

**SPC BENCHMARK 1™  
FULL DISCLOSURE REPORT**

**DELL, INC.  
DELL STORAGE SC4020**

**SPC-1 V1.14**

**Submitted for Review: August 29, 2014  
Submission Identifier: A00147**

**First Edition – August 2014**

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## AUDIT CERTIFICATION



Matt Reichow  
Dell, Inc.  
7625 Smetana Lane  
Eden Prairie, MN 55344

August 28, 2014

The SPC Benchmark 1™ Reported Data listed below for the Dell Storage 4020 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 4020	
Metric	Reported Result
SPC-1 IOPS™	106,243.76
SPC-1 Price-Performance	\$0.65/SPC-1 IOPS™
Total ASU Capacity	1,044,966 GB
Data Protection Level	Protected 2 ( <i>Mirroring</i> )
Total Price (including three-year maintenance)	\$68,765.99
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.
- An appropriate diagram of the Benchmark Configuration (BC)/Tested Storage Configuration (TSC).

Storage Performance Council  
643 Bair Island Road, Suite 103  
Redwood City, CA 94062  
[AuditService@storageperformance.org](mailto:AuditService@storageperformance.org)  
650.556.9384

## AUDIT CERTIFICATION (CONT.)

Dell Storage 4020  
SPC-1 Audit Certification

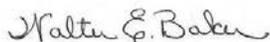
Page 2

- 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
- The difference between the Tested Storage Configuration and Priced Storage Configuration, if applied, would have no impact on the reported performance.
- The submitted pricing information met all of the requirements and constraints of Clause 8 of the SPC-1 Benchmark Specification.
- The Full Disclosure Report (FDR) met all of the requirements in Clause 9 of the SPC-1 Benchmark Specification.
- This successfully audited SPC measurement is not subject to an SPC Confidential Review.

**Audit Notes:**

There were no audit notes or exceptions.

Respectfully,



Walter E. Baker  
SPC Auditor

Storage Performance Council  
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Redwood City, CA 94062  
[AuditService@storageperformance.org](mailto:AuditService@storageperformance.org)  
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## LETTER OF GOOD FAITH



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

July 17, 2014

Subject: SPC-1 Letter of Good Faith for the Dell Storage SC4020 Array SAN

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,

A handwritten signature in black ink, appearing to read "Ed Fiore".

Ed Fiore  
Vice President  
Dell Storage  
Dell Inc.

## EXECUTIVE SUMMARY

### Test Sponsor and Contact Information

Test Sponsor and Contact Information	
<b>Test Sponsor Primary Contact</b>	Dell, Inc. – <a href="http://www.dell.com">http://www.dell.com</a> Matt Reichow – <a href="mailto:Matt_Reichow@dell.com">Matt_Reichow@dell.com</a> 7625 Smetana Lane Eden Prairie, MN 55344 Phone: (952) 563-9124 FAX: (952) 567-6600
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<b>Auditor</b>	Storage Performance Council – <a href="http://www.storageperformance.org">http://www.storageperformance.org</a> Walter E. Baker – <a href="mailto:AuditService@StoragePerformance.org">AuditService@StoragePerformance.org</a> 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	
<b>SPC-1 Specification revision number</b>	V1.14
<b>SPC-1 Workload Generator revision number</b>	V2.3.0
<b>Date Results were first used publicly</b>	August 29, 2014
<b>Date the FDR was submitted to the SPC</b>	August 29, 2014
<b>Date the Priced Storage Configuration is available for shipment to customers</b>	currently available
<b>Date the TSC completed audit certification</b>	August 28, 2014

### 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	
Metric	Reported Result
SPC-1 IOPS™	106,243.76
SPC-1 Price-Performance™	\$0.65/SPC-1 IOPS™
Total ASU Capacity	1,044.966 GB
Data Protection Level	Protected 2 ( <i>mirroring</i> )
Total Price	\$68,765.99
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.

