SPC Benchmark 1™
Full Disclosure Report

Dell, Inc.
Dell Storage SC4020 *(6 SSDs)*

SPC-1 V1.14

Submitted for Review: March 18, 2015
Submission Identifier: A00156

First Edition – March 2015

Trademarks

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AUDIT CERTIFICATION

Matt Reichow
Dell, Inc.
7625 Smetana Lane
Eden Prairie, MN 56344

March 18, 2015

The SPC Benchmark 1™ Reported Data listed below for the Dell Storage SC4020 *(6 SSDs)*was produced in compliance with the SPC Benchmark 1™ v1.14 Onsite Audit requirements.

SPC Benchmark 1™ v1.14 Reported Data	
Tested Storage Product (TSP) Name:	
Dell Storage SC4020 *(6 SSDs)*	
Metric	**Reported Result**
SPC-1 IOPS™	112,479.81
SPC-1 Price-Performance	$0.37/SPC-1 IOPS™
Total ASU Capacity	984.054 GB
Data Protection Level	Protected 2 *(Mirroring)*
Total Price (including three-year maintenance)	$41,836.40
Currency Used	U.S. Dollars
Target Country for availability, sales and support	USA

The following SPC Benchmark 1™ Onsite Audit requirements were reviewed and found compliant with 1.14 of the SPC Benchmark 1™ specification:

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

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AUDIT CERTIFICATION *(CONT.)*

- 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-1 Workload Generator commands and parameters used for the audited SPC Test Runs.

- The following Host System requirements were verified by physical inspection and information supplied by Dell, Inc.:
  - ✓ The type of Host System including the number of processors and main memory.
  - ✓ The presence and version number of the SPC-1 Workload Generator on the Host System.
  - ✓ The TSC boundary within the Host System.

- The execution of each Test, Test Phase, and Test Run was observed and found compliant with all of the requirements and constraints of Clauses 4, 5, and 11 of the SPC-1 Benchmark Specification.

- The Test Results Files and resultant Summary Results Files received from Dell, Inc. for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4 and 5 of the SPC-1 Benchmark Specification:
  - ✓ Data Persistence Test
  - ✓ Sustainability Test Phase
  - ✓ IOPS Test Phase
  - ✓ Response Time Ramp Test Phase
  - ✓ Repeatability Test

- There was no difference between the Tested Storage Configuration (TSC) and Priced Storage Configuration.

- The submitted pricing information met all of the requirements and constraints of Clause 8 of the SPC-1 Benchmark Specification.

- The Full Disclosure Report (FDR) met all of the requirements in Clause 9 of the SPC-1 Benchmark Specification.

- This successfully audited SPC measurement is not subject to an SPC Confidential Review.

Audit Notes:

There are no audit notes.

Respectfully,
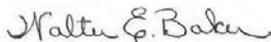
Walter E. Baker

Walter E. Baker
SPC Auditor

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LETTER OF GOOD FAITH

Dell Inc.
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tel +1 877 715-3300
www.dell.com

Mr. Walter E. Baker, SPC Auditor
Gradient Systems
643 Bair Island Road, Suite 103
Redwood City, CA 94063-2755

February 10, 2015

Subject: SPC-1 Letter of Good Faith for the Dell Storage SC4020 array SAN with six 480GB SSDs.

Dell Inc. is the SPC-1 Test Sponsor for the above listed product. To the best of our knowledge and belief, the required SPC-1 benchmark results and materials we have submitted for that product are complete, accurate, and in full compliance with v1.14 of the SPC-1 benchmark specification.

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

Sincerely,

Ed Fiore
Vice President
Dell Storage
Dell Inc.

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact	Dell, Inc. – http://www.dell.com Matt Reichow – Matt_Reichow@dell.com 7625 Smetana Lane Eden Prairie, MN 55344 Phone: (952) 563-9124 FAX: (952) 567-6600
Test Sponsor Alternate Contact	Dell, Inc. – http://www.dell.com John Shirley – John_Shirley@dell.com 7625 Smetana Lane Eden Prairie, MN 55344 Phone: (952) 563-9233 FAX: (952) 567-6600
Auditor	Storage Performance Council – http://www.storageperformance.org Walter E. Baker – AuditService@StoragePerformance.org 643 Bair Island Road, Suite 103 Redwood City, CA 94063 Phone: (650) 556-9384 FAX: (650) 556-9385

Revision Information and Key Dates

Revision Information and Key Dates	
SPC-1 Specification revision number	V1.14
SPC-1 Workload Generator revision number	V2.3.0
Date Results were first used publicly	March 18, 2015
Date the FDR was submitted to the SPC	March 18, 2015
Date the Priced Storage Configuration is available for shipment to customers	currently available
Date the TSC completed audit certification	March 17, 2015

Tested Storage Product (TSP) Description

Dell Storage SC4020 provides superior storage performance for the medium-to-large enterprise with easy management and maximized effectiveness. The full line of Dell Storage SC4020 solution provides a wide range of flexibility for both front-end and back-end connectivity, drive types and interfaces, and RAID levels.

Dell Storage SC4020 provides intuitive and automated tools and reports for easy management and comes with Dell Copilot support services that include 24x7 active system monitoring to help improve performance and stability. It also comes with perpetual software licensing even across hardware upgrades.

Summary of Results

SPC-1 Reported Data	
Tested Storage Product (TSP) Name: Dell Storage SC4020 *(6 SSDs)*	
Metric	**Reported Result**
SPC-1 IOPS™	112,479.81
SPC-1 Price-Performance™	$0.37/SPC-1 IOPS™
Total ASU Capacity	984.054 GB
Data Protection Level	Protected 2 *(mirroring)*
Total Price	$41,836.40
Currency Used	U.S. Dollars
Target Country for availability, sales and support	USA

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

SPC-1 Price-Performance™ is the ratio of **Total Price** to **SPC-1 IOPS™**.

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

A **Data Protection Level** of **Protected 2** using *Mirroring* configures two or more identical copies of user data.

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

Total Price includes the cost of the Priced Storage Configuration plus three years of hardware maintenance and software support as detailed on page 16.

Currency Used is formal name for the currency used in calculating the **Total Price** and **SPC-1 Price-Performance™**. That currency may be the local currency of the **Target Country** or the currency of a difference country *(non-local currency).*

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

Storage Capacities, Relationships, and Utilization

The following 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.

Physical Storage Capacity: 2,880.678 GB

Configured Storage Capacity:
2,879.411 GB
99.96%

Unused Physical Capacity:
0 Gb   0.00%

Storage Pool Capacity
1,439.705 GB
49.98%

Data Protection Capacity:
1,439.705 GB
49.98%

■ Global Storage Overhead:
1.267 GB 0.04%

Configured Storage Capacity: 2,897.411 GB

Configured Storage Capacity Available for Application Use:
2,879.391 GB
100.00%

Addressable Storage Capacity:
984.054 GB 34.18%

Data Protection Capacity *(used)*:
984.074 GB 34.18%

Unused Configured Capacity:
911.263 GB 31.65%

Includes 455.632 GB in Unused Data Protection Capacity

Addressable Storage Capacity: 984.054 GB

Unused Addressable Capacity:
0 GB 0.00%

ASU Capcity:
984.054 100.00%

4 Logical Volumes, 110.767 GB per Volume (ASU-1)
3 Logical Volumes, 147.508 GB per Volume (ASU-2)
1 Logical Volume, 98.459 GB per Volume (ASU-3)

ASU-1 Capacity:
443.069 GB 45.02%

ASU-2 Capacity:
442.525 GB 44.97%

ASU-3 Capacity:
98.459 GB 10.01%

Total Unused Storage Capacity Ratio and Details

Physical Storage Capacity:
2,880.678 GB

Unused Physical Capacity: 0.000 GB

Physical Storage Capacity Used: 1,969.414 GB 68.37%

Total Unused Storage Capacity: 911.263 GB 31.63%

Unused Configured Capacity: 911.263 GB

Includes 455.632 GB in Unused Data Protection Capacity

Unused Addressable Capacity: 0.000 GB

SPC-1 Storage Capacity Utilization	
Application Utilization	34.16%
Protected Application Utilization	68.32%
Unused Storage Ratio	31.63%

Application Utilization: Total ASU Capacity *(984.054 GB)* divided by Physical Storage Capacity *(2,880.678 GB)*.

Protected Application Utilization: (Total ASU Capacity *(984.054 GB)* plus total Data Protection Capacity *(1,439.705 GB)* minus unused Data Protection Capacity *(455.632 GB))* divided by Physical Storage Capacity *(2,880.678 GB)*.

Unused Storage Ratio: Total Unused Capacity *(307.004 GB)* divided by Physical Storage Capacity *(2,880.678 GB)* and may not exceed 45%.

Detailed information for the various storage capacities and utilizations is available on pages 22-23.

Response Time – Throughput Curve

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

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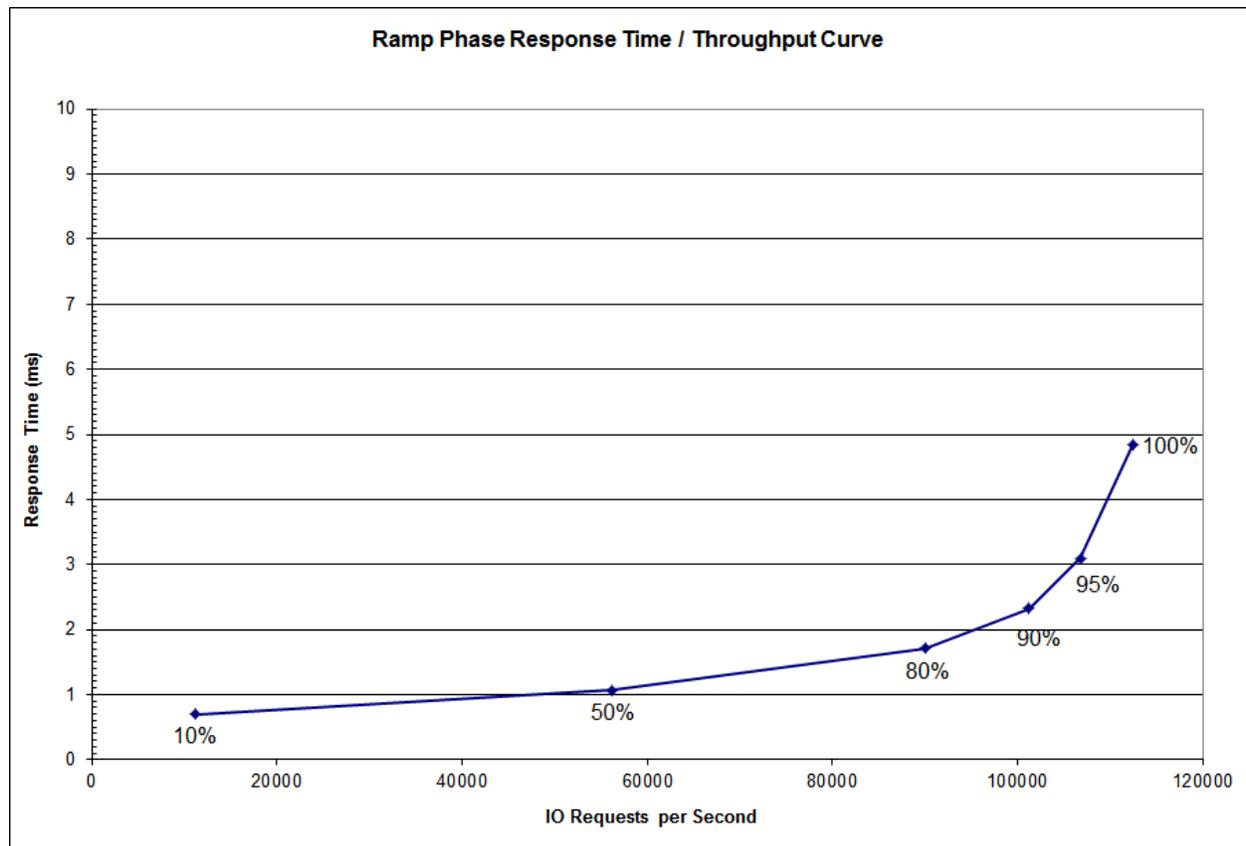
Response Time – Throughput Data

	10% Load	50% Load	80% Load	90% Load	95% Load	100% Load
I/O Request Throughput	11,249.97	56,250.78	90,004.15	101,249.03	106,829.21	112,479.81
Average Response Time (ms):						
All ASUs	0.70	1.07	1.71	2.32	3.10	4.83
ASU-1	0.68	1.05	1.76	2.41	3.32	5.06
ASU-2	0.75	1.04	1.50	1.86	2.18	2.91
ASU-3	0.73	1.11	1.70	2.35	3.02	5.19
Reads	0.53	0.93	1.43	1.77	2.31	3.24
Writes	0.81	1.16	1.90	2.68	3.61	5.87

Priced Storage Configuration Pricing

Product Description	Qty.	Unit List Price	Extended List Price	Discount	Purchase Price
Hardware Products					
SC4020 Dual Controller, 16 GB cache/controller 8x8Gb FC ports, 6x480GB 2.5" RI SSDs	1	$43,215.00	$43,215.00	45%	$23,768.25
Peripherals (Drive Blanks and Power Cords)	1	$200.00	$200.00	45%	$110.00
Qlogic Dual Port Fibre Channel HBA QLE2562 8G	4	$1,849.00	$7,396.00	45%	$4,067.80
LC-LC Optical Cable, 3M (Fibre Channel Cables)	16	$53.00	$848.00	45%	$466.40
Brocade 300 8-16-24 Port FC8 Switch includes 8x8Gb SFPs	2	$3,799.00	$7,598.00	45%	$4,178.90
Brocade 300 8 Port FC8 Upgrade, License and SFPs	2	$2,799.00	$5,598.00	45%	$3,078.90
Brocade Switch Rails	2	$80.00	$160.00	45%	$88.00
Hardware Product Total			**$65,015.00**		**$35,758.25**
Software Products					
SW, Storage Center OS Core License (Up To 48 Active Drives)	1	$0.00	$0.00		
Software Product Total		**$0.00**	**$0.00**		
Installation and Suport					
Brocade Switch Support 3yr 24x7x4Hr - Onsite	1	$628.02	$628.02	45%	$345.41
Support, 24x7, Dell/Compellent Series SC4020	1	$4,775.08	$4,775.08	45%	$2,626.29
Support, 24x7, SW, Storage Center OS Core	1	$1,800.09	$1,800.09	45%	$990.05
Dell Storage and Switch Installation Support (up to 2 hosts)	1	$3,848.00	$3,848.00	45%	$2,116.40
Installation and Support Total			**$11,051.19**	**45%**	**$6,078.15**
Total			**$76,066.19**		**$41,836.40**

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 within four (4) hours.

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

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

A second Borcade 300 switch was included in the Priced Storage Configuration as a spare to fulfill one of the requirements for a data protection level of **Protected 2**.

Priced Storage Configuration Diagram

4 – 2-port 8Gb FC HBAs

8 FC Connections

Brocade 300 8Gb FC Switch

8 FC Connections

Dell Storage SC4020

6 – 480GB, 2.5", SSD, SAS, HUSMR1650ASS200
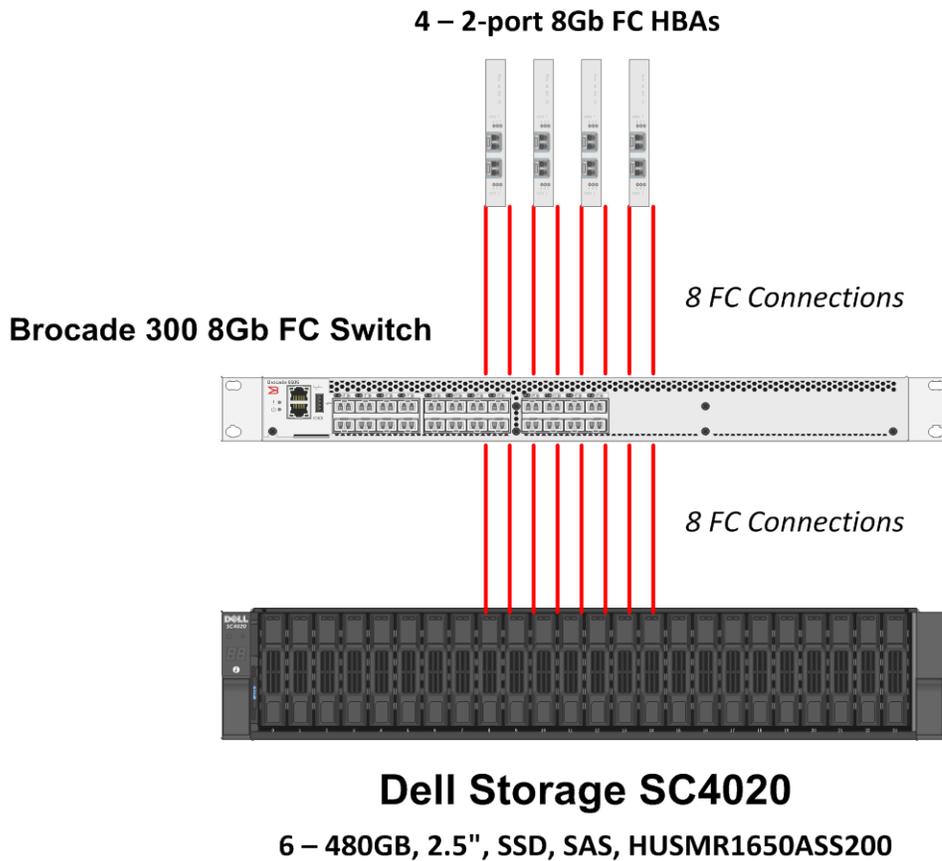
Priced Storage Configuration Components

Priced Storage Configuration
4 – QLogic QLE2562 Dual Port 8Gb FC HBAs
2 – Brocade 300 8Gb 12-24 port FC Switch *(16 ports/SFPs active)* *(second switch is a spare)*
Dell Storage SC4020   SC4020 Dual Controller   16 GB cache per controller *(32 GB total)*   8 – 8Gb FC ports *(4 ports per controller, 8 ports used)*   4 – backend 6Gb SAS connections *(2 connections per controller)* *(4 connections used)*   6 – 480GB 6Gb 2.5" SSDs

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

CONFIGURATION INFORMATION

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

Clause 9.4.3.4.1

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

The Benchmark Configuration (BC)/Tested Storage Configuration (TSC) is illustrated on page 19 *(Benchmark Configuration/Tested Storage Configuration Diagram)*.

Storage Network Configuration

Clause 9.4.3.4.1

…

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

Clause 9.4.3.4.2

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

The storage network portion of the Benchmark Configuration(BC)/Tested Storage Configuration (TSC) is illustrated on page *19 (Benchmark Configuration/Tested Storage Configuration Diagram)*.

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

Clause 9.4.3.4.3

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

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

Benchmark Configuration/Tested Storage Configuration Diagram

Dell PowerEdge R720 rack server

4 – 2-port 8Gb FC HBAs

8 FC Connections

Brocade 300 8Gb FC Switch

8 FC Connections

Dell Storage SC4020

6 – 480GB, 2.5", SSD, SAS, HUSMR1650ASS200

Host System and Tested Storage Configuration Components

Host System
1 – Dell PowerEdge R720 rack server, with:
2 – Intel® Xeon® 2.00 GHz E5-2650 processors   8 cores per processor and 20 MB Intel® Smart Cache
64 GB main memory
Windows Server 2008 R2 Enterprise with SP1
PCIe 3.0
Tested Storage Configuration (TSC) Components
4 – QLogic QLE2562 Dual Port 8Gb FC HBAs
2 – Brocade 300 8Gb 12-24 port FC Switch *(16 ports/SFPs active)*   *(second switch is a spare)*
Dell Storage SC4020
SC4020 Dual Controller   16 GB cache per controller *(32 GB total)*
8 – 8Gb FC ports *(4 ports per controller, 8 ports used)*
4 – backend 6Gb SAS connections *(2 connections per controller)*   *(4 connections used)*
6 – 480GB 6Gb 2.5" SSDs

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 98.

ASU Pre-Fill

Clause 5.3.3

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

The configuration file used to complete the required ASU pre-fill appears in Appendix D: SPC-1 Workload Generator Storage Commands and Parameters on page 98.

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 four charts documenting the storage capacities and relationships of the SPC-1 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-1 Storage Capacities

The Physical Storage Capacity consisted of 2,400.7152,880.678 GB distributed over 12 solid state drives (SSDs) each with a formatted capacity of 480.133 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 1.267 GB (0.04%) of the Physical Storage Capacity. There was 911.263 GB (31.65%) 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 1,439.705 GB of which 984.07 GB was utilized. The total Unused Storage capacity was 911.263 GB.

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

SPC-1 Storage Capacities		
Storage Hierarchy Component	**Units**	**Capacity**
Total ASU Capacity	Gigabytes (GB)	984.054
Addressable Storage Capacity	Gigabytes (GB)	984.054
Configured Storage Capacity	Gigabytes (GB)	2,879.411
Physical Storage Capacity	Gigabytes (GB)	2,880.678
Data Protection *(Mirroring)*	Gigabytes (GB)	1,439.705
Required Storage	Gigabytes (GB)	0.000
Global Storage Overhead	Gigabytes (GB)	1.267
Total Unused Storage	Gigabytes (GB)	911.263

SPC-1 Storage Hierarchy Ratios

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	34.18%	34.16%
Required for Data Protection *(Mirroring)*		50.00%	49.98%
Addressable Storage Capacity		34.18%	34.16%
Required Storage		0.00%	0.00%
Configured Storage Capacity			99.96%
Global Storage Overhead			0.04%
Unused Storage:			
Addressable	0.00%		
Configured		31.65%	
Physical			0.00%

SPC-1 Storage Capacity Charts

Physical Storage Capacity: 2,880.678 GB

Configured Storage Capacity: 2,879.411 GB 99.96%

Global Storage Overhead: 1.267 GB 0.04%

Unused Physical Capacity: 0 Gb 0.00%

Storage Pool Capacity 1,439.705 GB 49.98%

Data Protection Capacity: 1,439.705 GB 49.98%

Configured Storage Capacity: 2,897.411 GB

Configured Storage
Capacity Available
for Application Use:
2,879.391 GB
100.00%

Addressable Storage
Capacity:
984.054 GB 34.18%

Data Protection
Capacity *(used)*:
984.074 GB 34.18%

Unused Configured
Capacity:
911.263 GB 31.65%

*Includes 455.632 GB
in Unused Data
Protection Capacity*

Addressable Storage Capacity: 984.054 GB

Unused Addressable
Capacity:
0 GB   0.00%

ASU Capcity:
984.054 100.00%

4 Logical Volumes, 110.767 GB per Volume (ASU-1)
3 Logical Volumes, 147.508 GB per Volume (ASU-2)
1 Logical Volume,   98.459 GB per Volume (ASU-3)

ASU-1 Capacity:
443.069 GB 45.02%

ASU-2 Capacity:
442.525 GB 44.97%

ASU-3 Capacity:
98.459 GB 10.01%

Total Unused Storage Capacity Ratio and Details

Physical Storage Capacity:
2,880.678 GB

Physical Storage
Capacity Used:
1,969.414 GB
68.37%

Total Unused
Storage Capacity:
911.263 GB 31.63%

Unused Physical
Capacity: 0.000 GB

Unused Configured
Capacity:
911.263 GB

Includes 455.632 GB in Unused Data Protection Capacity

Unused Addressable
Capacity:
0.000 GB

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	34.16%
Protected Application Utilization	68.32%
Unused Storage Ratio	31.63%

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 (GB)	**ASU-2 (GB)**	**ASU-3 (GB)**
4 Logical Volumes 110.767 GB per Logical Volume (110.767 GB used per Logical Volume)	3 Logical Volumes 147.508 GB per Logical Volume (147.508 GB used per Logical Volume)	1 Logical Volume 98.459 GB per Logical Volume (98.459 GB used per Logical Volume)

The Data Protection Level used for all Logical Volumes was **Protected 2** using *Mirroring* as described on page 11. See "ASU Configuration" in the **IOPS Test Results File** for more detailed configuration information.

SPC-1 BENCHMARK EXECUTION RESULTS

This portion of the Full Disclosure Report documents the results of the various SPC-1 Tests, Test Phases, and Test Runs. An SPC-1 glossary on page 59 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
    - o 95% of IOPS Test Run
    - o 90% of IOPS Test Run
    - o 80% of IOPS Test Run
    - o 50% of IOPS Test Run
    - o 10% of IOPS Test Run (LRT)

- **Repeatability Test**
  - ➤ Repeatability Test Phase 1
    - o 10% of IOPS Test Run (LRT)
    - o IOPS Test Run
  - ➤ Repeatability Test Phase 2
    - o 10% of IOPS Test Run (LRT)
    - o 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 5.3.13

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 5.3.13.3

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

Clause 9.4.3.7.1

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

There were no "Ramp-Up" Test Runs executed.

Primary Metrics Test – Sustainability Test Phase

Clause 5.4.4.1.1

The Sustainability Test Phase has exactly one Test Run and shall demonstrate the maximum sustainable I/O Request Throughput within at least a continuous eight (8) hour Measurement Interval. This Test Phase also serves to insure that the TSC has reached Steady State prior to reporting the final maximum I/O Request Throughput result (SPC-1 IOPS™).

Clause 5.4.4.1.2

The computed I/O Request Throughput of the Sustainability Test must be within 5% of the reported SPC-1 IOPS™ result.

Clause 5.4.4.1.4

The Average Response Time, as defined in Clause 5.1.1, will be computed and reported for the Sustainability Test Run and cannot exceed 30 milliseconds. If the Average Response time exceeds that 30-milliseconds constraint, the measurement is invalid.

Clause 9.4.3.7.2

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 99.

