



**SPC BENCHMARK 1C™
FULL DISCLOSURE REPORT**

**SEAGATE TECHNOLOGY LLC
IBM 600GB 10K 6GBPS SAS 2.5" SFF SLIM-HS HDD**

SPC-1C V1.5

Submitted for Review: June 14, 2013

Submission Identifier: C00015

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AUDIT CERTIFICATION



Craig Parris
Seagate Technology LLC
1280 Disc Drive
Shakopee, MN 55379

June 14, 2013

The SPC Benchmark 1C™ results listed below for the IBM 600GB 10K 6Gbps SAS 2.5" SFF Slim-HS HDD were produced in compliance with the SPC Benchmark 1C™ V1.5 Audit requirements.

SPC Benchmark 1C™ V1.5 Reported Data	
Tested Storage Product (TSP): IBM 600GB 10K 6Gbps SAS 2.5" SFF Slim-HS HDD	
Metric	Reported Result
SPC-1C Submission Identifier	C00015
SPC-1C IOPS™	448.46
Total ASU Capacity	1,500,318 GB
Data Protection Level	Protected 1 (RAID-5)
Total Price – Priced Storage Configuration	\$9,213.00
Currency Used	U.S. Dollars
Target Country for availability, sales and support	USA

The following SPC Benchmark 1C™ Audit requirements were reviewed and found compliant with V1.5 of the SPC Benchmark 1C™ specification:

- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository storage items were verified by physical inspection and information supplied by Seagate Technology LLC:
 - ✓ Physical Storage Capacity and requirements.
 - ✓ Configured Storage Capacity and requirements.
 - ✓ Addressable Storage Capacity and requirements.
 - ✓ Capacity of each Logical Volume and requirements.
 - ✓ Capacity of each Application Storage Unit (ASU) and requirements.
- The entire Configured Storage Capacity was filled with random data, using an auditor approved tool, prior to the execution of the SPC-1C Tests.

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

AUDIT CERTIFICATION (CONT.)

IBM 600GB 10K 6Gbps SAS 2.5" SFF Slim-HS HDD
SPC-1C Audit Certification

Page 2

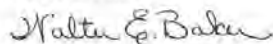
- An appropriate diagram of the Benchmark Configuration (BC)/Tested Storage Configuration (TSC).
- Physical verification of the components to match the above diagram.
- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters that were changed from default values.
- SPC-1C Workload Generator commands and parameters used for the audited SPC-1C Test Runs.
- The following Host System requirements were verified by physical inspection and information supplied by Seagate Technology LLC:
 - ✓ The type of Host System including the number of processors and main memory.
 - ✓ The presence and version number of the SPC-1C Workload Generator on the Host System.
 - ✓ The TSC boundary within the Host System.
- The execution of each Test, Test Phase, and Test Run was observed and found compliant with all of the requirements and constraints of Clauses 4 and 5 of the SPC-1C Benchmark Specification.
- The Test Results Files and resultant Summary Results Files for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4, 5 and 6 of the SPC-1C Benchmark Specification:
 - ✓ Data Persistence Test
 - ✓ Sustainability Test Phase
 - ✓ IOPS Test Phase
 - ✓ Response Time Ramp Test Phase
 - ✓ Repeatability Test
- There were no differences between the Tested Storage Configuration (TSC) used for the benchmark and Priced Storage Configuration.
- The submitted pricing information met all of the requirements and constraints of Clause 9 of the SPC-1C Benchmark Specification.
- The Full Disclosure Report (FDR) met all of the requirements in Clause 10 of the SPC-1C Benchmark Specification.
- IBM Corporation granted Seagate Technology LLC permission to submit this successfully audited SPC measurement for the IBM 600GB 10K 6Gbps SAS 2.5" SFF Slim-HS HDD to become a new SPC-1C Result.
- 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
AuditService@storageperformance.org
850.556.9384

LETTER OF GOOD FAITH



Date: *June 10th 2013*

From: Daniel Kuhl

To: *Walter Baker*

Subject: SPC-1C Letter of Good Faith for IBM 600GB 10K 6Gbps SAS 2.5" SFF Slim-HS HDD

Seagate Technology is the SPC-1C Test Sponsor for the above listed product. To the best of our knowledge and belief, the required SPC-1C benchmark results and materials we have submitted for that product are complete, accurate, and in full compliance with V1.5 of the SPC-1C benchmark specification.

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

Signed: 

Date: *6/12/2013*

Daniel Kuhl
Vice President, Enterprise SSD Development

Seagate Technology
1280 Disc Drive
Shakopee, MN 55379

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
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Test Sponsor Alternate Contact	Seagate Technology LLC – http://www.seagate.com Barbara Craig – barbara.l.craig@seagate.com 1280 Disc Drive Shakopee, MN 55379 Phone: (952) 402-2804
Auditor	Storage Performance Council – http://www.storageperformance.org Walter E. Baker – AuditService@StoragePerformance.org 643 Bair Island Road, Suite 103 Redwood City, CA 94063 Phone: (650) 556-9384 FAX: (650) 556-9385

Revision Information and Key Dates

Revision Information and Key Dates	
SPC-1C Specification revision number	V1.5
SPC-1C Workload Generator revision number	V1.2.0
Date Results were first used publicly	June 14, 2013
Date the FDR was submitted to the SPC	June 14, 2013
Date the Priced Storage Configuration is available for shipment to customers	currently available
Date the TSC completed audit certification	June 14, 2013

Tested Storage Product (TSP) Description

The IBM 600GB 10K 6Gbps SAS 2.5" SFF HDD is a mission critical enterprise hard drive with storage capacities of 300, 450, 600 and 900GB. Ideal for random and sequential mission critical applications, it delivers best-in-class 10K-rpm random performance and highest capacities that data centers need to meet demanding service level agreements and to keep up with data growth and reduce IT operating costs. With up to 2× the capacity and a smaller footprint, data centers can store and access data faster than ever, enabling them to keep pace with data growth while optimizing scarce IT real estate.

The latest IBM 600GB 10K 6Gbps SAS 2.5" SFF HDD drives stores up to 100% more data in half the rack space than even the highest capacity 3.5-inch 15K HDDs. It uses the same, proven enterprise development platform and feature set used by all IBM mission critical enterprise hard drives and is backed by a 1 year limited warranty.

Summary of Results

SPC-1C Reported Data	
Tested Storage Product (TSP) Name: IBM 600GB 10K 6Gbps SAS 2.5" SFF Slim-HS HDD	
Metric	Reported Result
SPC-1C Submission Identifier	C00015
SPC-1C IOPS™	448.46
Total ASU Capacity	1,500.318 GB
Data Protection Level	Protected 1 (RAID-5)
Total Price	\$9,213.00
Pricing Currency	U.S. Dollars
Target Country for availability, sales and support	USA

SPC-1C Submission Identifier is the unique identifier assigned to this specific SPC-1C Result.

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

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

A **Data Protection Level** of **Protected 1** using **RAID-5** by distributing check data corresponding to user data across multiple disk in the form of bit-by-bite parity.

***Protected 1:** The single point of failure of any **storage device** in the configuration will not result in permanent loss of access to or integrity of the SPC-1C Data Repository.*

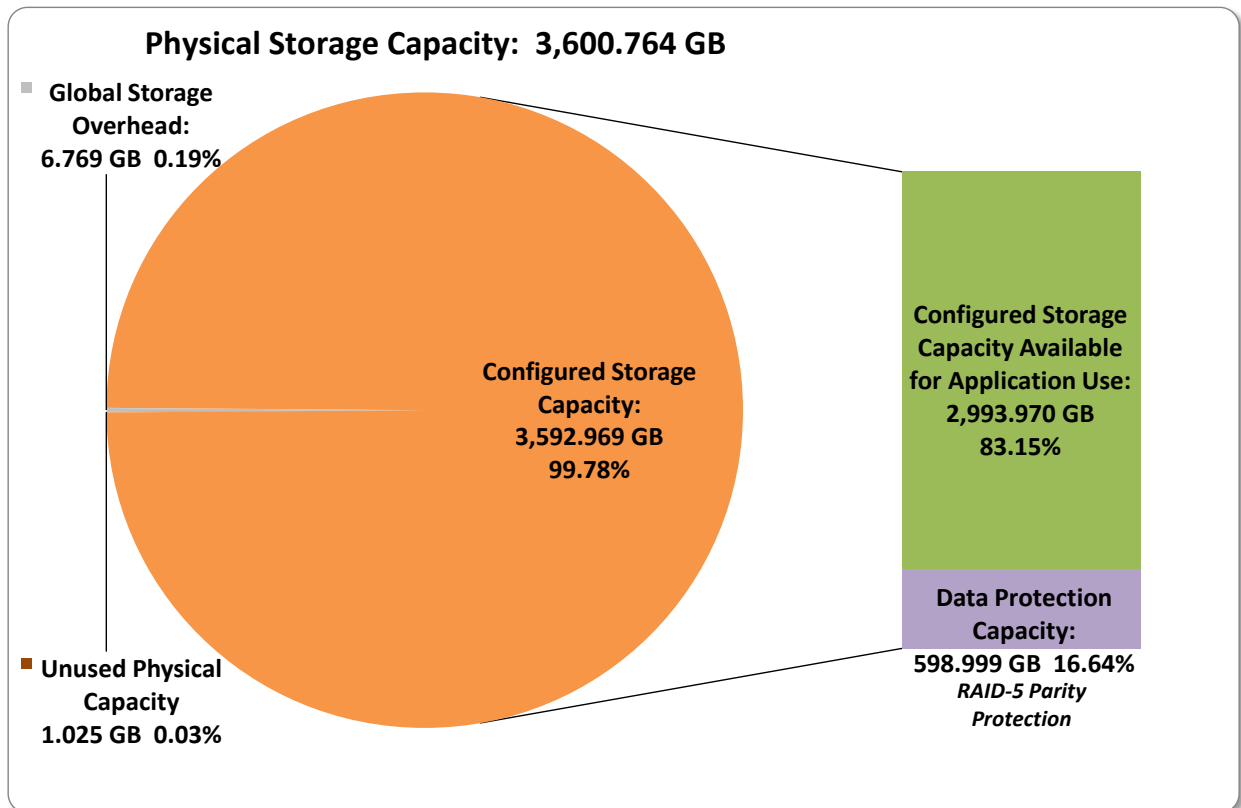
Total Price includes the cost of the Priced Storage Configuration plus three years of hardware maintenance and software support as detailed on page 17.

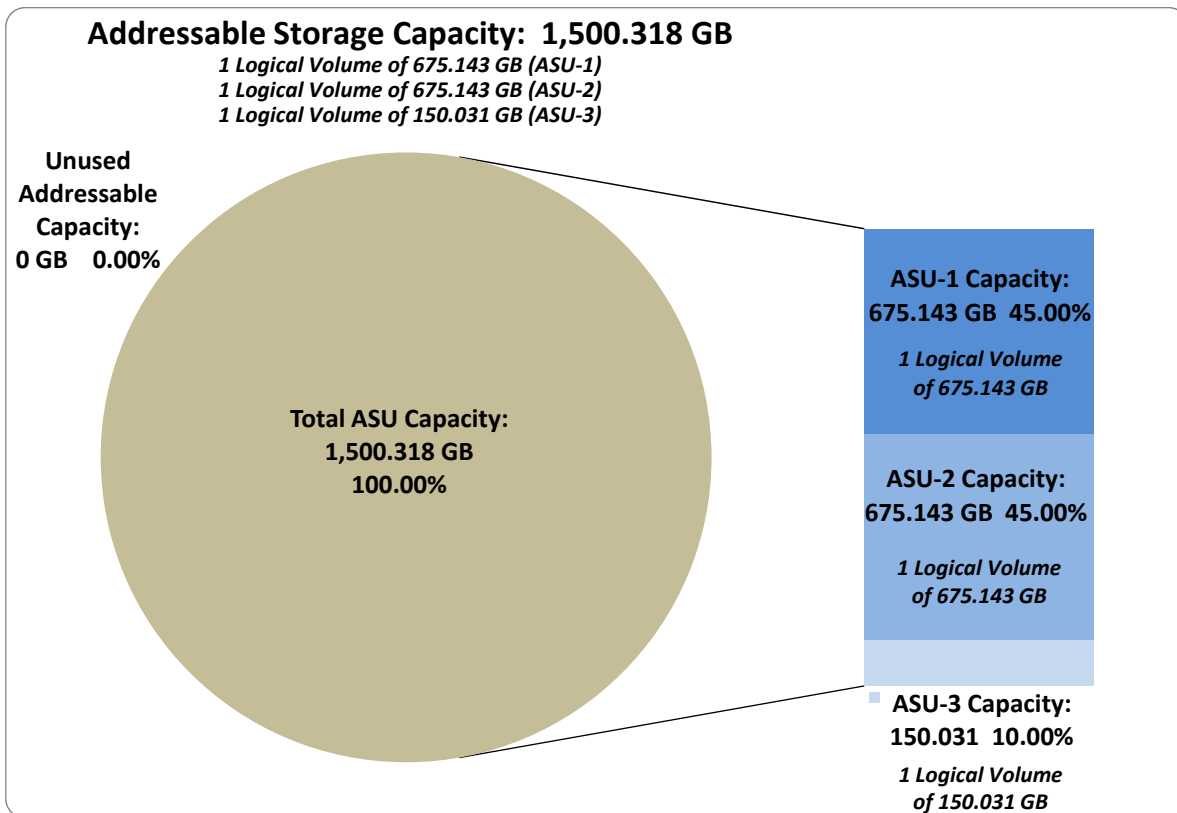
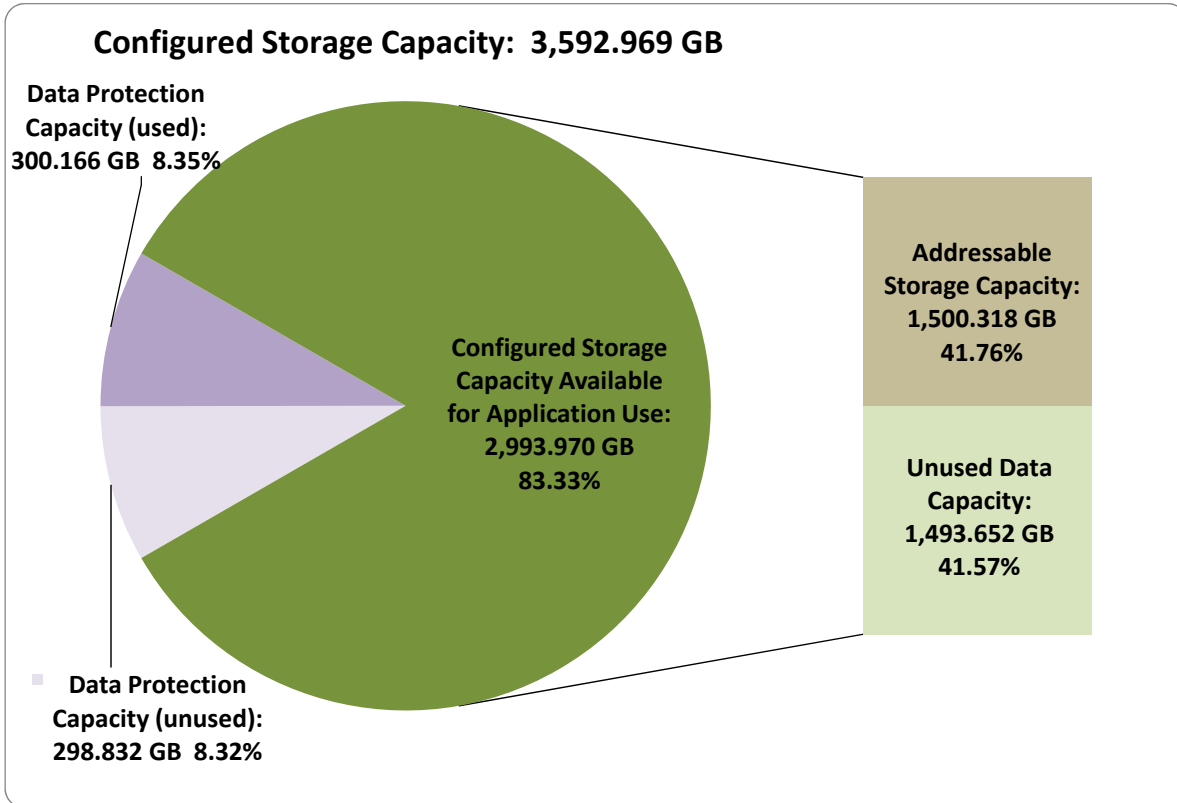
Pricing Currency is formal name for the currency used in calculating the **Total Price**. That currency may be the local currency of the **Target Country** or the currency of a difference country (*non-local currency*).

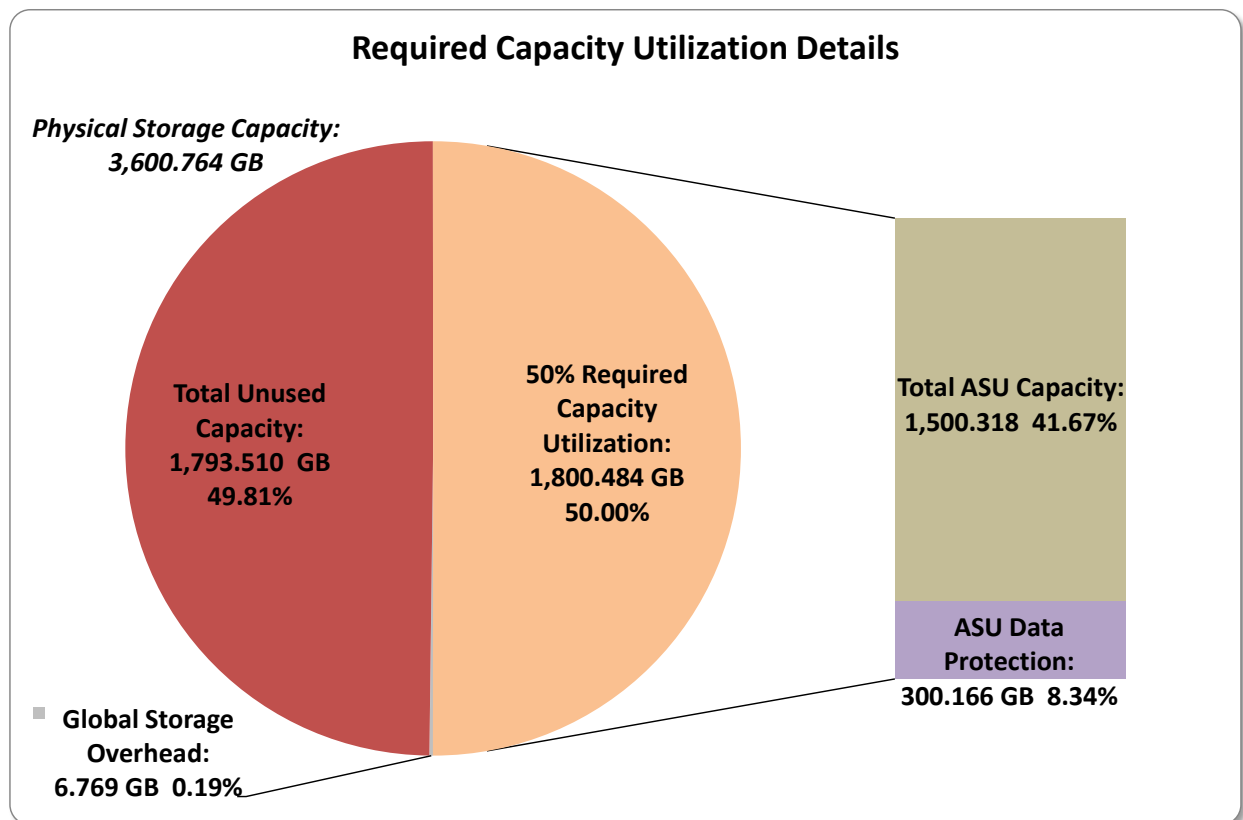
The **Target Country** is the country in which the Priced Storage Configuration is available for sale and in which the required hardware maintenance and software support is provided either directly from the Test Sponsor or indirectly via a third-party supplier.