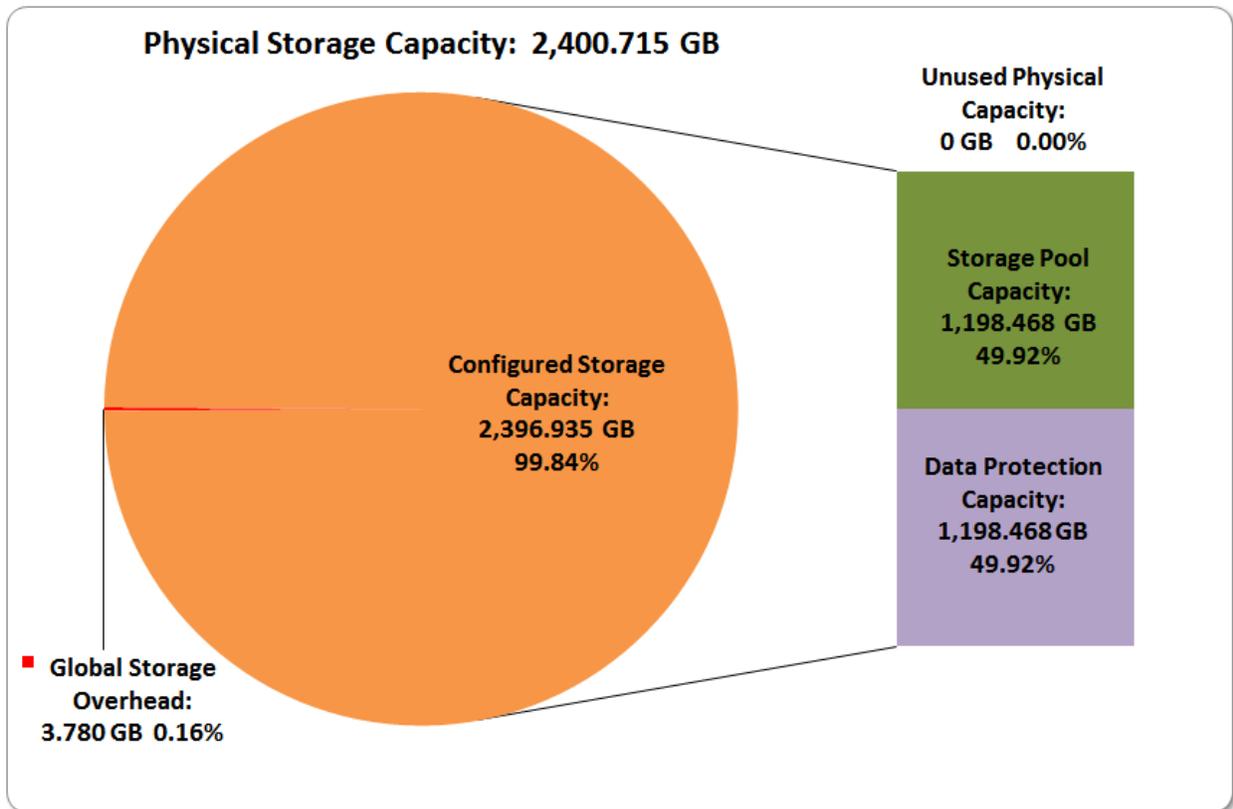
**Currency Used** is formal name for the currency used in calculating the **Total Price** and **SPC-1 Price-Performance™**. That currency may be the local currency of the **Target Country** or the currency of a difference country (*non-local currency*).