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
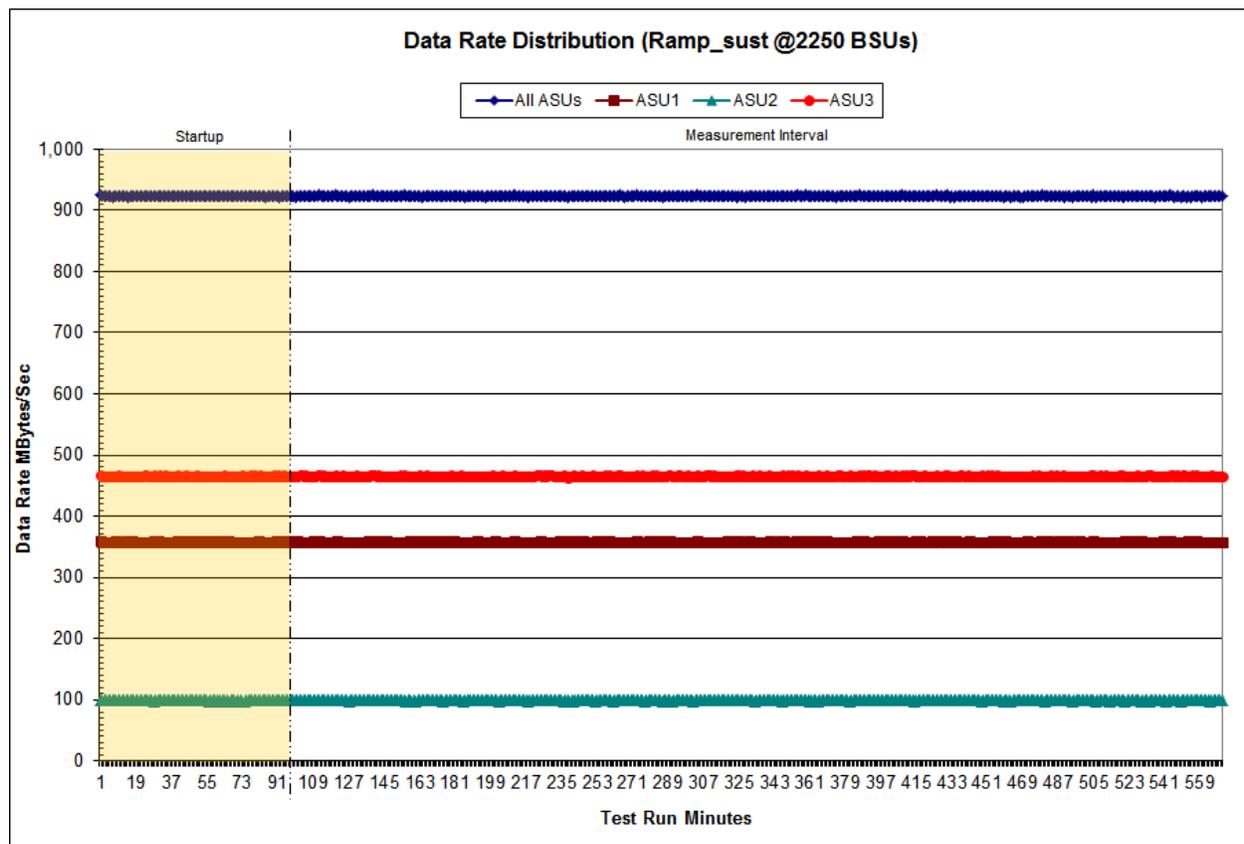
Sustainability – I/O Request Throughput Distribution Data

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
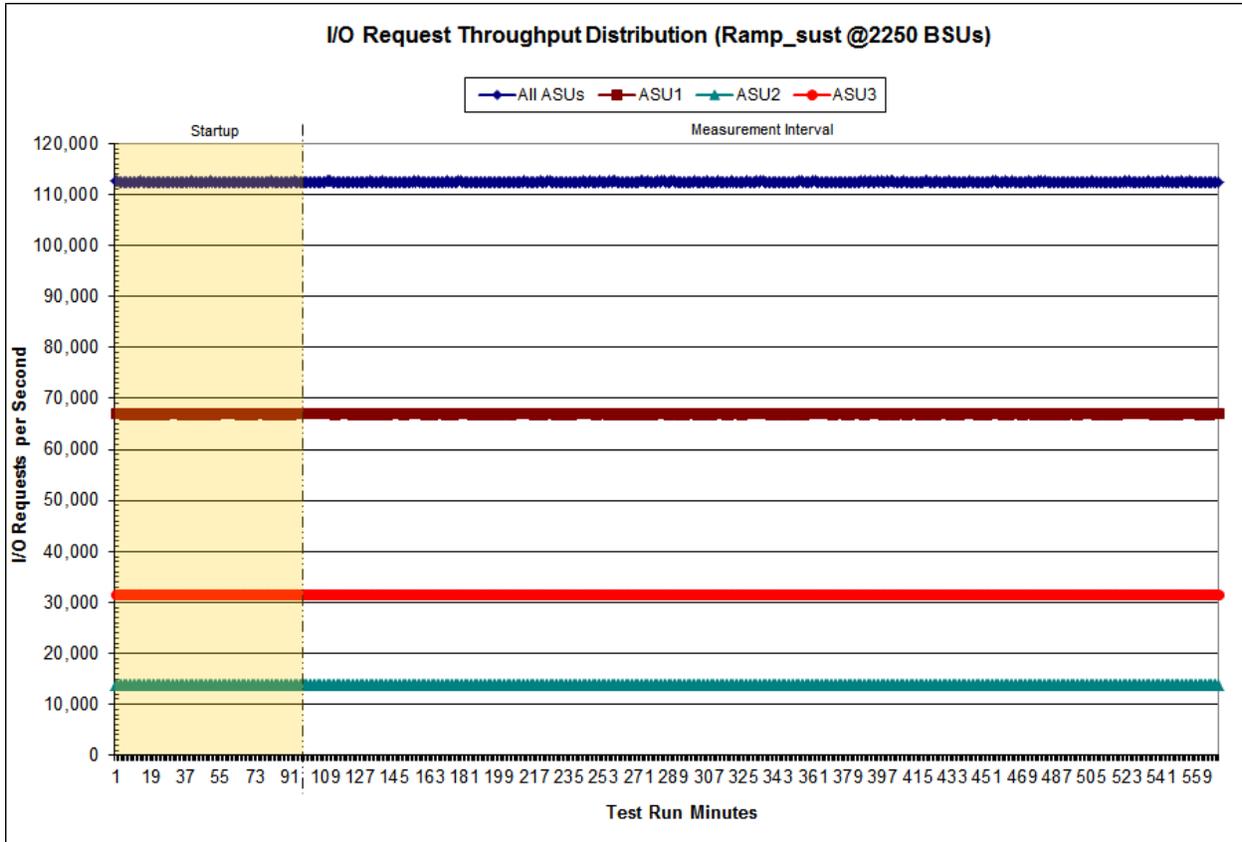
Sustainability – Average Response Time (ms) Distribution Data

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
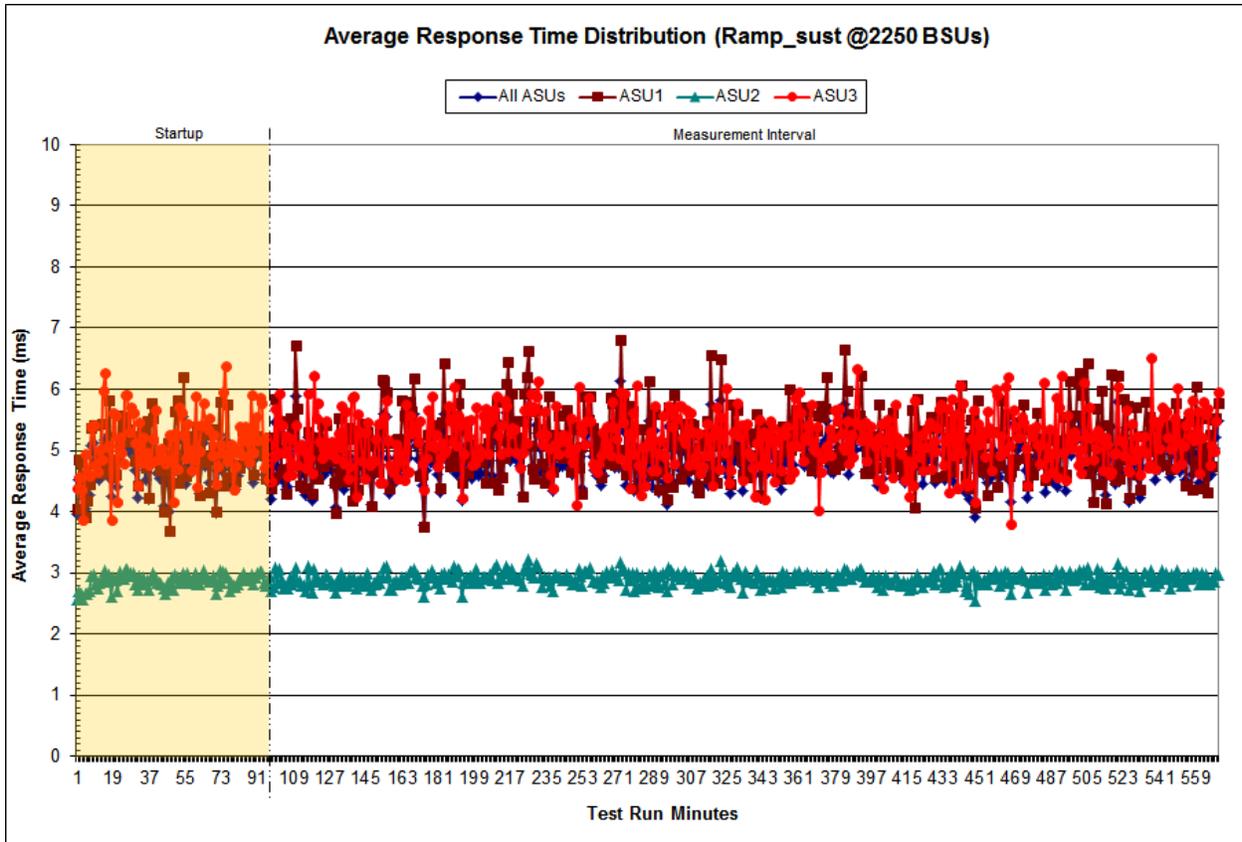
Sustainability – Response Time Frequency Distribution Data

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	34	4,835,452	162,429,989	382,233,226	108,655,274	36,578,107	82,940,762	94,651,618
Write	1	32,191	3,450,168	33,310,782	100,277,857	92,526,909	272,816,378	373,790,219
All ASUs	35	4,867,643	165,880,157	415,544,008	208,933,131	129,105,016	355,757,140	468,441,837
ASU1	9	3,346,070	126,068,686	323,289,160	135,333,511	69,790,923	186,804,634	235,157,144
ASU2	26	1,494,406	36,746,741	72,189,689	35,024,971	19,186,229	42,415,520	46,981,848
ASU3	0	27,167	3,064,730	20,065,159	38,574,649	40,127,864	126,536,986	186,302,845

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	44,710,951	101,081,004	34,167,755	50,627,085	11,301,280	20,214,672	17,386,697	10,757,611
Write	132,185,525	186,504,570	46,059,551	78,963,095	24,191,260	45,882,978	52,171,254	46,154,802
All ASUs	176,896,476	287,585,574	80,227,306	129,590,180	35,492,540	66,097,650	69,557,951	56,912,413
ASU1	87,801,319	160,491,946	47,083,361	76,901,499	19,611,040	36,381,055	35,701,408	27,443,824
ASU2	17,987,740	31,597,368	10,064,970	13,971,916	3,703,421	6,636,851	7,186,094	6,469,410
ASU3	71,107,417	95,496,260	23,078,975	38,716,765	12,178,079	23,079,744	26,670,449	22,999,179

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	7,990,396	6,669,359	5,990,657	24,460,220	19,082,931	19,538,296	16,205,389	15,351,622
Write	53,093,502	45,758,108	36,338,223	154,273,215	60,418,557	32,193,323	26,406,283	65,387,395
All ASUs	61,083,898	52,427,467	42,328,880	178,733,435	79,501,488	51,731,619	42,611,672	80,739,017
ASU1	26,125,460	25,001,864	23,748,271	108,508,213	44,842,521	38,495,903	33,109,475	60,010,324
ASU2	16,926,054	12,816,288	3,261,582	8,394,095	2,064,794	1,139,634	968,001	1,328,550
ASU3	18,032,384	14,609,315	15,319,027	61,831,127	32,594,173	12,096,082	8,534,196	19,400,143

Sustainability – Response Time Frequency Distribution Graph
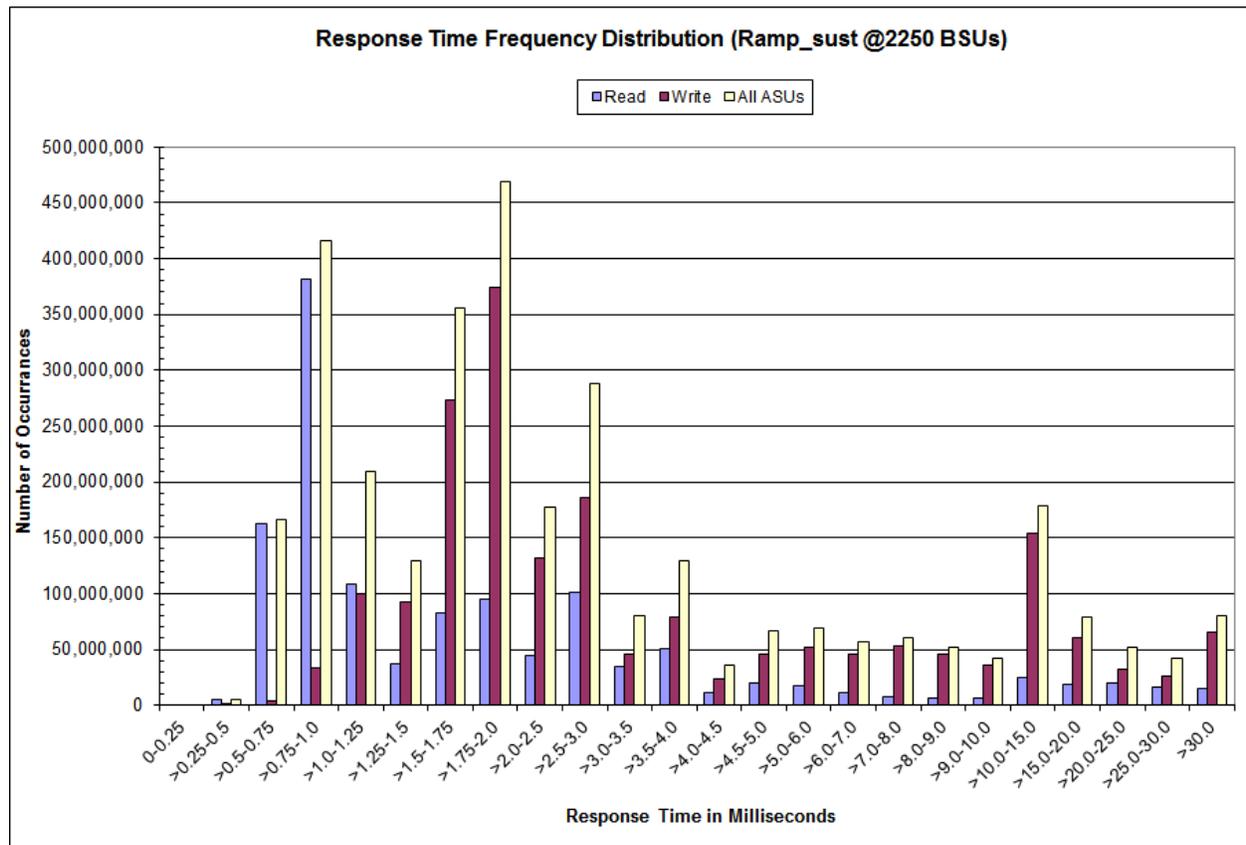
Sustainability – Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.15.2

MIM – Measured Intensity Multiplier: *The Measured Intensity Multiplier represents the ratio of measured I/Os for each I/O stream relative to the total I/Os measured for all I/O streams (ASU1-1 – ASU3-1). This value may differ from the corresponding Expected Intensity Multiplier by no more than 5%.*

Clause 5.3.15.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.002	0.001	0.001	0.001	0.003	0.001	0.002	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 9.4.3.7.3

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 99.

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

2,250 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	16:37:49	16:42:50	0-4	0:05:01
Measurement Interval	16:42:50	16:52:50	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	112,476.23	67,019.38	13,844.95	31,611.90
1	112,493.53	67,024.58	13,851.48	31,617.47
2	112,499.02	67,055.40	13,852.30	31,591.32
3	112,435.05	67,019.77	13,850.55	31,564.73
4	112,478.03	67,011.72	13,857.35	31,608.97
5	112,499.67	67,050.50	13,825.68	31,623.48
6	112,548.65	67,060.38	13,855.48	31,632.78
7	112,479.88	67,056.20	13,823.05	31,600.63
8	112,493.98	67,043.98	13,849.08	31,600.92
9	112,493.75	67,060.00	13,827.85	31,605.90
10	112,397.83	67,016.83	13,810.25	31,570.75
11	112,436.15	67,016.88	13,815.80	31,603.47
12	112,495.73	67,008.12	13,843.08	31,644.53
13	112,437.35	66,985.40	13,835.57	31,616.38
14	112,515.05	67,104.82	13,816.28	31,593.95
Average	112,479.81	67,040.31	13,830.21	31,609.28

IOPS Test Run – I/O Request Throughput Distribution Graph
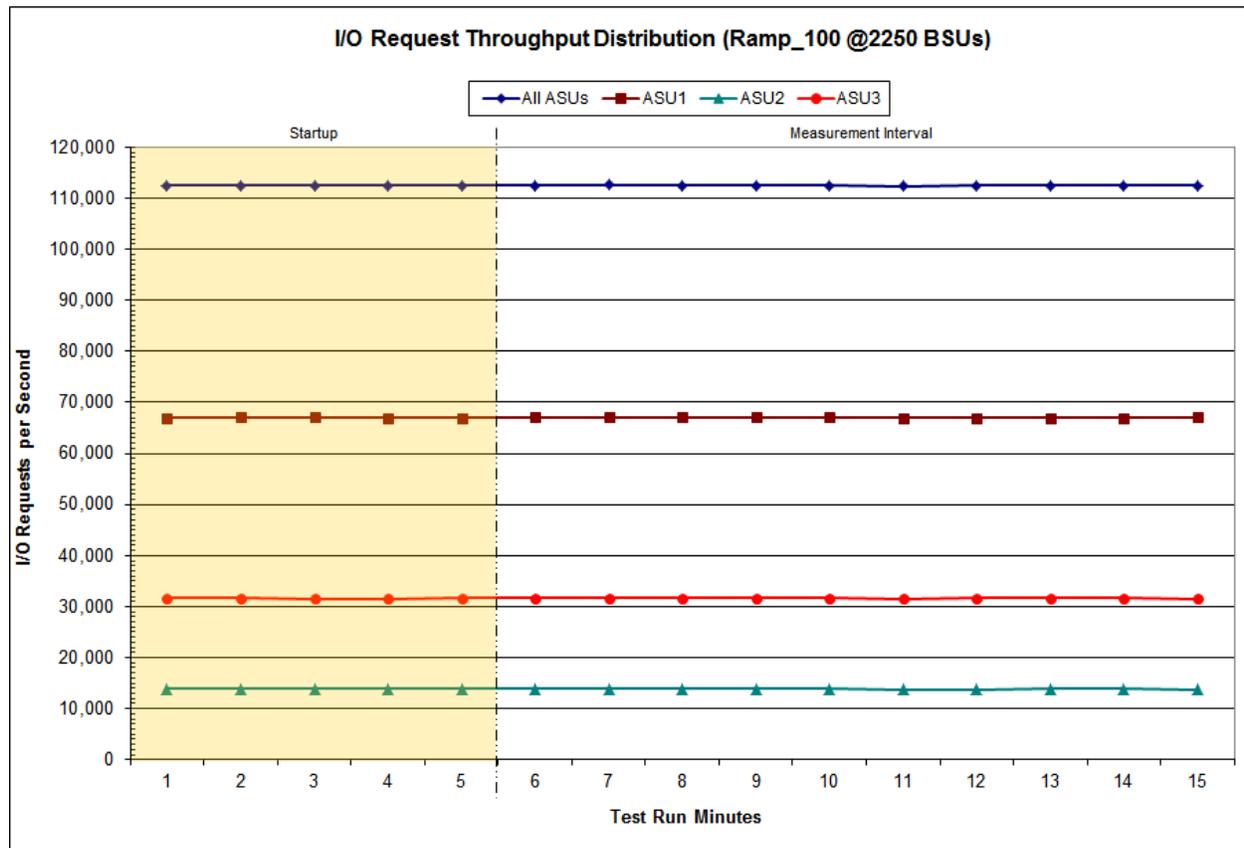
IOPS Test Run – Average Response Time (ms) Distribution Data

2,250 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	16:37:49	16:42:50	0-4	0:05:01
Measurement Interval	16:42:50	16:52:50	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	4.11	4.18	2.67	4.58
1	5.66	6.35	3.02	5.33
2	5.24	5.98	2.93	4.68
3	4.77	5.11	2.82	4.90
4	4.65	4.89	2.88	4.93
5	5.05	5.24	2.91	5.58
6	4.81	5.00	2.99	5.22
7	4.85	5.01	2.90	5.37
8	4.75	5.26	2.82	4.52
9	4.62	4.75	2.88	5.12
10	4.94	5.45	2.92	4.74
11	5.05	5.26	3.02	5.47
12	4.72	5.08	2.83	4.78
13	4.82	4.84	2.92	5.60
14	4.73	4.76	2.88	5.47
Average	*4.83*	*5.06*	*2.91*	*5.19*

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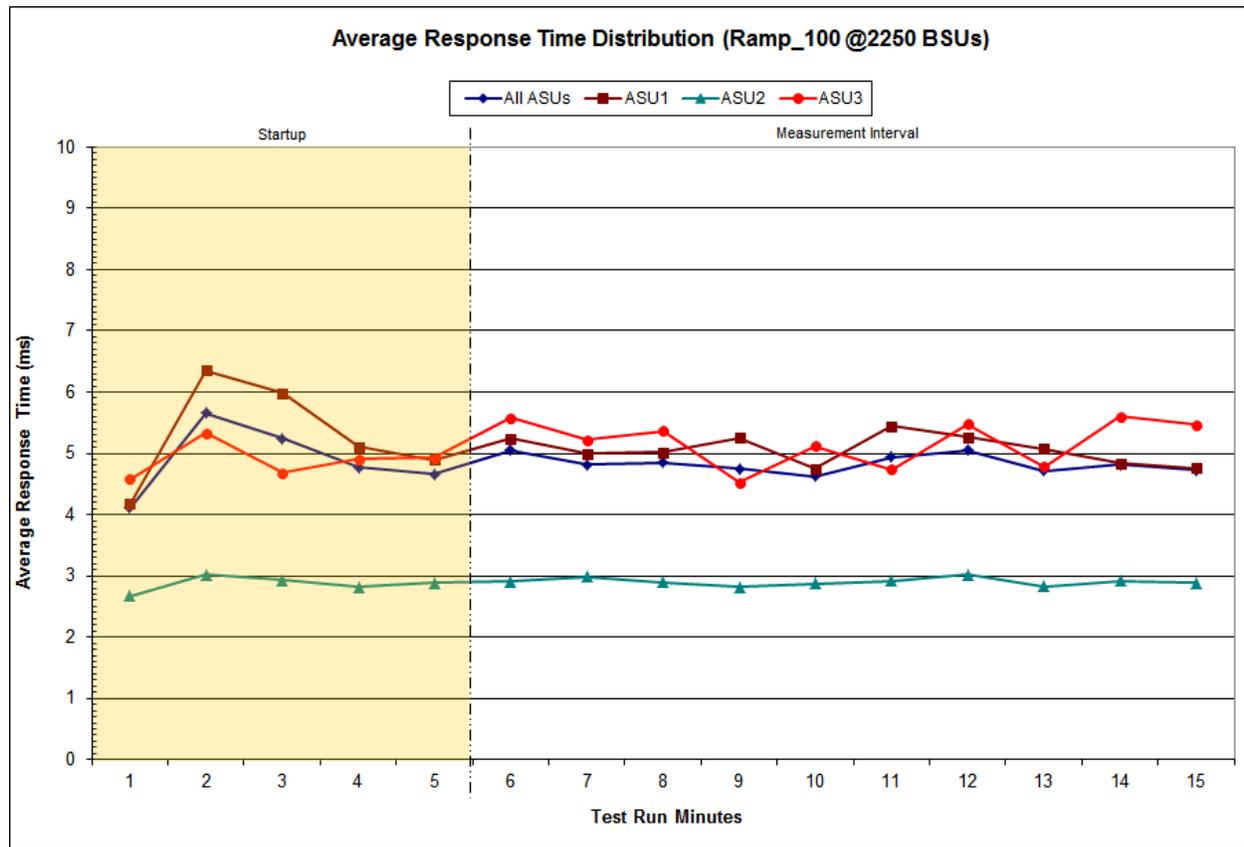
IOPS Test Run –Response Time Frequency Distribution Data

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	1	96,857	3,306,191	7,881,648	2,264,736	756,940	1,748,651	2,004,374
Write	0	650	71,491	687,174	2,079,298	1,897,654	5,673,815	7,815,182
All ASUs	1	97,507	3,377,682	8,568,822	4,344,034	2,654,594	7,422,466	9,819,556
ASU1	1	66,652	2,560,036	6,658,376	2,799,691	1,425,581	3,874,575	4,925,349
ASU2	0	30,318	754,016	1,492,672	731,549	396,469	888,476	984,172
ASU3	0	537	63,630	417,774	812,794	832,544	2,659,415	3,910,035

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	944,351	2,144,615	722,730	1,085,641	243,052	437,492	373,519	232,136
Write	2,748,837	3,926,341	969,827	1,665,791	509,926	969,788	1,082,299	944,838
All ASUs	3,693,188	6,070,956	1,692,557	2,751,432	752,978	1,407,280	1,455,818	1,176,974
ASU1	1,854,779	3,412,095	1,000,393	1,650,254	418,620	778,916	755,074	577,690
ASU2	373,886	667,197	209,996	296,288	79,026	140,448	149,692	132,935
ASU3	1,464,523	1,991,664	482,168	804,890	255,332	487,916	551,052	466,349

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	168,105	140,377	125,332	511,026	401,695	391,394	348,351	288,107
Write	1,103,975	943,268	773,424	3,191,259	1,234,158	666,433	565,159	1,348,098
All ASUs	1,272,080	1,083,645	898,756	3,702,285	1,635,853	1,057,827	913,510	1,636,205
ASU1	550,675	526,688	507,231	2,279,049	940,849	786,489	695,617	1,178,272
ASU2	354,062	258,206	67,615	174,819	43,417	23,431	20,567	28,684
ASU3	367,343	298,751	323,910	1,248,417	651,587	247,907	197,326	429,249

IOPS Test Run –Response Time Frequency Distribution Graph
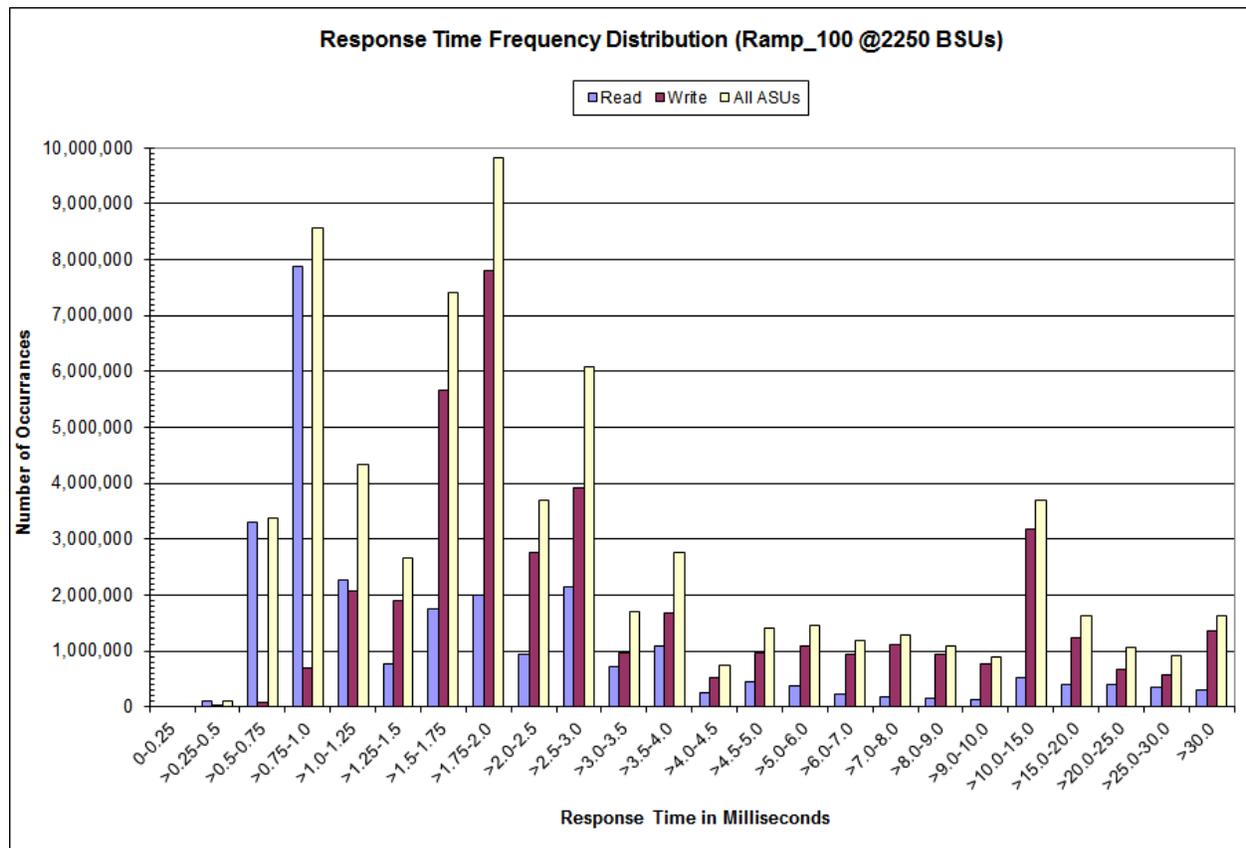
IOPS Test Run – I/O Request Information

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
67,486,006	65,849,801	1,636,205

IOPS Test Run – Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.15.2

MIM – Measured Intensity Multiplier: *The Measured Intensity Multiplier represents the ratio of measured I/Os for each I/O stream relative to the total I/Os measured for all I/O streams (ASU1-1 – ASU3-1). This value may differ from the corresponding Expected Intensity Multiplier by no more than 5%.*

Clause 5.3.15.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0350	0.2810	0.0700	0.2101	0.0180	0.0700	0.0350	0.2810
COV	0.002	0.001	0.001	0.001	0.003	0.001	0.003	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 15.

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 9.4.3.7.4

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 99.

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
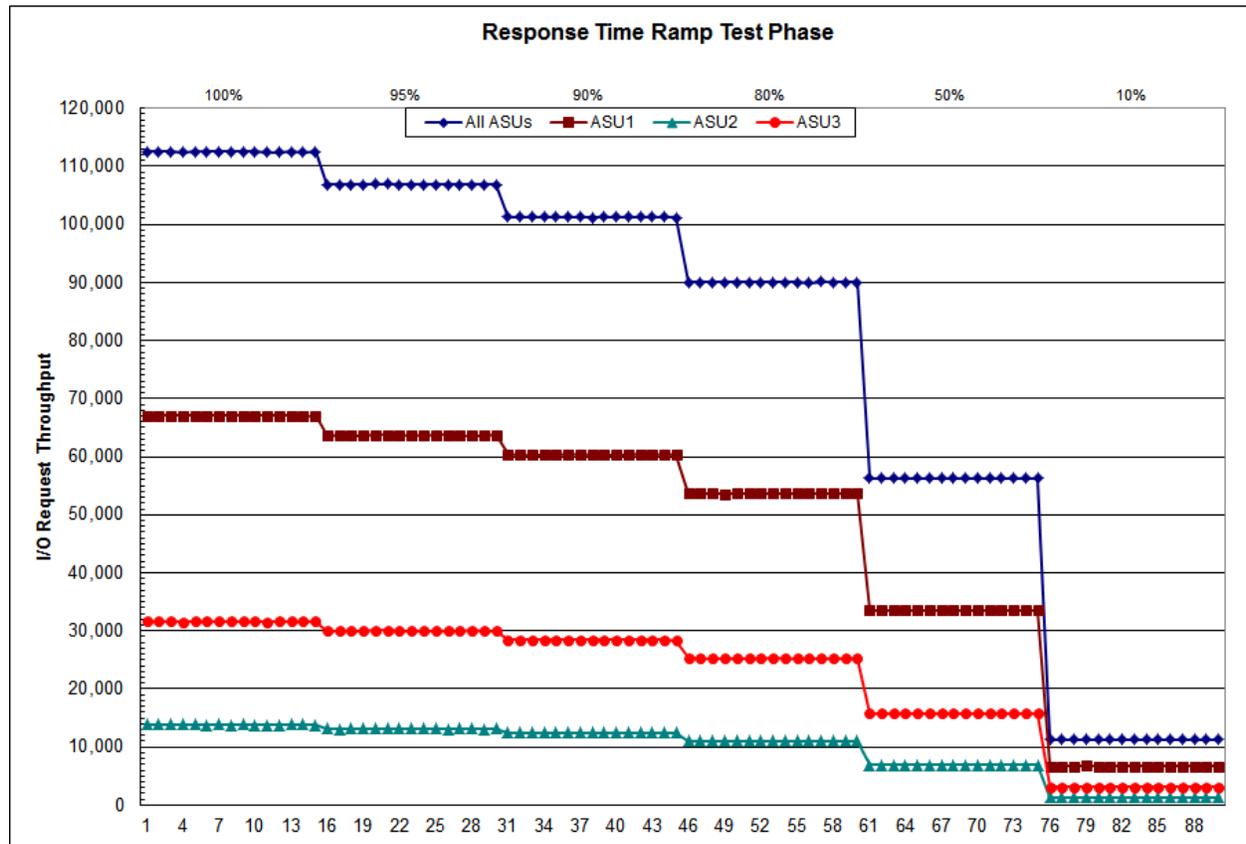
Response Time Ramp Distribution (IOPS) Data

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 table and graph for completeness.