Storage Capacities, Relationships, and Utilization

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







The Tested Storage Configuration (TSC) must be configured so that there is either no Unused Storage or that the sum of Total ASU Capacity and storage required for data protection equals 50% (+-1 GiB) of the Physical Storage Capacity.

The TSC meets the “50%” requirement as documented below:

3,600.764 GB (*Physical Storage Capacity*)

1,800.382 GB (*50% capacity requirement*)

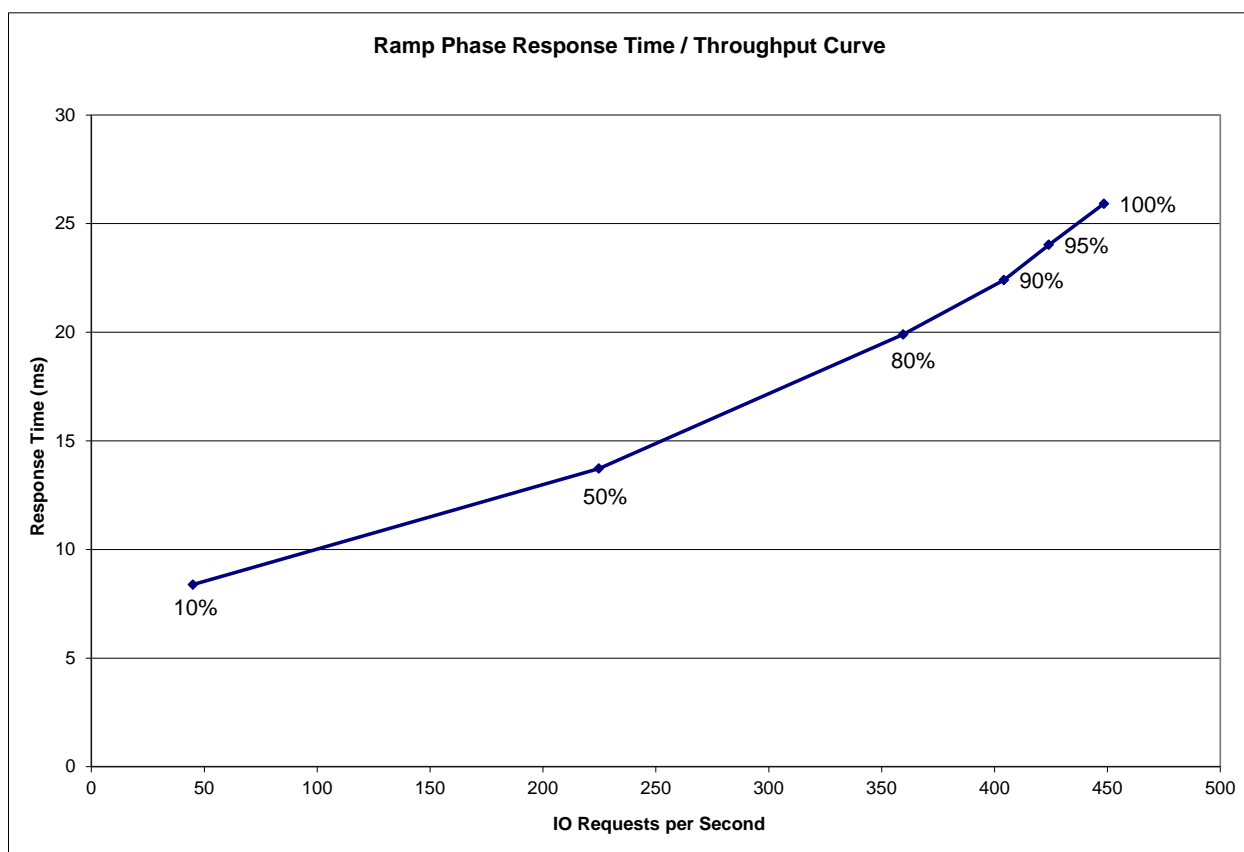
1,500.318 GB (*Total ASU Capacity*) + **300.166 GB** (*Data Protection*) = **1,800.484 GB**

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

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-1C IOPS™ metric.

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



Response Time – Throughput Data

	10% Load	50% Load	80% Load	90% Load	95% Load	100% Load
I/O Request Throughput	44.96	224.74	359.54	404.17	424.04	448.46
Average Response Time (ms):						
All ASUs	8.38	13.72	19.90	22.40	24.02	25.91
ASU-1	7.89	12.72	17.84	20.00	21.30	22.79
ASU-2	8.83	14.73	21.16	23.81	25.60	27.67
ASU-3	9.22	15.41	23.72	26.88	29.12	31.81
Reads	4.05	7.25	9.97	11.01	11.65	12.43
Writes	11.20	17.90	26.40	29.82	32.07	34.71

Priced Storage Configuration Pricing

Description		Part Numbers	Qty	Price	Extended Price
IBM 600GB 10K 6Gbps SAS 2.5" SFF Slim-HS HDD	Warranty period 1 year CRU & On-site 9x5 Next Business Day	49Y2003	6	\$ 579.00	\$3,474.00
IBM system x3650 M4	Base System w/1 Xeon Processor	7915B2U	1	\$ 2,565.00	\$2,565.00
	Primary drive	90Y8872	1	\$ 579.00	\$ 579.00
	Xeon Processor	69Y5325	1	\$ 485.00	\$ 485.00
	Power Supply	94Y6668	1	\$ 299.00	\$ 299.00
	4GB DDR3	49Y1559	1	\$ 115.00	\$ 115.00
	8GB DDR3	90Y3109	2	\$ 189.00	\$ 378.00
	RAID M5120 Controller	81Y4478	1	\$ 299.00	\$ 299.00
	RAID M5100 512MB RAID Cache	81Y4484	1	\$ 199.00	\$ 199.00
	Power cables	39Y7931	2	\$ 15.00	\$ 30.00
	3yr onsite repair 24x7 4hr response	00A4405	1	\$ 790.00	\$ 790.00
Total					\$9,213.00

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

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

Benchmark Configuration/Tested Storage Configuration Diagram

IBM System x3650 M4



6 – IBM 600GB 10K 6Gbps SAS 2.5" SFF Slim-HS HDD
(6 Seagate 600GB Hard Disk Drives)

Host System and Tested Storage Configuration Components

Tested Storage Configuration (TSC):

IBM System x3650 M4 rack server

2 – Intel® Xeon® E5-2609 quad core processors
 2.4 GHz, 10 MB L3 cache

20 GB – main memory

1 – system disk drive

IBM ServRAID M5110e SAS/SATA built-in controller

512 MB RAID cache

Single embedded PCIe front-end (*PCIe x8*) connection

Single SAS 6 Gb (*4 lanes*) backend connection

6 – IBM 600GB 10K 6Gbps SAS 2.5" SFF Slim-HS HDD
(Seagate 600GB Hard Disk Drives)

In each of the following sections of this document, the appropriate Full Disclosure Report requirement, from the SPC-1C 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 10.4.5.11

The Executive Summary will contain a one page BC/TSC diagram that illustrates all major components of the BC/TSC.

The Benchmark Configuration (BC)/Tested Storage Configuration (TSC) is illustrated on page [18](#) ([Benchmark Configuration \(BC\)/Tested Storage Configuration \(TSC\) Diagram](#)).

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

Clause 10.4.5.12

The Executive Summary will contain a table that lists the major components of each Host System and the Tested Storage Configuration (TSC).

The Host System(s) and TSC table of components may be found on page [19](#) ([Host System\(s\) and Tested Storage Configuration \(TSC\) Table of Components](#)).

Customer Tunable Parameters and Options

Clause 10.4.6.1

All Benchmark Configuration (BC) components with customer tunable parameters and options that have been altered from their default values must be listed in the Full Disclosure Report (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 [70](#) contains the customer tunable parameters and options that have been altered from their default values for this benchmark.

Tested Storage Configuration (TSC) Description

Clause 10.4.6.2

The Full Disclosure Report must include sufficient information to recreate the logical representation of the Tested Storage Configuration (TSC). In addition to customer tunable parameters and options (Clause 10.4.6.1), 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 10.4.5.10.*
 - *The logical representation of the TSC, configured from the above components that will be presented to the SPC-1C 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 [71](#) contains the detailed information that describes how to create and configure the logical TSC.

SPC-1C Workload Generator Storage Configuration

Clause 10.4.6.3

The Full Disclosure Report will include all SPC-1C Workload Generator storage configuration commands and parameters used in the SPC-1C benchmark measurements.

The SPC-1C Workload Generator storage configuration commands and parameters for this measurement appear in [Appendix D: SPC-1C Workload Generator Storage Commands and Parameters](#) on page [73](#).

ASU Pre-Fill

Clause 6.3.3

Each of the three SPC-1C ASUs (ASU-1, ASU-2 and ASU-3) is required to be completely filled with specified content prior to the execution of audited SPC-1C Tests. The content is required to consist of random data pattern such as that produced by an SPC recommended tool.

The configuration file used to complete the required ASU pre-fill appears in [Appendix D: SPC-1C Workload Generator Storage Commands and Parameters](#) on page [73](#).

SPC-1C DATA REPOSITORY

This portion of the Full Disclosure Report presents the detailed information that fully documents the various SPC-1C storage capacities and mappings used in the Tested Storage Configuration. [SPC-1C Data Repository Definitions](#) on page [66](#) contains definitions of terms specific to the SPC-1C Data Repository.

Storage Capacities and Relationships

Clause 10.4.7.1

Two tables and four charts documenting the storage capacities and relationships of the SPC-1C Storage Hierarchy (Clause 2.1) shall be included in the FDR. ... The capacity value in each chart may be listed as an integer value, for readability, rather than the decimal value listed in [the table below].

SPC-1C Storage Capacities

The Physical Storage Capacity consisted of 3,600.764 GB distributed over 6 disk drives, each with a formatted capacity of 600.127 GB. There was 1.025 GB (0.03%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 6.769 GB (0.19%) of the Physical Storage Capacity. There was 1,493.652 GB (41.76%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 100.00% of the Addressable Storage Capacity resulting in 0.00 GB (0.00%) of Unused Storage within the Addressable Storage Capacity. The Data Protection (*RAID-5*) capacity was 598.999 GB of which 300.166 GB was utilized. The total Unused Storage capacity was 1,793.510 GB.

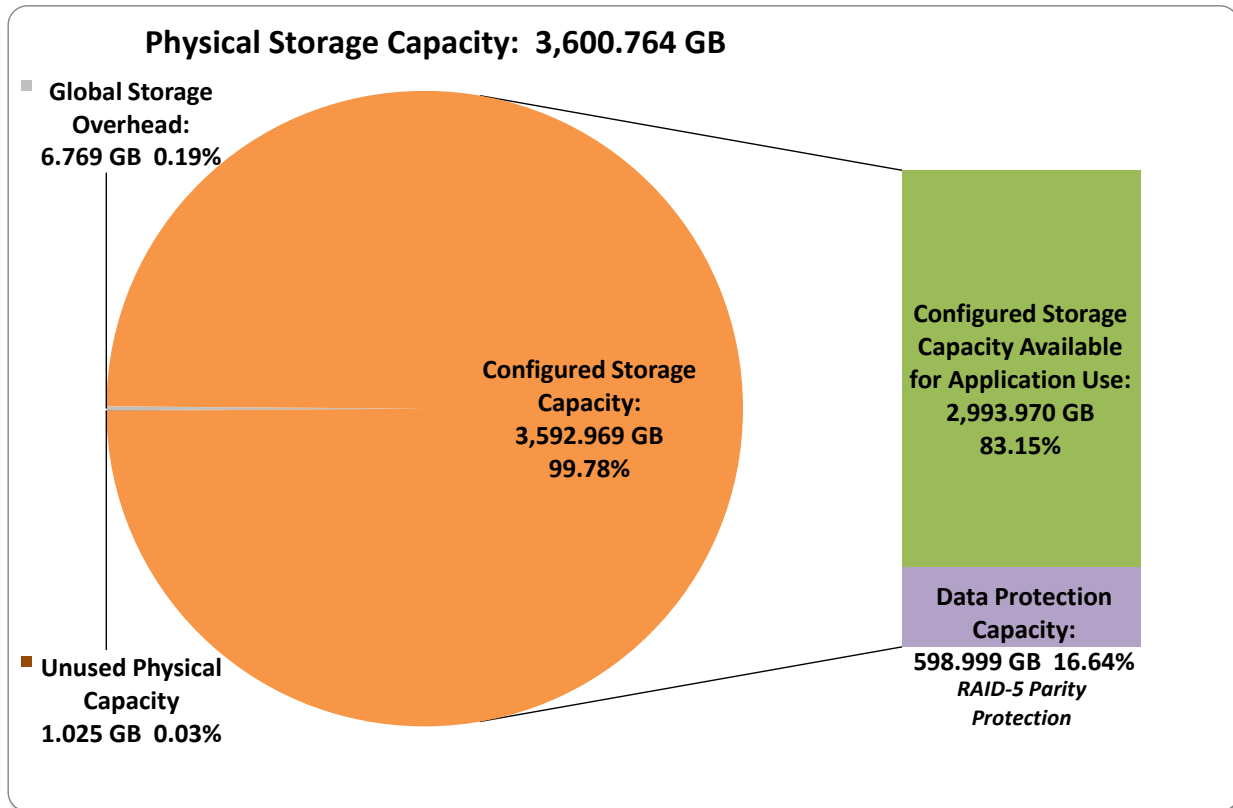
Note: The configured Storage Devices may include additional storage capacity reserved for system overhead, which is not accessible for application use. That storage capacity may not be included in the value presented for Physical Storage Capacity.

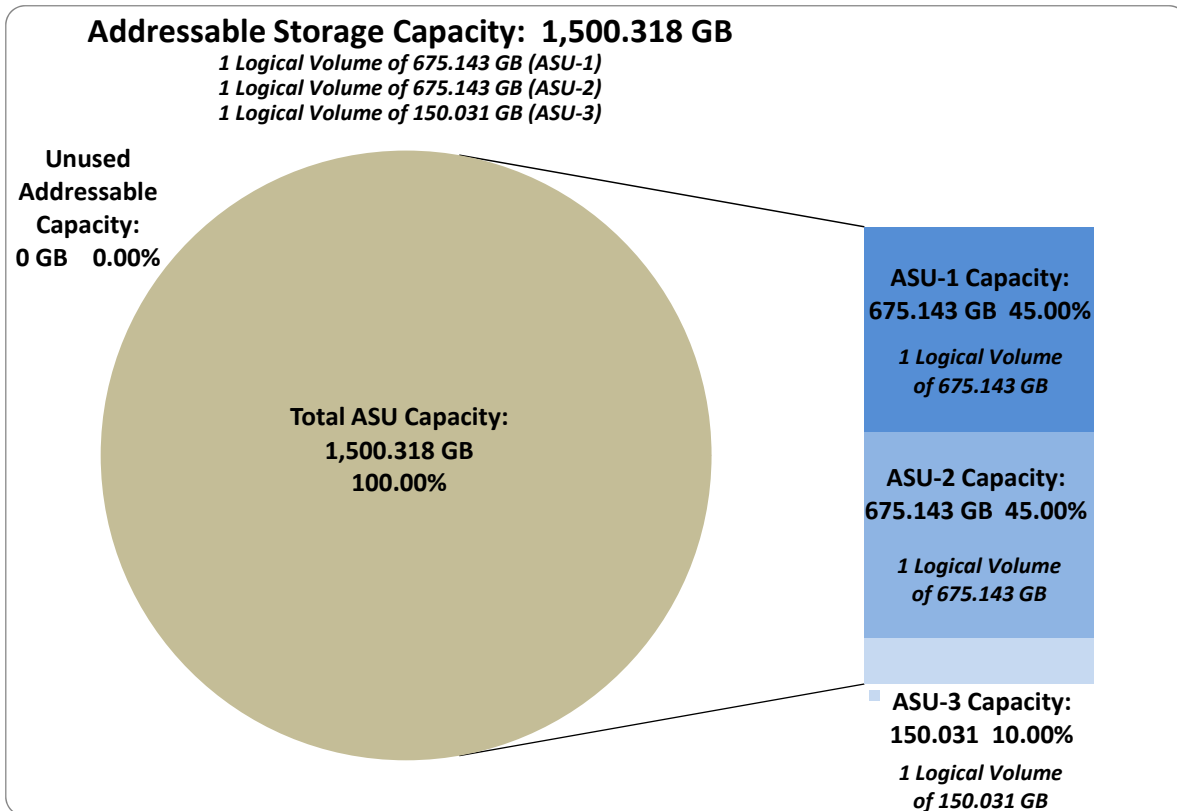
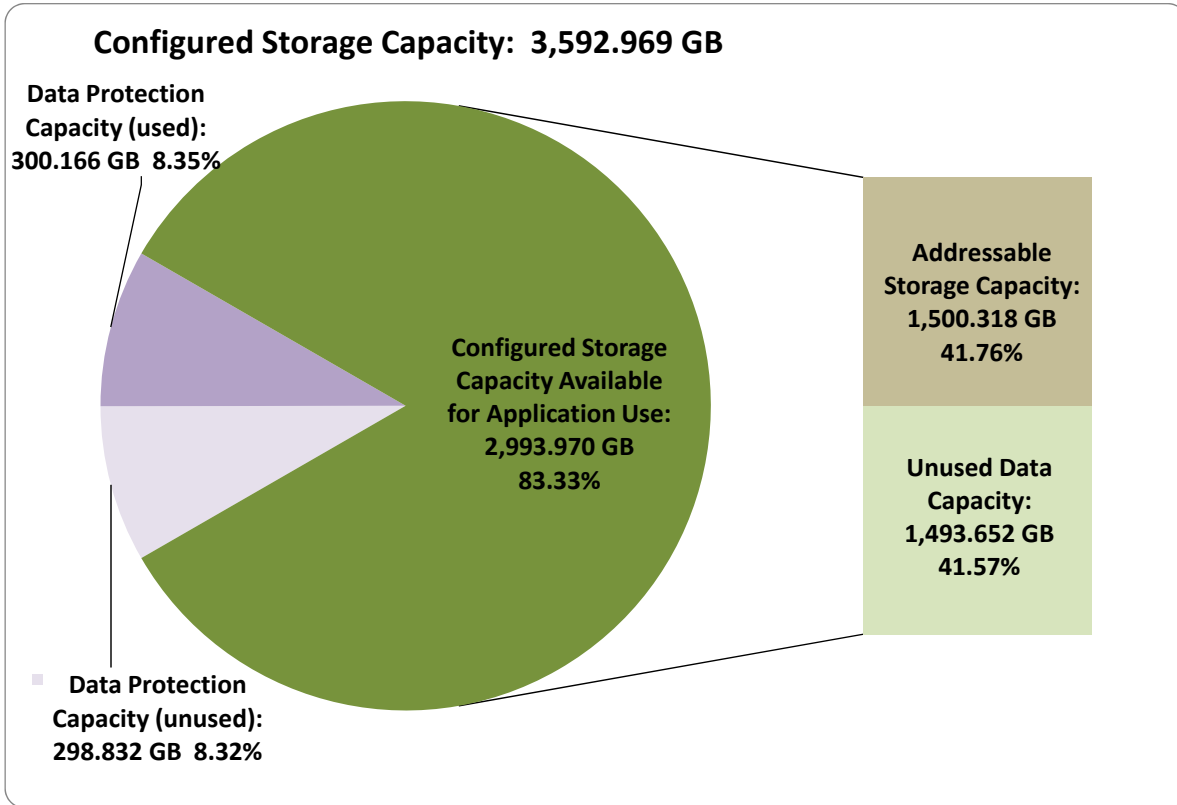
SPC-1C Storage Capacities		
Storage Hierarchy Component	Units	Capacity
Total ASU Capacity	Gigabytes (GB)	1,500.318
Addressable Storage Capacity	Gigabytes (GB)	1,500.318
Configured Storage Capacity	Gigabytes (GB)	3,592.969
Physical Storage Capacity	Gigabytes (GB)	3,600.764
Data Protection (<i>RAID-5</i>)	Gigabytes (GB)	598.999
Required Storage	Gigabytes (GB)	0.000
Global Storage Overhead	Gigabytes (GB)	6.769
Total Unused Storage	Gigabytes (GB)	1,793.510