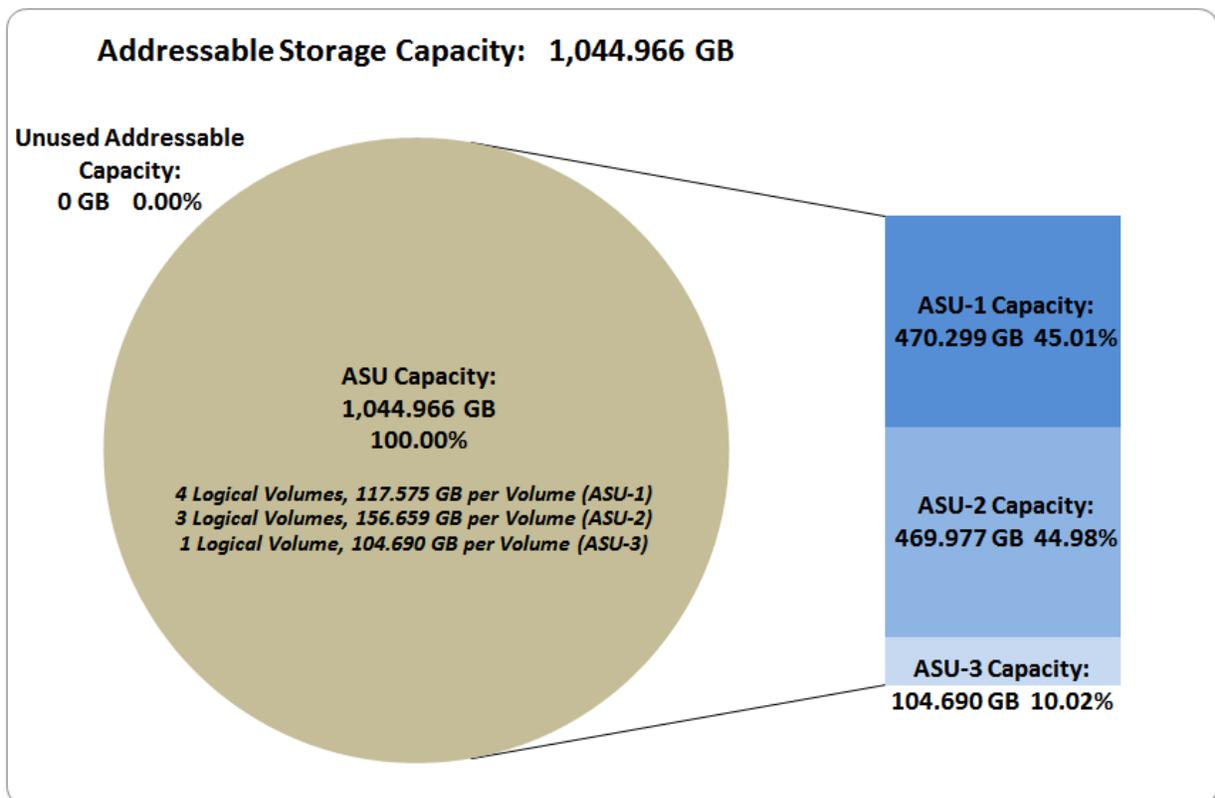
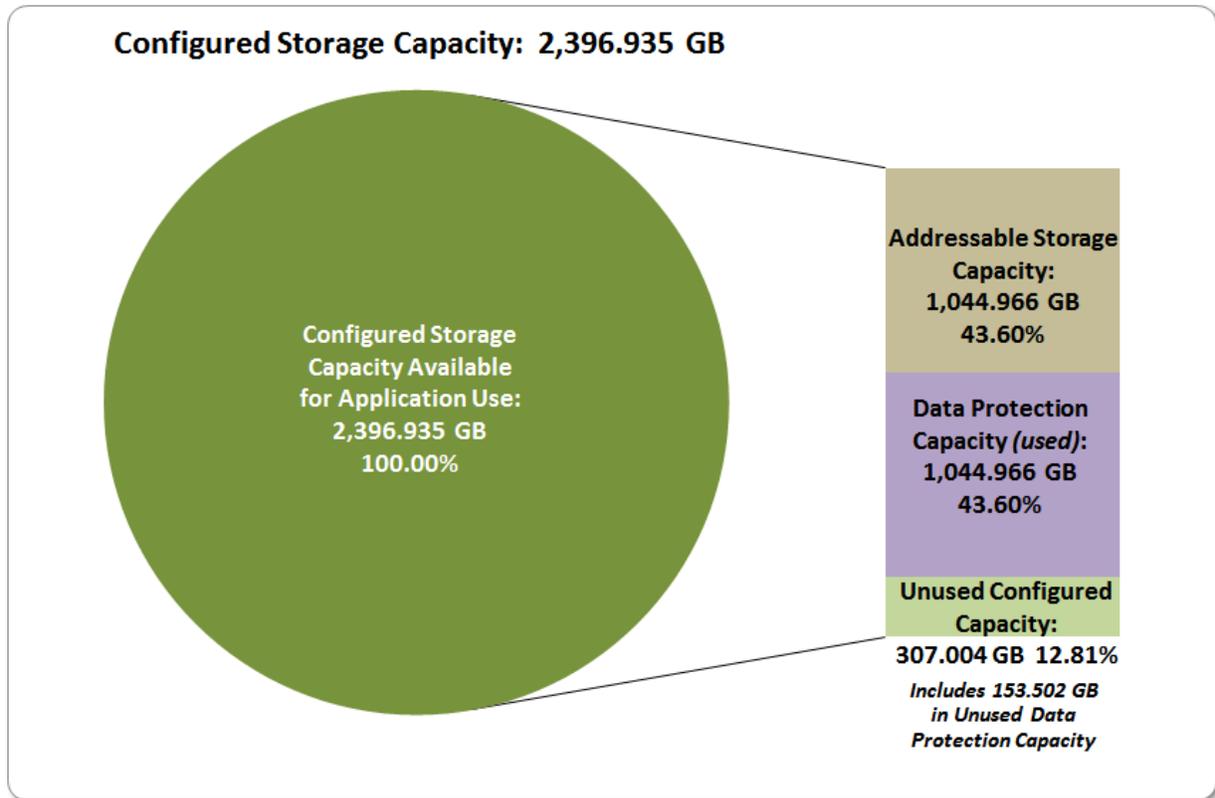
The **Target Country** is the country in which the Priced Storage Configuration is available for sale and in which the required hardware maintenance and software support is provided either directly from the Test Sponsor or indirectly via a third-party supplier.