100% Load Level: 2,250 BSUs	Start	Stop	Interval	Duration	95% Load Level: 2,137 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	16:37:49	16:42:50	0-4	0:05:01	Start-Up/Ramp-Up	16:53:11	16:58:12	0-4	0:05:01
Measurement Interval	16:42:50	16:52:50	5-14	0:10:00	Measurement Interval	16:58:12	17:08:12	5-14	0:10:00
(60 second intervals)	**All ASUs**	**ASU-1**	**ASU-2**	**ASU-3**	*(60 second intervals)*	**All ASUs**	**ASU-1**	**ASU-2**	**ASU-3**
Minutes of Test Run	All ASUs	ASU1	ASU2	ASU3	**Minutes of Test Run**	All ASUs	ASU1	ASU2	ASU3
0	112,476.23	67,019.38	13,844.95	31,611.90	0	106,845.30	63,708.00	13,133.05	30,004.25
1	112,493.53	67,024.58	13,851.48	31,617.47	1	106,819.05	63,669.17	13,104.85	30,045.03
2	112,499.02	67,055.40	13,852.30	31,591.32	2	106,814.60	63,661.15	13,135.90	30,017.55
3	112,435.05	67,019.77	13,850.55	31,564.73	3	106,815.32	63,661.28	13,140.03	30,014.00
4	112,478.03	67,011.72	13,857.35	31,608.97	4	106,894.33	63,702.32	13,136.35	30,055.67
5	112,499.67	67,050.50	13,825.68	31,623.48	5	106,903.05	63,691.50	13,138.00	30,073.55
6	112,548.65	67,060.38	13,855.48	31,632.78	6	106,801.23	63,625.97	13,140.33	30,034.93
7	112,479.88	67,056.20	13,823.05	31,600.63	7	106,826.77	63,693.72	13,135.57	29,997.48
8	112,493.98	67,043.98	13,849.08	31,600.92	8	106,780.80	63,643.27	13,120.95	30,016.58
9	112,493.75	67,060.00	13,827.85	31,605.90	9	106,833.25	63,713.27	13,126.42	29,993.57
10	112,397.83	67,016.83	13,810.25	31,570.75	10	106,804.10	63,690.52	13,110.10	30,003.48
11	112,436.15	67,016.88	13,815.80	31,603.47	11	106,854.37	63,660.92	13,158.80	30,034.65
12	112,495.73	67,008.12	13,843.08	31,644.53	12	106,857.30	63,652.62	13,136.63	30,068.05
13	112,437.35	66,985.40	13,835.57	31,616.38	13	106,773.38	63,669.65	13,119.03	29,984.70
14	112,515.05	67,104.82	13,816.28	31,593.95	14	106,857.87	63,702.37	13,143.33	30,012.17
Average	*112,479.81*	*67,040.31*	*13,830.21*	*31,609.28*	*Average*	*106,829.21*	*63,674.38*	*13,132.92*	*30,021.92*

90% Load Level: 2,025 BSUs	Start	Stop	Interval	Duration	80% Load Level: 1,800 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:08:32	17:13:33	0-4	0:05:01	Start-Up/Ramp-Up	17:23:53	17:28:54	0-4	0:05:01
Measurement Interval	17:13:33	17:23:33	5-14	0:10:00	Measurement Interval	17:28:54	17:38:54	5-14	0:10:00
(60 second intervals)	**All ASUs**	**ASU-1**	**ASU-2**	**ASU-3**	*(60 second intervals)*	**All ASUs**	**ASU-1**	**ASU-2**	**ASU-3**
Minutes of Test Run	All ASUs	ASU1	ASU2	ASU3	**Minutes of Test Run**	All ASUs	ASU1	ASU2	ASU3
0	101,318.85	60,428.73	12,434.15	28,455.97	0	90,065.40	53,644.48	11,076.02	25,344.90
1	101,274.00	60,353.10	12,448.57	28,472.33	1	90,015.85	53,667.33	11,077.17	25,271.35
2	101,227.68	60,310.88	12,465.32	28,451.48	2	89,996.12	53,624.92	11,077.22	25,293.98
3	101,235.62	60,335.32	12,462.35	28,437.95	3	90,003.73	53,606.23	11,090.45	25,307.05
4	101,257.23	60,364.47	12,444.90	28,447.87	4	89,998.38	53,648.42	11,069.25	25,280.72
5	101,223.03	60,300.25	12,453.77	28,469.02	5	89,975.27	53,628.98	11,061.40	25,284.88
6	101,314.65	60,369.97	12,463.28	28,481.40	6	90,009.02	53,643.88	11,077.53	25,287.60
7	101,207.42	60,353.82	12,432.98	28,420.62	7	90,031.10	53,643.10	11,053.87	25,334.13
8	101,240.85	60,356.97	12,429.00	28,454.88	8	89,990.10	53,631.05	11,066.92	25,292.13
9	101,253.83	60,360.52	12,448.87	28,444.45	9	89,974.85	53,625.47	11,043.30	25,306.08
10	101,244.60	60,355.72	12,449.88	28,439.00	10	89,936.50	53,616.73	11,056.47	25,263.30
11	101,291.50	60,378.53	12,440.58	28,472.38	11	90,096.93	53,714.90	11,079.60	25,302.43
12	101,269.77	60,355.93	12,452.30	28,461.53	12	90,009.13	53,643.12	11,085.72	25,280.30
13	101,257.73	60,390.30	12,449.37	28,418.07	13	89,998.45	53,616.15	11,086.68	25,295.62
14	101,186.92	60,359.30	12,435.67	28,391.95	14	90,020.13	53,663.47	11,069.72	25,286.95
Average	*101,249.03*	*60,358.13*	*12,445.57*	*28,445.33*	*Average*	*90,004.15*	*53,642.69*	*11,068.12*	*25,293.34*

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

| 50% Load Level: 1,025 BSUs	Start	Stop	Interval	Duration	10% Load Level: 225 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:39:09	17:44:10	0-4	0:05:01	Start-Up/Ramp-Up	17:54:19	17:59:20	0-4	0:05:01
Measurement Interval	17:44:10	17:54:10	5-14	0:10:00	Measurement Interval	17:59:20	18:09:20	5-14	0:10:00
(60 second intervals)	**All ASUs**	**ASU-1**	**ASU-2**	**ASU-3**	*(60 second intervals)*	**All ASUs**	**ASU-1**	**ASU-2**	**ASU-3**
Minutes of Test Run	All ASUs	ASU1	ASU2	ASU3	**Minutes of Test Run**	All ASUs	ASU1	ASU2	ASU3
0	56,244.43	33,486.07	6,932.65	15,825.72	0	11,267.93	6,710.78	1,385.98	3,171.17
1	56,285.43	33,566.45	6,912.33	15,806.65	1	11,233.83	6,699.25	1,381.35	3,153.23
2	56,248.58	33,524.77	6,916.75	15,807.07	2	11,234.90	6,692.22	1,385.32	3,157.37
3	56,251.93	33,504.37	6,940.23	15,807.33	3	11,271.53	6,726.83	1,380.33	3,164.37
4	56,255.50	33,563.40	6,905.05	15,787.05	4	11,255.08	6,704.50	1,386.38	3,164.20
5	56,245.95	33,538.78	6,913.68	15,793.48	5	11,261.17	6,714.47	1,384.35	3,162.35
6	56,253.92	33,519.47	6,923.80	15,810.65	6	11,252.87	6,719.30	1,376.95	3,156.62
7	56,223.30	33,491.82	6,931.68	15,799.80	7	11,258.05	6,711.18	1,379.10	3,167.77
8	56,245.10	33,510.38	6,911.48	15,823.23	8	11,237.38	6,697.97	1,381.93	3,157.48
9	56,274.70	33,518.53	6,934.87	15,821.30	9	11,243.17	6,702.20	1,382.17	3,158.80
10	56,238.00	33,506.67	6,922.87	15,808.47	10	11,268.95	6,717.58	1,385.28	3,166.08
11	56,292.55	33,527.45	6,938.17	15,826.93	11	11,228.62	6,684.38	1,375.22	3,169.02
12	56,234.77	33,527.75	6,929.67	15,777.35	12	11,249.17	6,697.68	1,392.65	3,158.83
13	56,241.67	33,523.50	6,910.05	15,808.12	13	11,247.93	6,700.45	1,389.72	3,157.77
14	56,257.82	33,550.57	6,917.45	15,789.80	14	11,252.35	6,693.93	1,386.95	3,171.47
Average	*56,250.78*	*33,521.49*	*6,923.37*	*15,805.91*	*Average*	*11,249.97*	*6,703.92*	*1,383.43*	*3,162.62*

Response Time Ramp Distribution (IOPS) Graph

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

225 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	17:54:19	17:59:20	0-4	0:05:01
Measurement Interval	17:59:20	18:09:20	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.67	0.64	0.70	0.74
1	0.69	0.67	0.70	0.72
2	0.69	0.67	0.72	0.72
3	0.74	0.73	0.79	0.74
4	0.67	0.64	0.70	0.74
5	0.70	0.68	0.75	0.70
6	0.70	0.67	0.73	0.74
7	0.68	0.67	0.73	0.69
8	0.68	0.67	0.71	0.70
9	0.74	0.70	0.83	0.80
10	0.70	0.68	0.76	0.73
11	0.67	0.65	0.71	0.72
12	0.72	0.69	0.75	0.76
13	0.71	0.70	0.74	0.72
14	0.69	0.68	0.74	0.71
Average	*0.70*	*0.68*	*0.75*	*0.73*

SPC-1 LRT™ Average Response Time (ms) Distribution Graph
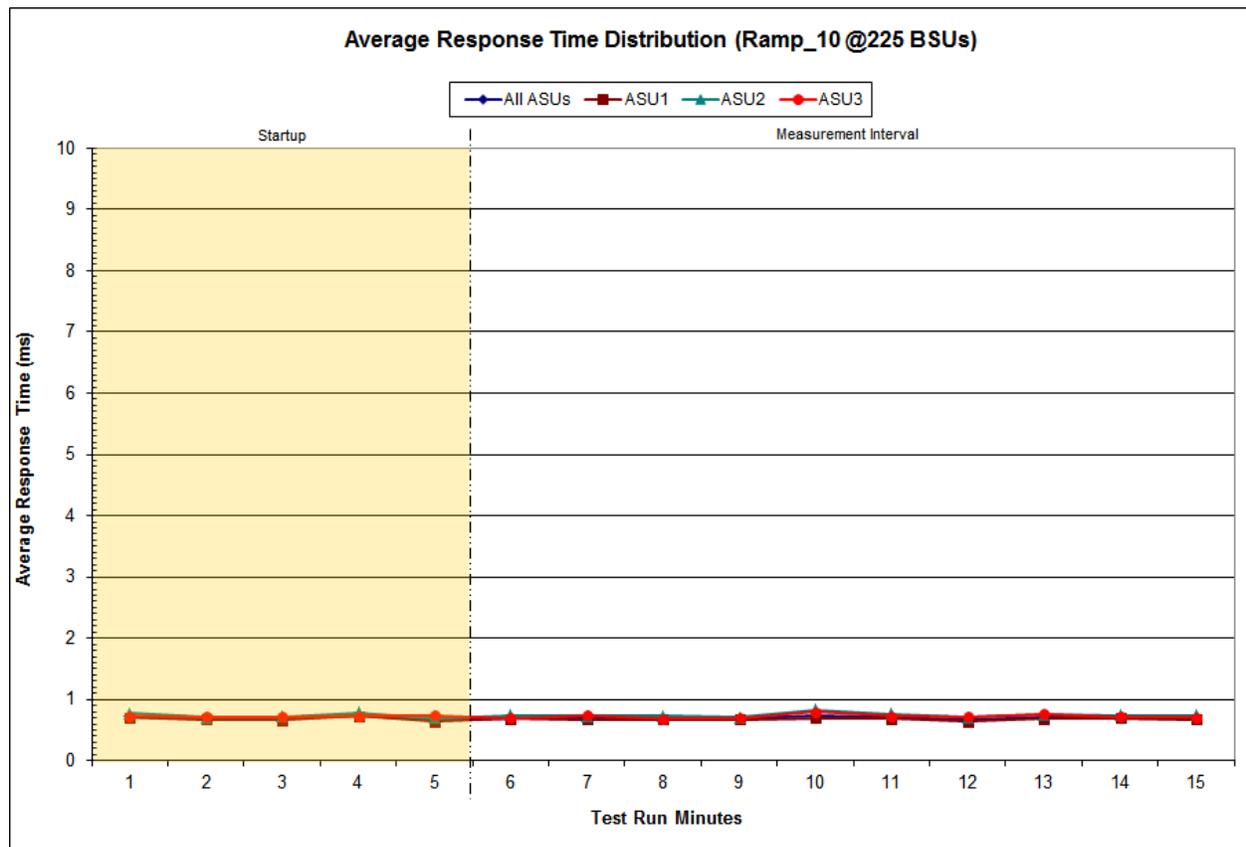
SPC-1 LRT™ (10%) – Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.15.2

MIM – Measured Intensity Multiplier: *The Measured Intensity Multiplier represents the ratio of measured I/Os for each I/O stream relative to the total I/Os measured for all I/O streams (ASU1-1 – ASU3-1). This value may differ from the corresponding Expected Intensity Multiplier by no more than 5%.*

Clause 5.3.15.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0351	0.2811	0.0700	0.2098	0.0180	0.0700	0.0349	0.2811
COV	0.007	0.002	0.005	0.002	0.010	0.006	0.006	0.002

Repeatability Test

<u>*Clause 5.4.5*</u>

The Repeatability Test demonstrates the repeatability and reproducibility of the SPC-1 IOPS™ primary metric and the SPC-1 LRT™ metric generated in earlier Test Runs.

There are two identical Repeatability Test Phases. Each Test Phase contains two Test Runs. Each of the Test Runs will have a Measurement Interval of no less than ten (10) minutes. The two Test Runs in each Test Phase will be executed without interruption or any type of manual intervention.

The first Test Run in each Test Phase is executed at the 10% load point. The Average Response Time from each of the Test Runs is compared to the SPC-1 LRT™ metric. Each Average Response Time value must be less than the SPC-1 LRT™ metric plus 5% or less than the SPC-1 LRT™ metric plus one (1) millisecond (ms).

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

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

<u>*Clause 9.4.3.7.5*</u>

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 <u>Appendix E: SPC-1 Workload Generator Input Parameters</u> on Page <u>99</u>.

Repeatability Test Results File

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

	SPC-1 IOPS™
Primary Metrics	*112,479.81*
Repeatability Test Phase 1	112,490.51
Repeatability Test Phase 2	112,483.78

The SPC-1 IOPS™ values in the above table were generated using 100% of the specified Business Scaling Unit (BSU) load level. Each of the Repeatability Test Phase values for SPC-1 IOPS™ must greater than 95% of the reported SPC-1 IOPS™ Primary Metric.

	SPC-1 LRT™
Primary Metrics	*0.70 ms*
Repeatability Test Phase 1	0.69 ms
Repeatability Test Phase 2	0.70 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 plus 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)
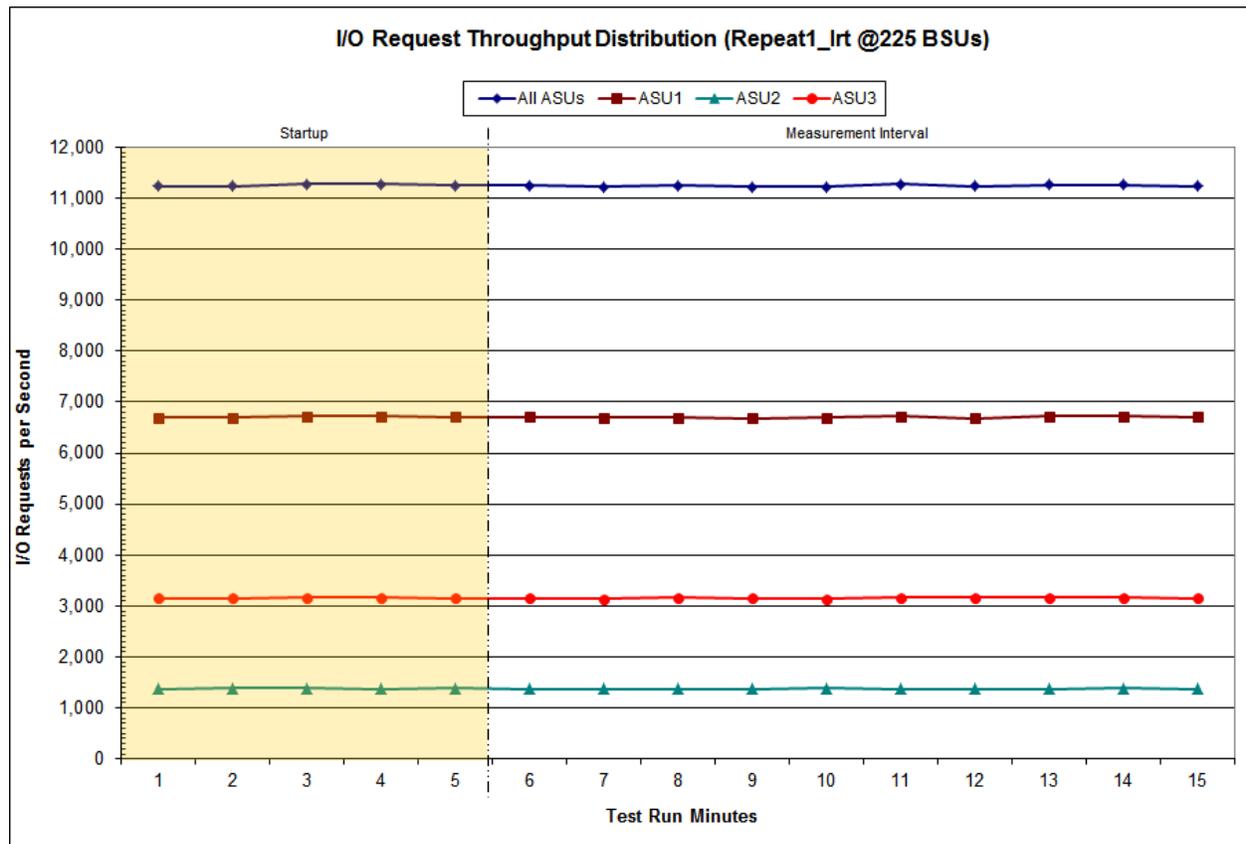**Repeatability Test Phase 2, Test Run 2 (IOPS)**

Repeatability 1 LRT – I/O Request Throughput Distribution Data

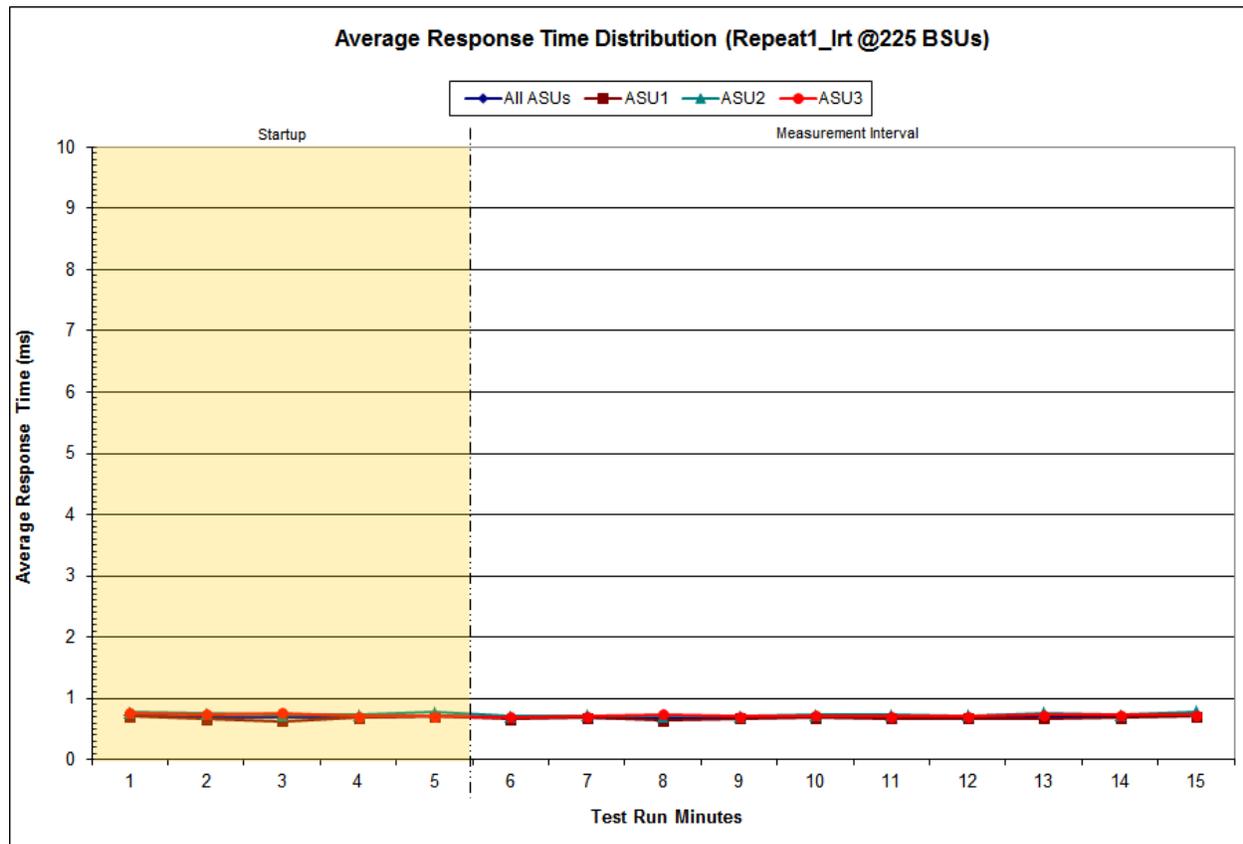| 225 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:09:35	18:14:35	0-4	0:05:00
Measurement Interval	18:14:35	18:24:35	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	11,237.52	6,700.80	1,381.97	3,154.75
1	11,237.28	6,696.33	1,382.38	3,158.57
2	11,268.30	6,715.85	1,387.02	3,165.43
3	11,270.00	6,721.65	1,381.98	3,166.37
4	11,246.55	6,707.92	1,386.67	3,151.97
5	11,245.90	6,704.82	1,381.73	3,159.35
6	11,220.38	6,695.88	1,379.62	3,144.88
7	11,249.42	6,700.60	1,380.55	3,168.27
8	11,219.17	6,684.73	1,375.87	3,158.57
9	11,223.77	6,698.87	1,383.47	3,141.43
10	11,276.90	6,726.67	1,381.47	3,168.77
11	11,230.75	6,687.40	1,380.70	3,162.65
12	11,257.08	6,717.03	1,377.98	3,162.07
13	11,267.63	6,717.07	1,389.90	3,160.67
14	11,240.45	6,702.93	1,381.00	3,156.52
Average	*11,243.15*	*6,703.60*	*1,381.23*	*3,158.32*

Repeatability 1 LRT – I/O Request Throughput Distribution Graph

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

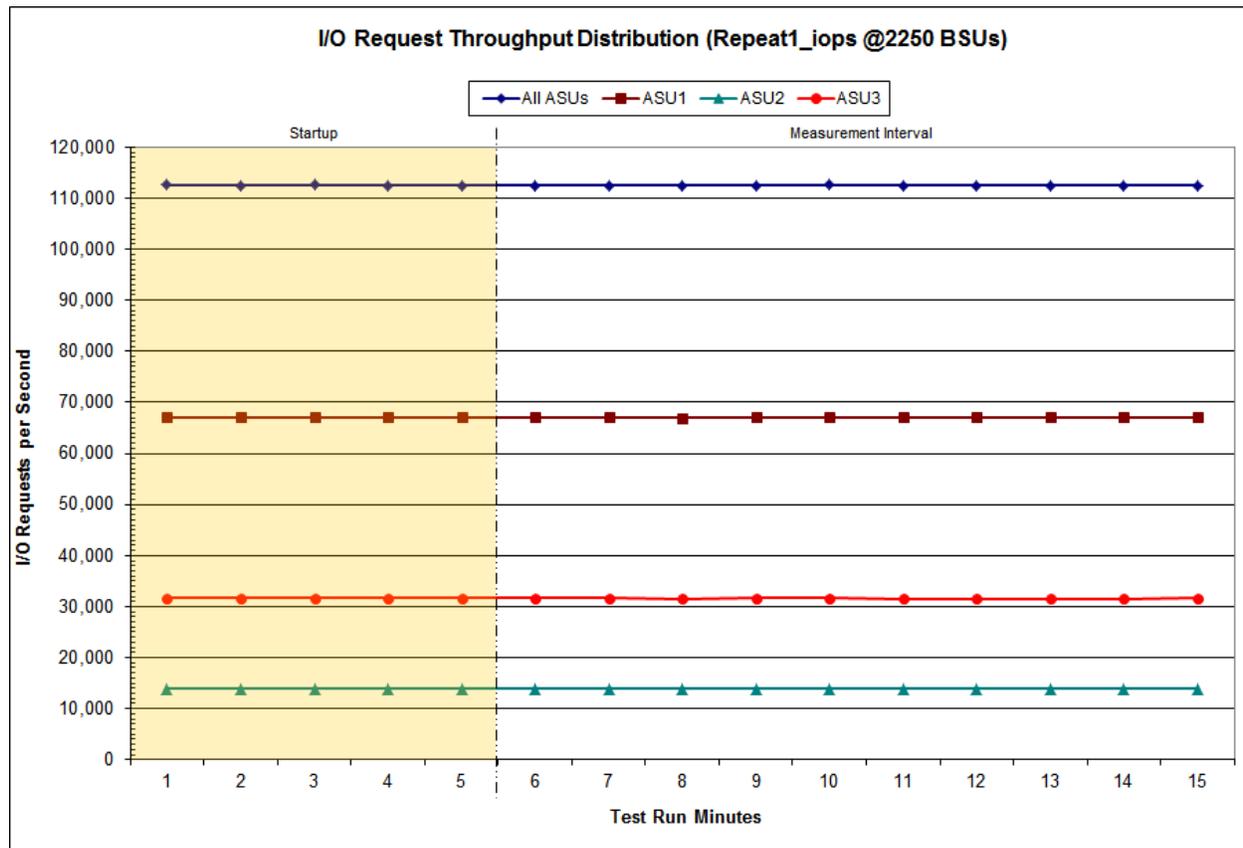| 225 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:09:35	18:14:35	0-4	0:05:00
Measurement Interval	18:14:35	18:24:35	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	0.73	0.71	0.78	0.76
1	0.69	0.66	0.75	0.74
2	0.68	0.63	0.73	0.77
3	0.70	0.69	0.73	0.71
4	0.72	0.71	0.78	0.71
5	0.68	0.67	0.71	0.69
6	0.70	0.69	0.72	0.71
7	0.68	0.64	0.71	0.74
8	0.69	0.67	0.70	0.71
9	0.70	0.69	0.73	0.72
10	0.69	0.68	0.73	0.71
11	0.69	0.67	0.72	0.70
12	0.70	0.67	0.77	0.73
13	0.71	0.69	0.74	0.73
14	0.72	0.70	0.78	0.73
Average	*0.69*	*0.68*	*0.73*	*0.72*

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

Repeatability 1 IOPS – I/O Request Throughput Distribution Data

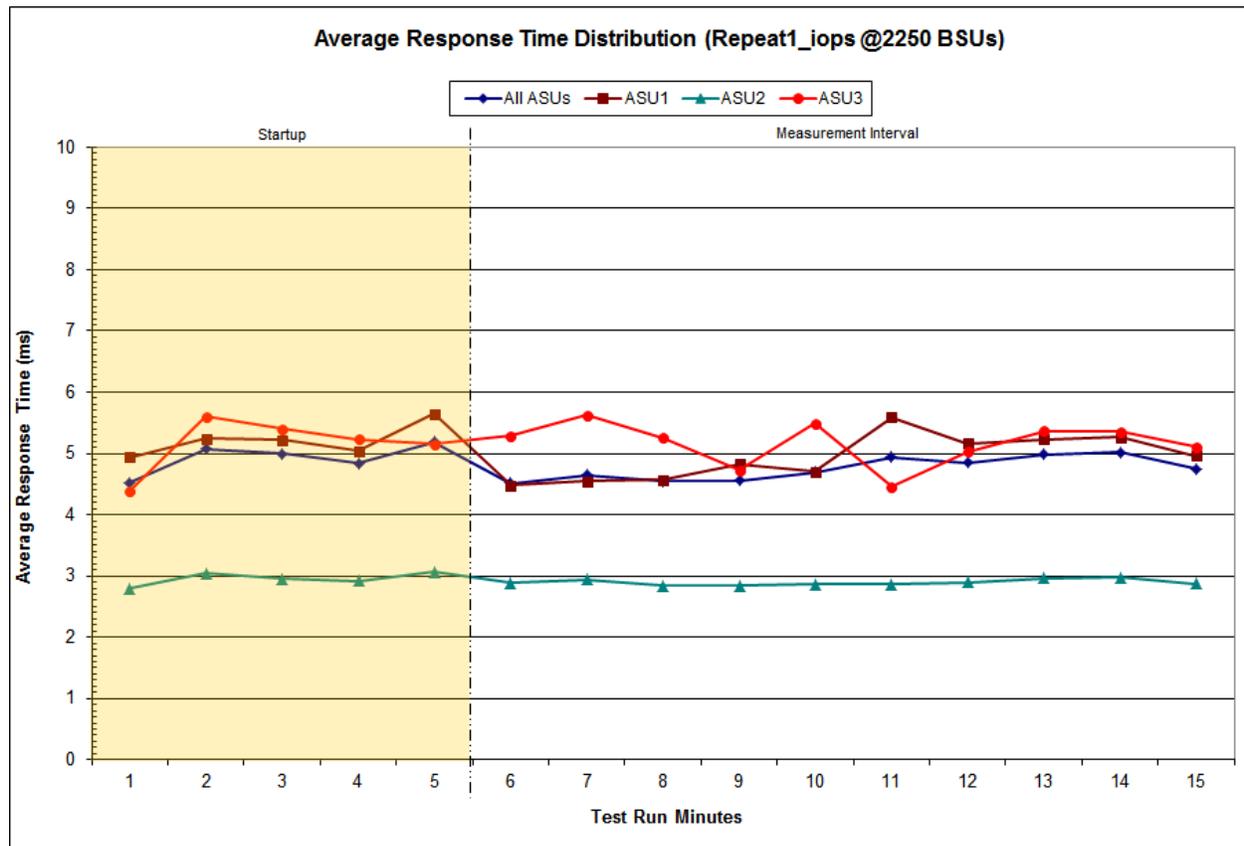| 2,250 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:24:59	18:30:00	0-4	0:05:01
Measurement Interval	18:30:00	18:40:00	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	112,551.72	67,093.40	13,826.95	31,631.37
1	112,520.88	67,035.60	13,824.98	31,660.30
2	112,596.03	67,105.50	13,847.33	31,643.20
3	112,537.63	67,063.20	13,849.82	31,624.62
4	112,503.52	67,038.22	13,859.17	31,606.13
5	112,493.52	67,049.78	13,843.20	31,600.53
6	112,483.18	67,033.95	13,827.80	31,621.43
7	112,424.43	66,985.38	13,858.82	31,580.23
8	112,509.03	67,048.20	13,831.17	31,629.67
9	112,550.45	67,055.33	13,840.12	31,655.00
10	112,480.98	67,048.47	13,850.30	31,582.22
11	112,499.82	67,047.60	13,854.60	31,597.62
12	112,477.32	67,035.10	13,849.55	31,592.67
13	112,508.58	67,081.92	13,841.82	31,584.85
14	112,477.82	67,052.60	13,822.62	31,602.60
Average	*112,490.51*	*67,043.83*	*13,842.00*	*31,604.68*