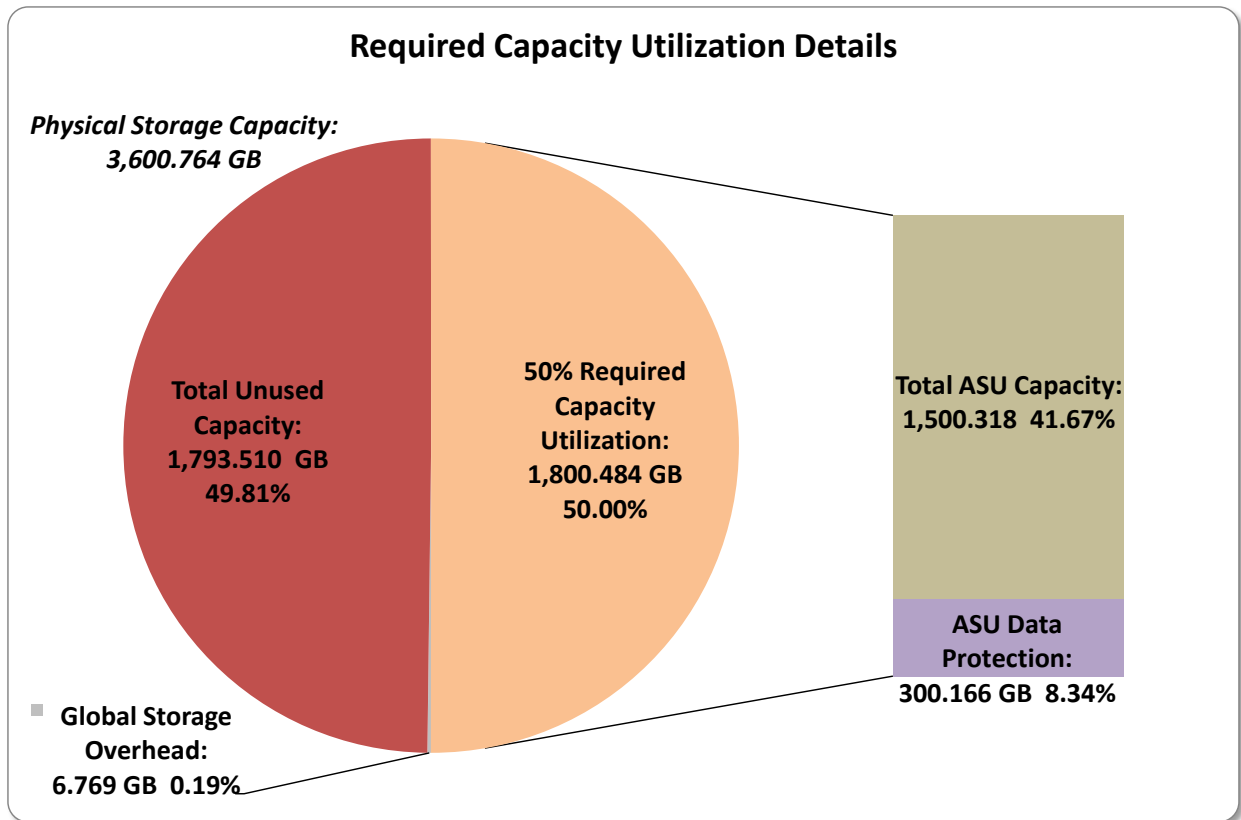
SPC-1C Storage Hierarchy Ratios

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	41.76%	41.67%
Required for Data Protection (RAID-5)		16.67%	16.64%
Addressable Storage Capacity		41.76%	41.67%
Required Storage		0.00%	0.00%
Configured Storage Capacity			99.78%
Global Storage Overhead			0.19%
Unused Storage:			
Addressable	0.00%		
Configured		41.57%	
Physical			0.03%

SPC-1C Storage Capacity Charts







Storage Capacity Utilization

Clause 2.6.8

The Total ASU Capacity must be configured in one of the following relationships to the Physical Storage Capacity.

Clause 2.6.8.1

100%: The Tested Storage Configuration must be configured so there is 1 GiB or less of total Unused Storage

Clause 2.6.8.2

50%: Total ASU Capacity must be configured so that the sum of Total ASU Capacity and capacity required for data protection is 50% of the Physical Storage Capacity within a tolerance of ±1 GiB or 0.5% of the Physical Storage Capacity, whichever is greater.

The Tested Storage Configuration meets the “50%” requirement as documented below:

3,600.764 GB (Physical Storage Capacity)

1,800.382 GB (50% capacity requirement)

1,500.318 GB (Total ASU Capacity) + **300.166 GB** (Data Protection) = **1,800.484 GB**

Logical Volume Capacity and ASU Mapping

Clause 10.4.7.2

A table illustrating the capacity of each ASU and the mapping of Logical Volumes to ASUs shall be provided in the FDR. ... Logical Volumes shall be sequenced in the table from top to bottom per its position in the contiguous address space of each ASU. The capacity of each Logical Volume shall be stated. ... In conjunction with this table, the Test Sponsor shall provide a complete description of the type of data protection (see Clause 2.7) used on each Logical Volume.

Logical Volume Capacity and Mapping		
ASU-1 (675.143 GB)	ASU-2 (675.143 GB)	ASU-3 (150.031 GB)
1 Logical Volume 675.143 GB per Logical Volume (675.143 GB used per Logical Volume)	1 Logical Volume 675.143 GB per Logical Volume (675.143 GB used per Logical Volume)	1 Logical Volume 150.031 GB per Logical Volume (150.031 GB used per Logical Volume)

The Data Protection Level used for all Logical Volumes was [Protected 1](#) using **RAID-5** as described on page [12](#). See “ASU Configuration” in the [IOPS Test Results File](#) for more detailed configuration information.

SPC-1C BENCHMARK EXECUTION RESULTS

This portion of the Full Disclosure Report documents the results of the various SPC-1C Tests, Test Phases, and Test Runs. An [SPC-1C glossary](#) on page 66 contains definitions of terms specific to the SPC-1C Tests, Test Phases, and Test Runs.

Clause 6.4.2

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 selected Test sequence. If the selected Test sequence is interrupted, the SPC-1C measurement is invalid. This does not apply to the interruption caused by the Host System/TSC power cycle between Persistence Test Run 1 and Persistence Test Run 2.

SPC-1C Tests, Test Phases, and Test Runs

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

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

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

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

“Ramp-Up” Test Runs

Clause 6.3.12

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

Clause 6.3.12.4

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

Clause 10.4.8.1

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

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

Primary Metrics Test – Sustainability Test Phase

Clause 6.4.3.2

The Sustainability Test Phase has exactly one Test Run and shall demonstrate the maximum sustainable I/O Request Throughput within a continuous one (1) hour Measurement Interval.

Clause 6.4.3.2.6

The computed I/O Request Throughput of the Sustainability Test Run must be no less than 95% of the reported SPC-1C IOPS™ result or the Test Run is invalid.

Clause 6.4.3.2.7

The Average Response Time, as defined in Clause 0, will be computed and reported for the Sustainability Test Run and cannot exceed 30 milliseconds. If the Average Response Time exceeds that 30-millisecond constraint, the Test Run is invalid.

Clause 10.4.8.2

The FDR shall contain the following for the single Test Run in the Sustainability/IOPS Test Phase:

- 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-1C Workload Generator Input Parameters

The SPC-1C Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in [Appendix E: SPC-1C Workload Generator Input Parameters](#) on Page 74.

Sustainability Test Results File

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

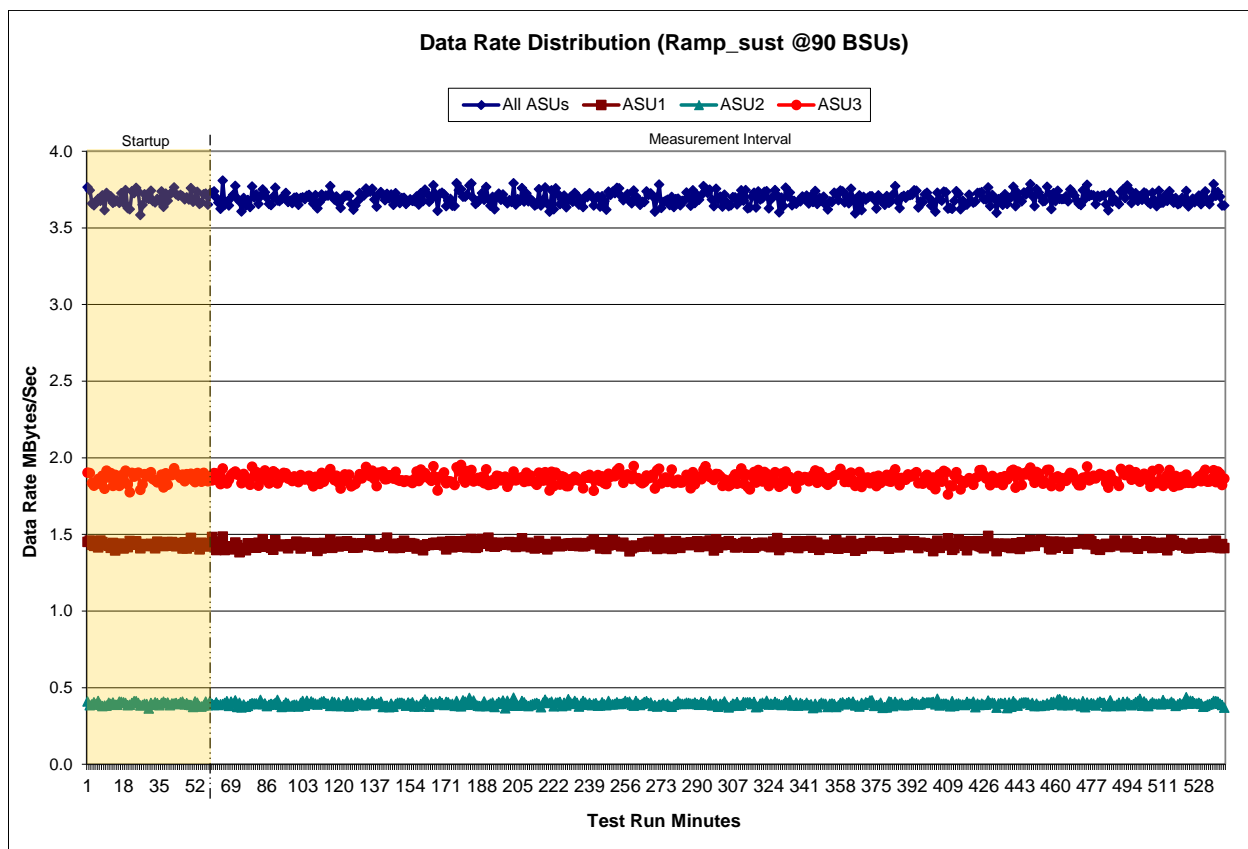
[Sustainability Test Results File](#)

Sustainability – Data Rate Distribution Data (MB/second)

The Sustainability Data Rate table of data is not embedded in this document due to its size. The table is available via the following URL:

[Sustainability Data Rate Table](#)

Sustainability – Data Rate Distribution Graph

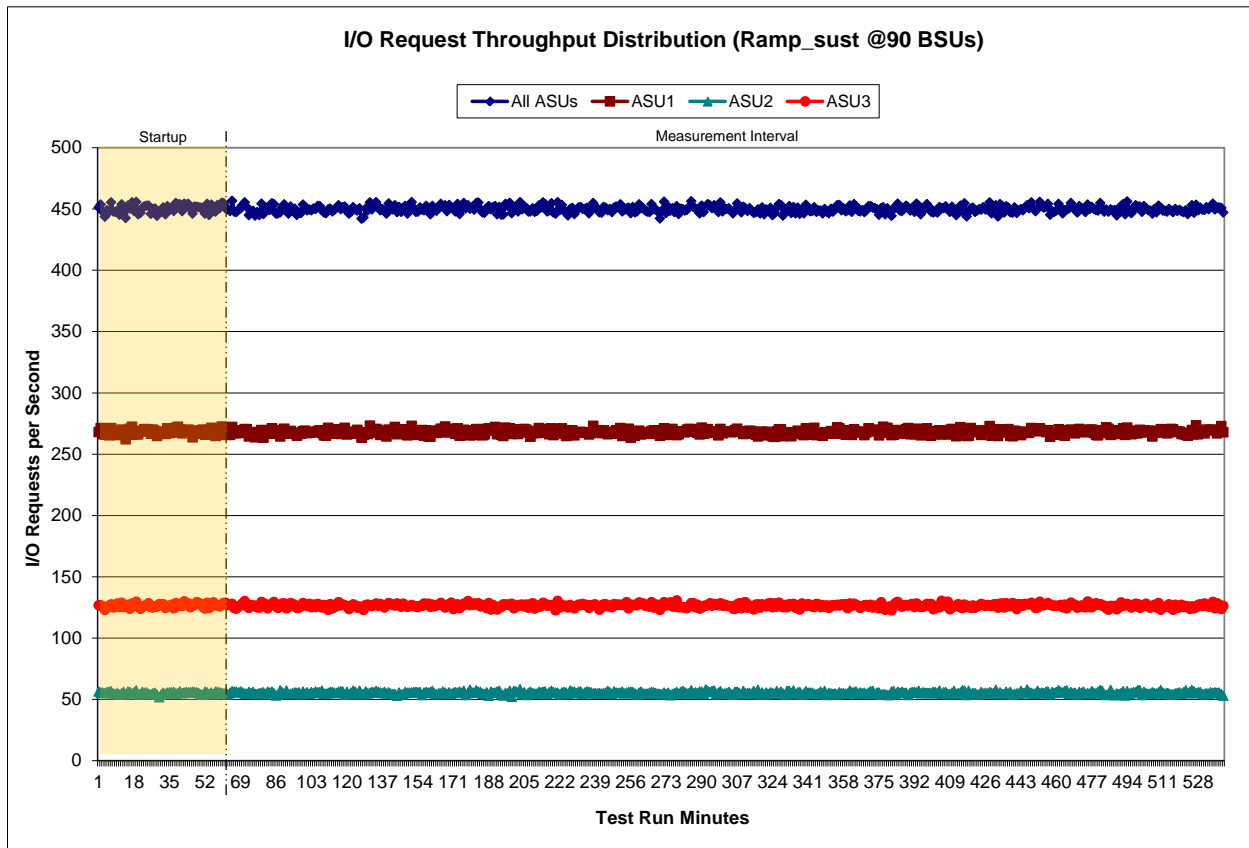


Sustainability – I/O Request Throughput Distribution Data

The Sustainability I/O Request Throughput table of data is not embedded in this document due to its size. The table is available via the following URL:

[Sustainability I/O Request Throughput Table](#)

Sustainability – I/O Request Throughput Distribution Graph

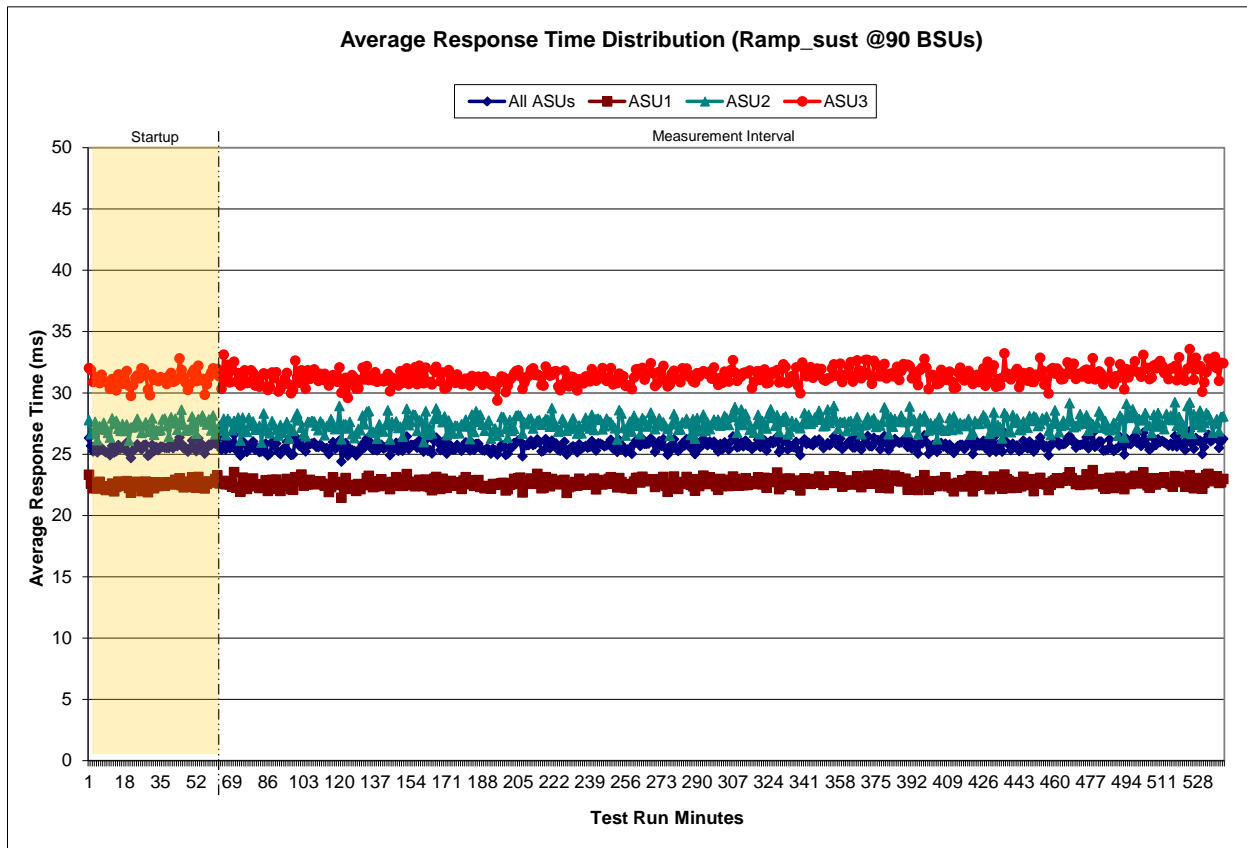


Sustainability – Average Response Time (ms) Distribution Data

The Sustainability Average Response Time table of data is not embedded in this document due to its size. The table is available via the following URL:

[Sustainability Average Response Time Table](#)