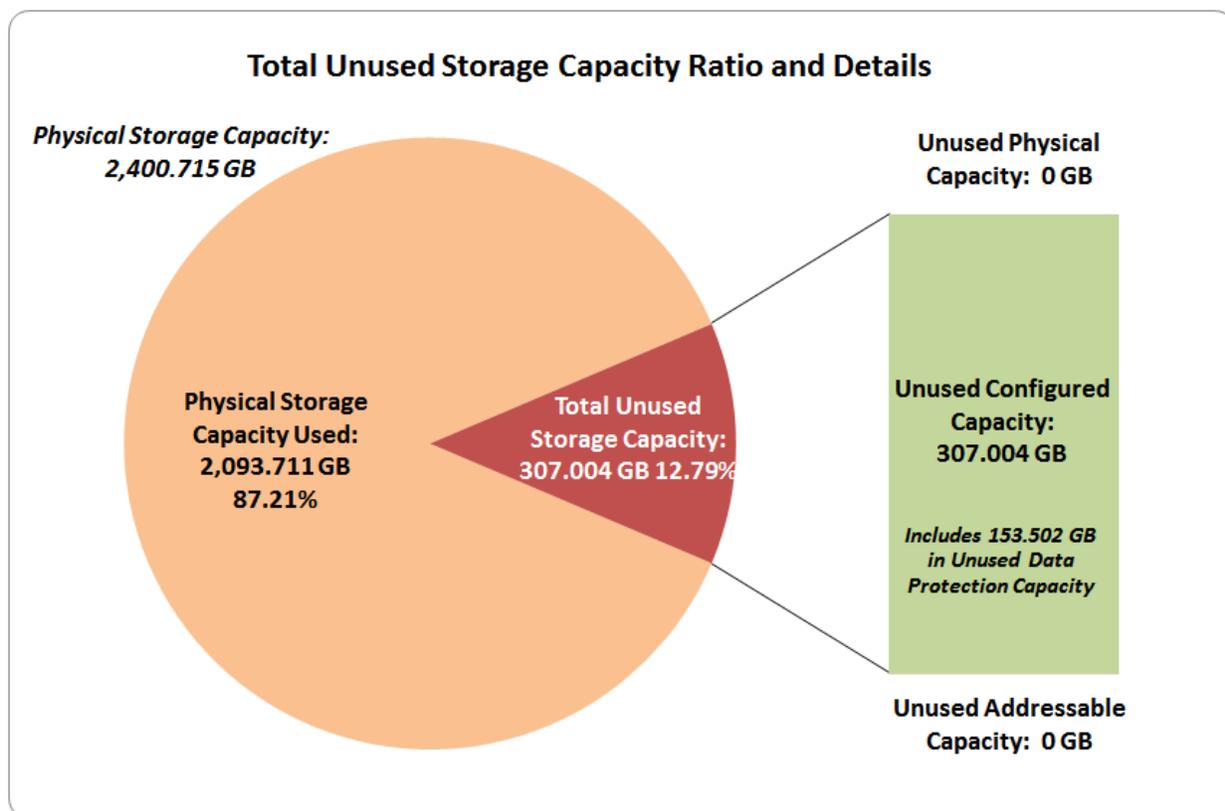
### Storage Capacities, Relationships, and Utilization

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.