Repeatability 1 IOPS – I/O Request Throughput Distribution Graph

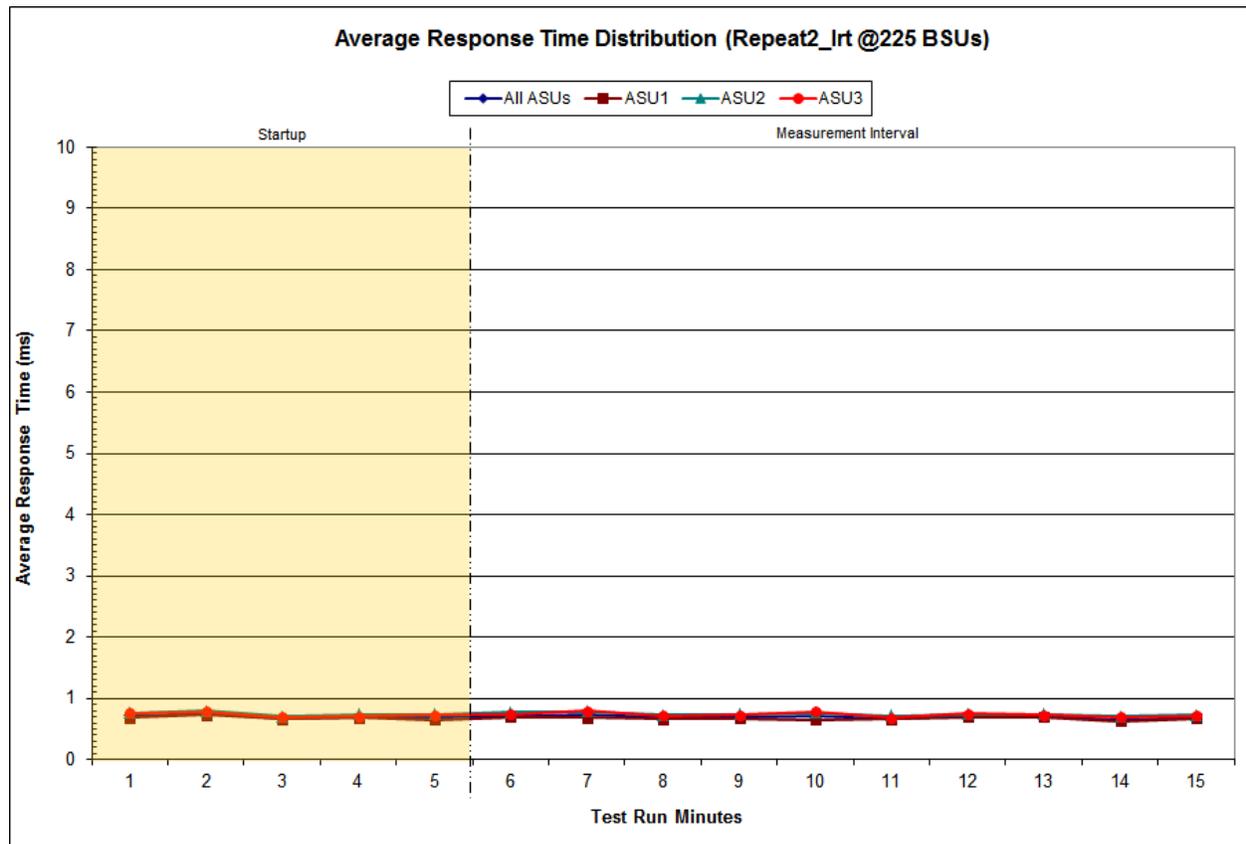## Repeatability 1 IOPS –Average Response Time (ms) Distribution Data

2,250 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:24:59	18:30:00	0-4	0:05:01
Measurement Interval	18:30:00	18:40:00	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	4.52	4.94	2.79	4.39
1	5.07	5.24	3.04	5.60
2	4.99	5.22	2.95	5.40
3	4.84	5.04	2.92	5.24
4	5.19	5.65	3.06	5.15
5	4.51	4.48	2.89	5.29
6	4.65	4.54	2.94	5.62
7	4.55	4.56	2.84	5.25
8	4.55	4.83	2.84	4.73
9	4.70	4.70	2.87	5.49
10	4.94	5.59	2.87	4.46
11	4.85	5.17	2.89	5.03
12	4.99	5.23	2.97	5.36
13	5.01	5.27	2.98	5.36
14	4.74	4.96	2.88	5.11
Average	*4.75*	*4.93*	*2.90*	*5.17*

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

SPC BENCHMARK 1™ V1.14
Dell, Inc.
Dell Storage SC4020 *(6 SSDs)*

FULL DISCLOSURE REPORT

Submission Identifier: A00156
Submitted for Review: MARCH 18, 2015

Repeatability 2 LRT – I/O Request Throughput Distribution Data

| 225 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:40:16	18:45:16	0-4	0:05:00
Measurement Interval	18:45:16	18:55:16	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	11,233.85	6,694.98	1,381.72	3,157.15
1	11,270.07	6,731.12	1,387.92	3,151.03
2	11,236.83	6,689.75	1,379.28	3,167.80
3	11,261.18	6,713.27	1,390.95	3,156.97
4	11,254.92	6,708.18	1,381.25	3,165.48
5	11,243.18	6,690.77	1,387.55	3,164.87
6	11,262.80	6,705.30	1,384.90	3,172.60
7	11,262.63	6,708.92	1,392.95	3,160.77
8	11,246.85	6,695.12	1,381.88	3,169.85
9	11,257.22	6,707.03	1,385.48	3,164.70
10	11,246.85	6,701.78	1,381.48	3,163.58
11	11,256.78	6,705.98	1,389.50	3,161.30
12	11,263.77	6,715.60	1,382.50	3,165.67
13	11,239.53	6,697.50	1,387.22	3,154.82
14	11,247.73	6,695.30	1,382.77	3,169.67
Average	*11,252.74*	*6,702.33*	*1,385.62*	*3,164.78*

Repeatability 2 LRT – I/O Request Throughput Distribution Graph
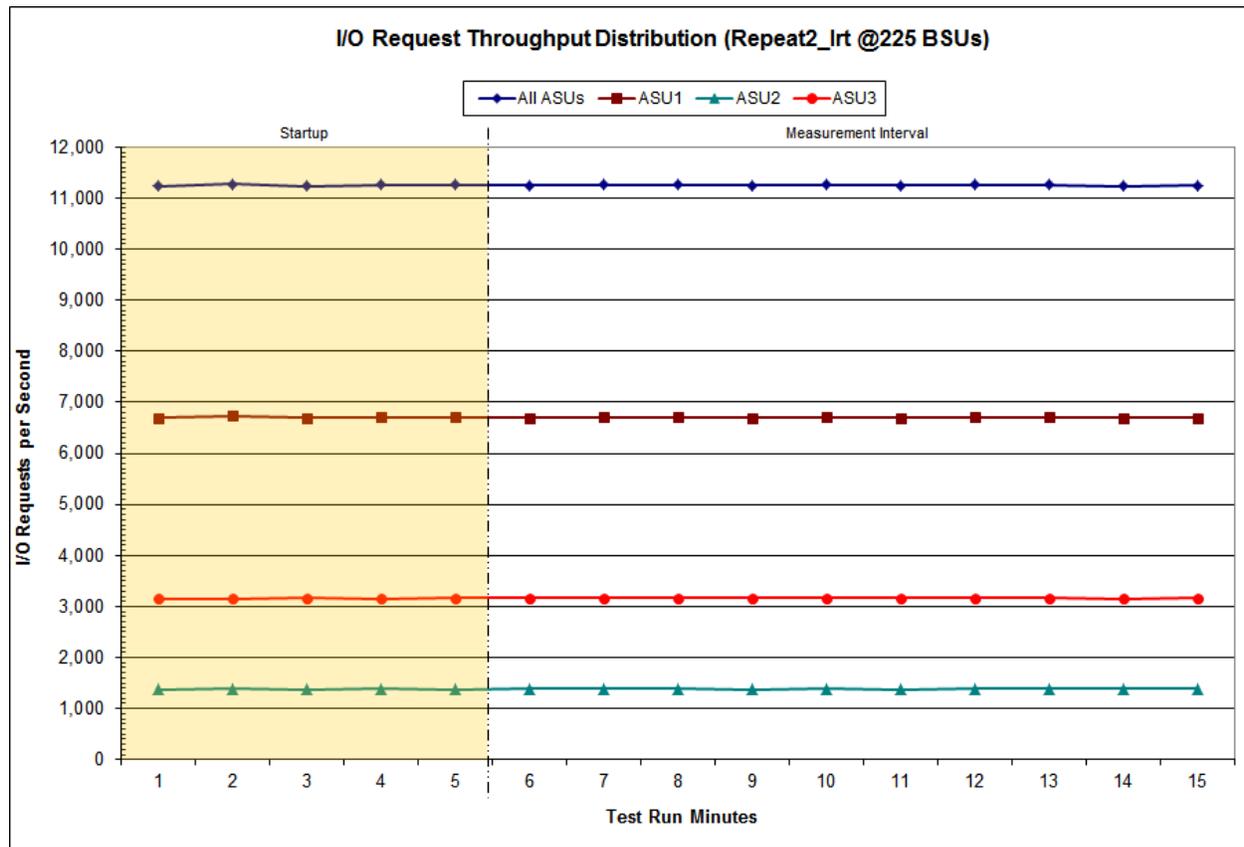
Repeatability 2 LRT –Average Response Time (ms) Distribution Data

225 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:40:16	18:45:16	0-4	0:05:00
Measurement Interval	18:45:16	18:55:16	5-14	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.72	0.68	0.77	0.77
1	0.75	0.73	0.79	0.79
2	0.68	0.66	0.71	0.69
3	0.70	0.69	0.75	0.71
4	0.69	0.66	0.74	0.73
5	0.72	0.70	0.78	0.74
6	0.73	0.68	0.79	0.79
7	0.69	0.67	0.73	0.72
8	0.70	0.67	0.74	0.73
9	0.70	0.65	0.76	0.78
10	0.68	0.67	0.72	0.69
11	0.72	0.70	0.74	0.75
12	0.72	0.70	0.74	0.73
13	0.65	0.62	0.70	0.70
14	0.69	0.68	0.73	0.72
Average	*0.70*	*0.67*	*0.74*	*0.74*

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

Repeatability 2 IOPS – I/O Request Throughput Distribution Data

2,250 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:55:39	19:00:40	0-4	0:05:01
Measurement Interval	19:00:40	19:10:40	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	112,532.82	67,050.38	13,856.92	31,625.52
1	112,472.65	67,003.48	13,849.57	31,619.60
2	112,518.53	67,068.82	13,833.25	31,616.47
3	112,500.98	67,030.57	13,847.37	31,623.05
4	112,521.73	67,071.45	13,848.75	31,601.53
5	112,511.65	67,022.68	13,851.33	31,637.63
6	112,489.73	67,013.73	13,850.35	31,625.65
7	112,492.72	67,065.92	13,833.03	31,593.77
8	112,457.65	67,038.00	13,827.28	31,592.37
9	112,424.47	67,003.02	13,825.75	31,595.70
10	112,480.88	67,051.08	13,830.00	31,599.80
11	112,516.62	67,044.93	13,836.18	31,635.50
12	112,461.25	67,019.60	13,846.93	31,594.72
13	112,509.00	67,075.23	13,842.82	31,590.95
14	112,493.82	67,049.92	13,833.23	31,610.67
Average	*112,483.78*	*67,038.41*	*13,837.69*	*31,607.68*

Repeatability 2 IOPS – I/O Request Throughput Distribution Graph

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

2,250 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	18:55:39	19:00:40	0-4	0:05:01
Measurement Interval	19:00:40	19:10:40	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	4.50	4.70	2.78	4.82
1	5.01	5.04	3.05	5.80
2	5.13	5.33	3.04	5.60
3	4.31	4.35	2.76	4.90
4	4.49	4.33	2.89	5.54
5	5.05	5.47	3.00	5.06
6	4.45	4.72	2.82	4.59
7	4.94	5.29	2.92	5.08
8	4.52	4.39	2.92	5.49
9	5.06	4.96	3.03	6.17
10	5.71	5.69	3.23	6.85
11	5.42	5.50	3.19	6.24
12	5.14	5.31	3.05	5.71
13	5.22	5.76	2.99	5.05
14	4.12	3.98	2.75	5.01
Average	*4.96*	*5.11*	*2.99*	*5.52*

Repeatability 2 IOPS –Average Response Time (ms) Distribution Graph
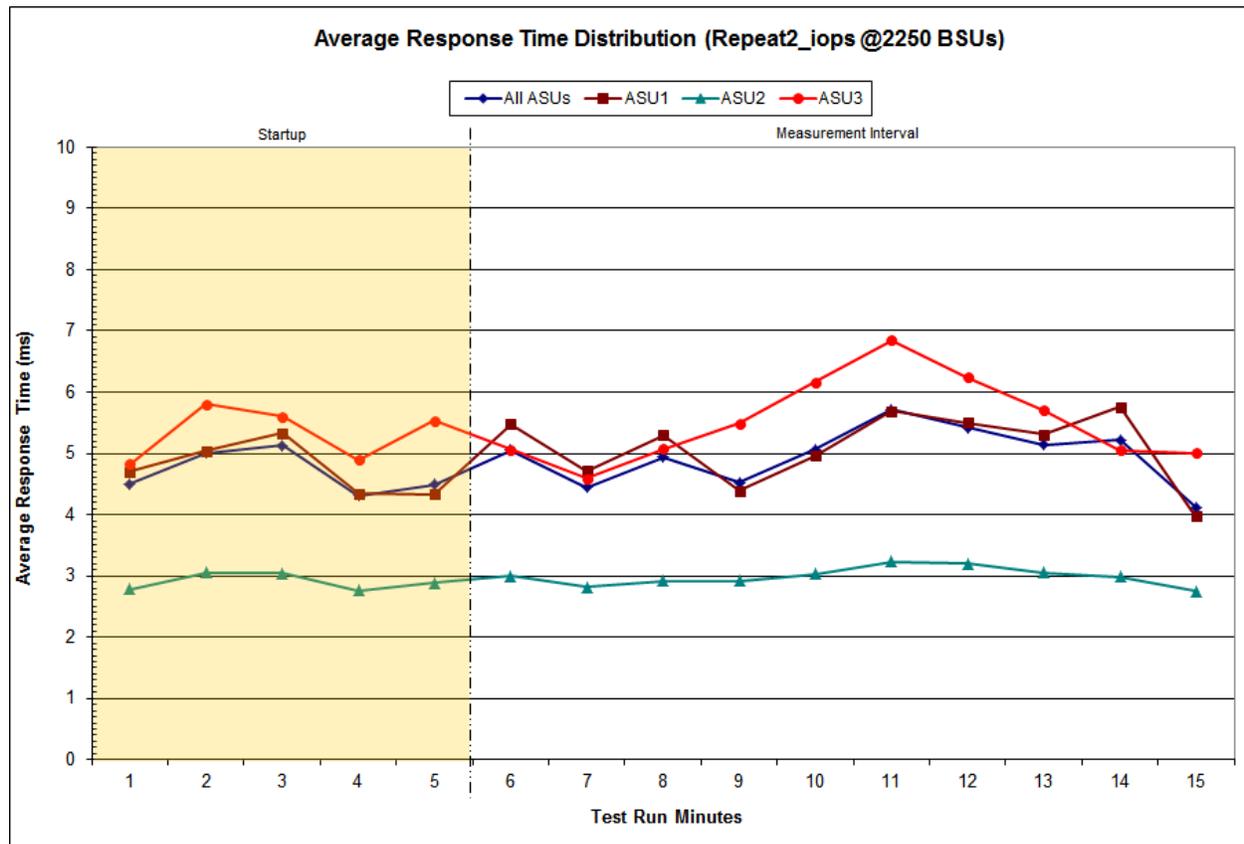
Repeatability 1 (LRT)
Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

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

Clauses5.1.10 and 5.3.15.2

MIM – Measured Intensity Multiplier: *The Measured Intensity Multiplier represents the ratio of measured I/Os for each I/O stream relative to the total I/Os measured for all I/O streams (ASU1-1 – ASU3-1). This value may differ from the corresponding Expected Intensity Multiplier by no more than 5%.*

Clause 5.3.15.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0350	0.2813	0.0699	0.2100	0.0180	0.0699	0.0350	0.2809
COV	0.006	0.001	0.003	0.002	0.009	0.003	0.004	0.002

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0350	0.2811	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.003	0.000	0.001	0.001	0.003	0.001	0.002	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
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0350	0.2812	0.0699	0.2095	0.0180	0.0701	0.0350	0.2812
COV	0.006	0.002	0.003	0.003	0.006	0.005	0.007	0.002

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	*0.0350*	*0.2810*	*0.0700*	*0.2100*	*0.0180*	*0.0700*	*0.0350*	*0.2810*
MIM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
COV	0.002	0.000	0.001	0.001	0.003	0.001	0.001	0.000

Data Persistence Test

Clause 6

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

- *Is capable of maintain data integrity across a power cycle.*

- *Ensures the transfer of data between Logical Volumes and host systems occurs without corruption or loss.*

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

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

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

Clause 9.4.3.8

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

1. *A listing or screen image of all input parameters supplied to the Workload Generator.*

2. *For the successful Data Persistence Test Run, a table illustrating key results. The content, appearance, and format of this table are specified in Table 9-12. Information displayed in this table shall be obtained from the Test Run Results File referenced below in #3.*

3. *For the successful Data Persistence Test Run, the human readable Test Run Results file produced by the Workload Generator (may be contained in an appendix).*

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in Appendix E: SPC-1 Workload Generator Input Parameters on Page 99.

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	269,634,688
Total Number of Logical Blocks Verified	106,404,576
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 9.4.3.9

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

The Dell Storage SC4020 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 be found in the Priced Storage Configuration Pricing section on page 16.

Tested Storage Configuration (TSC) and Priced Storage Configuration Differences

Clause 9.4.3.3.8

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

A list of all differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration may be found in the Executive Summary portion of this document on page 16.

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 Onsite Audit of the Dell Storage SC4020.

APPENDIX A: SPC-1 GLOSSARY

"Decimal" *(powers of ten)* Measurement Units

In the storage industry, the terms "kilo", "mega", "giga", "tera", "peta", and "exa" are commonly used prefixes for computing performance and capacity. For the purposes of the SPC workload definitions, all of the following terms are defined in "powers of ten" measurement units.

A kilobyte (KB) is equal to 1,000 (10^3) bytes.

A megabyte (MB) is equal to 1,000,000 (10^6) bytes.

A gigabyte (GB) is equal to 1,000,000,000 (10^9) bytes.

A terabyte (TB) is equal to 1,000,000,000,000 (10^{12}) bytes.

A petabyte (PB) is equal to 1,000,000,000,000,000 (10^{15}) bytes

An exabyte (EB) is equal to 1,000,000,000,000,000,000 (10^{18}) bytes

"Binary" *(powers of two)* Measurement Units

The sizes reported by many operating system components use "powers of two" measurement units rather than "power of ten" units. The following standardized definitions and terms are also valid and may be used in this document.

A kibibyte (KiB) is equal to 1,024 (2^{10}) bytes.

A mebibyte (MiB) is equal to 1,048,576 (2^{20}) bytes.

A gigibyte (GiB) is equal to 1,073,741,824 (2^{30}) bytes.

A tebibyte (TiB) is equal to 1,099,511,627,776 (2^{40}) bytes.

A pebibyte (PiB) is equal to 1,125,899,906,842,624 (2^{50}) bytes.

An exbibyte (EiB) is equal to 1,152,921,504,606,846,967 (2^{60}) bytes.

SPC-1 Data Repository Definitions

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

Application Storage Unit (ASU): The logical interface between the storage and SPC-1 Workload Generator. The three ASUs (Data, User, and Log) are typically implemented on one or more Logical Volume.

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

Addressable Storage Capacity: The total storage (sum of Logical Volumes) that can be read and written by application programs such as the SPC-1 Workload Generator.

Configured Storage Capacity: This capacity includes the Addressable Storage Capacity and any other storage (parity disks, hot spares, etc.) necessary to implement the Addressable Storage Capacity.

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

Data Protection Overhead: The storage capacity required to implement the selected level of data protection.

Required Storage: The amount of Configured Storage Capacity required to implement the Addressable Storage Configuration, excluding the storage required for the three ASUs.

Global Storage Overhead: The amount of Physical Storage Capacity that is required for storage subsystem use and unavailable for use by application programs.

Total Unused Storage: The amount of storage capacity available for use by application programs but not included in the Total ASU Capacity.

SPC-1 Data Protection Levels

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

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

SPC-1 Test Execution Definitions

Average Response Time: The sum of the Response Times for all Measured I/O Requests divided by the total number of Measured I/O Requests.

Completed I/O Request: An I/O Request with a Start Time and a Completion Time (see "I/O Completion Types" below).

Completion Time: The time recorded by the Workload Generator when an I/O Request is satisfied by the TSC as signaled by System Software.

Data Rate: The data transferred in all Measured I/O Requests in an SPC-1 Test Run divided by the length of the Test Run in seconds.

Expected I/O Count: For any given I/O Stream and Test Phase, the product of 50 times the BSU level, the duration of the Test Phase in seconds, and the Intensity Multiplier for that I/O Stream.

Failed I/O Request: Any I/O Request issued by the Workload Generator that could not be completed or was signaled as failed by System Software. A Failed I/O Request has no Completion Time (see "I/O Completion Types" below).

I/O Request Throughput: The total number of Measured I/O requests in an SPC-1 Test Run divided by the duration of the Measurement Interval in seconds.

In-Flight I/O Request: An I/O Request issued by the I/O Command Generator to the TSC that has a recorded Start Time, but does not complete within the Measurement Interval (see "I/O Completion Types" below).

Measured I/O Request: A Completed I/O Request with a Completion Time occurring within the Measurement Interval (see "I/O Completion Types" below).

Measured Intensity Multiplier: The percentage of all Measured I/O Requests that were issued by a given I/O Stream.

Measurement Interval: The finite and contiguous time period, after the TSC has reached Steady State, when data is collected by a Test Sponsor to generate an SPC-1 test result or support an SPC-1 test result.

Ramp-Up: The time required for the Benchmark Configuration (BC) to produce Steady State throughput after the Workload Generator begins submitting I/O Requests to the TSC for execution.

Ramp-Down: The time required for the BC to complete all I/O Requests issued by the Workload Generator. The Ramp-Down period begins when the Workload Generator ceases to issue new I/O Requests to the TSC.

Response Time: The Response Time of a Measured I/O Request is its Completion Time minus its Start Time.

Start Time: The time recorded by the Workload Generator when an I/O Request is submitted, by the Workload Generator, to the System Software for execution on the Tested Storage Configuration (TSC).

Start-Up: The period that begins after the Workload Generator starts to submit I/O requests to the TSC and ends at the beginning of the Measurement Interval.

Shut-Down: The period between the end of the Measurement Interval and the time when all I/O Requests issued by the Workload Generator have completed or failed.

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

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

Test Run: The execution of SPC-1 for the purpose of producing or supporting an SPC-1 test result. SPC-1 Test Runs may have a finite and measured Ramp-Up period, Start-Up period, Shut-Down period, and Ramp-Down period as illustrated in the "SPC-1 Test Run Components" below. All SPC-1 Test Runs shall have a Steady State period and a Measurement Interval.

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

I/O Completion Types

Start Time

Completion Time

Completed I/O

Measured I/O

Completed I/O

Failed I/O

In-Flight I/O

Error or Failure

Failed I/O

Time

Start-Up

Measurement Interval

Shut-Down

SPC-1 Test Run Components

Measurement
Interval

Start-Up

Shut-Down

I/O Request
Throughput

Time

Ramp-Up

Ramp-Down

Steady State Period
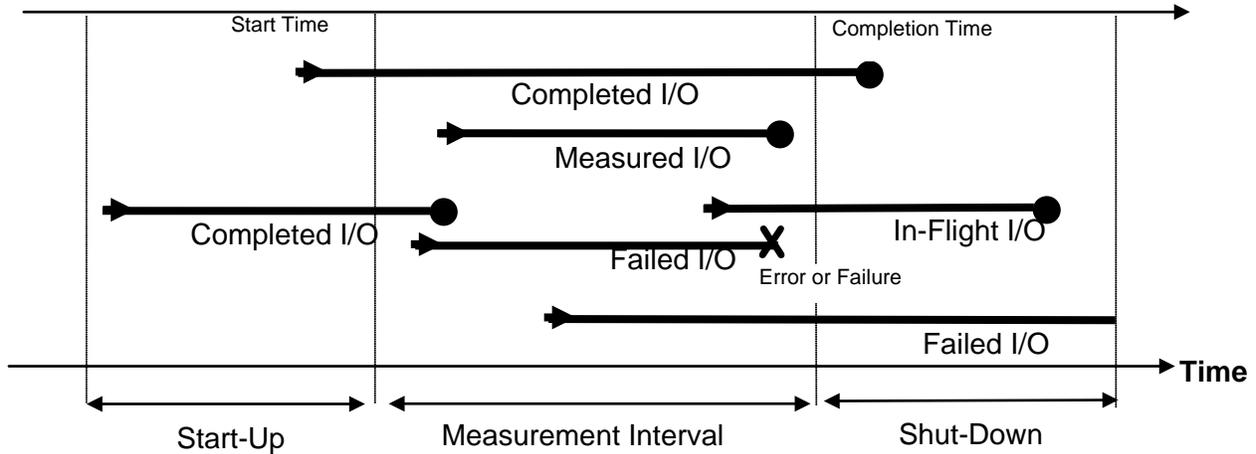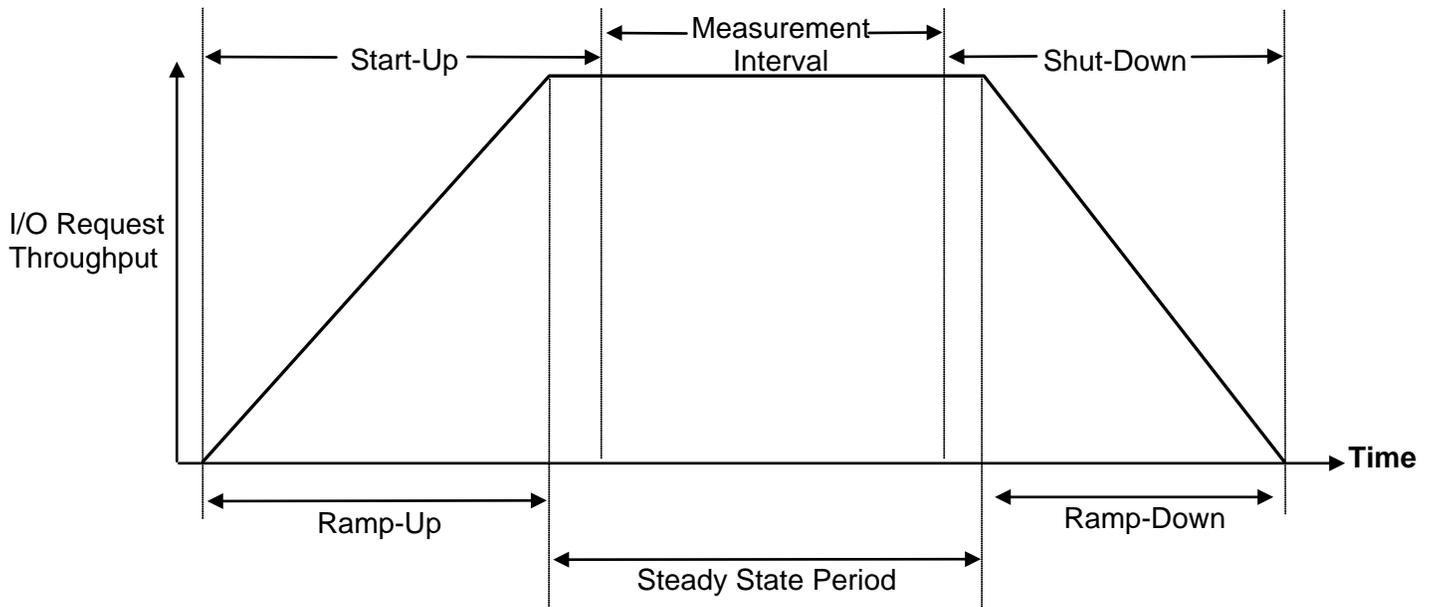
APPENDIX B: CUSTOMER TUNABLE PARAMETERS AND OPTIONS

Data Progression

This process migrates old data from Tier 1 to Tier 2 to Tier 3. The Tested Storage Configuration only used a single tier, so this feature was not needed. Data Progression was automatically disabled when the **Daily** box was unchecked as documented in Appendix C on page 69.