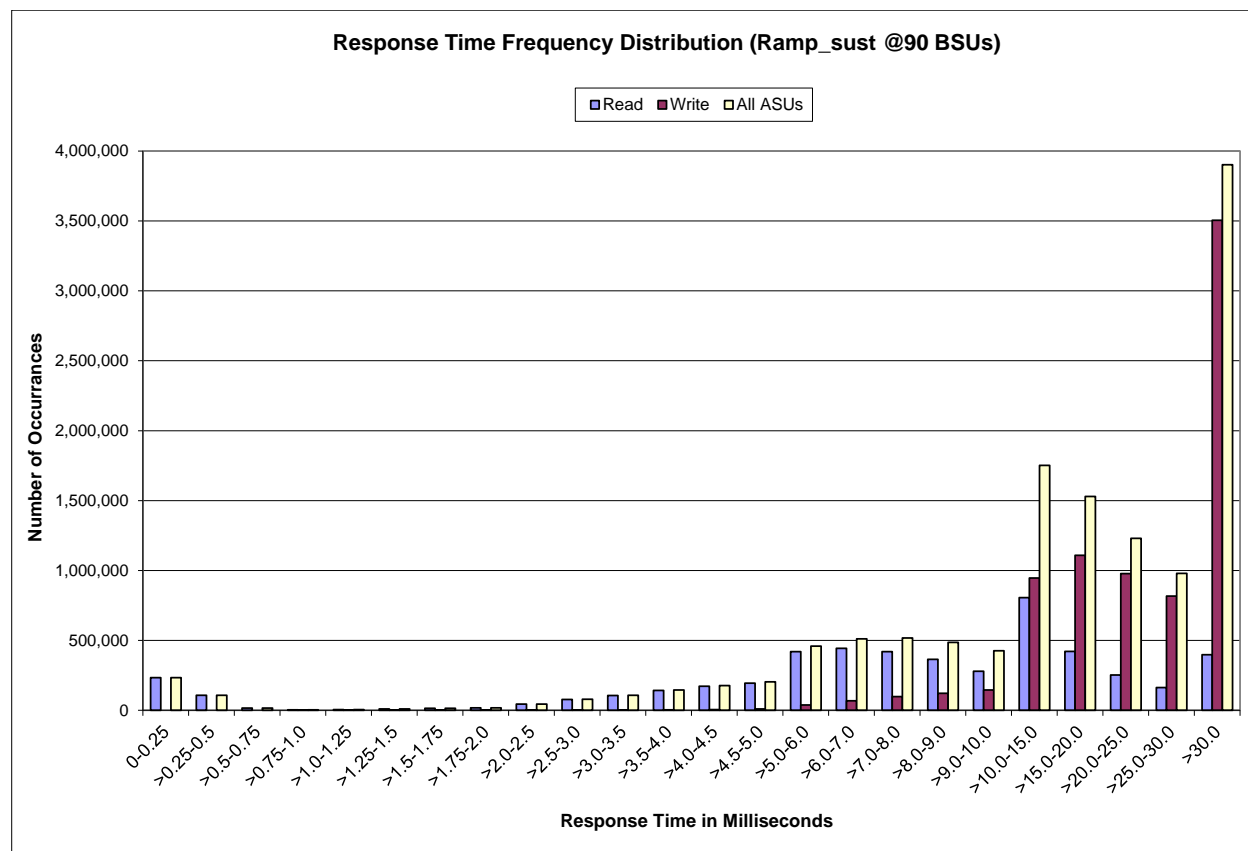
Sustainability – Average Response Time (ms) Distribution Graph



Sustainability – Response Time Frequency Distribution Data

Response Time (ms)	0-0.25	>0.25-0.5	>0.5-0.75	>0.75-1.0	>1.0-1.25	>1.25-1.5	>1.5-1.75	>1.75-2.0
Read	233,195	107,146	16,278	3,339	5,316	10,288	14,205	17,128
Write	-	-	-	4	4	7	15	25
All ASUs	233,195	107,146	16,278	3,343	5,320	10,295	14,220	17,153
ASU1	202,610	90,792	13,899	2,935	5,136	9,964	13,676	16,316
ASU2	30,585	16,354	2,379	404	180	324	530	819
ASU3	-	-	-	4	4	7	14	18
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	44,540	77,684	105,809	141,781	171,865	194,514	419,675	442,667
Write	136	589	1,394	2,741	5,037	9,720	38,536	67,946
All ASUs	44,676	78,273	107,203	144,522	176,902	204,234	458,211	510,613
ASU1	42,002	71,105	90,882	119,150	147,066	167,675	363,742	387,007
ASU2	2,569	6,703	15,234	23,220	25,921	28,872	63,402	68,289
ASU3	105	465	1,087	2,152	3,915	7,687	31,067	55,317
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	418,809	364,228	279,846	806,243	421,251	253,151	163,119	398,071
Write	98,292	121,582	145,468	946,183	1,108,865	977,416	816,513	3,504,664
All ASUs	517,101	485,810	425,314	1,752,426	1,530,116	1,230,567	979,632	3,902,735
ASU1	366,544	325,123	269,692	1,023,513	836,640	662,072	522,205	1,968,696
ASU2	70,312	63,710	44,660	177,160	165,978	141,107	116,783	529,428
ASU3	80,245	96,977	110,962	551,753	527,498	427,388	340,644	1,404,611

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 6.1.10

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).

Clause 6.3.14.3

COV – Coefficient of Variation: This measure of variation for the Measured Intensity Multiplier cannot exceed 0.5.

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
MIM	0.0351	0.2810	0.0699	0.2098	0.0180	0.0700	0.0351	0.2811
COV	0.031	0.009	0.021	0.011	0.046	0.023	0.031	0.101

Primary Metrics Test – IOPS Test Phase

Clause 6.4.3.3

The IOPS Test Phase consists of one Test Run at the 100% load point with a Measurement Interval of five (5) minutes. The IOPS Test Phase immediately follows the Sustainability Test Phase without any interruption or manual intervention.

The IOPS Test Run generates the SPC-1C 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 10.4.8.3

For the IOPS Test Phase the FDR shall contain:

- 1. I/O Request Throughput Distribution (data and graph).*
- 2. Response Time Frequency Distribution (data and graph).*
- 3. Average Response Time Distribution (data and graph).*
- 4. The human readable SPC-1C Test Run Results File produced by the SPC-1C Workload Generator.*
- 5. A listing of all input parameters supplied to the SPC-1C Workload Generator.*
- 6. The Measured Intensity Multiplier for each I/O Stream.*
- 7. The variability of the Measured Intensity Multiplier, as defined in Clause 6.3.13.3.*
- 8. 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-1C Workload Generator Input Parameters

The SPC-1C Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in [Appendix E: SPC-1C Workload Generator Input Parameters](#) on Page [74](#).

IOPS Test Results File

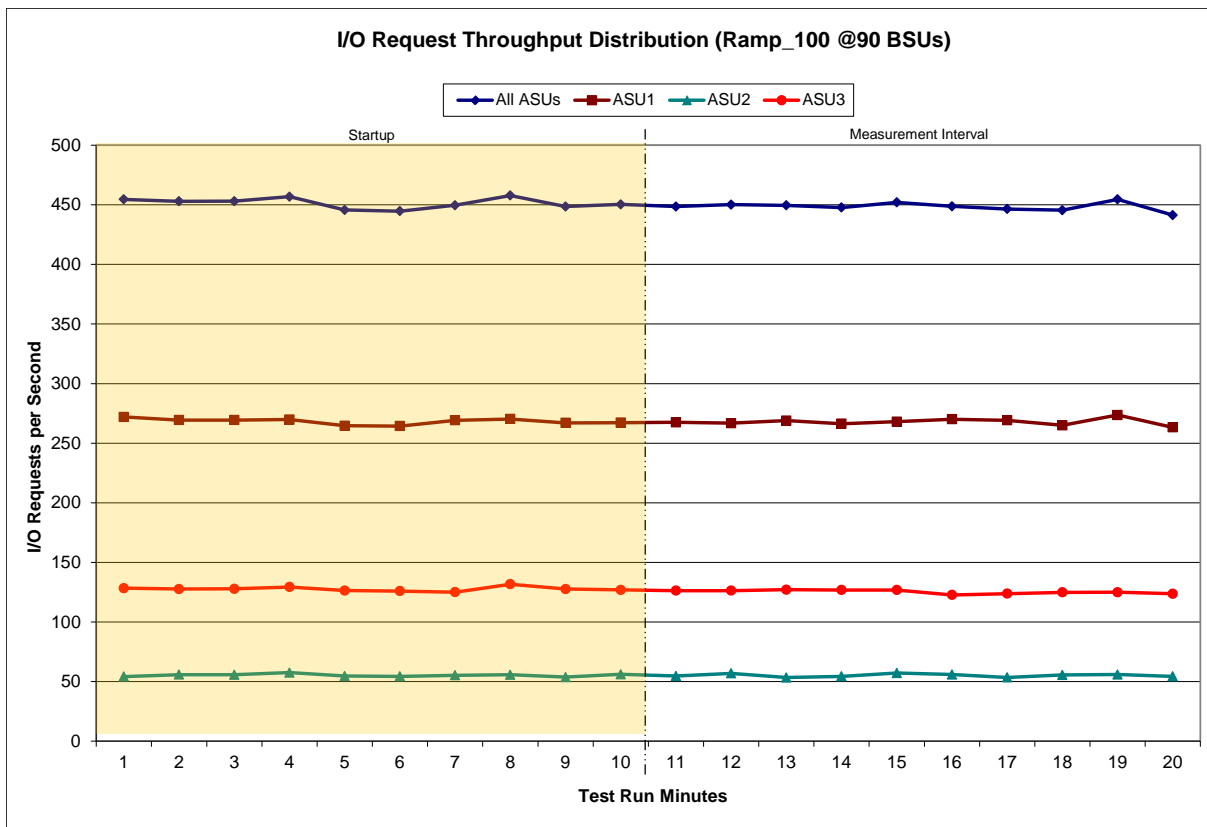
A link to the test results file generated from the IOPS Test Run is listed below.

[IOPS Test Results File](#)

IOPS Test Run – I/O Request Throughput Distribution Data

205 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	0:50:33	1:00:33	0-9	0:10:00
<i>Measurement Interval</i>	1:00:33	1:10:33	10-19	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	454.58	272.02	54.22	128.35
1	452.90	269.38	55.82	127.70
2	453.03	269.43	55.77	127.83
3	456.78	269.87	57.57	129.35
4	445.70	264.60	54.72	126.38
5	444.72	264.42	54.38	125.92
6	449.63	269.27	55.32	125.05
7	457.83	270.33	55.78	131.72
8	448.53	267.05	53.78	127.70
9	450.32	267.23	56.15	126.93
10	448.53	267.48	54.72	126.33
11	450.12	266.80	56.97	126.35
12	449.55	268.95	53.45	127.15
13	447.70	266.37	54.45	126.88
14	452.08	268.02	57.18	126.88
15	448.75	270.12	55.95	122.68
16	446.50	269.22	53.52	123.77
17	445.48	265.02	55.60	124.87
18	454.58	273.67	55.92	125.00
19	441.32	263.25	54.37	123.70
Average	448.46	267.89	55.21	125.36

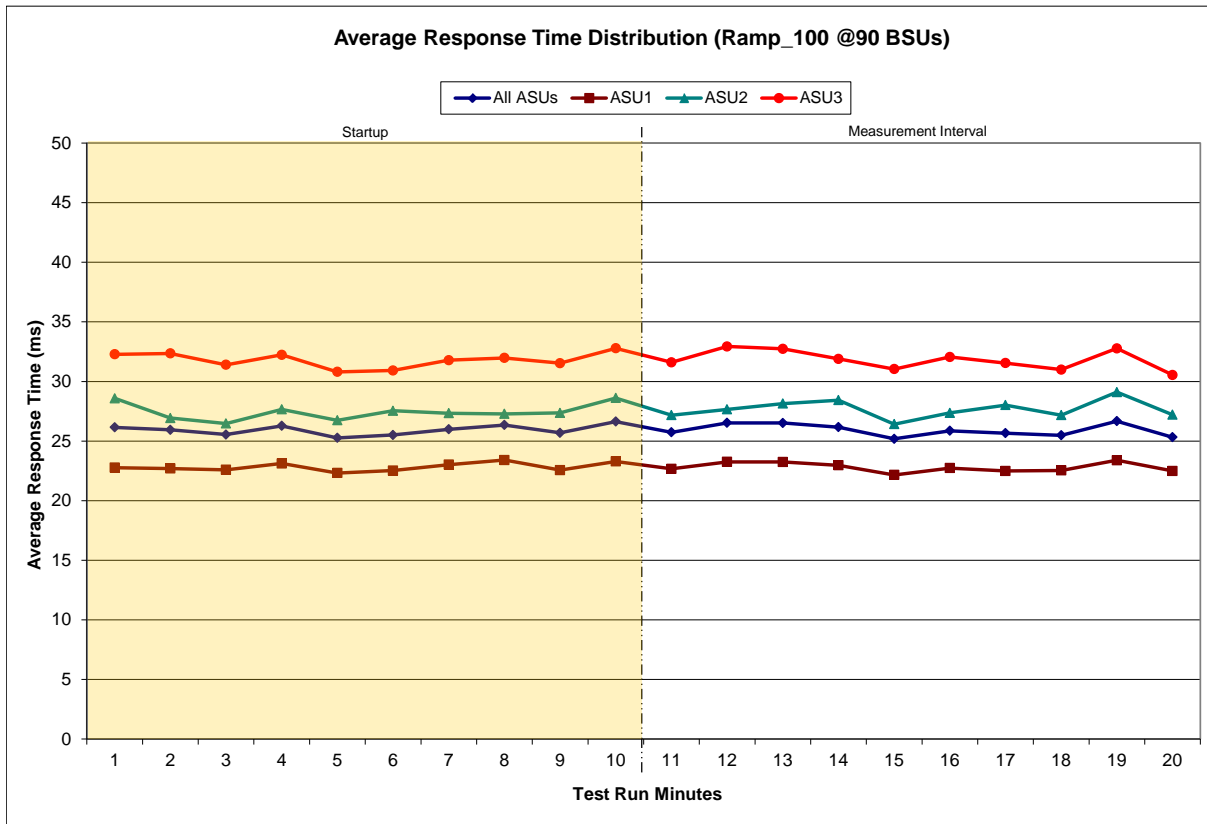
IOPS Test Run – I/O Request Throughput Distribution Graph



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

205 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	0:50:33	1:00:33	0-9	0:10:00
<i>Measurement Interval</i>	1:00:33	1:10:33	10-19	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	26.15	22.77	28.59	32.28
1	25.94	22.70	26.93	32.35
2	25.55	22.59	26.48	31.40
3	26.27	23.12	27.66	32.23
4	25.27	22.32	26.74	30.80
5	25.52	22.53	27.54	30.92
6	25.99	23.02	27.34	31.79
7	26.34	23.41	27.29	31.97
8	25.69	22.56	27.36	31.53
9	26.63	23.30	28.62	32.79
10	25.74	22.67	27.17	31.61
11	26.53	23.26	27.66	32.94
12	26.52	23.25	28.14	32.74
13	26.16	22.97	28.44	31.89
14	25.19	22.15	26.42	31.04
15	25.86	22.74	27.36	32.05
16	25.66	22.49	28.02	31.55
17	25.49	22.54	27.18	31.00
18	26.67	23.39	29.11	32.78
19	25.33	22.49	27.21	30.54
Average	25.91	22.79	27.67	31.81

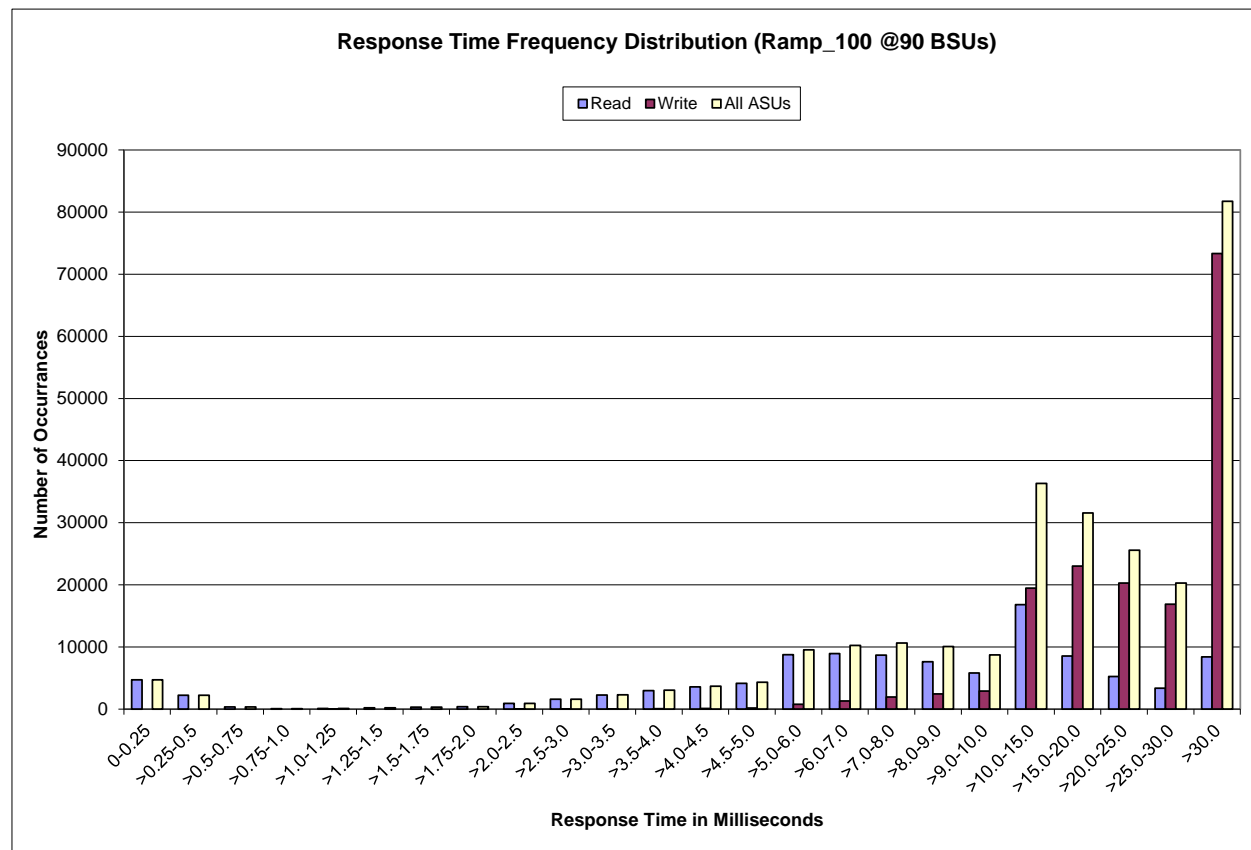
IOPS Test Run – Average Response Time (ms) Distribution Graph



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	4,725	2,255	353	69	97	209	328	380
Write	0	-	-	-	1	-	-	-
All ASUs	4,725	2,255	353	69	98	209	328	380
ASU1	4,080	1,900	299	61	91	204	318	362
ASU2	645	355	54	8	6	5	10	18
ASU3	0	-	-	-	1	-	-	-
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	938	1,587	2,264	2,995	3,603	4,165	8,770	8,937
Write	5	12	32	57	96	179	774	1,319
All ASUs	943	1,599	2,296	3,052	3,699	4,344	9,544	10,256
ASU1	885	1,438	1,976	2,499	3,070	3,575	7,602	7,850
ASU2	54	153	295	510	554	629	1,316	1,337
ASU3	4	8	25	43	75	140	626	1,069
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	8,685	7,634	5,823	16,833	8,536	5,266	3,384	8,395
Write	1,954	2,458	2,897	19,485	23,028	20,309	16,896	73,344
All ASUs	10,639	10,092	8,720	36,318	31,564	25,575	20,280	81,739
ASU1	7,562	6,794	5,675	21,452	17,218	13,808	10,744	41,270
ASU2	1,500	1,342	890	3,637	3,452	2,993	2,387	10,977
ASU3	1,577	1,956	2,155	11,229	10,894	8,774	7,149	29,492

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
269,077	187,338	81,739

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 6.1.10

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).