The capacity values in each of the following four charts are listed as integer values, for readability, rather than the decimal values listed elsewhere in this document.







SPC-1 Storage Capacity Utilization	
Application Utilization	43.53%
Protected Application Utilization	87.05%
Unused Storage Ratio	12.79%

**Application Utilization:** Total ASU Capacity (1,044.996 GB) divided by Physical Storage Capacity (2,400.715 GB).

**Protected Application Utilization:** (Total ASU Capacity (1,044.996 GB) plus total Data Protection Capacity (1,198.468 GB) minus unused Data Protection Capacity (153.502 GB)) divided by Physical Storage Capacity (2,400.715 GB).

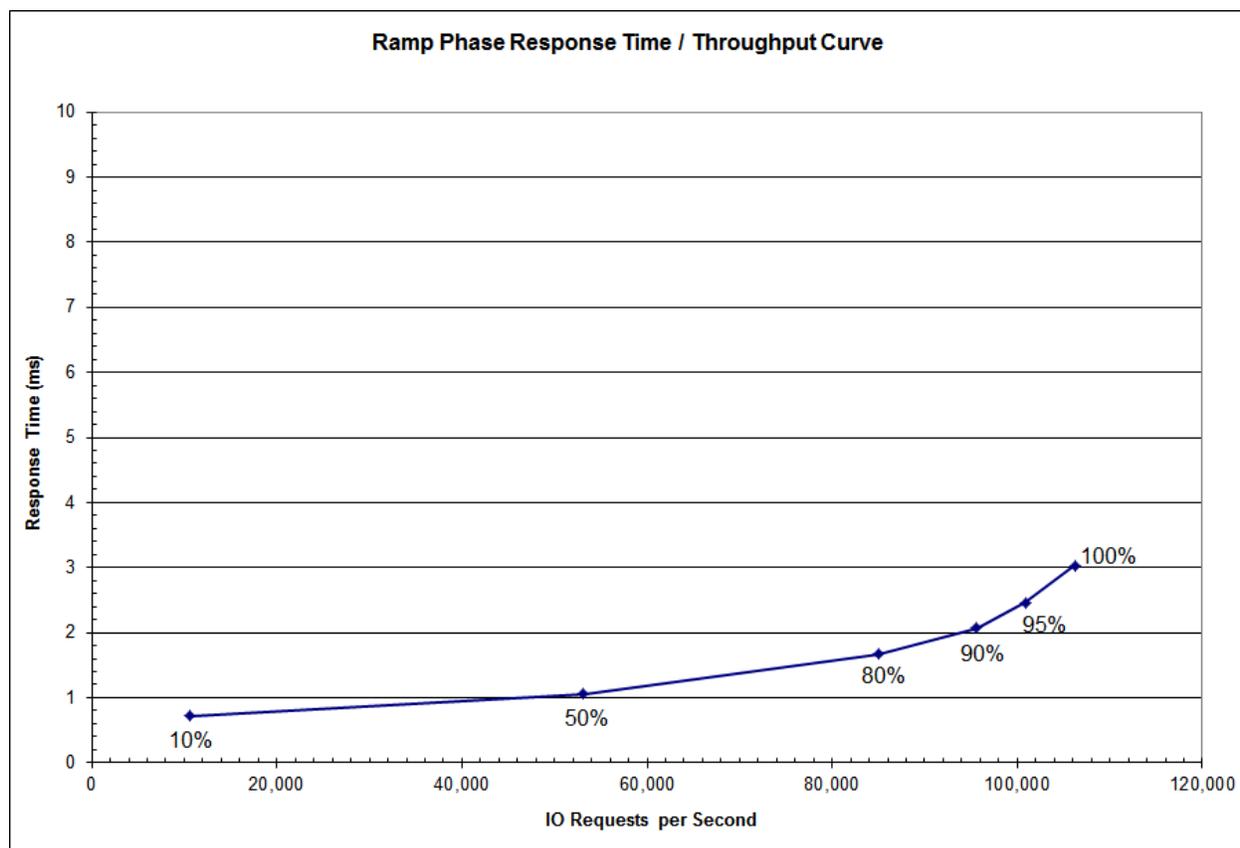
**Unused Storage Ratio:** Total Unused Capacity (307.004 GB) divided by Physical Storage Capacity (2,400.715 GB) and may not exceed 45%.