RAID Scrub

This process runs in the background at low priority. It ensures RAID stripe parity information is consistent with RAID stripe data and only executes if the RAID device has not been scrubbed for a week. Given that this process executes so infrequently, it was disabled for the benchmark measurements.

The following command, via the comman line interface, disables RAID Scrub:

raid global set ScrubAdminStatus disable

System Read Cache and System Write Cache

Both the system read cache and system write cache were disabled as described on page 70 of *Appendix C: Tested Storage Configuration (TSC) Creation*.

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

Logon to the System Manager

Follow these steps to log on to System Manager:

1. In the address bar of a web browser on the Host System, enter the IP address of the Management controller.

2. Click **Continue** to acknowledge the messages and alerts. The Storage Center Storage Center Login dialog box will appear.
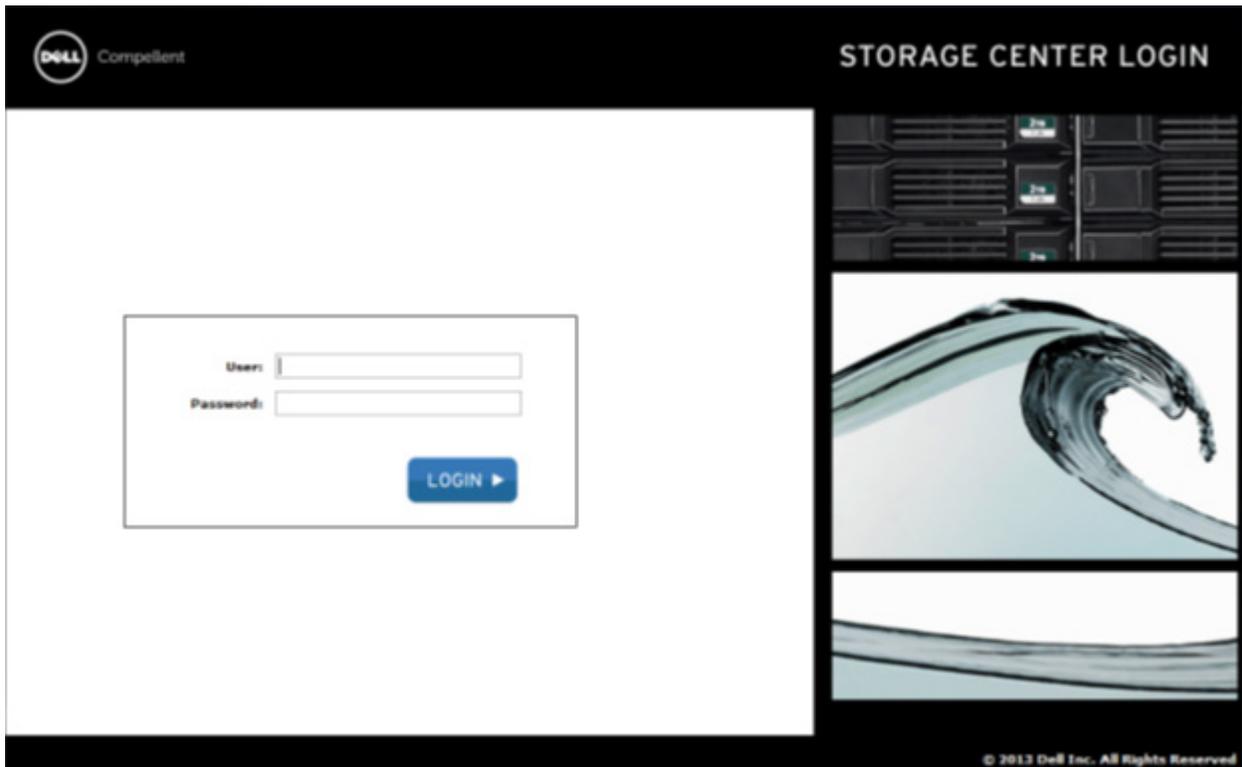
3. In the **User** field, enter the default administrator username: **Admin**

4. Enter the administrative password for Storage Center. If a new password has not been set, enter the default password: **mmm**

5. Click **Login**. If additional security alerts appear, click **Yes** and **Run** to continue.

View the System Dashboard

The center pane of the **System Explorer** opens to the system dashboard with **Storage Summary** and **Storage History** displayed.
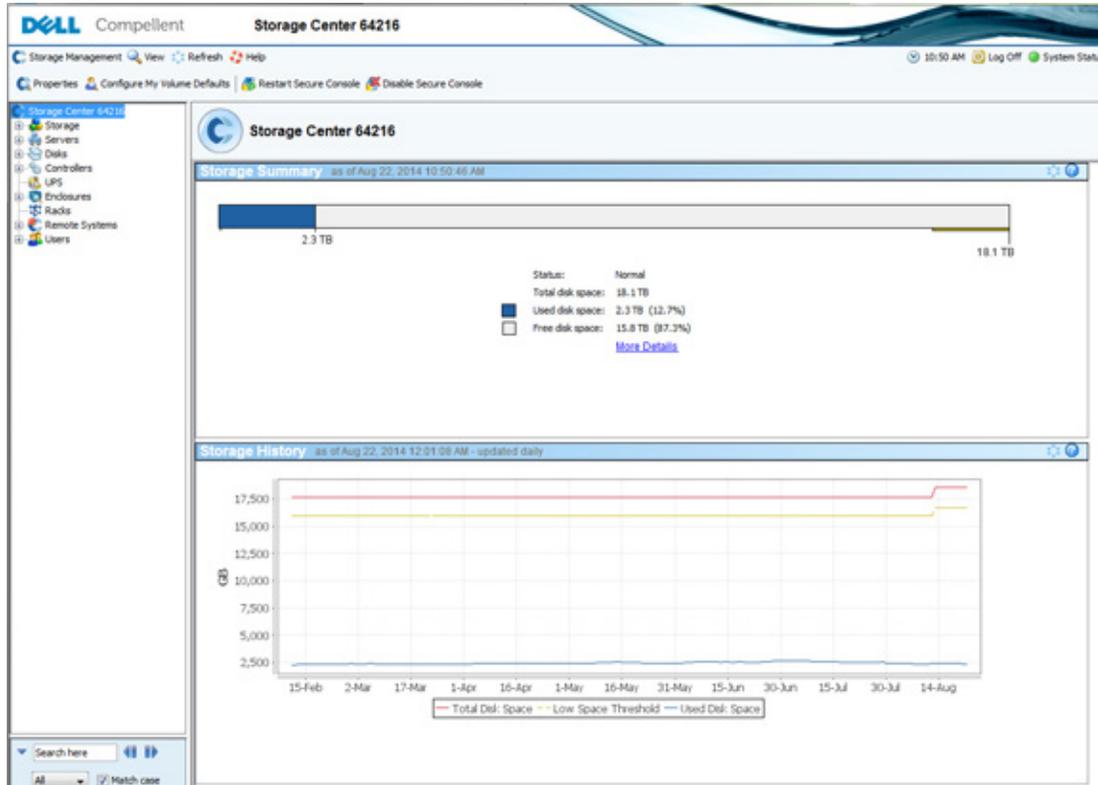
Configure Volume Defaults

1. Select **Storage Management**, select **Volume** and then select **Configure My Volume Defaults**.
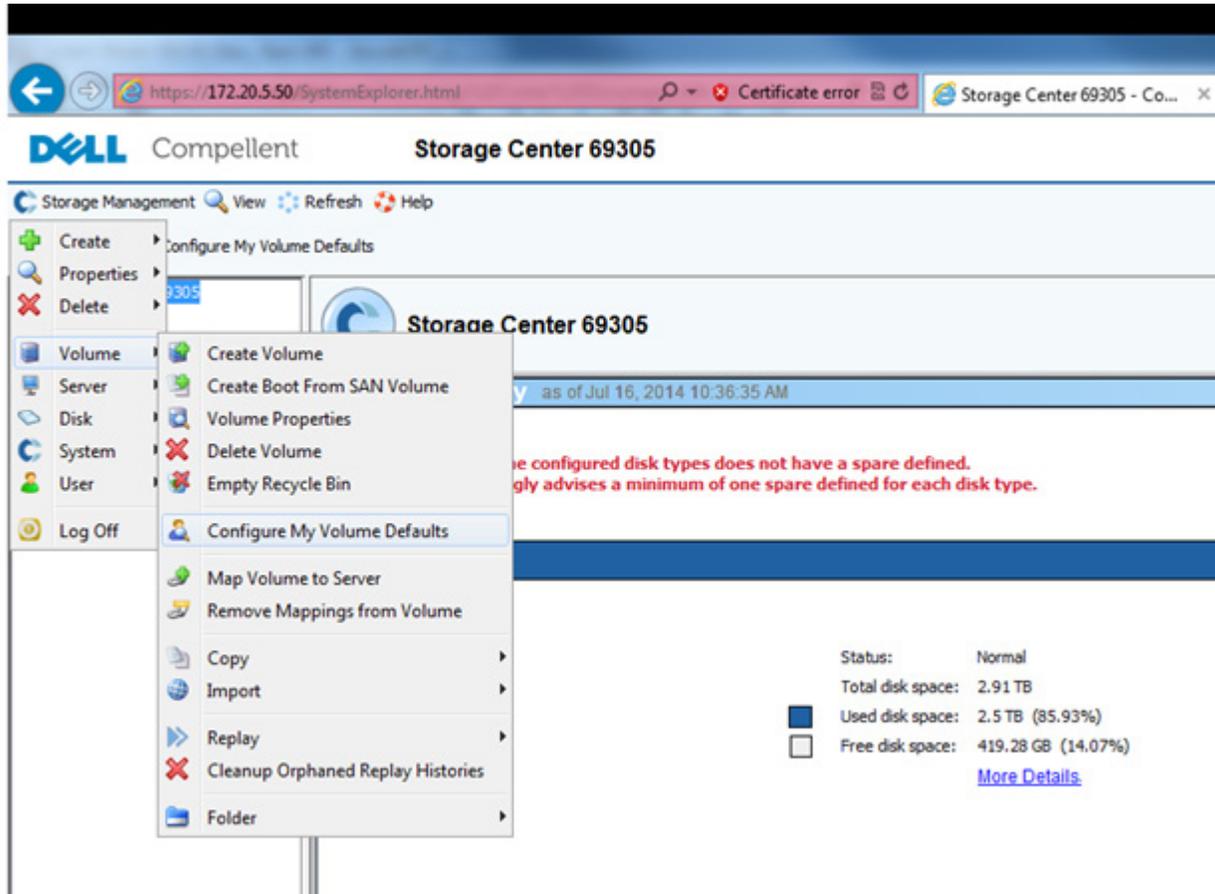
2. The **Configure User Volume Defaults** screen will be displayed. Select the **Advanced** tab.
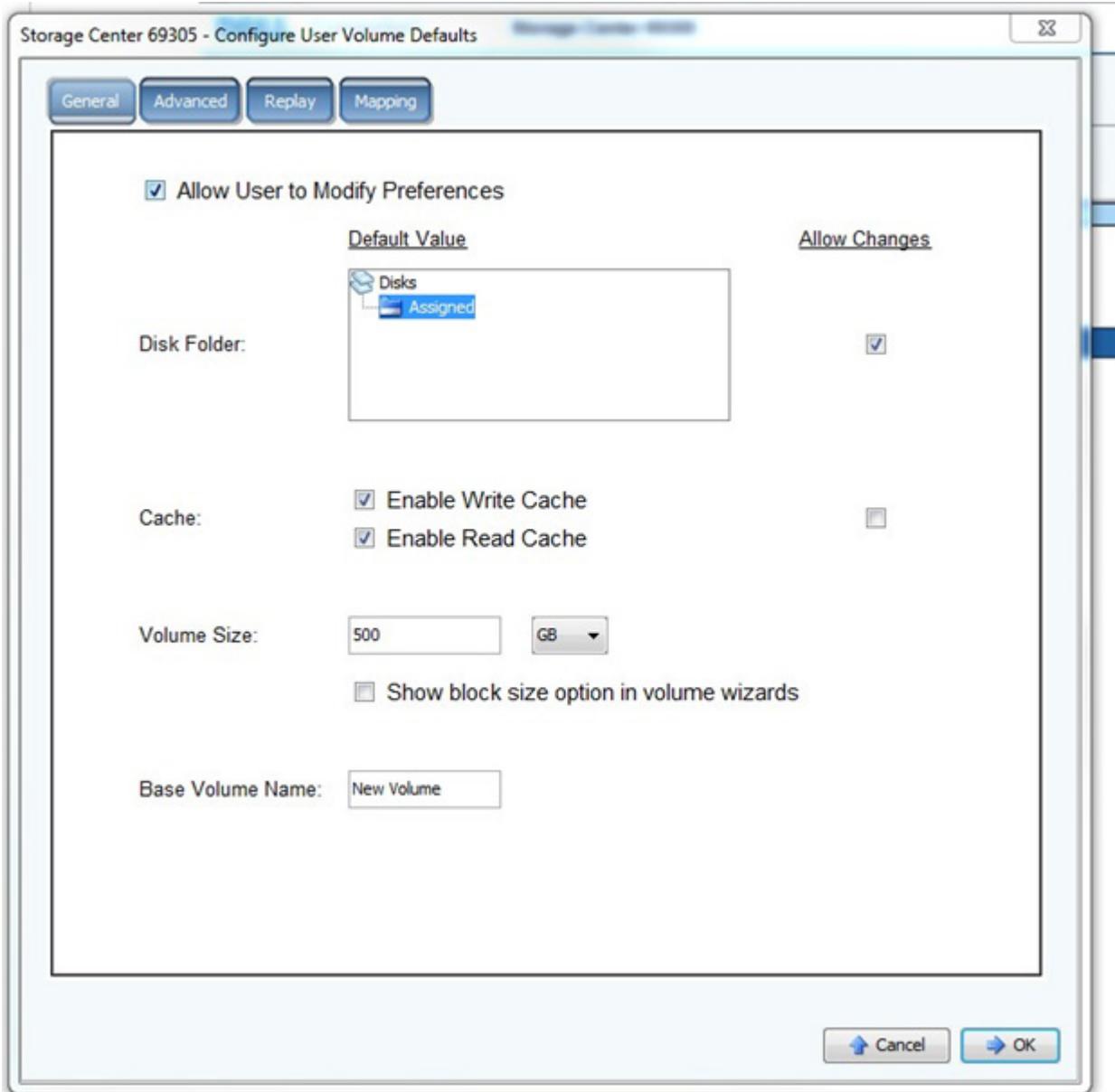
3. Select the following on the **Advanced** screen:

- *Only use standard redundant storage*

- *Allow Storage Profile selection*

- *Allow removal of storage classes*
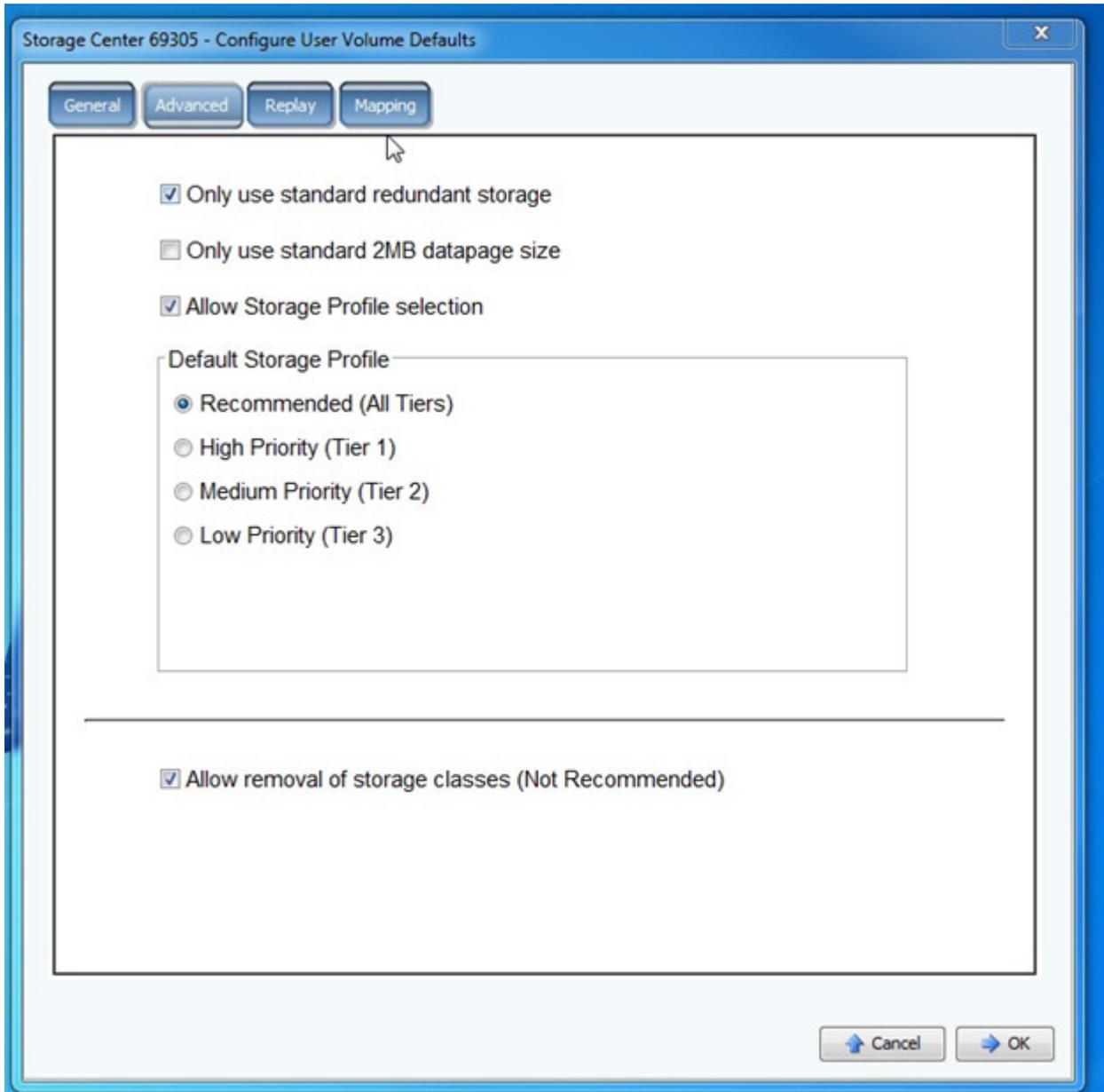
4. Select the **Replay** tab, clear the *Daily* checkbox in the **Default Replay Profiles** section.

5. Click **OK**.
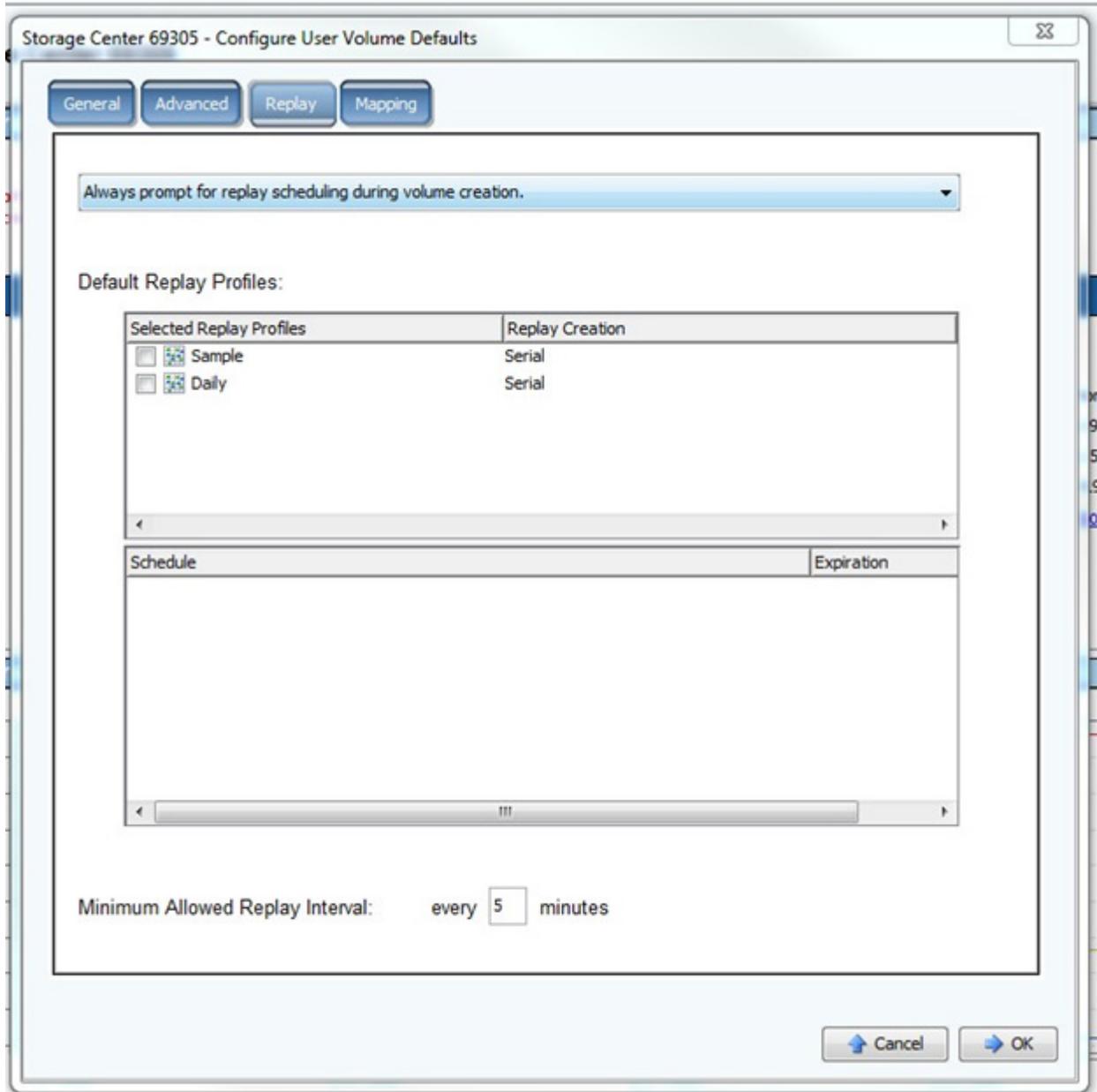
Disable Cache

1. Select **Storage Management**, select **Properties>System** and then select **Cache**.

2. Uncheck **Enable Read Cache** and **Enable Write Cache**.

3. Click **OK**.
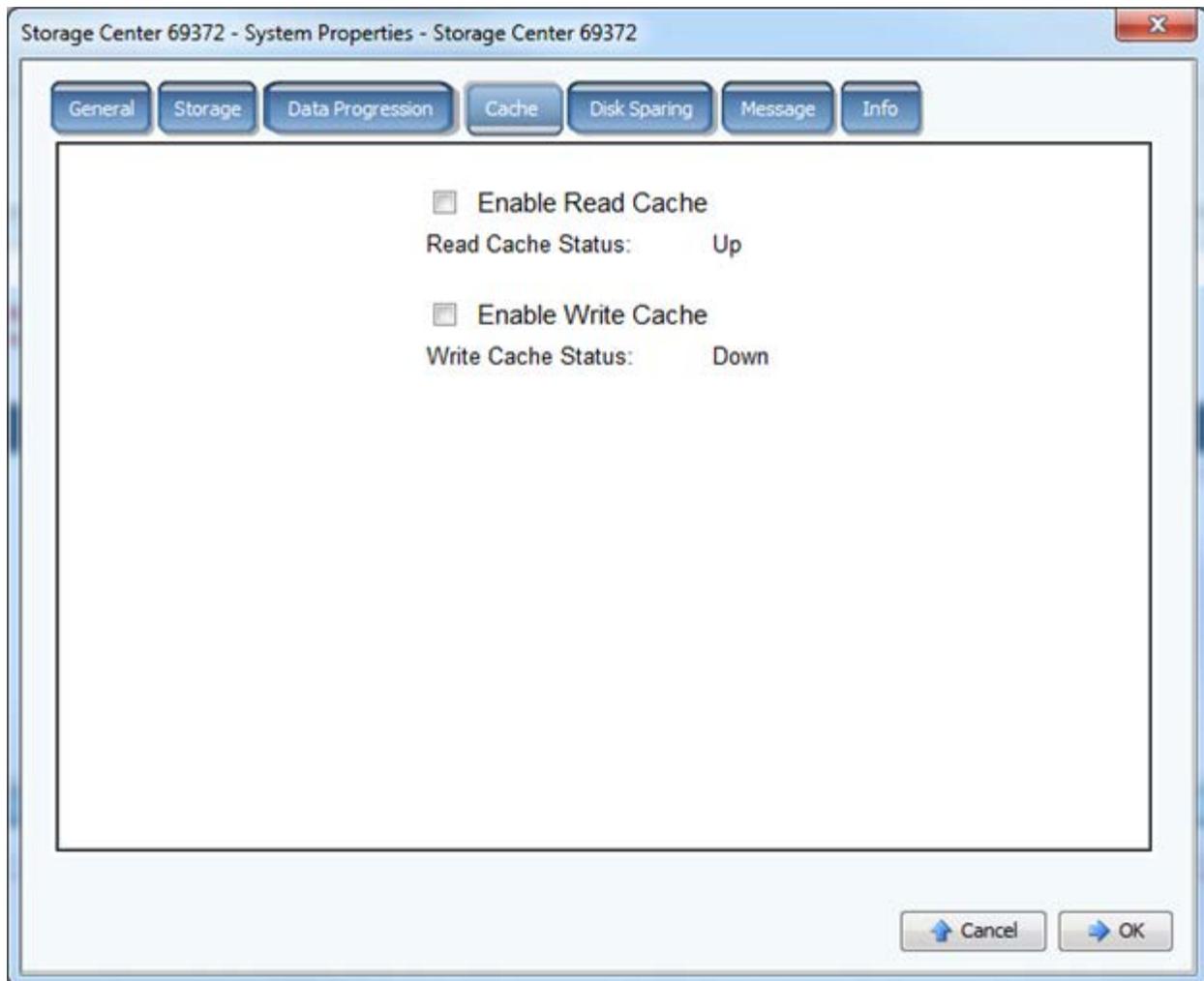
Configure Storage

1. Select **Storage Management**, select **Disk** and then select **Configure Storage**.

2. Select **Modify Storage Type** on the **Configure Storage** screen.
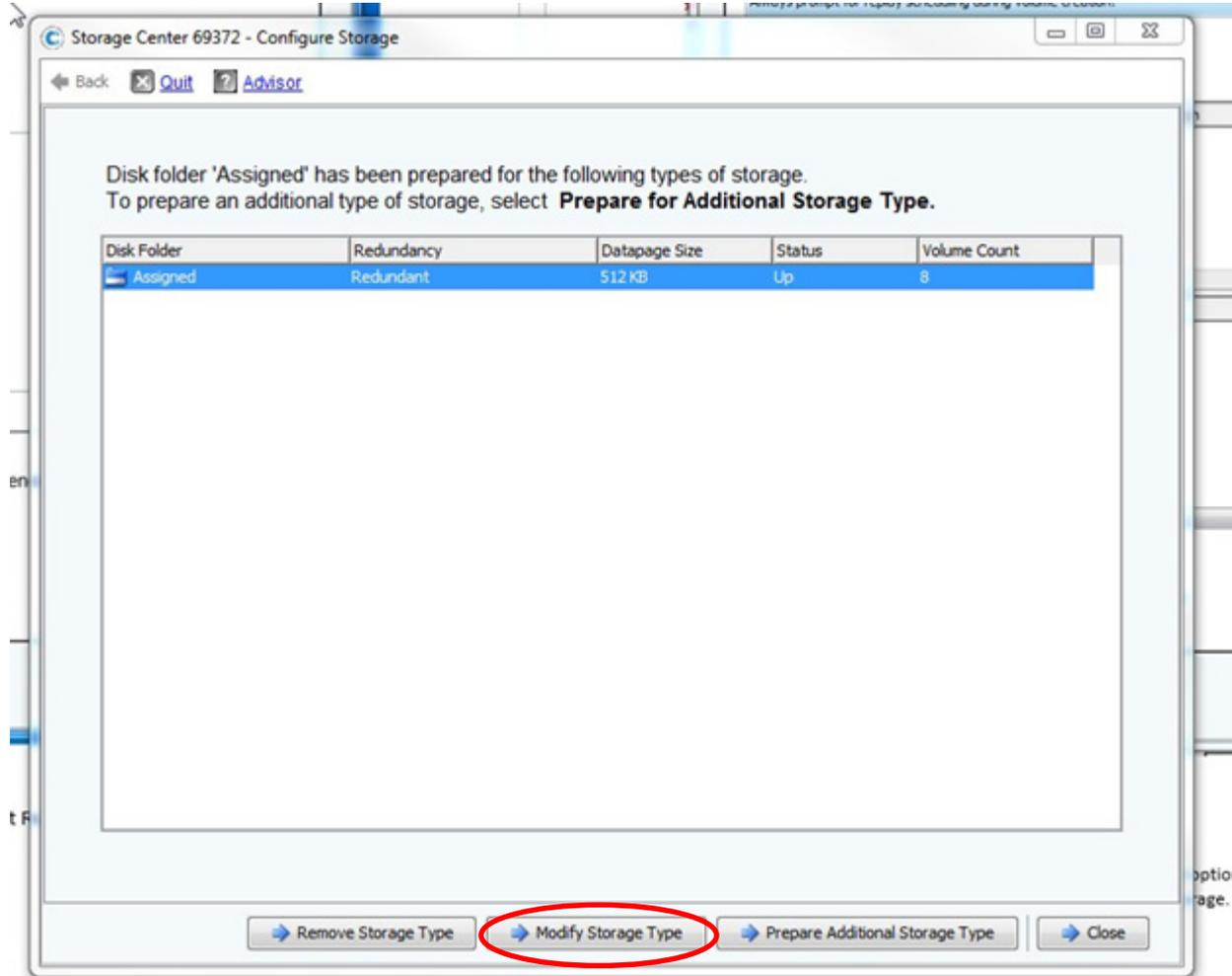
3. Select all RAID 5 checkboxes from all tiers.