Clause 6.3.14.3

COV – Coefficient of Variation: This measure of variation for the Measured Intensity Multiplier cannot exceed 0.5.

	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	0.0354	0.2819	0.0700	0.2100	0.0180	0.0699	0.0353	0.2795
COV	0.024	0.007	0.027	0.013	0.053	0.014	0.039	0.012

Primary Metrics Test – Response Time Ramp Test Phase

Clause 6.4.3.4

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-1C IOPS™ primary metric. Each of the five Test Runs has a Measurement Interval of five (5) 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 16.

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

Clause 10.4.8.4

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

- 1. A Response Time Ramp Distribution graph.*
- 2. The human readable Test Run Results File produced by the SPC-1C C Workload Generator for each Test Run within the Response Time Ramp Test Phase.*
- 3. An Average Response Time Distribution graph and table for the 10% BSU Level Test Run (the SPC-1C LRT™ metric).*
- 4. A listing of all input parameters supplied to the SPC-1C Workload Generator.*

SPC-1C Workload Generator Input Parameters

The SPC-1C Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in [Appendix E: SPC-1C Workload Generator Input Parameters](#) on Page [74](#).

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-1C IOPS™ primary metric. The 100% BSU load level is included in the following Response Time Ramp data table and graph for completeness.

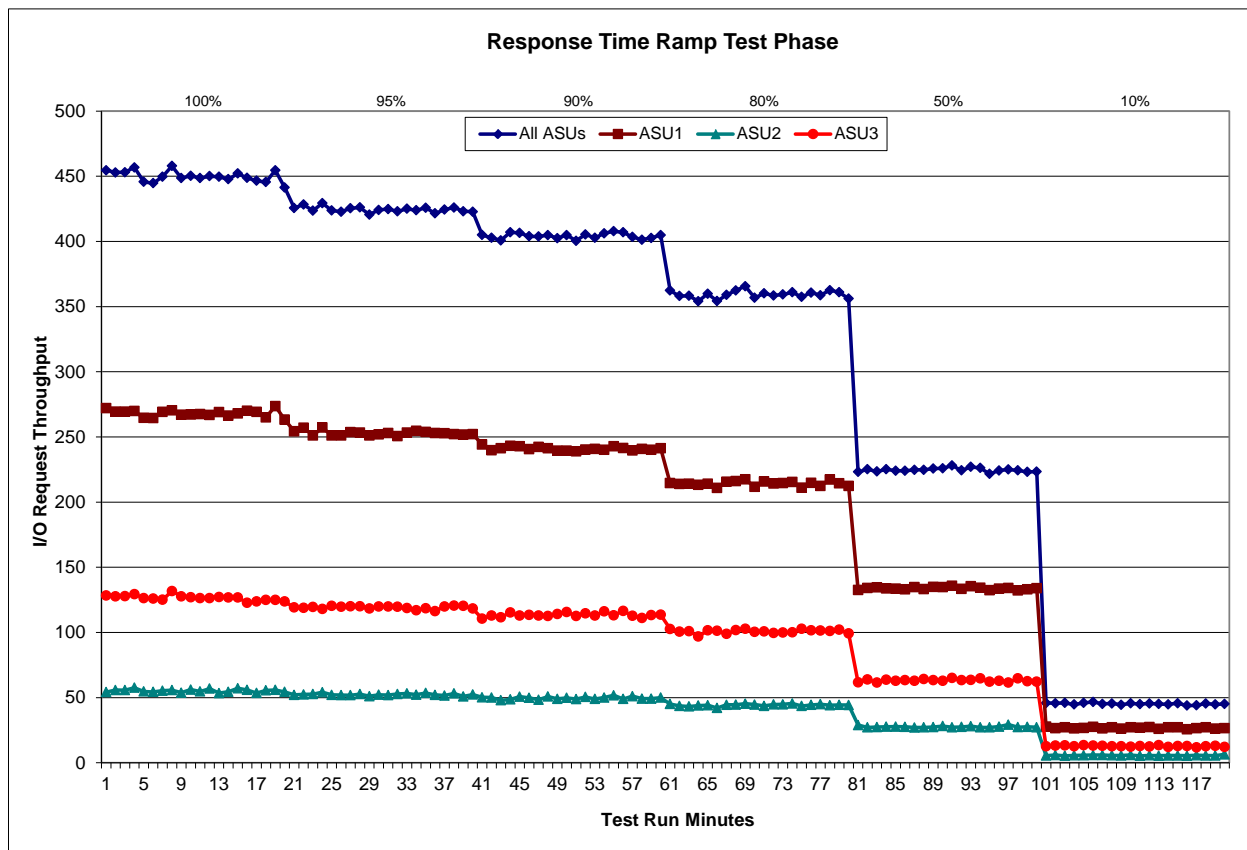
100% Load Level - 90 BSUs					95% Load Level - 85 BSUs				
Start	Stop	Interval	Duration		Start	Stop	Interval	Duration	
0:50:33	1:00:33	0-9	0:10:00		1:10:35	1:20:35	0-9	0:10:00	
Measurement Interval					Measurement Interval				
1:00:33	1:10:33	10-19	0:10:00		1:20:35	1:30:35	10-19	0:10:00	
(60 second intervals)					(60 second intervals)				
All ASUs	ASU-1	ASU-2	ASU-3		All ASUs	ASU-1	ASU-2	ASU-3	
0	454.58	272.02	54.22	128.35	0	425.62	254.33	52.13	119.15
1	452.90	269.38	55.82	127.70	1	428.28	257.02	52.43	118.83
2	453.03	269.43	55.77	127.83	2	423.50	251.17	52.73	119.60
3	456.78	269.87	57.57	129.35	3	429.35	257.15	54.12	118.08
4	445.70	264.60	54.72	126.38	4	423.70	251.12	52.12	120.47
5	444.72	264.42	54.38	125.92	5	422.78	251.12	51.95	119.72
6	449.63	269.27	55.32	125.05	6	425.38	253.57	51.85	119.97
7	457.83	270.33	55.78	131.72	7	426.10	253.30	52.72	120.08
8	448.53	267.05	53.78	127.70	8	420.60	251.10	51.12	118.38
9	450.32	267.23	56.15	126.93	9	424.10	252.00	52.23	119.87
10	448.53	267.48	54.72	126.33	10	424.80	253.03	51.97	119.80
11	450.12	266.80	56.97	126.35	11	423.00	250.58	52.78	119.63
12	449.55	268.95	53.45	127.15	12	425.05	253.22	53.20	118.63
13	447.70	266.37	54.45	126.88	13	423.88	254.60	52.30	116.98
14	452.08	268.02	57.18	126.88	14	425.85	253.73	53.53	118.58
15	448.75	270.12	55.95	122.68	15	421.50	253.03	52.10	116.37
16	446.50	269.22	53.52	123.77	16	424.37	252.85	51.58	119.93
17	445.48	265.02	55.60	124.87	17	425.97	252.13	53.23	120.60
18	454.58	273.67	55.92	125.00	18	423.13	251.83	50.92	120.38
19	441.32	263.25	54.37	123.70	19	422.82	252.18	52.35	118.28
Average	448.46	267.89	55.21	125.36	Average	424.04	252.72	52.40	118.92

90% Load Level - 81 BSUs					80% Load Level - 72BSUs				
Start	Stop	Interval	Duration		Start	Stop	Interval	Duration	
1:30:37	1:40:37	0-9	0:10:00		1:50:39	2:00:39	0-9	0:10:00	
Measurement Interval					Measurement Interval				
1:40:37	1:50:37	10-19	0:10:00		2:00:39	2:10:39	10-19	0:10:00	
(60 second intervals)					(60 second intervals)				
All ASUs	ASU-1	ASU-2	ASU-3		All ASUs	ASU-1	ASU-2	ASU-3	
0	404.93	244.18	50.23	110.52	0	362.32	214.55	45.10	102.67
1	402.77	239.70	50.12	112.95	1	358.10	213.92	43.63	100.55
2	400.82	241.23	47.98	111.60	2	358.28	214.08	43.20	101.00
3	407.07	243.17	48.65	115.25	3	354.10	213.22	43.95	96.93
4	406.48	242.82	50.72	112.95	4	359.85	214.15	44.17	101.53
5	403.95	240.68	49.87	113.40	5	354.18	210.83	42.07	101.28
6	403.72	242.33	48.37	113.02	6	358.98	215.60	44.48	98.90
7	404.82	241.27	50.88	112.67	7	362.37	216.03	44.62	101.72
8	402.48	239.38	49.05	114.05	8	365.63	217.47	45.33	102.83
9	404.87	239.45	49.80	115.62	9	356.78	211.68	44.68	100.42
10	400.42	238.88	48.87	112.67	10	360.15	215.73	43.68	100.73
11	405.37	240.25	50.50	114.62	11	358.52	214.17	44.75	99.60
12	402.77	240.82	49.02	112.93	12	359.25	214.53	44.82	99.90
13	406.22	240.08	50.05	116.08	13	361.00	215.42	45.52	100.07
14	407.80	242.88	51.75	113.17	14	357.40	210.95	43.58	102.87
15	406.95	241.50	48.95	116.50	15	360.70	214.73	44.38	101.58
16	403.40	239.53	51.10	112.77	16	358.70	212.42	44.88	101.40
17	401.30	240.87	49.27	111.17	17	362.58	217.33	44.15	101.10
18	402.63	240.08	49.22	113.33	18	361.00	214.48	44.42	102.10
19	404.87	241.32	49.97	113.58	19	356.07	212.43	44.33	99.30
Average	404.17	240.62	49.87	113.68	Average	359.54	214.22	44.45	100.87

Response Time Ramp Distribution (IOPS) Data (continued)

50% Load Level - 45 BSUs					10% Load Level - 9 BSUs				
Start	Stop	Interval	Duration		Start	Stop	Interval	Duration	
2:10:41	2:20:41	0-9	0:10:00		2:30:43	2:40:43	0-9	0:10:00	
2:20:41	2:30:41	10-19	0:10:00		2:40:43	2:50:43	10-19	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	223.17	132.60	28.93	61.63	0	45.83	27.72	5.52	12.60
1	225.15	134.03	27.13	63.98	1	45.65	26.57	5.95	13.13
2	223.53	134.63	27.38	61.52	2	45.97	27.27	5.32	13.38
3	225.15	133.77	27.68	63.70	3	44.73	26.42	5.68	12.63
4	224.10	133.52	27.77	62.82	4	45.90	26.67	5.75	13.48
5	224.02	133.03	27.60	63.38	5	46.72	27.55	5.95	13.22
6	224.75	134.83	27.07	62.85	6	45.22	26.32	5.93	12.97
7	224.77	133.28	27.20	64.28	7	45.52	27.20	5.70	12.62
8	225.70	134.97	27.40	63.33	8	44.50	26.22	5.60	12.68
9	225.93	134.83	28.17	62.93	9	45.58	27.23	5.97	12.38
10	228.08	135.75	27.27	65.07	10	45.03	26.92	5.32	12.80
11	224.32	133.37	27.52	63.43	11	45.50	27.38	5.68	12.43
12	227.08	135.37	28.08	63.63	12	45.07	26.05	5.45	13.57
13	226.22	134.32	27.18	64.72	13	44.87	27.13	5.62	12.12
14	221.67	132.35	27.13	62.18	14	45.65	27.18	5.63	12.83
15	224.25	133.62	27.78	62.85	15	43.92	25.68	5.42	12.82
16	225.00	134.13	29.28	61.58	16	44.05	26.47	5.75	11.83
17	224.32	132.27	27.35	64.70	17	45.55	27.18	5.62	12.75
18	223.12	133.07	27.57	62.48	18	44.78	26.27	5.52	13.00
19	223.37	133.95	27.22	62.20	19	45.15	26.57	6.43	12.15
Average	224.74	133.82	27.64	63.29	Average	44.96	26.68	5.64	12.63

Response Time Ramp Distribution (IOPS) Graph

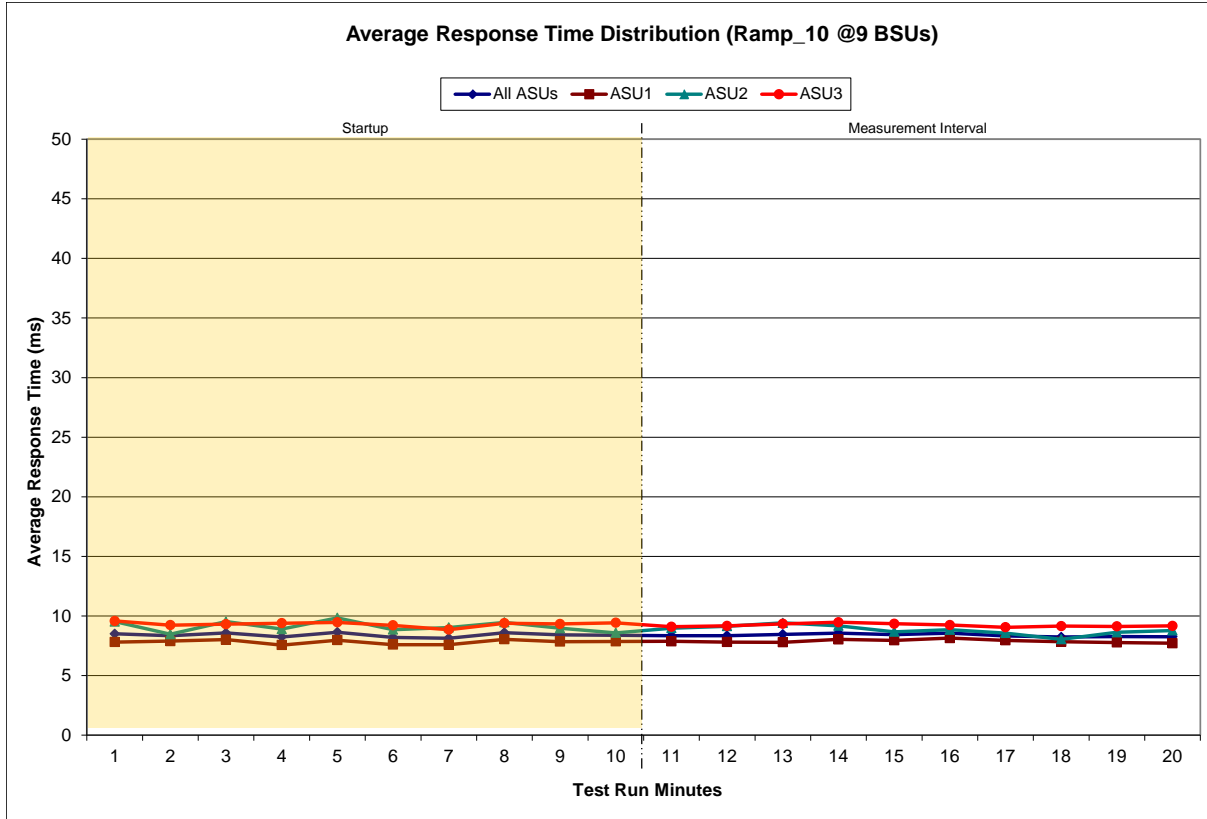


SPC-1C LRT™ Average Response Time (ms) Distribution Data

9 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	2:30:43	2:40:43	0-9	0:10:00
<i>Measurement Interval</i>	2:40:43	2:50:43	10-19	0:10:00

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	8.51	7.81	9.53	9.59
1	8.36	7.89	8.47	9.24
2	8.58	8.02	9.53	9.32
3	8.25	7.56	8.90	9.40
4	8.64	7.97	9.85	9.46
5	8.21	7.59	8.86	9.21
6	8.14	7.59	9.03	8.85
7	8.60	8.05	9.47	9.40
8	8.42	7.85	8.97	9.34
9	8.39	7.87	8.58	9.43
10	8.36	7.88	8.99	9.10
11	8.35	7.81	9.14	9.17
12	8.46	7.79	9.43	9.34
13	8.57	8.04	9.18	9.47
14	8.44	7.95	8.68	9.35
15	8.56	8.15	8.85	9.24
16	8.33	7.96	8.57	9.06
17	8.24	7.84	8.05	9.15
18	8.27	7.78	8.63	9.13
19	8.26	7.72	8.79	9.17
Average	8.38	7.89	8.83	9.22

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



SPC-1C 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 6.1.10

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).

Clause 6.3.14.3

COV – Coefficient of Variation: This measure of variation for the Measured Intensity Multiplier cannot exceed 0.5.

	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	0.0361	0.2803	0.0688	0.2083	0.0186	0.0716	0.0354	0.2809
COV	0.107	0.033	0.030	0.058	0.154	0.043	0.109	0.039

Repeatability Test

Clause 6.4.4

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

The second Test Run in each Test Phase is executed at the 100% load point. The I/O Request Throughput from the Test Runs is compared to the SPC-1C IOPS™ primary metric. Each I/O Request Throughput value must be greater than the SPC-1C 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 10.4.8.5

The FDR shall contain the following for the Repeatability Test:

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

SPC-1C Workload Generator Input Parameters

The SPC-1C Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in [Appendix E: SPC-1C Workload Generator Input Parameters](#) on Page [74](#).

Repeatability Test Results File

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

	SPC-1C IOPS™
Primary Metrics	448.46
Repeatability Test Phase 1	450.24
Repeatability Test Phase 2	449.90

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

	SPC-1C LRT™
Primary Metrics	8.38 ms
Repeatability Test Phase 1	8.50 ms
Repeatability Test Phase 2	8.51 ms

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

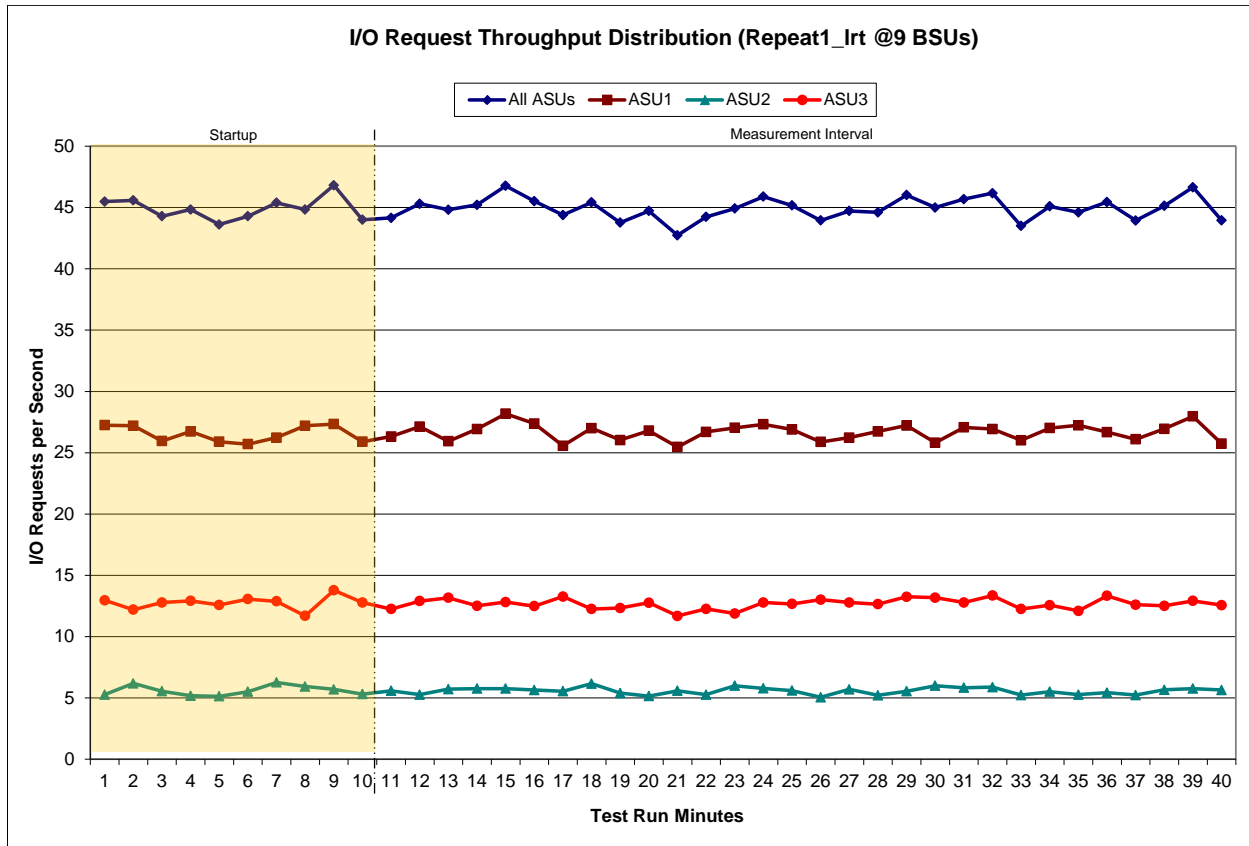
A link to the test result file generated from each Repeatability Test Run is listed below.

