabled=false;
set volume["LUN_1"0002"] mirrorEnabled=true;
set volume["LUN_1"0002"] readCacheEnabled=true;
set volume["LUN_1"0002"] writeCacheEnabled=true;
set volume["LUN_1"0002"] mediaScanEnabled=false;
set volume["LUN_1"0002"] redundancyCheckEnabled=false;
set volume["LUN_1"0002"] readAheadMultiplier=0;
set volume["LUN_1"0002"] modificationPriority=high;
set volume["LUN_1"0002"] preReadRedundancyCheck=false;
show "Creating Volume-to-LUN Mapping for Volume "LUN_1"0002 to LUN 5.";
set volume ["LUN_1"0002"] logicalUnitNumber=5 hostGroup=defaultGroup;

show "Creating RAID 1 Volume "LUN_1"0003 on existing Volume Group g0002.";
//This command creates volume <"LUN_1"0003> with offset 292438016 on volume group
<g0002>.
// NOTE: For Volume Groups that use all available capacity, the last Volume on this
group is
// created using all remaining capacity by omitting the capacity= volume creation
parameter.
create volume volumeGroup["g0002"] raidLevel=1 userLabel="LUN_1"0003" owner=B
segmentSize=128 capacity=1796738364928 Bytes dssPreAllocate=true;
show "Setting additional attributes for Volume "LUN_1"0003.";
// Configuration settings that can not be set during Volume creation.
set volume["LUN_1"0003"] cacheFlushModifier=10;
set volume["LUN_1"0003"] cacheWithoutBatteryEnabled=false;
set volume["LUN_1"0003"] mirrorEnabled=true;
set volume["LUN_1"0003"] readCacheEnabled=true;
set volume["LUN_1"0003"] writeCacheEnabled=true;
set volume["LUN_1"0003"] mediaScanEnabled=false;
set volume["LUN_1"0003"] redundancyCheckEnabled=false;
set volume["LUN_1"0003"] readAheadMultiplier=0;
set volume["LUN_1"0003"] modificationPriority=high;
set volume["LUN_1"0003"] preReadRedundancyCheck=false;
show "Creating Volume-to-LUN Mapping for Volume "LUN_1"0003 to LUN 6.";
set volume ["LUN_1"0003"] logicalUnitNumber=6 hostGroup=defaultGroup;

show "Creating RAID 1 Volume "LUN_1"0004 on existing Volume Group g0002.";
//This command creates volume <"LUN_1"0004> with offset 438657024 on volume group
<g0002>.
// NOTE: For Volume Groups that use all available capacity, the last Volume on this
group is
// created using all remaining capacity by omitting the capacity= volume creation
parameter.
create volume volumeGroup["g0002"] raidLevel=1 userLabel="LUN_1"0004" owner=B
segmentSize=128 capacity=1796738364928 Bytes dssPreAllocate=true;
show "Setting additional attributes for Volume "LUN_1"0004.";
```

```
// Configuration settings that can not be set during Volume creation.
set volume["LUN_1"0004] cacheFlushModifier=10;
set volume["LUN_1"0004] cacheWithoutBatteryEnabled=false;
set volume["LUN_1"0004] mirrorEnabled=true;
set volume["LUN_1"0004] readCacheEnabled=true;
set volume["LUN_1"0004] writeCacheEnabled=true;
set volume["LUN_1"0004] mediaScanEnabled=false;
set volume["LUN_1"0004] redundancyCheckEnabled=false;
set volume["LUN_1"0004] readAheadMultiplier=0;
set volume["LUN_1"0004] modificationPriority=high;
set volume["LUN_1"0004] preReadRedundancyCheck=false;
show "Creating Volume-to-LUN Mapping for Volume "LUN_1"0004 to LUN 7.";
set volume ["LUN_1"0004] logicalUnitNumber=7 hostGroup=defaultGroup;