4. Click **Remove Selected Class**.

5. Click **Continue**.
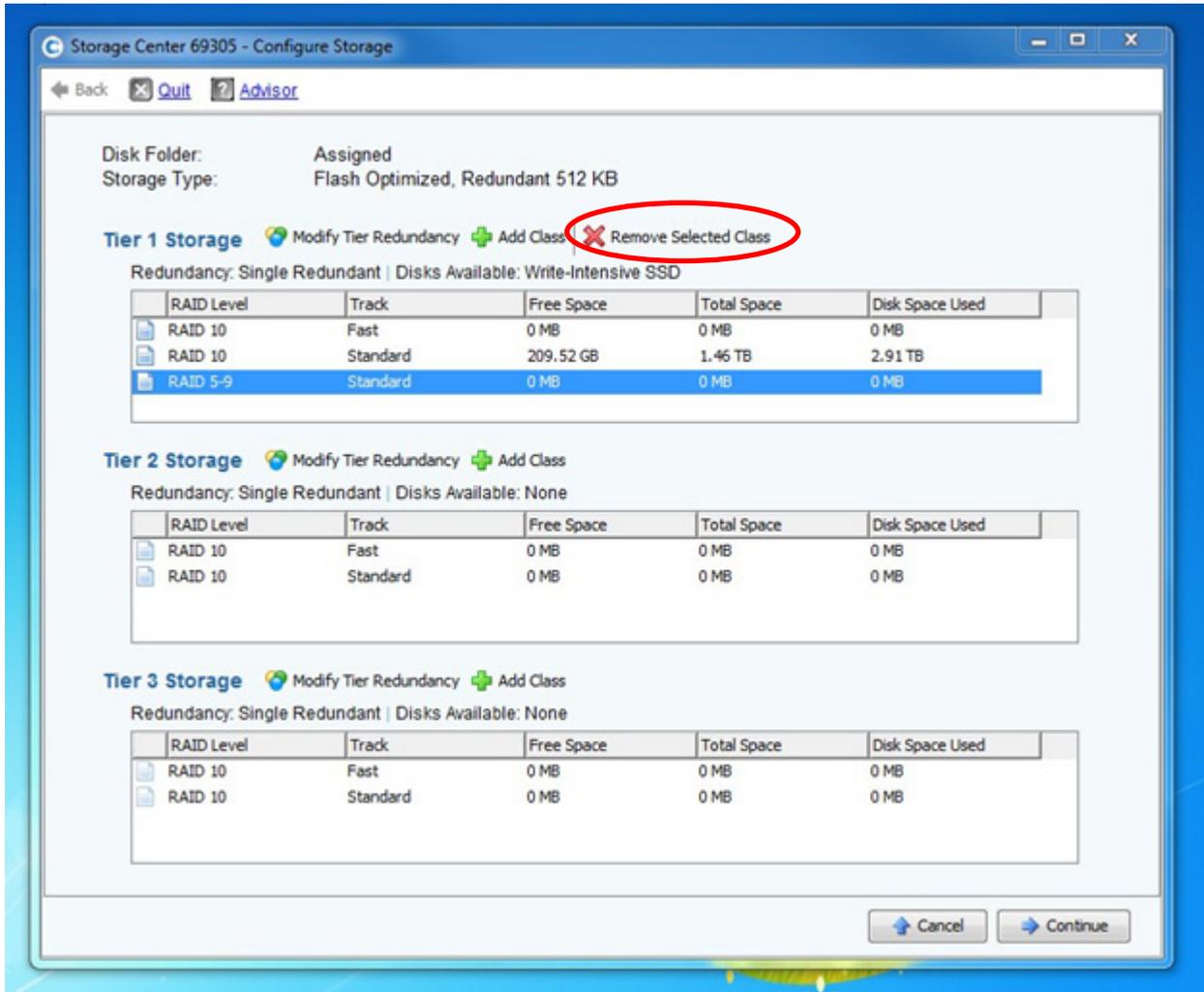
6. Return to **Storage Management** menu, and click on **Disk**, then **RAID Rebalance**.

7. Click **Rebalance Now** on the **RAID Rebalance** screen and wait until the ***Rebalance Not Needed*** message appears.
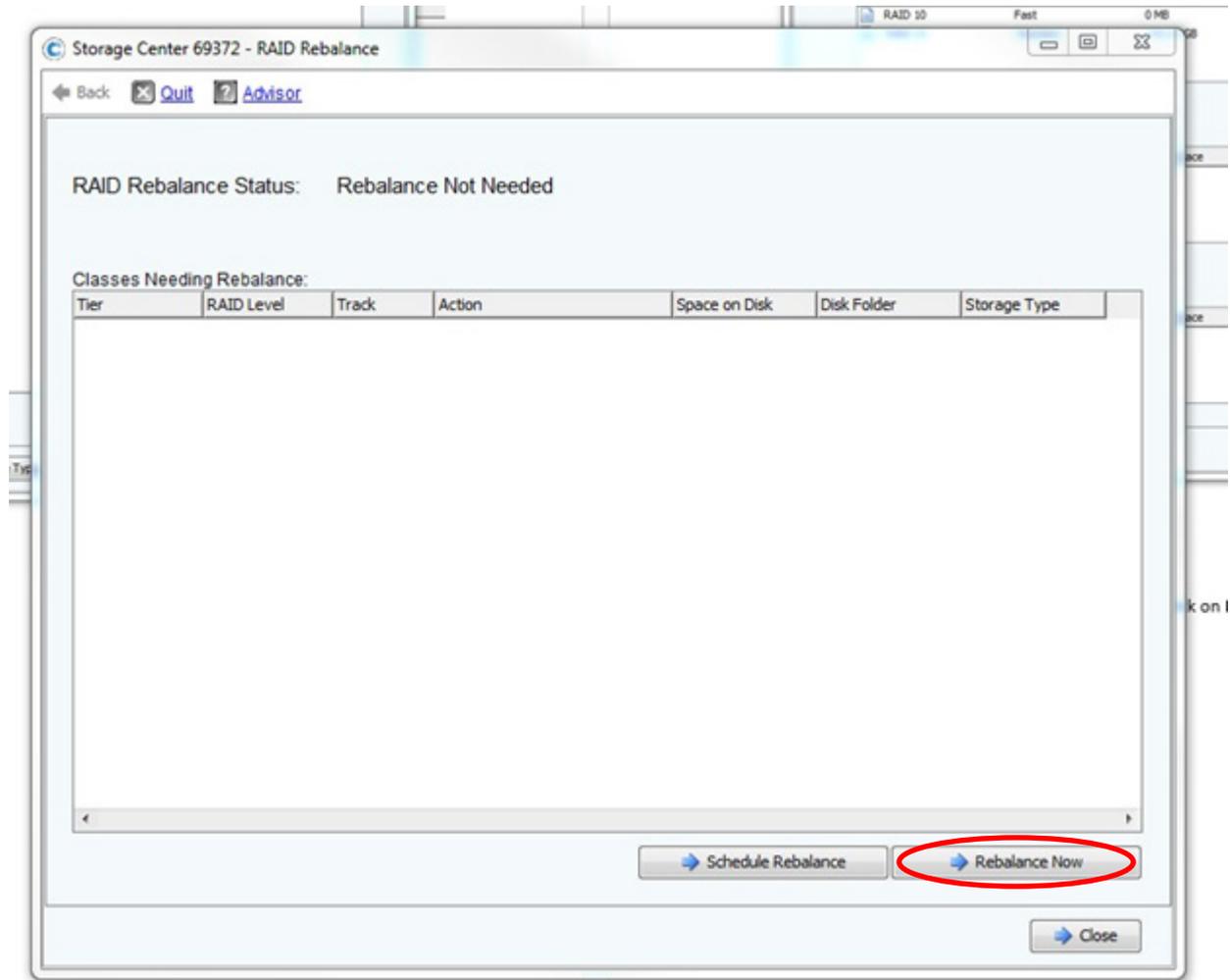
Create Volumes

This section will create eight volumes with the follow capacities:

- Four volumes, each with a capacity of 103.16 GiB

- Three volumes, each with a capacity of 137.38 GiB

- One volume with a capacity of 91.7 GiB

Initially, eight volumes, each with a capacity of 103.17 GiB, will be created.

1. In the System Tree, select **Storage**

2. Click on **Create Volumes** to create the first volume
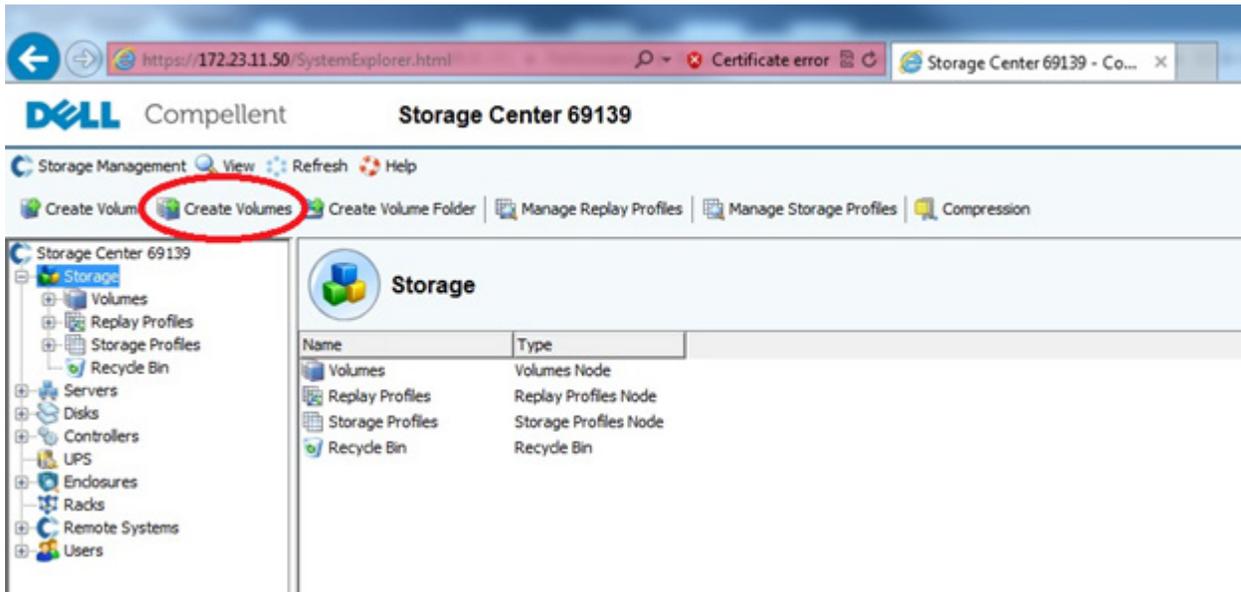
The Create Volumes wizard appears showing a default volume to create.

3. Select **Modify Selected Volume**.on the Create Volumes screen.
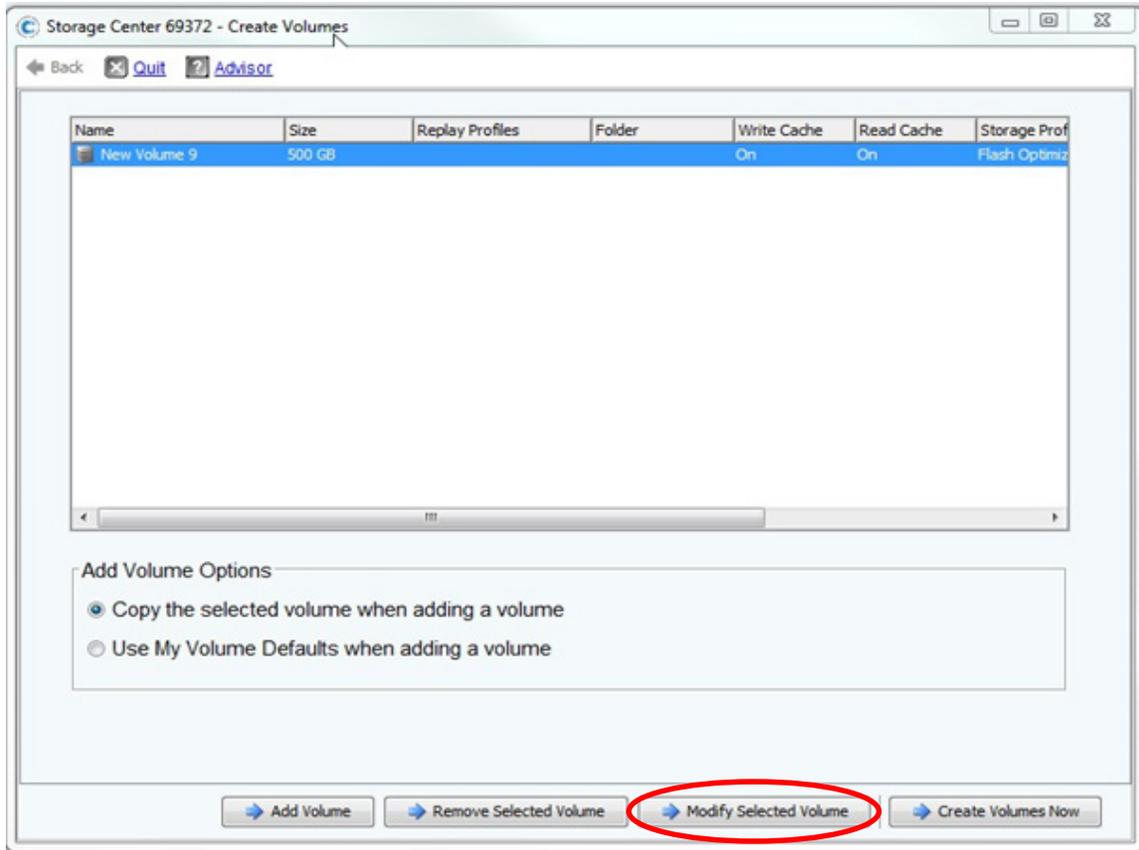
4. Change the value in the **Size** box to 103.17 and click **Apply Changes.**

APPENDIX C: Page 77 of 99
TESTED STORAGE CONFIGURATION (TSC) CREATION
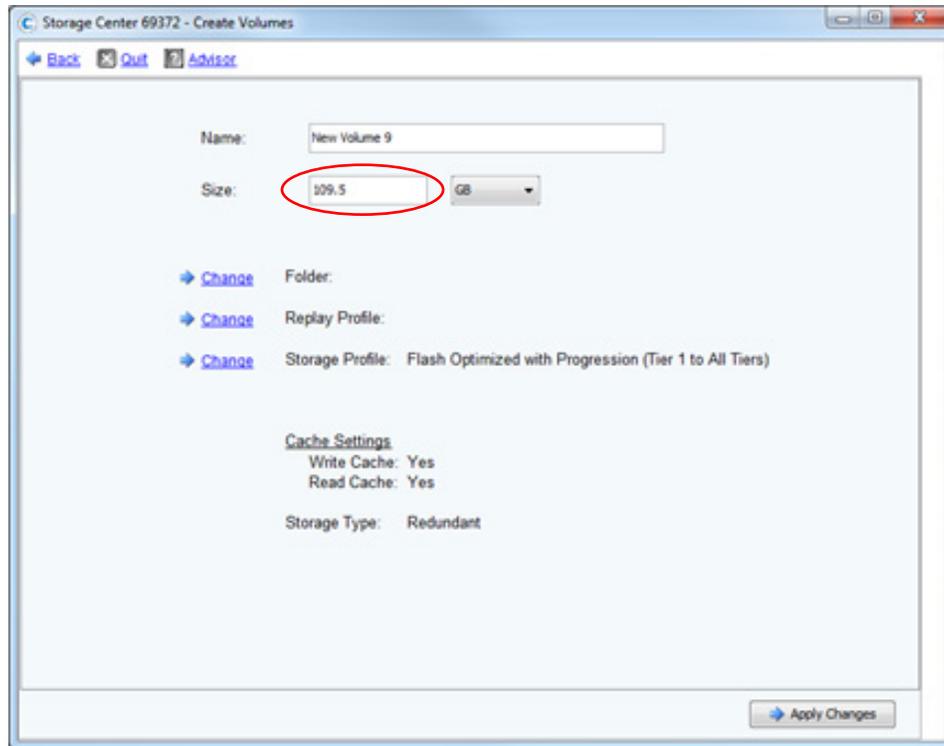
5. Create seven additional volume each with a capacity of 103.17 GiB by clicking **Add Volume** seven times, once for each additional item.

SPC BENCHMARK 1™ V1.14   FULL DISCLOSURE REPORT   Submission Identifier: A00156
Dell, Inc.   Submitted for Review: MARCH 18, 2015
Dell Storage SC4020 *(6 SSDs)*
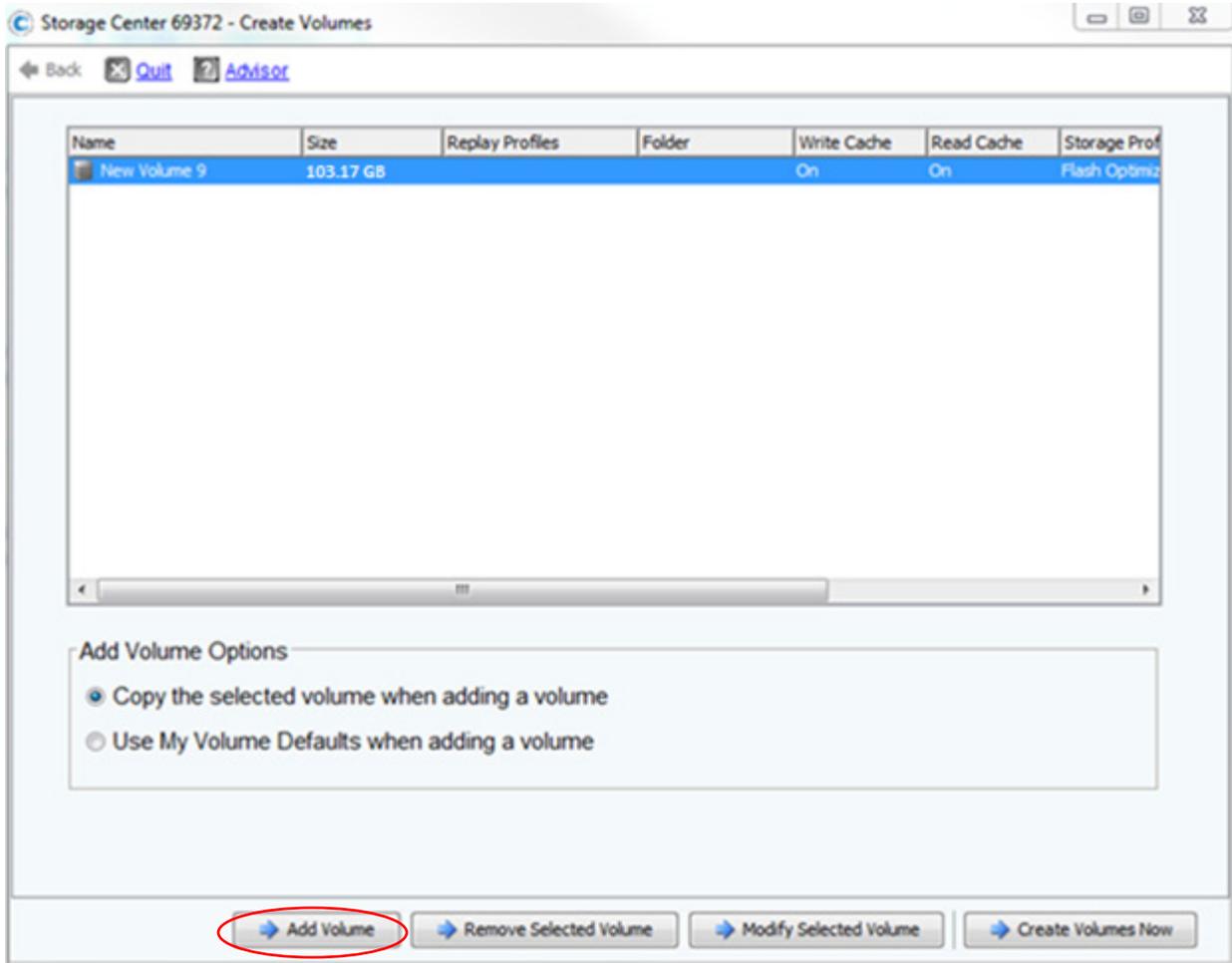
6. Select *New Volume 13* and click **Modify Selected Volume**.
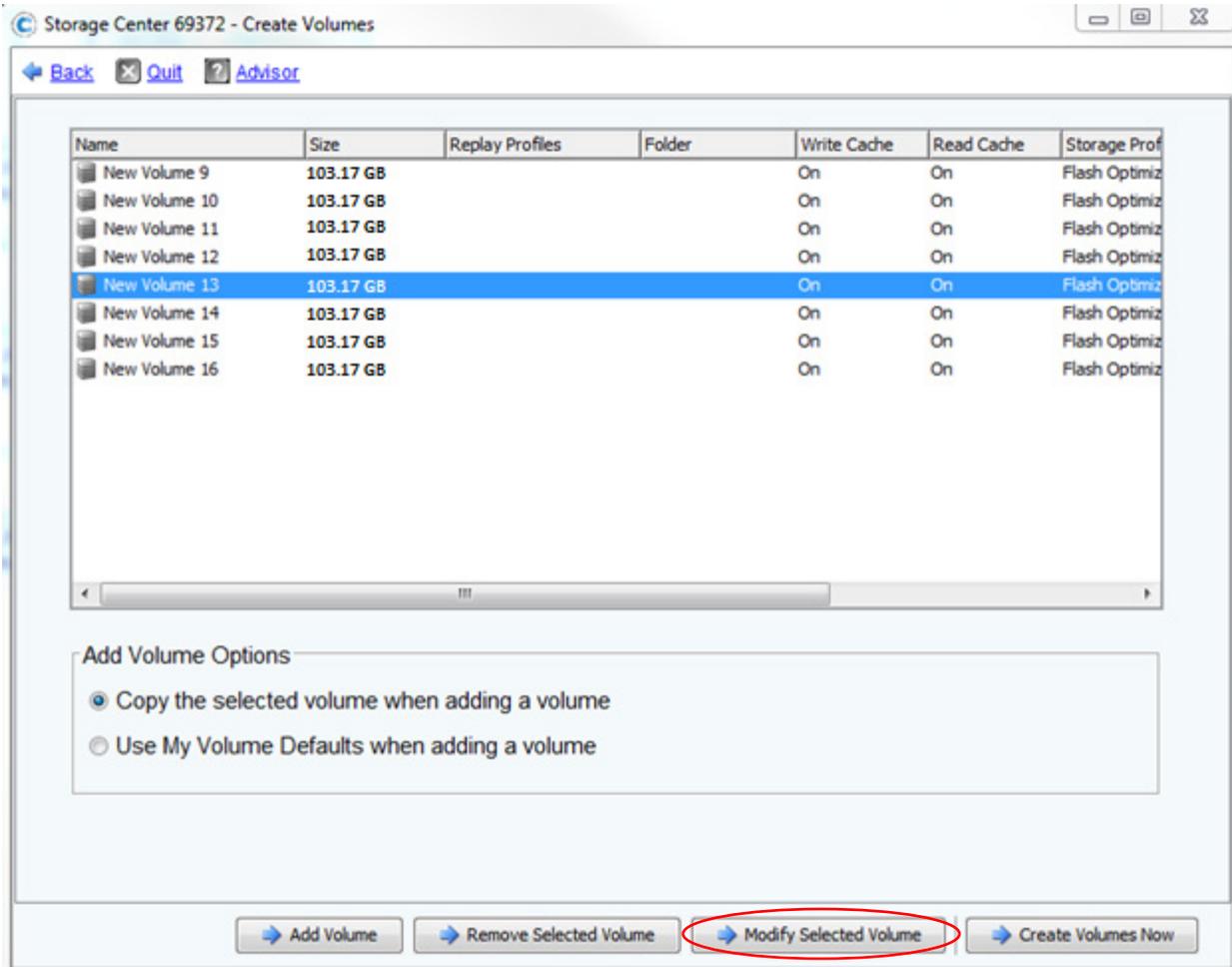
7. Change the value in the **Size** box to 137.38 and click **Apply Changes.**

8. Repeat steps #6 and #7 twice, selecting *New Volume 14* and then *New Volume 15*, which will result in three volumes, each with a capacity of 137.38 GiB..
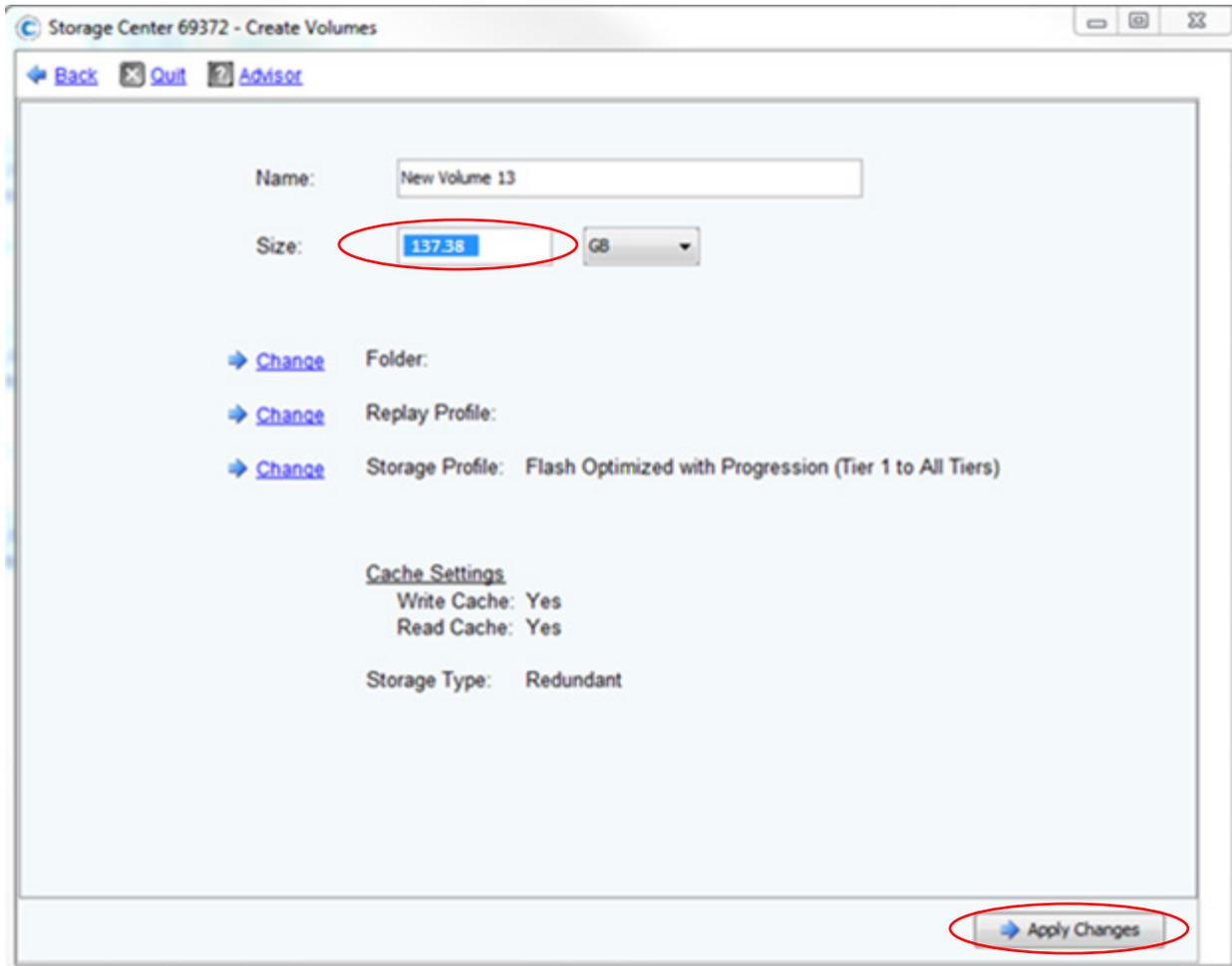
9. Select *New Volume 16* and click **Modify Selected Volume**.
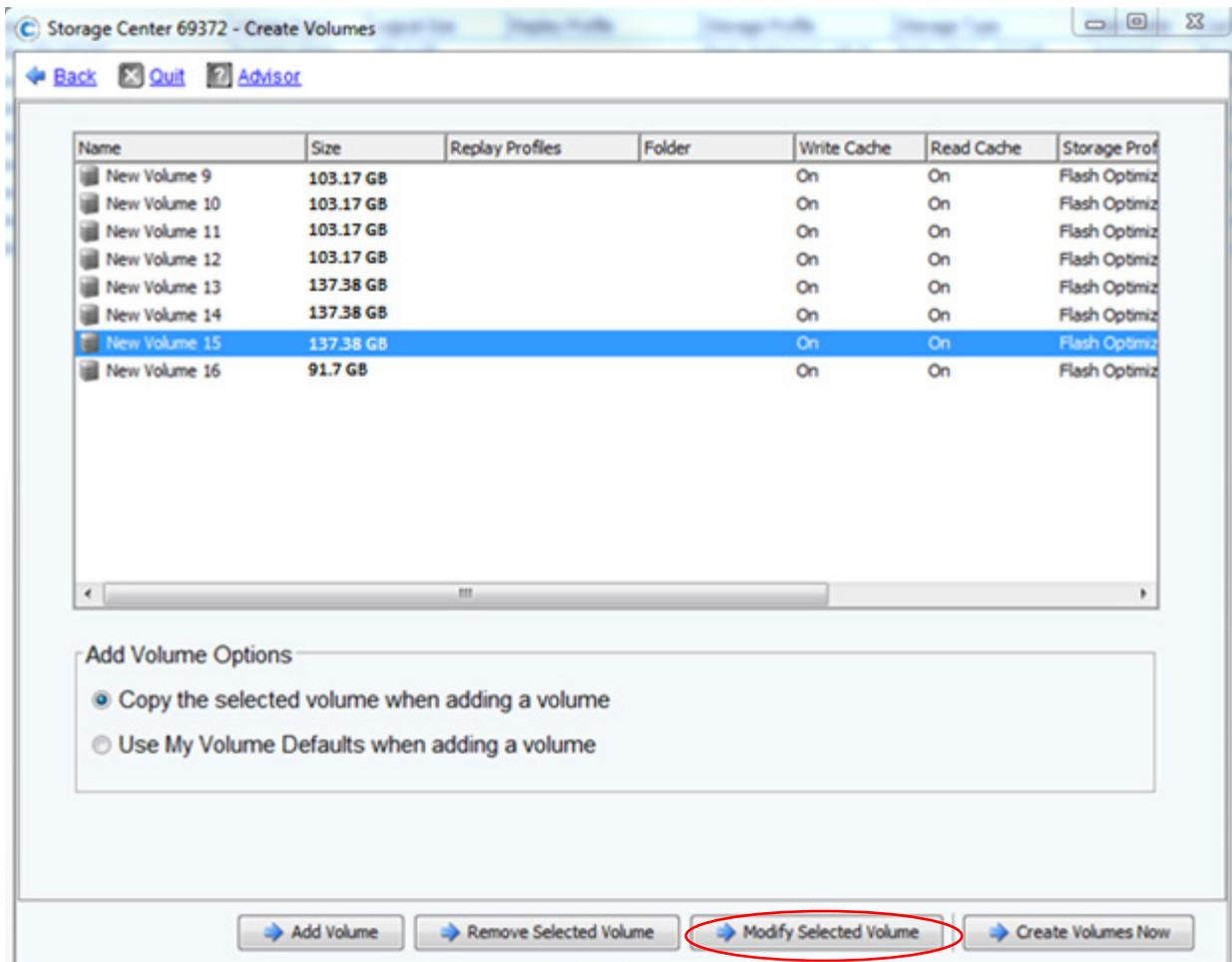
10. Change the value in the **Size** box to 91.7 and click **Apply Changes.**
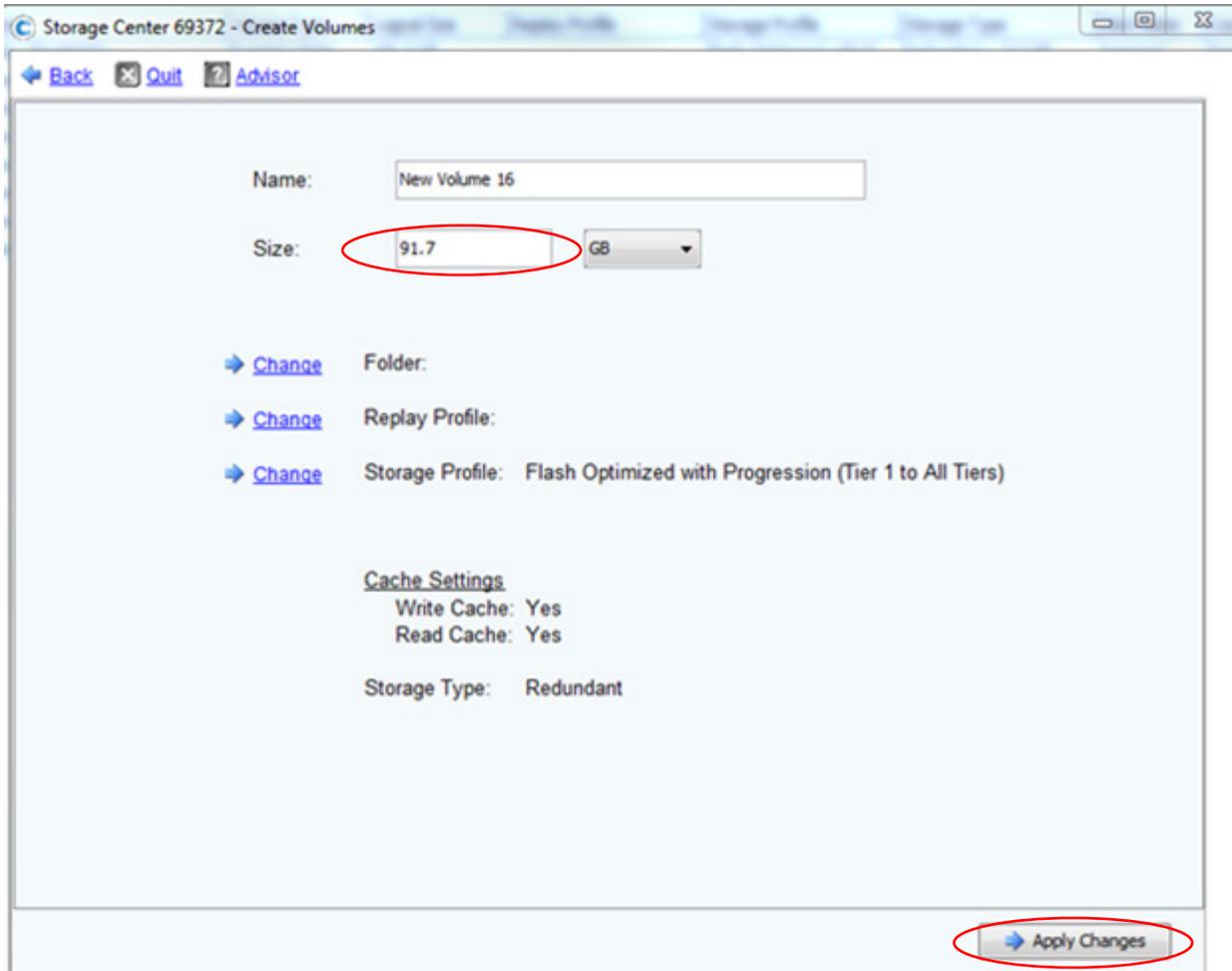
The Create Volumes screen should list eight volumes as follows:

- Four volumes, each with a capacity of 103.17 GB *(GiB)*

- Three volumes, each with a capacity of 137.38 GB *(GiB)*

- One volume with a capacity of 91.7 GB *(GiB)*

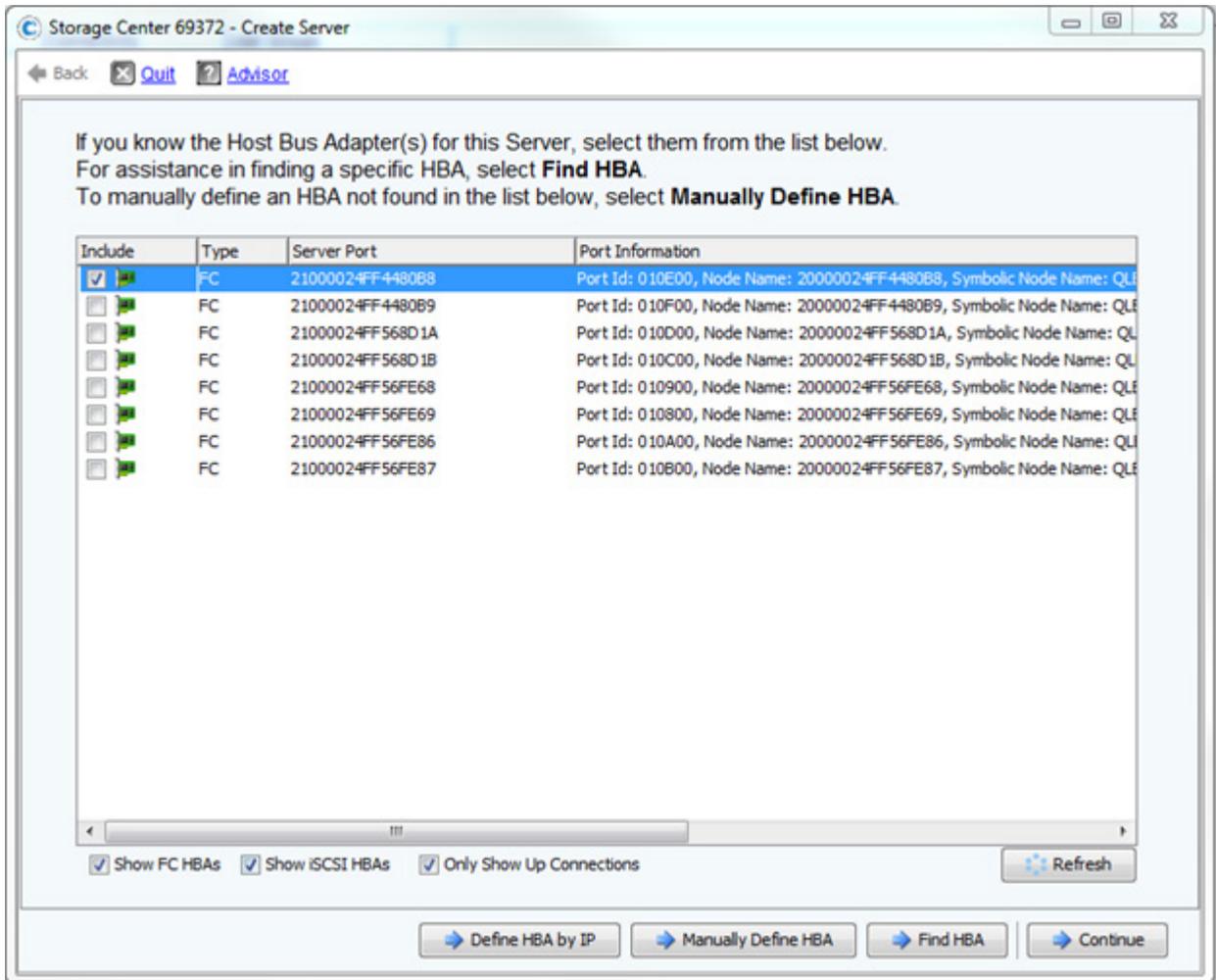11. Click **Create Volumes Now** and the System Manager creates the volumes specified.
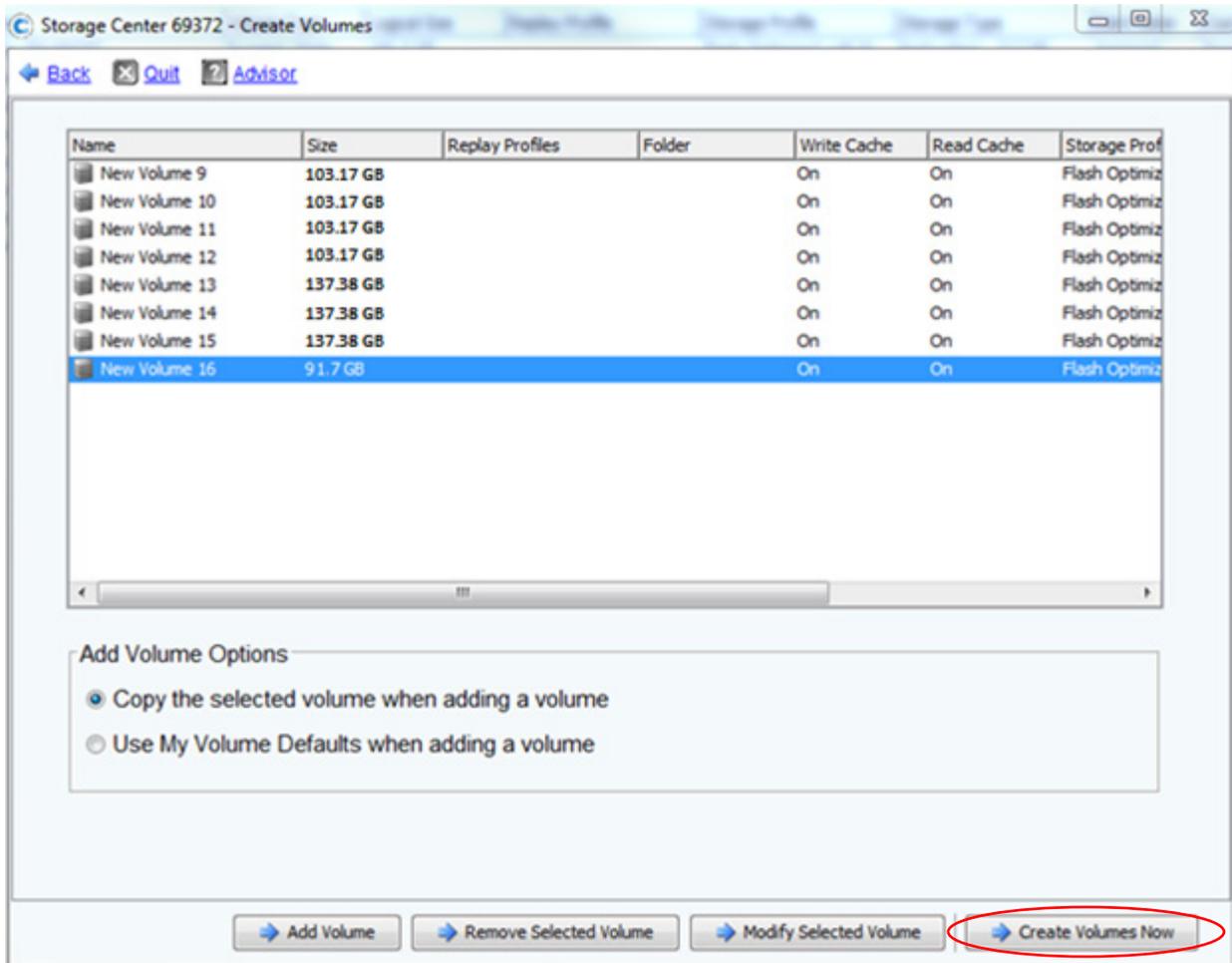
Create Servers

1. Select **Servers** and then click on **Create Server**.
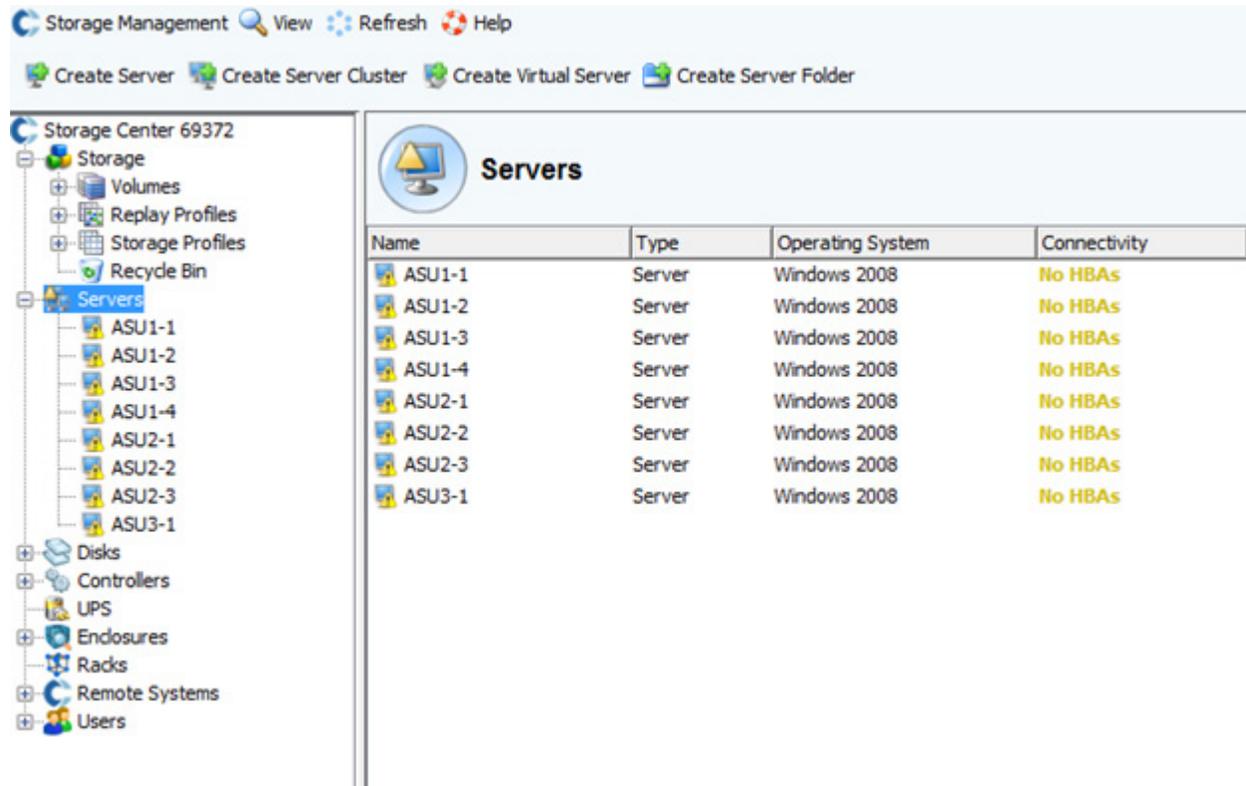
2. Select the first HBA port from the list and click **Continue**.

3. On the next page enter a name for the server.

4. Repeat steps #1-#3 to create servers for ASU1-2, ASU1-3, ASU1-4, ASU2-1, ASU2-2, ASU2-3, and ASU3-1.

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TESTED STORAGE CONFIGURATION (TSC) CREATION

Volume to Server Mapping

1. Select server **ASU1-1**, then click on **Map Volume to Server**.

SPC BENCHMARK 1™ V1.14   FULL DISCLOSURE REPORT   Submission Identifier: A00156
Dell, Inc.   Submitted for Review: MARCH 18, 2015
Dell Storage SC4020 *(6 SSDs)*
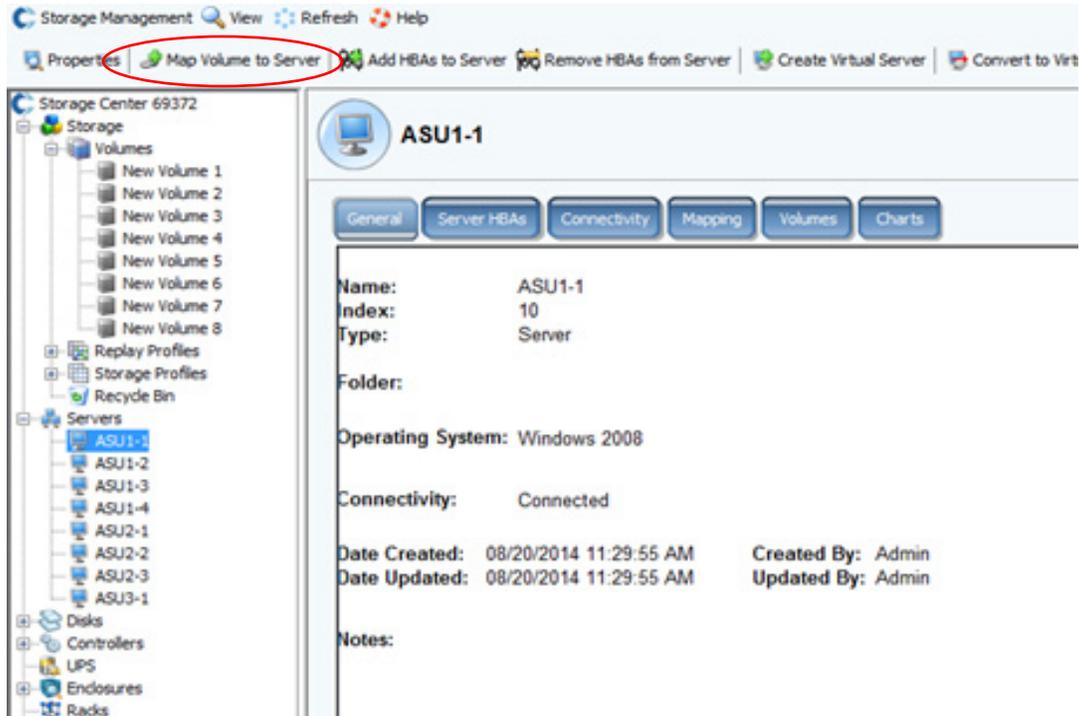
2. A list of volumes will be displayed. Select **New Volume 1** and click **Continue.**
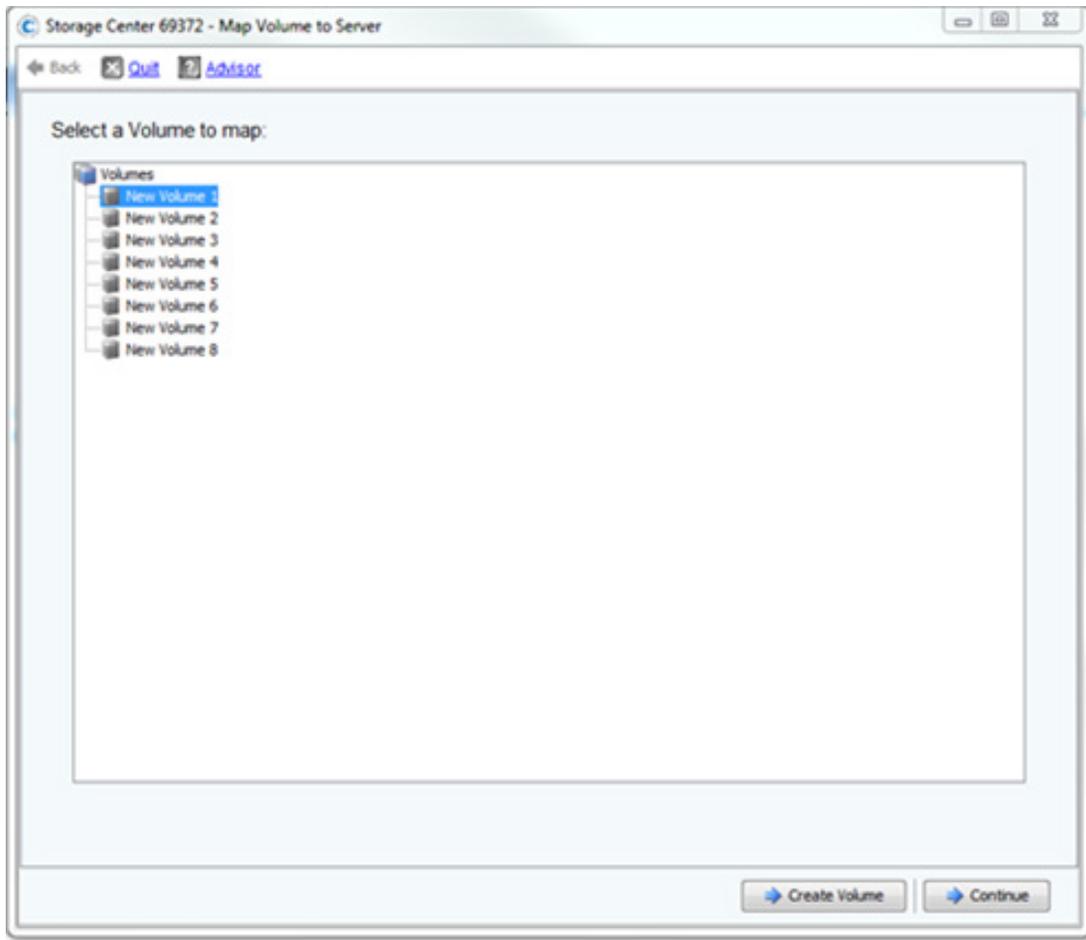
3. Click **Advanced** to assign the LUN and Restrict mapping paths.
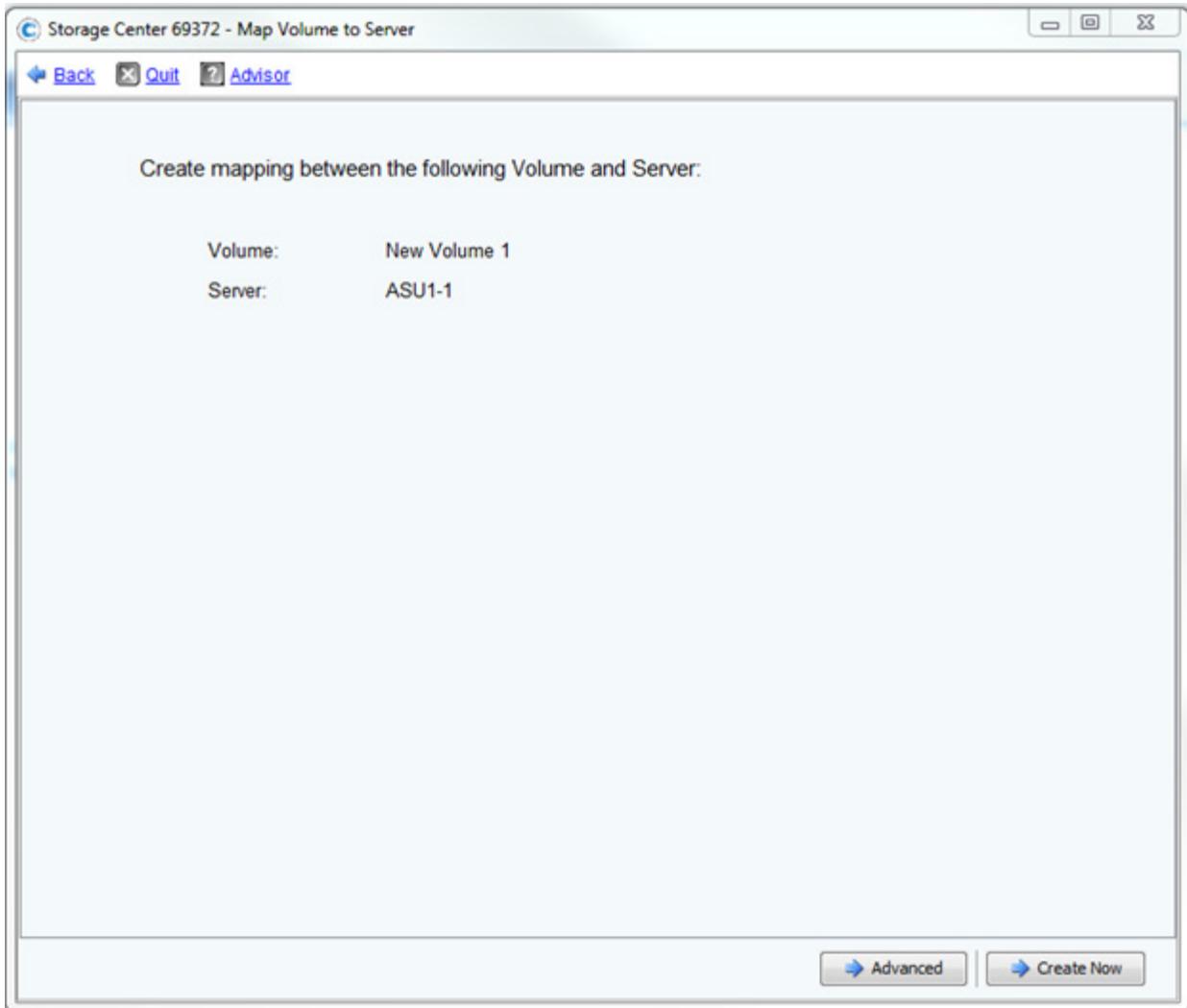
4. Select the checkbox *Use LUN when mapping the selected volume to the selected server*.