- [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

9 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	12:16:12	12:26:12	0-9	0:10:00
<i>Measurement Interval</i>	12:26:12	12:56:12	10-39	0:30:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	45.48	27.25	5.27	12.97
1	45.58	27.20	6.18	12.20
2	44.28	25.95	5.55	12.78
3	44.83	26.73	5.18	12.92
4	43.62	25.90	5.13	12.58
5	44.28	25.70	5.52	13.07
6	45.38	26.23	6.27	12.88
7	44.83	27.20	5.93	11.70
8	46.82	27.33	5.70	13.78
9	44.00	25.90	5.32	12.78
10	44.15	26.32	5.58	12.25
11	45.30	27.13	5.27	12.90
12	44.82	25.93	5.72	13.17
13	45.22	26.93	5.77	12.52
14	46.77	28.18	5.77	12.82
15	45.52	27.38	5.65	12.48
16	44.38	25.57	5.55	13.27
17	45.42	27.00	6.17	12.25
18	43.77	26.03	5.40	12.33
19	44.72	26.80	5.15	12.77
20	42.73	25.47	5.58	11.68
21	44.23	26.70	5.27	12.27
22	44.92	27.03	6.00	11.88
23	45.88	27.32	5.78	12.78
24	45.17	26.90	5.60	12.67
25	43.95	25.88	5.05	13.02
26	44.72	26.23	5.70	12.78
27	44.60	26.73	5.22	12.65
28	46.02	27.22	5.55	13.25
29	45.00	25.82	6.00	13.18
30	45.68	27.07	5.83	12.78
31	46.17	26.93	5.88	13.35
32	43.50	26.02	5.23	12.25
33	45.10	27.02	5.52	12.57
34	44.60	27.23	5.27	12.10
35	45.45	26.68	5.43	13.33
36	43.93	26.10	5.23	12.60
37	45.13	26.95	5.67	12.52
38	46.65	27.97	5.77	12.92
39	43.95	25.73	5.65	12.57
Average	44.91	26.68	5.58	12.66

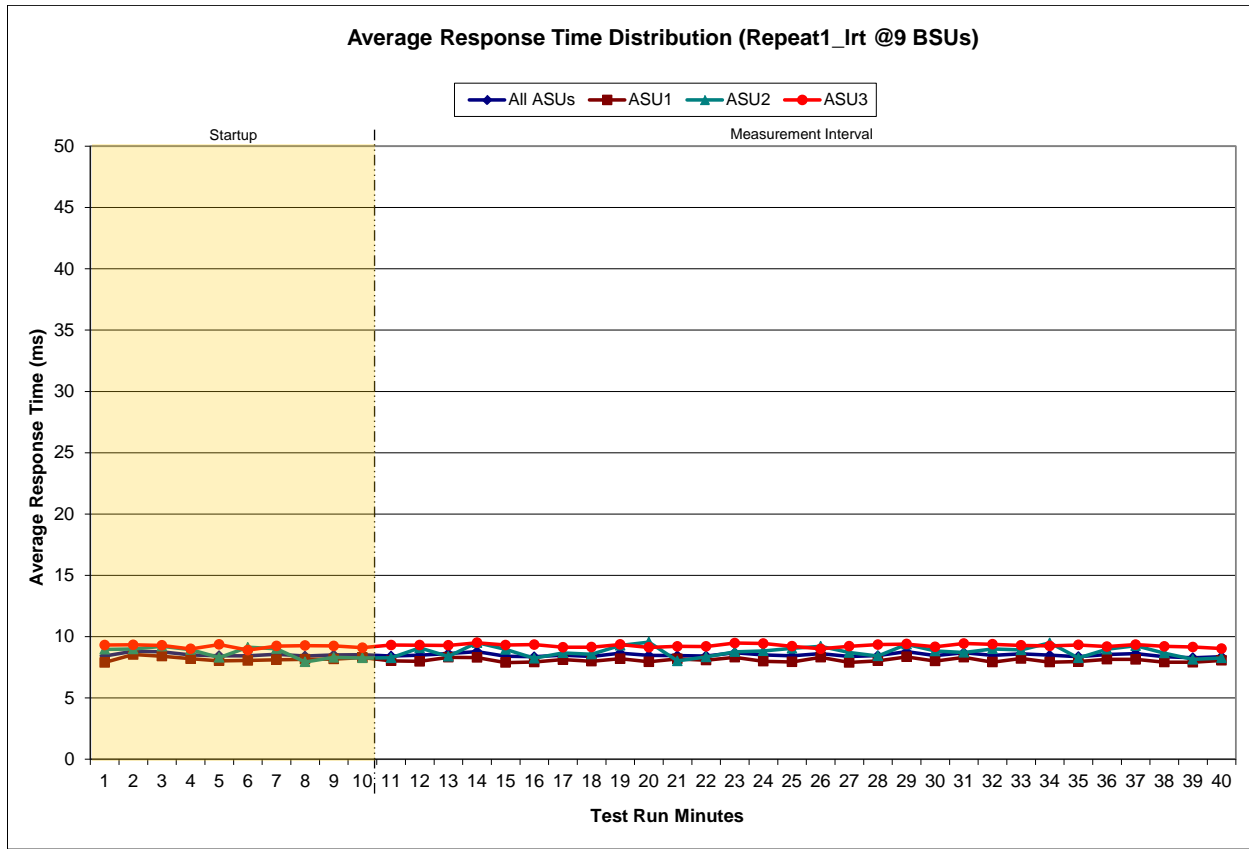
Repeatability 1 LRT – I/O Request Throughput Distribution Graph



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

9 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	12:16:12	12:26:12	0-9	0:10:00
Measurement Interval	12:26:12	12:56:12	10-39	0:30:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	8.43	7.90	8.97	9.32
1	8.81	8.54	8.99	9.33
2	8.76	8.41	9.22	9.28
3	8.51	8.20	8.94	9.00
4	8.45	8.03	8.30	9.36
5	8.44	8.06	9.14	8.90
6	8.56	8.12	9.02	9.24
7	8.42	8.16	7.94	9.27
8	8.51	8.17	8.31	9.24
9	8.53	8.30	8.27	9.10
10	8.42	8.03	8.28	9.32
11	8.49	7.98	9.08	9.31
12	8.61	8.32	8.39	9.29
13	8.79	8.29	9.52	9.50
14	8.41	7.88	8.96	9.31
15	8.36	7.93	8.23	9.35
16	8.50	8.13	8.68	9.14
17	8.38	7.99	8.57	9.15
18	8.66	8.20	9.29	9.36
19	8.47	7.95	9.56	9.12
20	8.45	8.19	8.02	9.21
21	8.42	8.08	8.34	9.20
22	8.68	8.31	8.77	9.48
23	8.50	7.99	8.84	9.44
24	8.43	7.94	9.04	9.21
25	8.63	8.32	9.22	9.01
26	8.38	7.90	8.70	9.22
27	8.45	8.03	8.42	9.35
28	8.78	8.36	9.37	9.39
29	8.46	8.01	8.83	9.17
30	8.68	8.32	8.71	9.44
31	8.48	7.92	9.00	9.38
32	8.61	8.22	8.92	9.29
33	8.48	7.93	9.49	9.24
34	8.37	7.97	8.27	9.32
35	8.55	8.15	8.97	9.19
36	8.62	8.15	9.26	9.35
37	8.37	7.92	8.66	9.21
38	8.28	7.91	8.15	9.15
39	8.36	8.06	8.27	9.03
Average	8.50	8.08	8.79	9.27

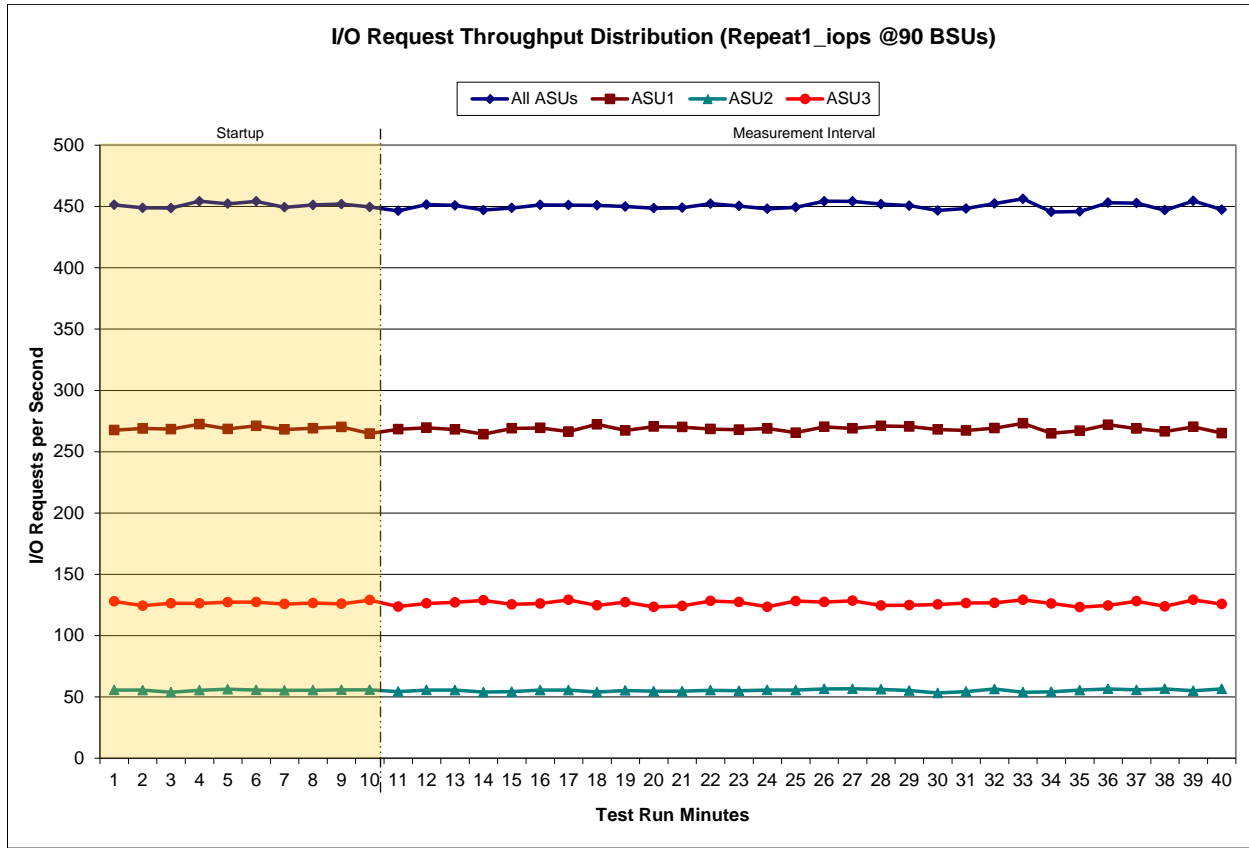
Repeatability 1 LRT –Average Response Time (ms) Distribution Graph



Repeatability 1 IOPS – I/O Request Throughput Distribution Data

90 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	12:56:15	13:06:15	0-9	0:10:00
<i>Measurement Interval</i>	13:06:15	13:36:15	10-39	0:30:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	451.30	267.65	55.68	127.97
1	448.90	268.93	55.58	124.38
2	448.72	268.45	53.87	126.40
3	454.30	272.50	55.48	126.32
4	452.20	268.57	56.30	127.33
5	454.18	271.08	55.67	127.43
6	449.38	268.18	55.40	125.80
7	451.25	269.13	55.52	126.60
8	451.97	270.18	55.82	125.97
9	449.65	264.78	55.88	128.98
10	446.45	268.33	54.40	123.72
11	451.57	269.58	55.67	126.32
12	450.87	268.17	55.55	127.15
13	447.13	264.32	53.97	128.85
14	448.85	269.02	54.28	125.55
15	451.28	269.40	55.62	126.27
16	451.12	266.43	55.53	129.15
17	450.97	272.33	53.95	124.68
18	449.95	267.32	55.35	127.28
19	448.60	270.52	54.68	123.40
20	449.03	270.12	54.68	124.23
21	452.28	268.55	55.45	128.28
22	450.45	267.95	55.07	127.43
23	448.08	268.93	55.63	123.52
24	449.33	265.57	55.58	128.18
25	454.27	270.28	56.60	127.38
26	454.18	269.08	56.62	128.48
27	451.92	271.07	56.20	124.65
28	450.73	270.58	55.23	124.92
29	446.73	268.13	53.22	125.38
30	448.33	267.32	54.42	126.60
31	452.43	269.23	56.47	126.73
32	456.25	273.20	53.87	129.18
33	445.55	265.03	54.27	126.25
34	445.95	267.08	55.57	123.30
35	453.17	272.00	56.57	124.60
36	452.73	268.87	55.75	128.12
37	447.05	266.53	56.60	123.92
38	454.55	270.30	55.03	129.22
39	447.50	265.17	56.57	125.77
Average	450.24	268.68	55.28	126.28

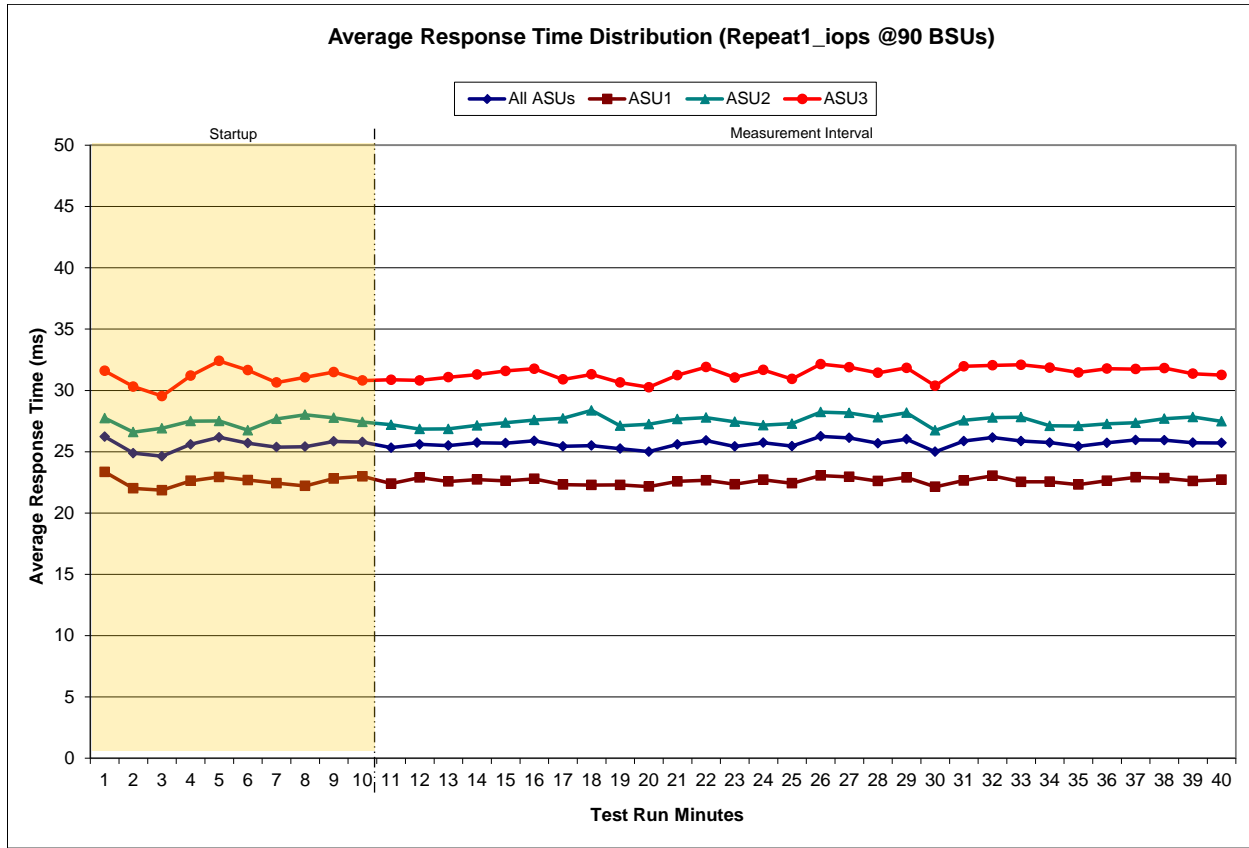
Repeatability 1 IOPS – I/O Request Throughput Distribution Graph



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

90 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	12:56:15	13:06:15	0-9	0:10:00
<i>Measurement Interval</i>	13:06:15	13:36:15	10-39	0:30:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	26.23	23.36	27.74	31.59
1	24.88	22.01	26.60	30.31
2	24.63	21.86	26.92	29.54
3	25.60	22.62	27.50	31.20
4	26.18	22.94	27.50	32.40
5	25.70	22.69	26.75	31.65
6	25.38	22.44	27.68	30.64
7	25.41	22.22	28.02	31.07
8	25.84	22.81	27.77	31.50
9	25.79	22.99	27.43	30.81
10	25.33	22.40	27.20	30.87
11	25.60	22.90	26.85	30.82
12	25.50	22.57	26.86	31.07
13	25.73	22.73	27.15	31.29
14	25.70	22.62	27.37	31.58
15	25.89	22.79	27.58	31.76
16	25.44	22.32	27.72	30.89
17	25.51	22.28	28.37	31.31
18	25.25	22.29	27.12	30.65
19	25.01	22.16	27.24	30.25
20	25.60	22.58	27.66	31.25
21	25.92	22.67	27.79	31.91
22	25.43	22.35	27.44	31.05
23	25.73	22.71	27.17	31.67
24	25.46	22.43	27.29	30.93
25	26.25	23.06	28.23	32.15
26	26.13	22.95	28.16	31.89
27	25.69	22.61	27.80	31.43
28	26.03	22.90	28.18	31.84
29	25.00	22.14	26.74	30.37
30	25.87	22.65	27.56	31.96
31	26.15	23.04	27.78	32.05
32	25.87	22.54	27.82	32.09
33	25.75	22.56	27.11	31.85
34	25.44	22.32	27.11	31.46
35	25.73	22.64	27.27	31.77
36	25.96	22.92	27.36	31.74
37	25.94	22.84	27.69	31.82
38	25.74	22.62	27.83	31.36
39	25.72	22.72	27.48	31.25
Average	25.68	22.61	27.50	31.41