// Disable Auto Volume Transfer (AVT) for all host types
set controller[a] HostNVS RAMByte[0x00, 0x24]=0x00;
set controller[a] HostNVS RAMByte[0x01, 0x24]=0x00;
set controller[a] HostNVS RAMByte[0x02, 0x24]=0x00;
set controller[a] HostNVS RAMByte[0x03, 0x24]=0x00;
set controller[a] HostNVS RAMByte[0x04, 0x24]=0x00;
set controller[a] HostNVS RAMByte[0x05, 0x24]=0x00;
set controller[a] HostNVS RAMByte[0x06, 0x24]=0x00;
set controller[a] HostNVS RAMByte[0x07, 0x24]=0x00;
set controller[a] HostNVS RAMByte[0x08, 0x24]=0x00;
set controller[a] HostNVS RAMByte[0x09, 0x24]=0x00;
set controller[a] HostNVS RAMByte[0x0a, 0x24]=0x00;
set controller[a] HostNVS RAMByte[0x0b, 0x24]=0x00;
set controller[a] HostNVS RAMByte[0x0c, 0x24]=0x00;
set controller[a] HostNVS RAMByte[0x0d, 0x24]=0x00;
set controller[a] HostNVS RAMByte[0x0e, 0x24]=0x00;
set controller[a] HostNVS RAMByte[0x0f, 0x24]=0x00;

set controller[b] HostNVS RAMByte[0x00, 0x24]=0x00;
set controller[b] HostNVS RAMByte[0x01, 0x24]=0x00;
set controller[b] HostNVS RAMByte[0x02, 0x24]=0x00;
set controller[b] HostNVS RAMByte[0x03, 0x24]=0x00;
set controller[b] HostNVS RAMByte[0x04, 0x24]=0x00;
set controller[b] HostNVS RAMByte[0x05, 0x24]=0x00;
set controller[b] HostNVS RAMByte[0x06, 0x24]=0x00;
set controller[b] HostNVS RAMByte[0x07, 0x24]=0x00;
set controller[b] HostNVS RAMByte[0x08, 0x24]=0x00;
set controller[b] HostNVS RAMByte[0x09, 0x24]=0x00;
set controller[b] HostNVS RAMByte[0x0a, 0x24]=0x00;
set controller[b] HostNVS RAMByte[0x0b, 0x24]=0x00;
set controller[b] HostNVS RAMByte[0x0c, 0x24]=0x00;
set controller[b] HostNVS RAMByte[0x0d, 0x24]=0x00;
set controller[b] HostNVS RAMByte[0x0e, 0x24]=0x00;
set controller[b] HostNVS RAMByte[0x0f, 0x24]=0x00;
```

## **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 to execute the Primary Metrics, Repeatability and Persistence Tests, is listed below.

```
* spc1_persist.cfg

javaparms="-Xms1024m -Xmx1024m"

sd=asu1_1,lun=\\.L:,size=6035796393984
sd=asu2_1,lun=\\.M:,size=6035796393984
sd=asu3_1,lun=\\.N:,size=1341288087552

eof
```

## **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.

```
REM Get storage array profile
"c:\program files\StorageManager\client\smcli" 172.22.201.161 172.22.201.162 -c
"show storageArray profile;" -o
"c:\bench\vdbench\spc1\output\spc1_profile_before_run.txt"

copy /y spc1_iops.cfg spc1.cfg
java metrics -b 489 -s 300
java repeat1 -b 489 -s 300
java repeat2 -b 489 -s 300

copy /y spc1_persist.cfg spc1.cfg
java persist1 -b 489
```

### **Persistence Test Run 2**

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

```
copy /y spc1_persist.cfg spc1.cfg
java persist2

REM Get storage array profile
"c:\program files\StorageManager\client\smcli" 172.22.201.161 172.22.201.162 -c
"show storageArray profile;" -o
"c:\bench\vdbench\spc1\output\spc1_profile_after_run.txt"
```