5. Update the LUN value to be 1.

6. Select the checkbox *Map to controller if possible*.

7. Select controller **SN 69372** from the dropdown menu.

8. Click **Continue**
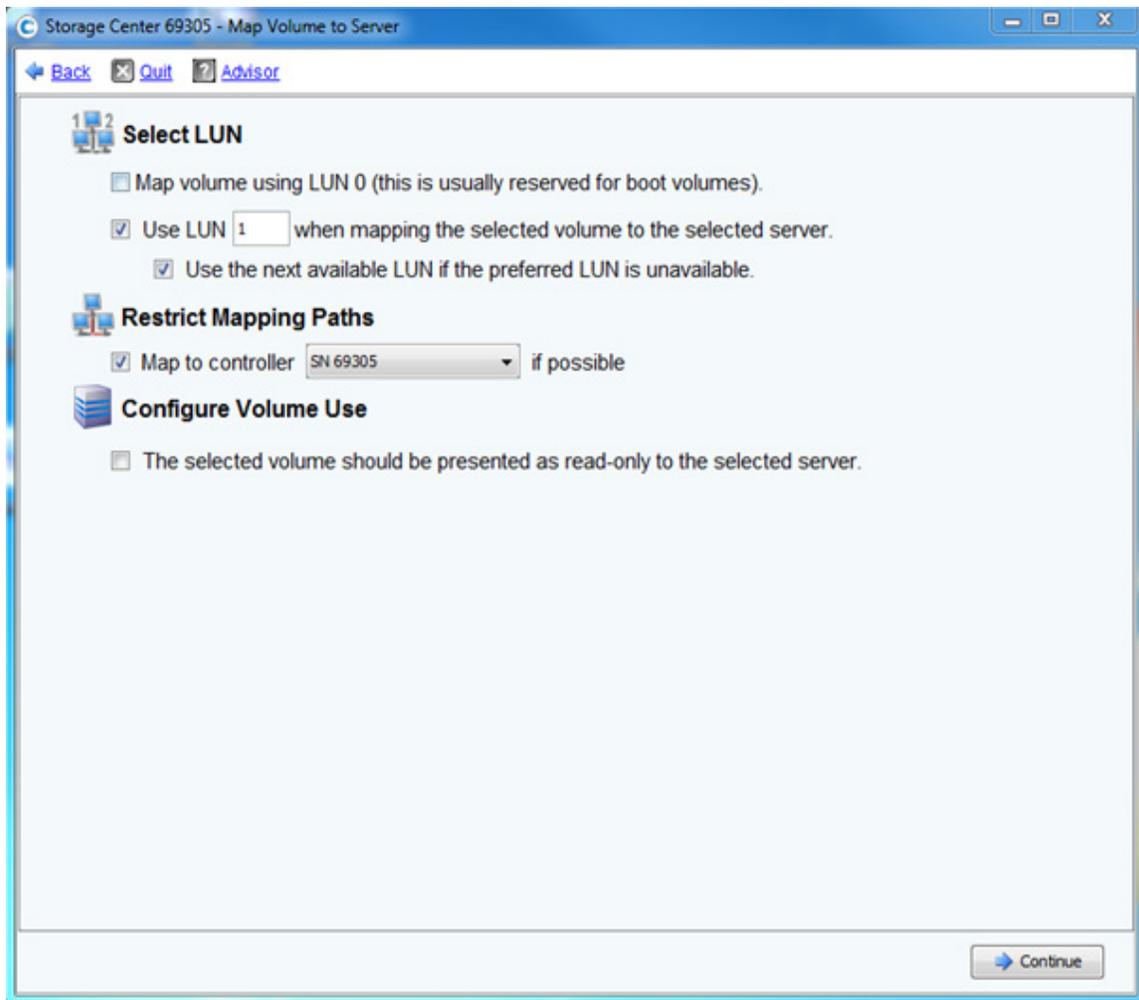
9. Repeat steps #1- #8 until the volume/server/controller mappings match the table below.

| Volume	Server	LUN	Controller
New Volume 1	ASU1-1	1	SN 69372
New Volume 2	ASU1-2	2	SN 69373
New Volume 3	ASU1-3	3	SN 69372
New Volume 4	ASU1-4	4	SN 69373
New Volume 5	ASU2-1	5	SN 69372
New Volume 6	ASU2-2	6	SN 69373
New Volume 7	ASU2-3	7	SN 69372
New Volume 8	ASU3-1	8	SN 69373

Check Configuration

1. Login to the Host System, use Windows Disk Manager to bring all disks online.

2. If all eight disks are not displayed, right click **Disk Manager** and select **Rescan Disks**.

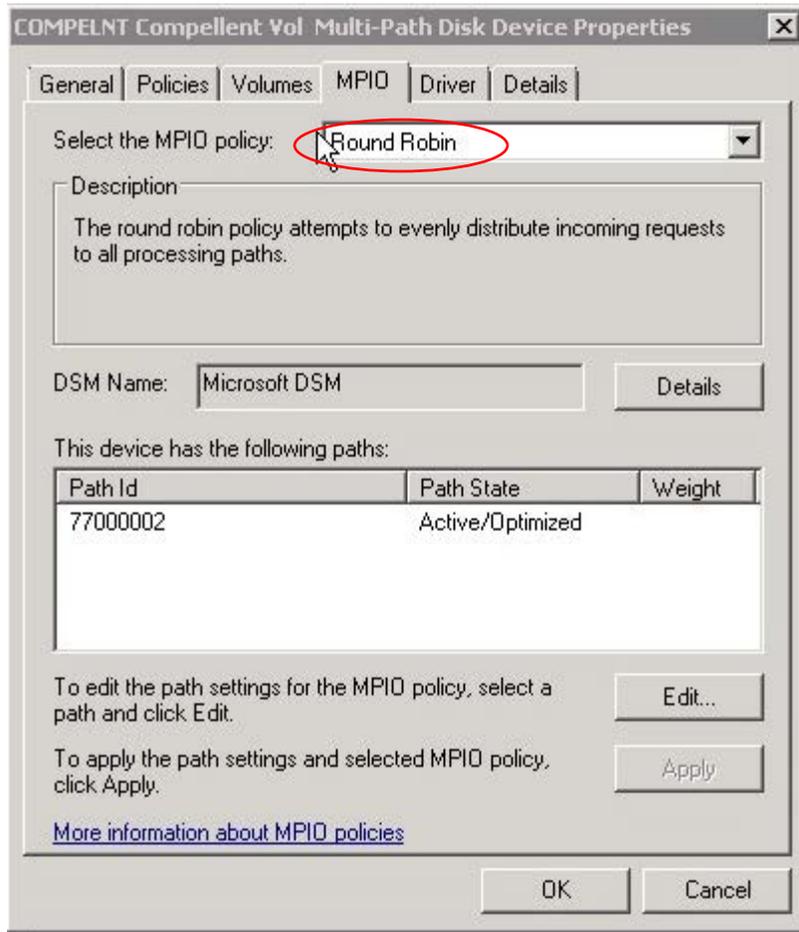3. When prompted to initialize disks, select **OK**.
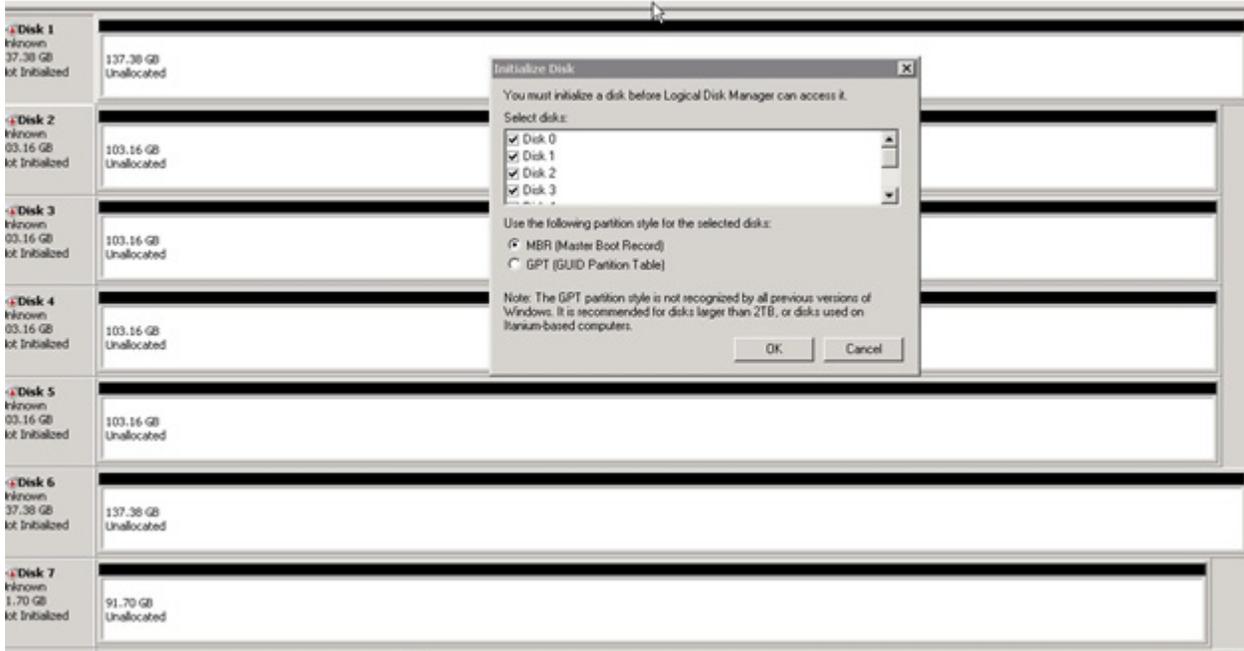
4. Reboot the Host System and make sure all of the volumes are listed.
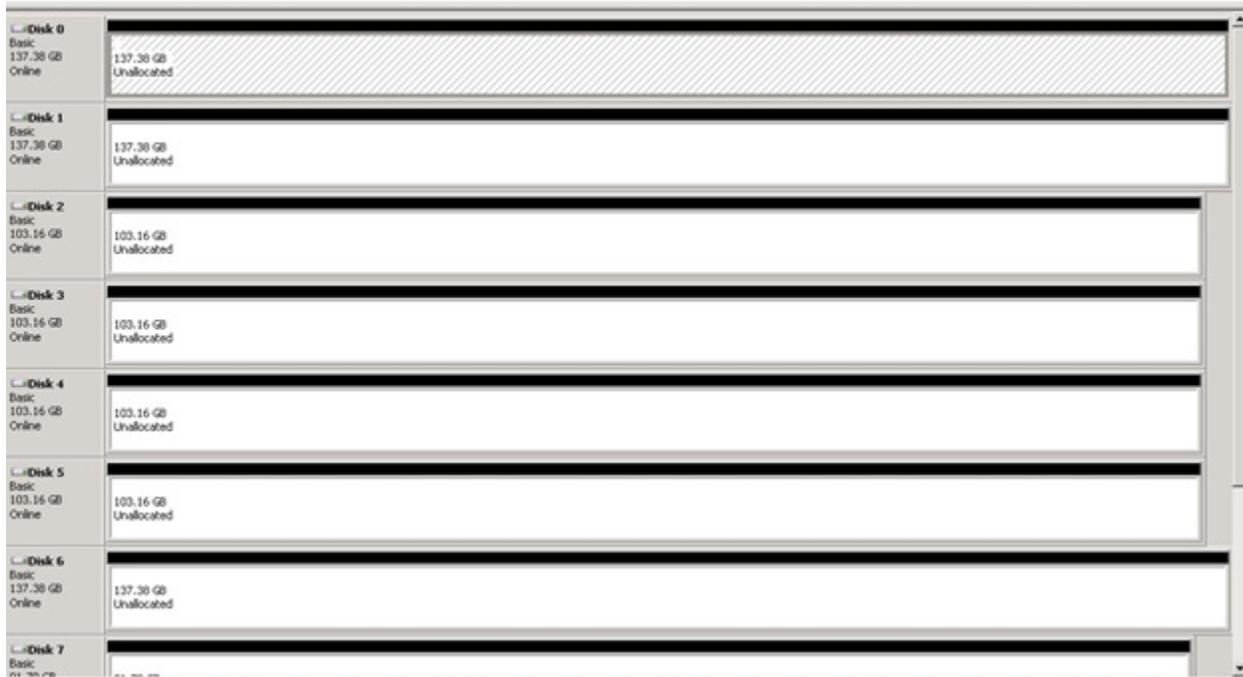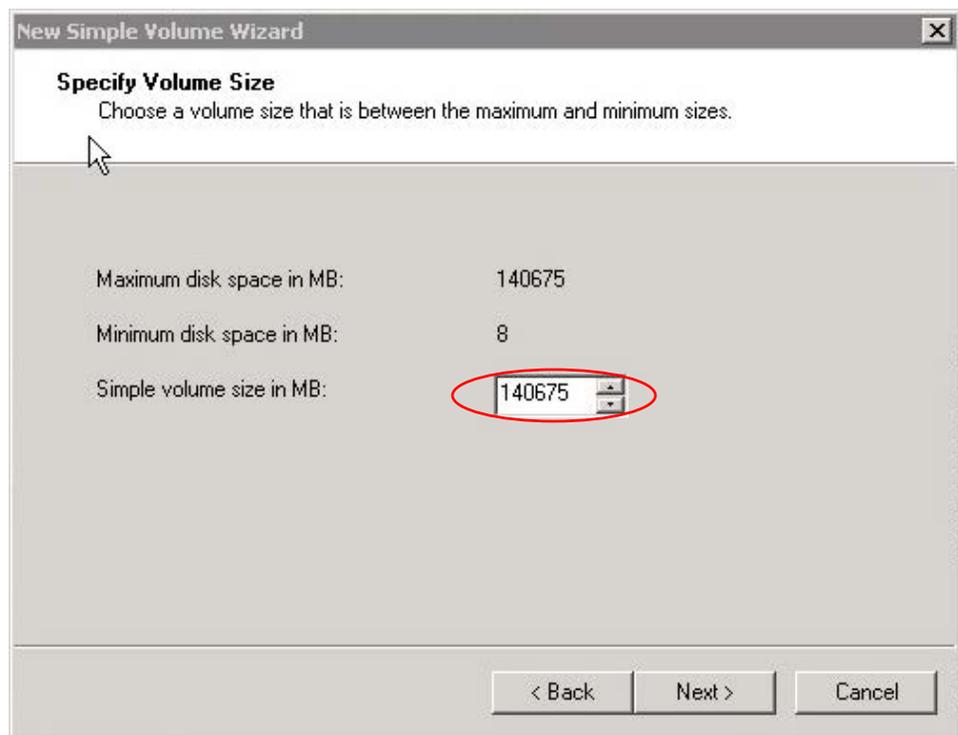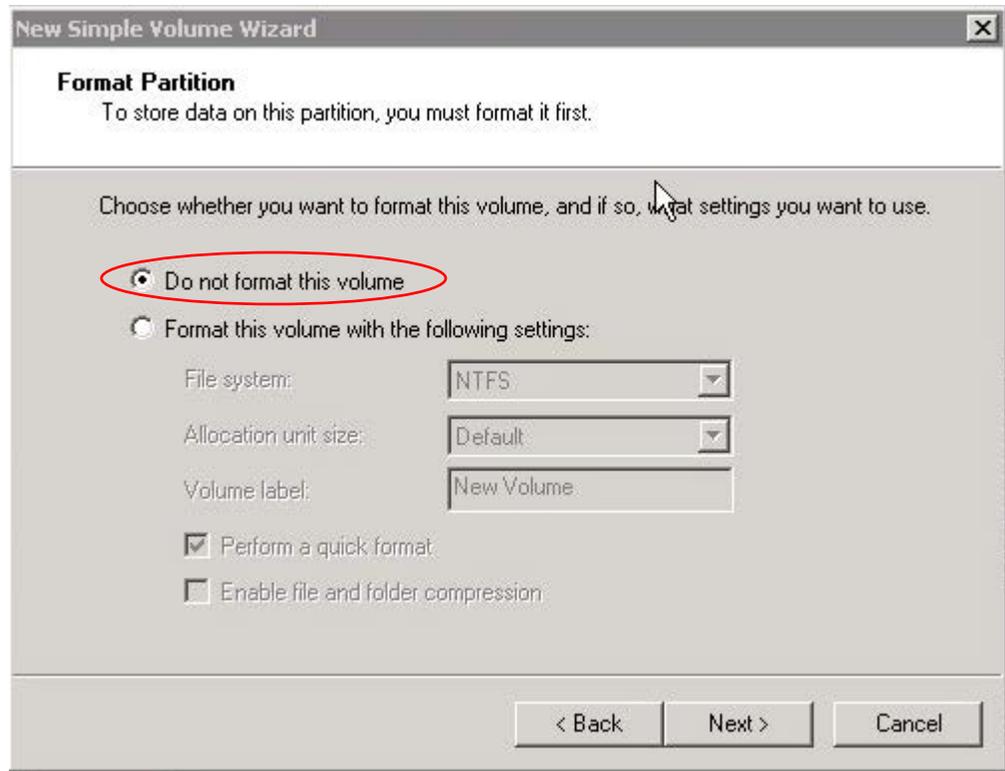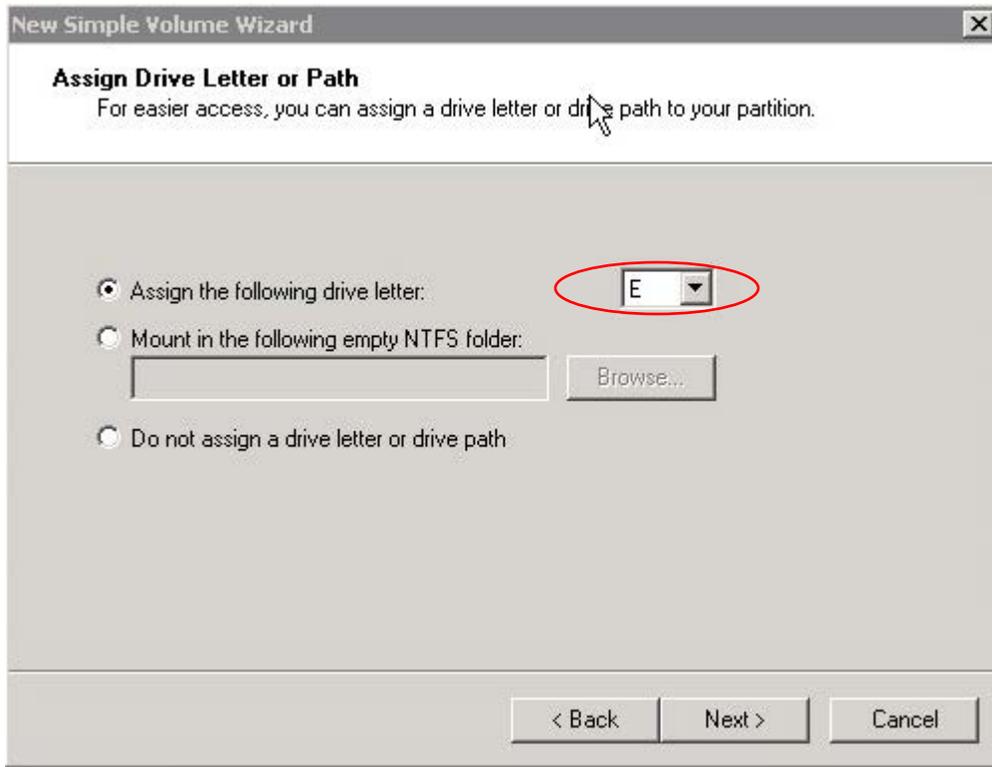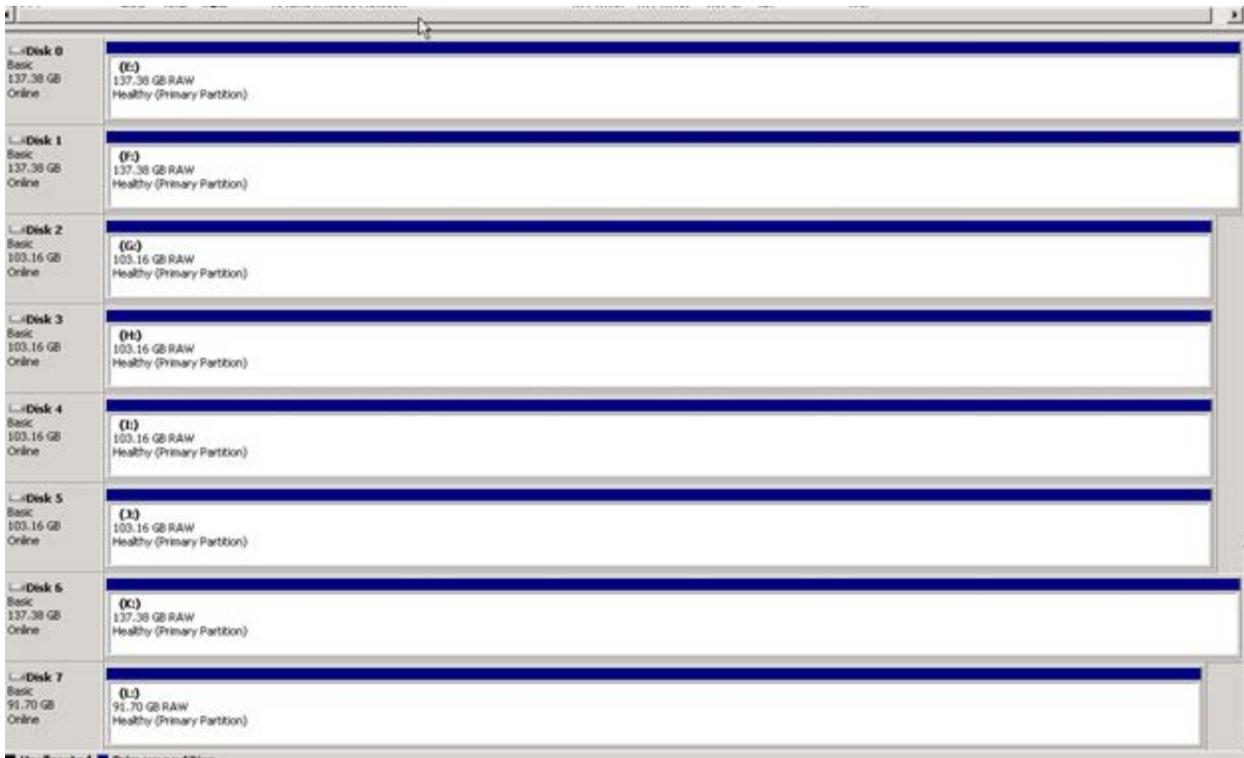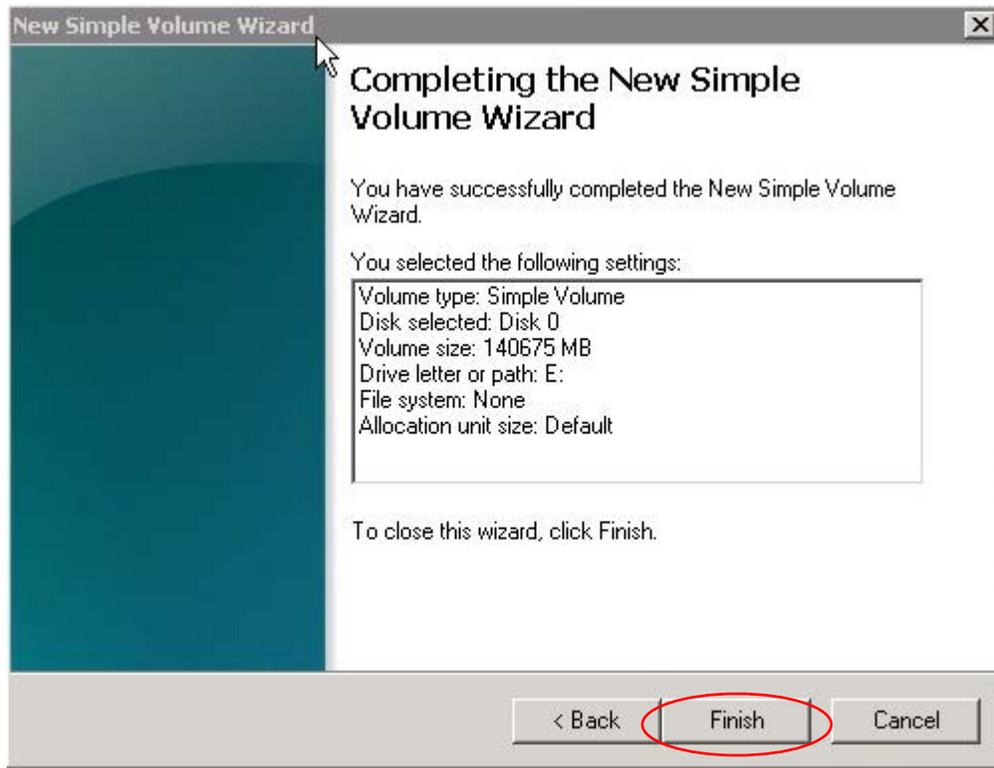
5. Enable Multipath I/O
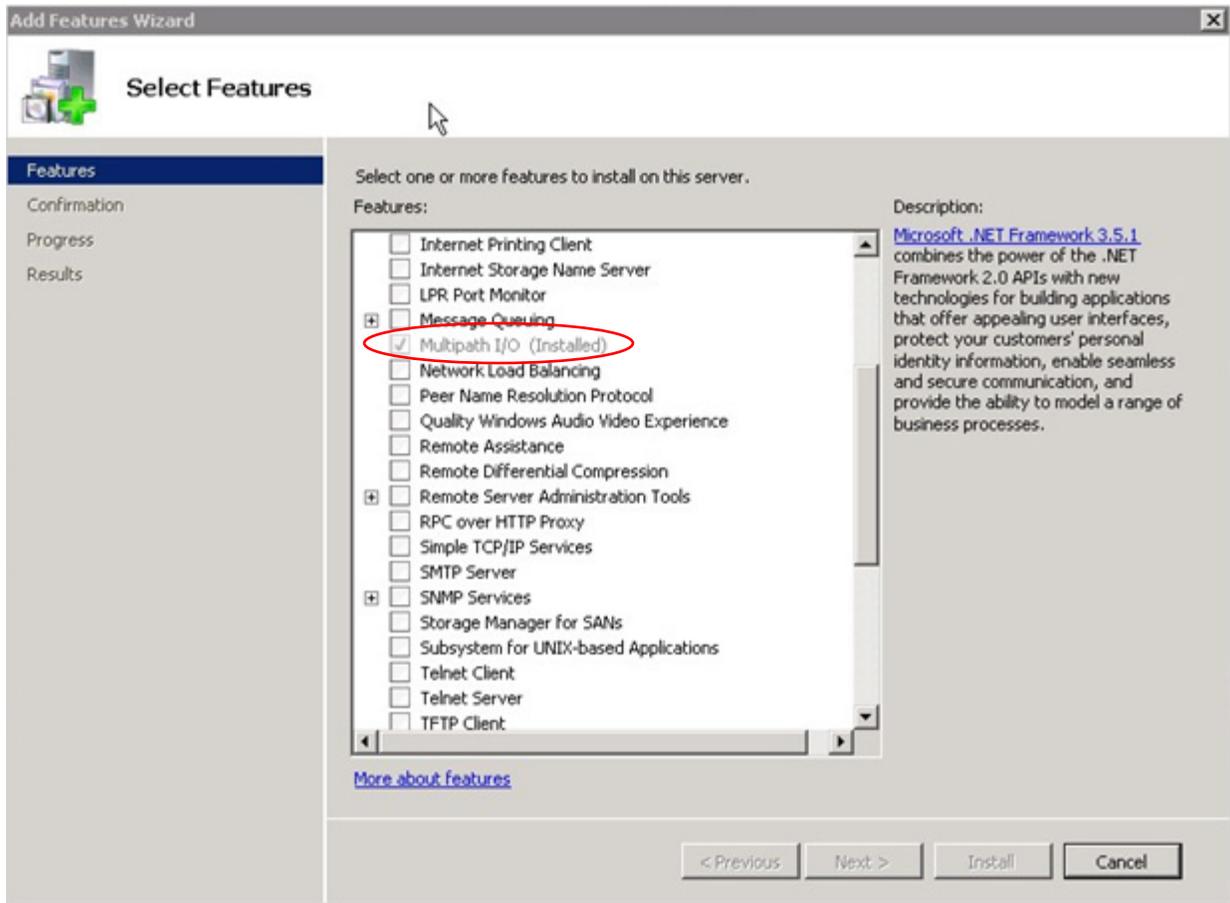
6. Select **Round Robin** as the MPIO policy.

7. Select the maximum disk space displayed and assign a drive letter to each of the eight volumes using the Volume Wizard. Do not format any of the eight volumes.

New Simple Volume Wizard

Assign Drive Letter or Path
For easier access, you can assign a drive letter or drive path to your partition.

● Assign the following drive letter: E

○ Mount in the following empty NTFS folder:
                                                        Browse...

○ Do not assign a drive letter or drive path

< Back   Next >   Cancel

New Simple Volume Wizard

Format Partition
To store data on this partition, you must format it first.

Choose whether you want to format this volume, and if so, what settings you want to use.

● Do not format this volume

○ Format this volume with the following settings:

File system: NTFS

Allocation unit size: Default

Volume label: New Volume

☑ Perform a quick format

☐ Enable file and folder compression

< Back   Next >   Cancel

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

ASU Pre-Fill

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

```
compratio=1

 sd=sd1,lun=\\.\PhysicalDrive0
 sd=sd2,lun=\\.\PhysicalDrive1
 sd=sd3,lun=\\.\PhysicalDrive2
 sd=sd4,lun=\\.\PhysicalDrive3
 sd=sd5,lun=\\.\PhysicalDrive4
 sd=sd6,lun=\\.\PhysicalDrive5
 sd=sd7,lun=\\.\PhysicalDrive6
 sd=sd8,lun=\\.\PhysicalDrive7

 wd=wd1,sd=sd1,rdpct=0,seek=-1,xfersize=1m
 wd=wd2,sd=sd2,rdpct=0,seek=-1,xfersize=1m
 wd=wd3,sd=sd3,rdpct=0,seek=-1,xfersize=1m
 wd=wd4,sd=sd4,rdpct=0,seek=-1,xfersize=1m
 wd=wd5,sd=sd5,rdpct=0,seek=-1,xfersize=1m
 wd=wd6,sd=sd6,rdpct=0,seek=-1,xfersize=1m
 wd=wd7,sd=sd7,rdpct=0,seek=-1,xfersize=1m
 wd=wd8,sd=sd8,rdpct=0,seek=-1,xfersize=1m
 rd=prefill,wd=wd*,iorate=max,elapsed=36000,interval=10
```

Primary Metrics, Repeatability and SPC-1 Persistence Tests

The content of SPC-1 Workload Generator command and parameter file used in this benchmark to execute the Primary Metrics *(Sustainability Test Phase, IOPS Test Phase, and Response Time Ramp Test Phase)*, Repeatability *(Repeatability Test Phase 1 and Repeatability Test Phase 2)*, and SPC-1 Persistence Tests is listed below.

```
 javaparms="-Xmx1280m -Xms1280m -Xss512k"
sd=asu2_5,lun=\\.\E:
sd=asu2_6,lun=\\.\F:
sd=asu1_1,lun=\\.\G:
sd=asu1_2,lun=\\.\H:
sd=asu1_3,lun=\\.\I:
sd=asu1_4,lun=\\.\J:
sd=asu2_7,lun=\\.\K:
sd=asu3_8,lun=\\.\L:
```

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

The following script calls the standard **vdbench.bat** script to execute the required ASU pre-fill and upon completion of that first step, invoke the commands to execute the Primary Metrics Test *(Sustainability Test Phase, IOPS Test Phase, and Response Time Ramp Test Phase)*, the Repeatability Test *(Repeatability Test Phase 1 and Repeatability Test Phase 2)*, and SPC-1 Persistence Test Run 1 *(write phase)* in an uninterrupted sequence.

```
@ECHO OFF
REM This script is for execution of SPC testing only
REM It requires the spc1.cfg file to be preconfigured and placed in C:\spc1.cfg

ECHO SPC-1 Persistence Test Run 1 is started.

SET OUTPUTDIR=C:\SC4020_SPC1
mkdir %OUTPUTDIR%
cd %OUTPUTDIR%

copy C:\spc1.cfg %OUTPUTDIR%

mkdir %OUTPUTDIR%\Prefill
call C:\vdbench503rc11\vdbench.bat -f C:\vdbench503rc11\Prefill.txt -o
%OUTPUTDIR%\Prefill
java -cp C:\spc\spc1 metrics -b 2250 -t 28800 -s 5400:300
java -cp C:\spc\spc1 repeat1 -b 2250 -s 300
java -cp C:\spc\spc1 repeat2 -b 2250 -s 300
java -cp C:\spc\spc1 -Xmx768m -Xss256k persist1 -b 2250

ECHO SPC-1 Persistence Test Run 1 is complete.
ECHO Follow the TSC power off
```

SPC-1 Persistence Test Run 2

The following script is executed to invoke the SPC-1 Persistence Test Run 2 *(read phase)* after completion of the required TSC power off/power on cycle.

```
@ECHO OFF
REM This script is for execution of SPC-1 Test Run 2
REM SPC-1 Test Run 1 should be run first, and the TSC power cycle completed.

ECHO SPC-1 Persistence Test Run 2 is started.

SET OUTPUTDIR=C:\SC4020_SPC1
cd %OUTPUTDIR%

java -cp C:\spc\spc1 persist2

ECHO SPC-1 Persistence Test Run 2 is complete.
```