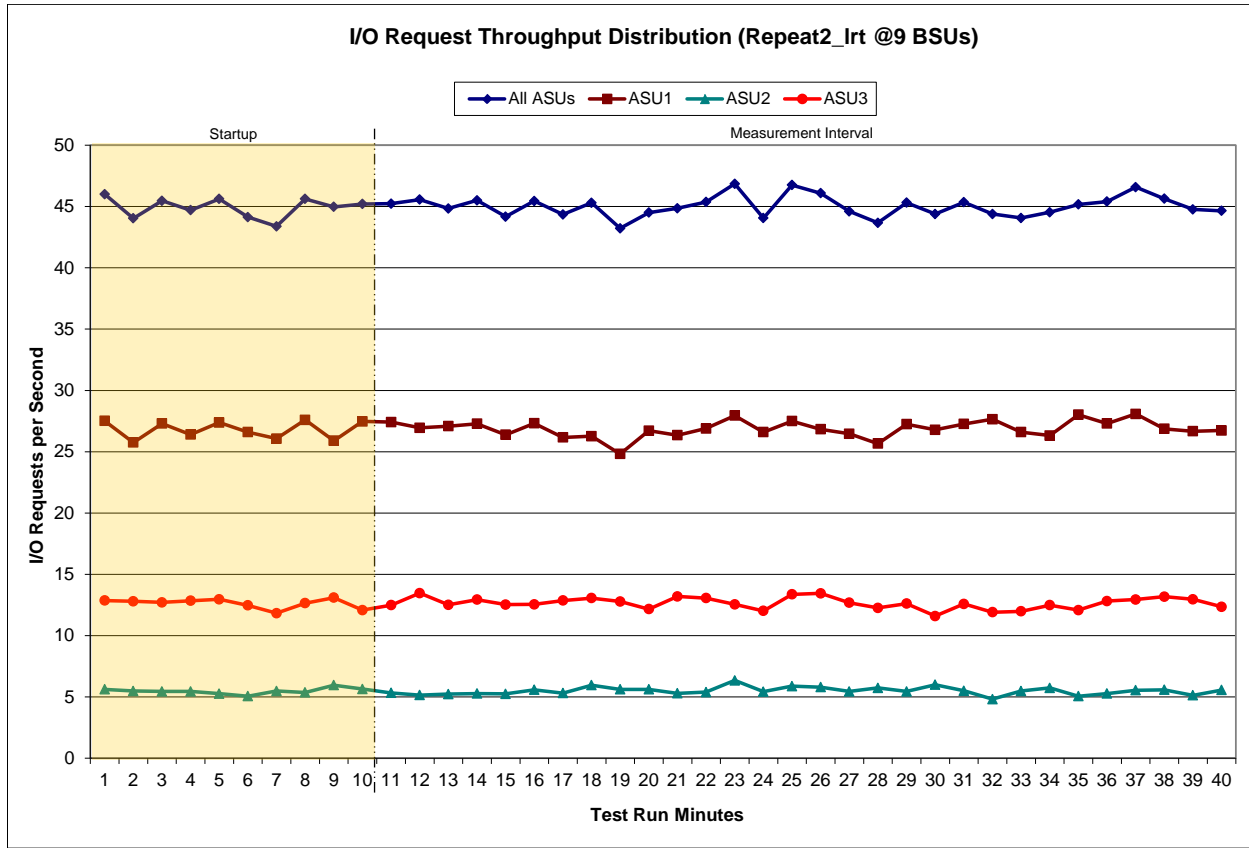
Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph



Repeatability 2 LRT – I/O Request Throughput Distribution Data

9 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	13:36:18	13:46:18	0-9	0:10:00
<i>Measurement Interval</i>	13:46:18	14:16:18	10-39	0:30:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	46.00	27.52	5.62	12.87
1	44.03	25.75	5.48	12.80
2	45.47	27.30	5.45	12.72
3	44.70	26.40	5.45	12.85
4	45.62	27.38	5.27	12.97
5	44.13	26.60	5.07	12.47
6	43.38	26.07	5.48	11.83
7	45.62	27.60	5.37	12.65
8	44.97	25.90	5.97	13.10
9	45.20	27.47	5.65	12.08
10	45.23	27.42	5.33	12.48
11	45.57	26.95	5.15	13.47
12	44.83	27.08	5.23	12.52
13	45.50	27.28	5.28	12.93
14	44.17	26.38	5.25	12.53
15	45.45	27.32	5.58	12.55
16	44.35	26.17	5.32	12.87
17	45.30	26.27	5.97	13.07
18	43.22	24.82	5.62	12.78
19	44.50	26.72	5.62	12.17
20	44.85	26.35	5.30	13.20
21	45.37	26.90	5.40	13.07
22	46.85	27.95	6.35	12.55
23	44.05	26.60	5.43	12.02
24	46.75	27.50	5.88	13.37
25	46.08	26.83	5.80	13.45
26	44.60	26.47	5.45	12.68
27	43.67	25.67	5.73	12.27
28	45.32	27.25	5.45	12.62
29	44.38	26.78	6.00	11.60
30	45.35	27.27	5.50	12.58
31	44.38	27.65	4.82	11.92
32	44.07	26.60	5.48	11.98
33	44.53	26.32	5.73	12.48
34	45.17	28.02	5.07	12.08
35	45.40	27.30	5.28	12.82
36	46.58	28.08	5.55	12.95
37	45.63	26.87	5.58	13.18
38	44.77	26.67	5.13	12.97
39	44.65	26.73	5.57	12.35
Average	45.02	26.87	5.50	12.65

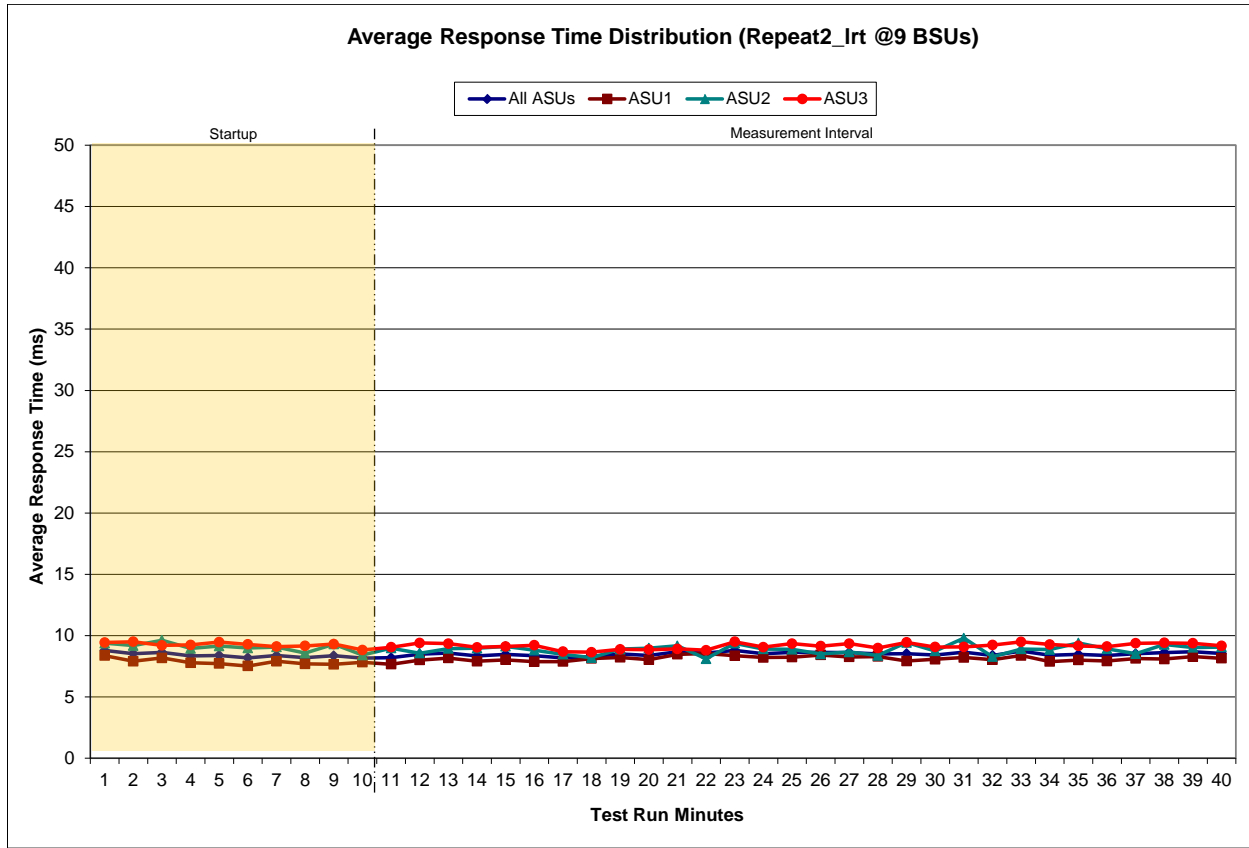
Repeatability 2 LRT – I/O Request Throughput Distribution Graph



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

9 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	13:36:18	13:46:18	0-9	0:10:00
Measurement Interval	13:46:18	14:16:18	10-39	0:30:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	8.79	8.37	9.39	9.44
1	8.53	7.91	9.19	9.50
2	8.64	8.18	9.63	9.21
3	8.35	7.78	8.95	9.25
4	8.38	7.72	9.15	9.47
5	8.19	7.52	8.99	9.29
6	8.38	7.91	9.07	9.11
7	8.21	7.70	8.58	9.16
8	8.36	7.66	9.30	9.31
9	8.17	7.84	8.41	8.83
10	8.20	7.67	8.98	9.05
11	8.49	8.01	8.57	9.41
12	8.59	8.17	8.95	9.35
13	8.36	7.91	8.97	9.04
14	8.47	8.03	9.13	9.12
15	8.36	7.87	8.81	9.22
16	8.19	7.89	8.47	8.69
17	8.30	8.14	8.20	8.65
18	8.51	8.22	8.90	8.88
19	8.38	8.04	8.98	8.85
20	8.69	8.48	9.17	8.92
21	8.58	8.55	8.11	8.82
22	8.81	8.36	9.38	9.50
23	8.53	8.22	8.91	9.06
24	8.64	8.25	8.88	9.35
25	8.65	8.43	8.51	9.14
26	8.62	8.27	8.67	9.35
27	8.51	8.30	8.38	8.99
28	8.53	7.93	9.44	9.45
29	8.42	8.07	8.75	9.07
30	8.65	8.22	9.80	9.08
31	8.38	8.04	8.28	9.23
32	8.75	8.38	8.91	9.49
33	8.40	7.89	8.87	9.28
34	8.47	8.01	9.40	9.17
35	8.38	7.93	8.92	9.11
36	8.53	8.13	8.53	9.38
37	8.62	8.10	9.28	9.41
38	8.69	8.29	9.04	9.38
39	8.55	8.16	9.07	9.17
Average	8.51	8.13	8.88	9.15

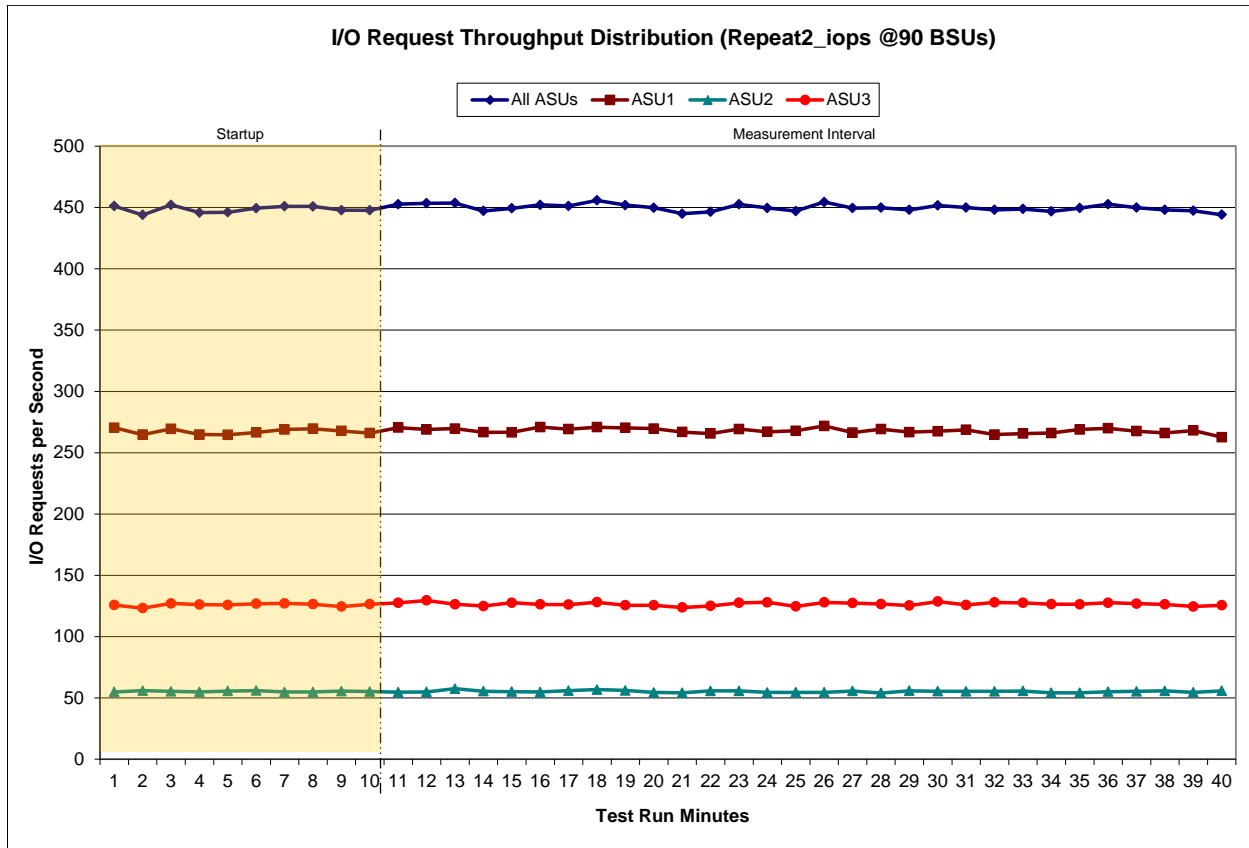
Repeatability 2 LRT –Average Response Time (ms) Distribution Graph



Repeatability 2 IOPS – I/O Request Throughput Distribution Data

90 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	14:16:21	14:26:21	0-9	0:10:00
<i>Measurement Interval</i>	14:26:21	14:56:21	10-39	0:30:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	451.12	270.42	54.92	125.78
1	444.00	264.75	55.95	123.30
2	452.10	269.52	55.43	127.15
3	445.88	264.80	54.97	126.12
4	446.15	264.67	55.65	125.83
5	449.40	266.53	56.02	126.85
6	450.93	268.95	54.85	127.13
7	450.88	269.55	54.83	126.50
8	447.85	267.75	55.58	124.52
9	447.77	266.02	55.23	126.52
10	452.70	270.47	54.67	127.57
11	453.47	268.92	54.97	129.58
12	453.63	269.72	57.53	126.38
13	447.18	266.70	55.48	125.00
14	449.38	266.60	55.13	127.65
15	452.12	270.90	54.88	126.33
16	451.23	269.23	55.90	126.10
17	455.83	270.85	56.83	128.15
18	451.98	270.28	56.12	125.58
19	449.78	269.72	54.47	125.60
20	444.92	266.88	54.27	123.77
21	446.43	265.67	55.75	125.02
22	452.57	269.28	55.72	127.57
23	449.62	267.10	54.47	128.05
24	447.12	267.85	54.55	124.72
25	454.45	271.85	54.63	127.97
26	449.48	266.45	55.68	127.35
27	449.85	269.25	54.02	126.58
28	448.05	266.78	55.88	125.38
29	451.67	267.52	55.47	128.68
30	449.97	268.68	55.42	125.87
31	448.13	264.80	55.40	127.93
32	448.85	265.62	55.65	127.58
33	446.83	266.08	54.22	126.53
34	449.53	268.92	54.20	126.42
35	452.72	269.90	55.17	127.65
36	449.90	267.57	55.37	126.97
37	448.08	266.07	55.72	126.30
38	447.37	268.12	54.63	124.62
39	444.10	262.65	55.83	125.62
Average	449.90	268.01	55.27	126.62

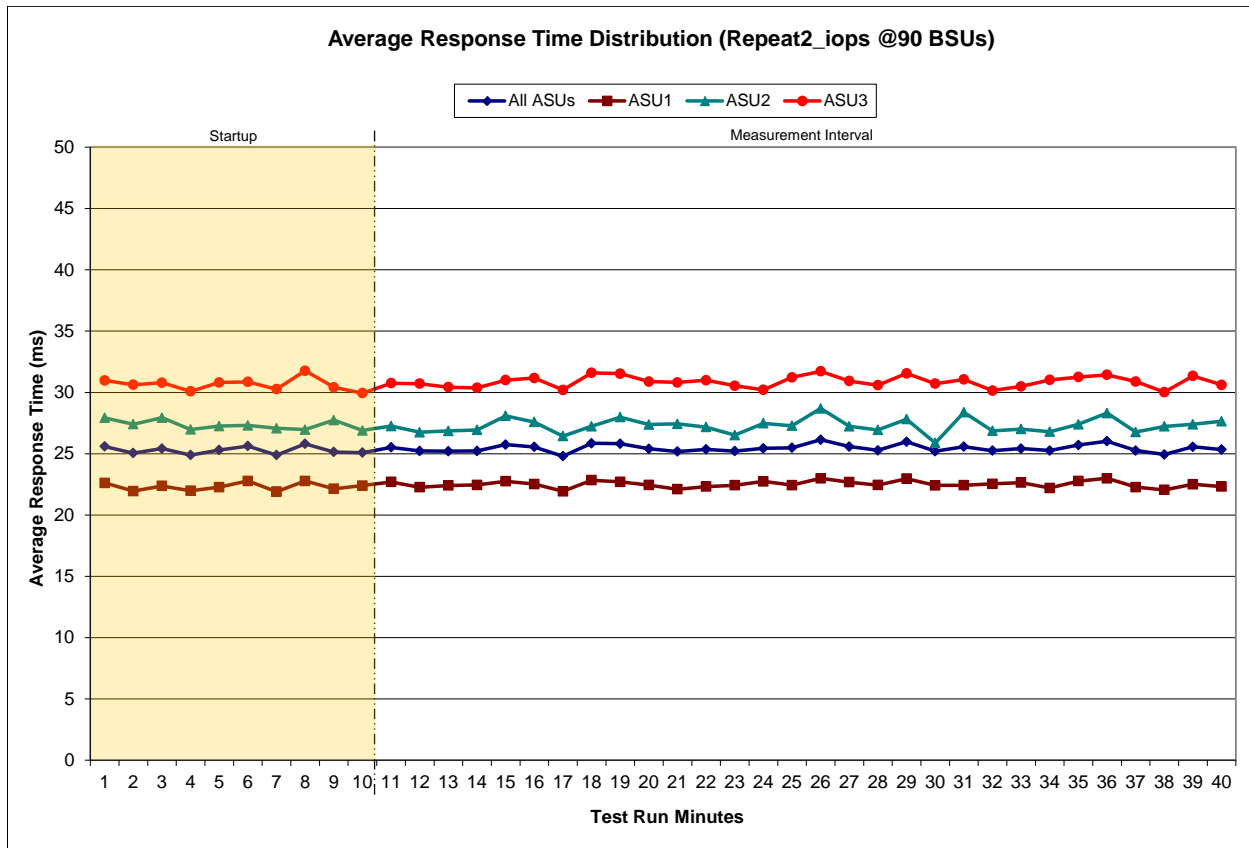
Repeatability 2 IOPS – I/O Request Throughput Distribution Graph



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

90 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	14:16:21	14:26:21	0-9	0:10:00
Measurement Interval	14:26:21	14:56:21	10-39	0:30:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	25.59	22.61	27.93	30.98
1	25.05	21.95	27.40	30.63
2	25.42	22.37	27.94	30.80
3	24.89	21.98	26.98	30.08
4	25.31	22.28	27.26	30.82
5	25.63	22.78	27.31	30.86
6	24.89	21.91	27.07	30.26
7	25.81	22.78	26.97	31.77
8	25.14	22.14	27.74	30.42
9	25.09	22.40	26.90	29.94
10	25.52	22.70	27.25	30.76
11	25.22	22.26	26.75	30.72
12	25.21	22.41	26.86	30.43
13	25.23	22.46	26.94	30.38
14	25.75	22.75	28.09	31.00
15	25.56	22.53	27.59	31.17
16	24.80	21.94	26.44	30.20
17	25.85	22.84	27.23	31.59
18	25.82	22.71	27.99	31.54
19	25.40	22.45	27.39	30.88
20	25.18	22.10	27.43	30.81
21	25.35	22.32	27.17	30.99
22	25.22	22.43	26.51	30.54
23	25.44	22.74	27.48	30.21
24	25.48	22.44	27.28	31.23
25	26.14	23.00	28.70	31.72
26	25.58	22.68	27.23	30.93
27	25.27	22.44	26.94	30.59
28	25.98	22.97	27.82	31.55
29	25.21	22.42	25.88	30.72
30	25.57	22.42	28.38	31.06
31	25.25	22.55	26.87	30.15
32	25.42	22.65	27.01	30.49
33	25.26	22.20	26.80	31.02
34	25.71	22.77	27.40	31.26
35	26.02	23.00	28.31	31.43
36	25.26	22.28	26.77	30.89
37	24.94	22.05	27.22	30.02
38	25.57	22.51	27.40	31.34
39	25.34	22.32	27.65	30.62
Average	25.45	22.51	27.29	30.87

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 6.1.10

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).

Clause 6.3.14.3

COV – Coefficient of Variation: This measure of variation for the Measured Intensity Multiplier cannot exceed 0.5.

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
MIM	0.0349	0.2810	0.0711	0.2069	0.0176	0.707	0.0358	0.2819
COV	0.122	0.035	0.078	0.042	0.134	0.067	0.116	0.029

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
MIM	0.0349	0.2817	0.0701	0.2101	0.0179	0.0702	0.0347	0.2805
COV	0.022	0.013	0.023	0.012	0.035	0.022	0.037	0.013

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
MIM	0.0355	0.2825	0.0692	0.2098	0.0181	0.0688	0.0352	0.2810
COV	0.096	0.035	0.071	0.038	0.132	0.077	0.089	0.032

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	0.0348	0.2809	0.0701	0.2099	0.0181	0.0699	0.0348	0.2814
COV	0.038	0.012	0.027	0.013	0.043	0.020	0.033	0.008

Data Persistence Test

Clause 7

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

Clause 10.4.8.6

The FDR shall contain the following for the Data Persistence Test:

1. *A listing of the SPC-1C Workload Generator commands and parameters used to execute each of the Test Runs in the Persistence Test.*
2. *The human readable SPC-1C Test Results File for each of the Test Runs in the Data Persistence Test.*
3. *A table from the successful Persistence Test, which contains the results from the test.*

SPC-1C Workload Generator Input Parameters

The SPC-1C Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in [Appendix E: SPC-1C Workload Generator Input Parameters](#) on Page [74](#).

Data Persistence Test Results File

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

[Persistence 1 Test Results File](#)

[Persistence 2 Test Results File](#)

Data Persistence Test Results

Data Persistence Test Results	
Data Persistence Test Run Number: 1	
Total Number of Logical Blocks Written	1,062,672
Total Number of Logical Blocks Verified	1,059,344
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 10.4.9

The committed delivery date for general availability (Availability Date) of all products that comprise the Priced Storage Configuration must be reported. When the Priced Storage Configuration includes products or components with different availability dates, the reported Availability Date must be the date at which all components are committed to be available. All availability dates, whether for individual components or for the Priced Storage Configuration as a whole, must be disclosed to a precision of one day.

The Availability Date shall be stated in the FDR by either a combination of specific alphanumeric month, numeric day, and numeric year or as "Currently Available" in the case where all components that comprise the Priced Storage Configuration are currently available for customer order and shipment.

The IBM 600GB 10K 6Gbps SAS 2.5" SFF Slim-HS HDD as documented in this Full Disclosure Report is currently available for customer purchase and shipment.

PRICING INFORMATION

Clause 10.4.5.6

The Executive Summary shall contain a pricing spreadsheet as documented in Clause 9.3.1.

Pricing information may be found in the Priced Storage Configuration Pricing section on page 17.

TESTED STORAGE CONFIGURATION (TSC) AND PRICED STORAGE CONFIGURATION DIFFERENCES

Clause 10.4.5.8

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

A list of all differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration may be found in the Executive Summary portion of this document on page 17.

ANOMALIES OR IRREGULARITIES

Clause 10.4.10

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

There were no anomalies or irregularities encountered during the SPC-1C Onsite Audit of the IBM 600GB 10K 6Gbps SAS 2.5" SFF Slim-HS HDD.

APPENDIX A: SPC-1C 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-1C Data Repository Definitions

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

Application Storage Unit (ASU): The logical interface between the storage and SPC-1C 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-1C 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-1C 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-1C Data Protection Levels

Protected 1: The single point of failure of any *storage device* in the configuration will not result in permanent loss of access to or integrity of the SPC-1C Data Repository.

Protected 2: The single point of failure of any *component* in the configuration will not result in permanent loss of access to or integrity of the SPC-1C Data Repository.

Unprotected: The Test Sponsor asserts no claim of data protection in the event of a single point of failure.

SPC-1C 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-1C 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-1C 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-1C test result or support an SPC-1C 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.

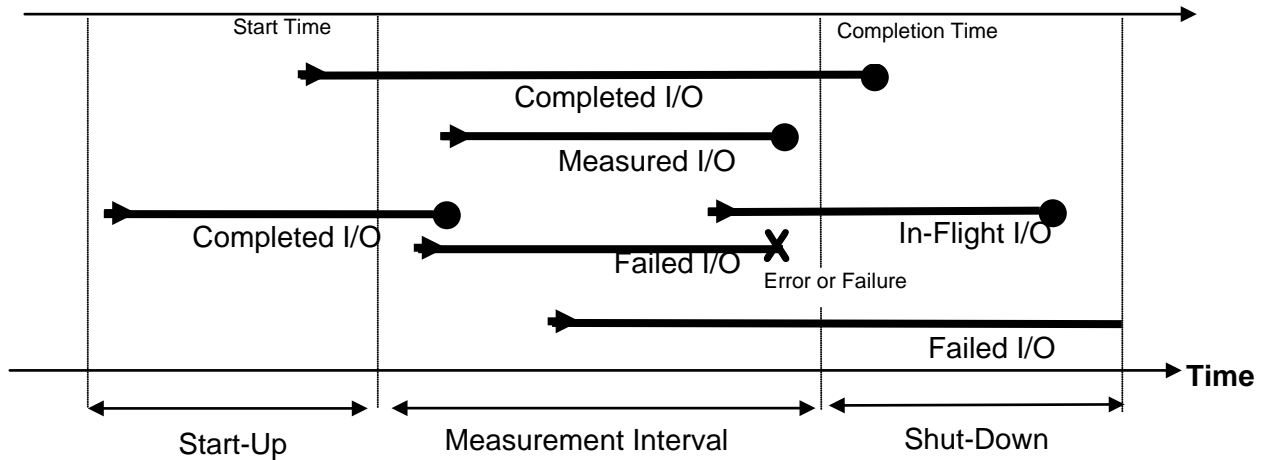
Test: A collection of Test Phases and or Test Runs sharing a common objective.

Test Run: The execution of SPC-1C for the purpose of producing or supporting an SPC-1C test result. SPC-1C Test Runs may have a finite and measured Ramp-Up period, Start-Up

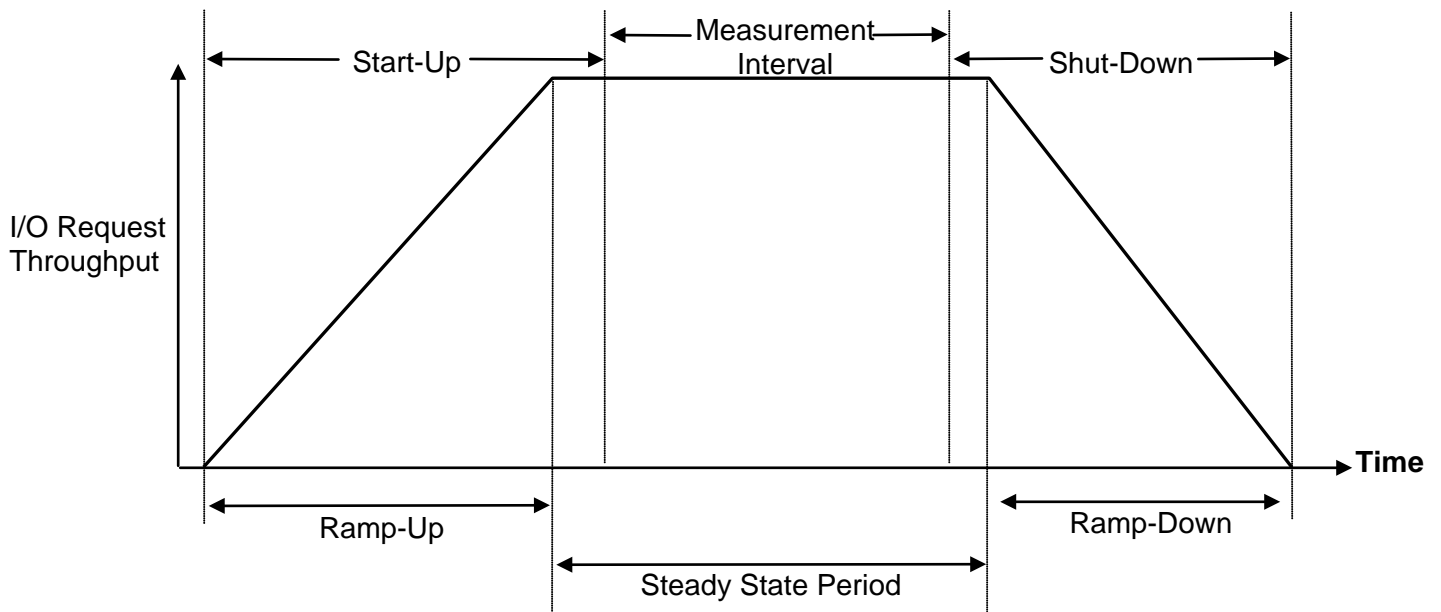
period, Shut-Down period, and Ramp-Down period as illustrated in the “SPC-1C Test Run Components” below. All SPC-1C Test Runs shall have a Steady State period and a Measurement Interval.

Test Phase: A collection of one or more SPC-1C Test Runs sharing a common objective and intended to be run in a specific sequence.

I/O Completion Types



SPC-1C Test Run Components



APPENDIX B: CUSTOMER TUNABLE PARAMETERS AND OPTIONS

The customer tunable parameters and options that were changed for the benchmark measurements are documented in the [Change Parameters](#) section of [Appendix C: Tested Storage Configuration \(TSC\) Creation](#) on page [72](#).

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

Create RAID-5 Array

Download the **MegaCLI (Command Line) Utility for Storage Management** from the IBM website at the following URL:

<http://www-947.ibm.com/support/entry/portal/docdisplay?lnocid=MIGR-5082326>

Execute the following script from the Host System, without any parameters, to create a RAID-5 array.

RB01_LVL.cmd

```
echo off
REM *****Clear All *****
REM MegaCLI64 -cfgclr -aALL
REM
REM Phys HDD List : 0,1,2,3 etc
REM Spares : NO
REM RAID Level : 5
REM Stripe Size : 1MB
REM Array set Name :A0-A4
REM LD Read Policy : Read look ahead
REM LD Write Policy : Write Back, Bad BBU
REM LD IO Policy : Direct IO
REM Access Policy : Read / Write
REM *****
set adptr=0
set Array=-[252:2,252:3,252:4,252:5,252:6,252:7]
set level=5
set WriteCache=WT
set stripe=1024
set ReadCache=RA
Set BBU=NoCachedBadBBU
set IOpolicy=Direct
set access=RW
@echo on
REM ***** Create RAID 5 *****
MegaCli64 -CfgLdAdd -r%level%%Array% %WriteCache% %ReadCache% %IOpolicy% %BBU% -
strpsz%stripe% -a%adptr%
```

Create SPC-1C Logical Volumes

Invoke the Windows **DiskPart** command line utility, from a Windows command session, with the following command, which will execute the commands in **diskmkhdd.txt** to create the three SPC-1C Logical Volumes.

```
diskpart /s diskmkhdd.txt Reference file diskmkhdd.txt
```

diskmkhdd.txt

```
select disk 1
clean
convert gpt
create partition primary size=643867 align=1024
```

```
create partition primary size=643867 align=1024
create partition primary size=143081 align=1024
select volume 1
assign letter=x
select volume 2
assign letter=y
select volume 3
assign letter=z
list volume
exit
```

Change Parameters

Execute the following MegaCLI script, without any parameters, from the Host System to create a change the appropriate user tunable parameter/options.

TuneParm_LVL.cmd

```
REM abort any background Initialization
MegaCli64 -LDBI -abort -Lall -aALL

REM disable load balance i.e.configure as failover mode
MegaCli64 -AdpSetProp -LoadBalanceMode 1 -aALL

REM powersaving let disks do power savings
MegaCli64 -AdpSetProp -DefaultLdPSPolicy -none -aALL

REM disable background Initialization
MegaCli64 -LDBI -dsbl -Lall -aALL
```


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

ASU Pre-Fill

The content of command and parameter file, used in this benchmark to execute the required ASU pre-fill, is listed below.

```
*
* This will produce a random data pattern of the entire LBA range using LFSR 32bit
*
*
sd=default,threads=32
sd=sd1,lun=\\.x:,size=643867m
sd=sd2,lun=\\.y:,size=643867m
sd=sd3,lun=\\.z:,size=143081m
*
*
compratio=1
wd=wd1,sd=sd1,rdpct=0,seek=-1,xfersize=64k
wd=wd2,sd=sd2,rdpct=0,seek=-1,xfersize=64k
wd=wd3,sd=sd3,rdpct=0,seek=-1,xfersize=64k
*=====
* Use 10 hours as a max elapse time
*=====
*
*
rd=Prefill_ASu1,wd=wd1,iorate=max,elapsed=36000,interval=30
rd=Prefill_ASu2,wd=wd2,iorate=max,elapsed=36000,interval=30
rd=Prefill_ASu3,wd=wd3,iorate=max,elapsed=36000,interval=30
```

Primary Metrics Test, Repeatability and Persistence Tests

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

```
sd=asu1_1,lun=\\.x:
sd=asu2_1,lun=\\.y:
sd=asu3_1,lun=\\.z:
```

APPENDIX E: SPC-1C WORKLOAD GENERATOR INPUT PARAMETERS

ASU Pre-Fill

The following CLI command was used to execute the required ASU pre-fill.

```
vdbench -f prefill.txt -o hybrid_prefill001
```

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 SPC-1C Persistence Test Run 1 in an uninterrupted sequence.

```
rem spc-1C
rem hybrid set /a bsu=205
rem
rem nonhybrid
set /a bsu=205
set java=c:\java\jre7\bin\java
echo
%java% -Xmx512m -Xms512m metrics -b %bsu% -t 28800 -s 3600:600 -r 600
%java% -Xmx512m -Xms512m repeat1 -b %bsu% -t 1200 -s 600
%java% -Xmx512m -Xms512m repeat2 -b %bsu% -t 1200 -s 600
%java% -Xmx512m -Xms512m persist1 -b %bsu%
echo power cycle device << then execute java -Xmx1g -Xss128k -Xms128m persist2 >>
pause
REM %java% -Xmx512m -Xms512m persist2
```


Persistence Test Run 2

The following command was used to execute Persistence Test Run 2 from a CLI session.

```
c:\java\jre7\bin\java -Xmx512m -Xms512m persist2
```

APPENDIX F: THIRD-PARTY QUOTATIONS

Priced Storage Configuration


Your IBM quote
Use your browsers [Print](#) option to print this summary.

Fulfillment Center: USA CBS Fulfillment Center
Phone: 444 444 4444
Fax 919 486 9690

Payment information:

Send To:

First name: craig
Last name: parris
E-mail: craig.a.parris@seagate.com
Address 1 (we are unable to ship to PO boxes): 1280 disc drive
City: shakopee
State: MN
Zip: 55379
Within city limits?: Yes
Country: United States
Phone number: 952 402 2418
Company (required for business lease or PO): Seagate

Quote items

Your quote items

Quantity	Item Description	Item price	Line total
1	3 Year Onsite Repair 24x7 4 Hour Response		
	Product: <u>00A4405</u>	\$790.00	\$790.00
2	Power Cable - C13 / NEMA 5-15P 14ft		
	Product: <u>39Y7931</u>	\$15.00	\$30.00
	Availability: In Stock**		
1	ServeRAID M5100 Series 512MB Cache/RAID 5 Upgrade for IBM System x		

Priced Storage Configuration (continued)

	Product:	<u>81Y4484</u>	\$199.00	\$199.00
1	ServeRAID M5120 SAS/SATA Controller for IBM System x			
	Product:	<u>81Y4478</u>	\$299.00	\$299.00
2	8GB (1x8GB, 2Rx4, 1.5V) PC3-12800 CL11 ECC DDR3 1600MHz LP RDIMM			
	Product:	<u>90Y3109</u>	\$189.00	\$378.00
	Availability:	Within 8 days**		
1	IBM System x 550W High Efficiency Platinum AC Power Supply			
	Product:	<u>94Y6668</u>	\$299.00	\$299.00
1	Intel Xeon Processor E5-2609 4C 2.4GHz 10MB 1066MHz 80W W/Fan			
	Product:	<u>69Y5325</u>	\$485.00	\$485.00
1	IBM 600GB 10K 6Gbps SAS 2.5" SFF G2HS HDD			
	Product:	<u>90Y8872</u>	\$579.00	\$579.00
1	IBM System x3650 M4			
	Product:	<u>7915B2U</u>	\$2,565.00	\$2,565.00
6	IBM 600GB 10K 6Gbps SAS 2.5" SFF Slim-HS HDD			
	Product:	<u>49Y2003</u>	\$579.00	\$3,474.00
	Availability:	In Stock**		
1	4GB (1x4GB, 1Rx4, 1.5V) PC3-12800 CL11 ECC DDR3 1600MHz LP RDIMM			
	Product:	<u>49Y1559</u>	\$115.00	\$115.00
	Availability:	Within 13 days**		
		Subtotal		\$9,213.00
		Shipping (<u>about shipping</u>)		\$116.00
		Tax (<u>about tax</u>)		\$641.37
		Total		\$9,970.37