Detailed information for the various storage capacities and utilizations is available on pages 23-24.

### Response Time – Throughput Curve

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

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



### Response Time – Throughput Data

	10% Load	50% Load	80% Load	90% Load	95% Load	100% Load
<b>I/O Request Throughput</b>	10,599.32	53,108.83	84,995.76	95,611.15	100,918.82	106,243.76
<b>Average Response Time (ms):</b>						
<b>All ASUs</b>	0.72	1.06	1.67	2.07	2.46	3.03
<b>ASU-1</b>	0.71	1.08	1.72	2.15	2.54	3.15
<b>ASU-2</b>	0.78	1.10	1.68	2.04	2.36	2.74
<b>ASU-3</b>	0.70	1.01	1.57	1.93	2.35	2.90
<b>Reads</b>	0.65	1.11	1.79	2.19	2.52	3.01
<b>Writes</b>	0.76	1.03	1.60	2.00	2.42	3.04

## Priced Storage Configuration Pricing

Product Description	Qty.	Unit List Price	Extended List Price	Discount	Purchase Price
<b>Hardware Products</b>					
Dell Storage SC4020 Dual Controller, 16GB RAM w/Base Storage Center Licensing	1	\$12,100.00	\$12,100.00		
SC4020 8GB Connectivity, Qlogic 2564 Quad Port	2		\$0.00		
SC4020 Controller Power Cords	2	\$20.00	\$40.00		
6-Pack, Dell 200GB, SAS, 6Gb, 2.5" WISSD	2	\$37,050.00	\$74,100.00		
6-Pack, Enclosure Blank, SAS, Drive Bay Blanks, 2.5"	2	\$60.00	\$120.00		
0.6 M SAS cables (2)	1	\$150.00	\$150.00		
Qlogic Dual Port Fibre Channel HBA QLE2562 8G	4	\$2,434.00	\$9,736.00		
LC-LC Optical Cable, 3M (Fibre Channel Cables)	16	\$53.00	\$848.00		
Brocade 300 Switch - 8GB, 12-24 port, 16 SFP Bundle, Full Fabric	2	\$6,848.00	\$13,696.00		
Brocade Switch Rails	1	\$200.00	\$200.00		
<b>Hardware Product Total</b>		<b>\$58,915.00</b>	<b>\$110,990.00</b>	<b>48%</b>	<b>\$57,714.80</b>
<b>Software Products</b>					
SW, Storage Center OS Core License (Up To 48 Active Drives)	1	\$0.00	\$0.00		
<b>Software Product Total</b>		<b>\$0.00</b>	<b>\$0.00</b>	<b>48%</b>	<b>\$0.00</b>
<b>Installation and Support</b>					
Brocade Switch Support 3yr 24x7x4Hr - Onsite	1	\$628.02	\$628.02		
Support, 24x7, Dell/Compellent Series SC4020	1	\$4,775.08	\$4,775.08		
Support, 24x7, SW, Storage Center OS Core	1	\$1,800.09	\$1,800.09		
Dell Storage and Switch Installation Support (up to 2 hosts)	1	\$3,848.00	\$3,848.00		
<b>Installation and Support Total</b>		<b>\$11,051.19</b>	<b>\$11,051.19</b>	<b>0%</b>	<b>\$11,051.19</b>
<b>Total</b>		<b>\$69,966.19</b>	<b>\$122,041.19</b>		<b>\$68,765.99</b>

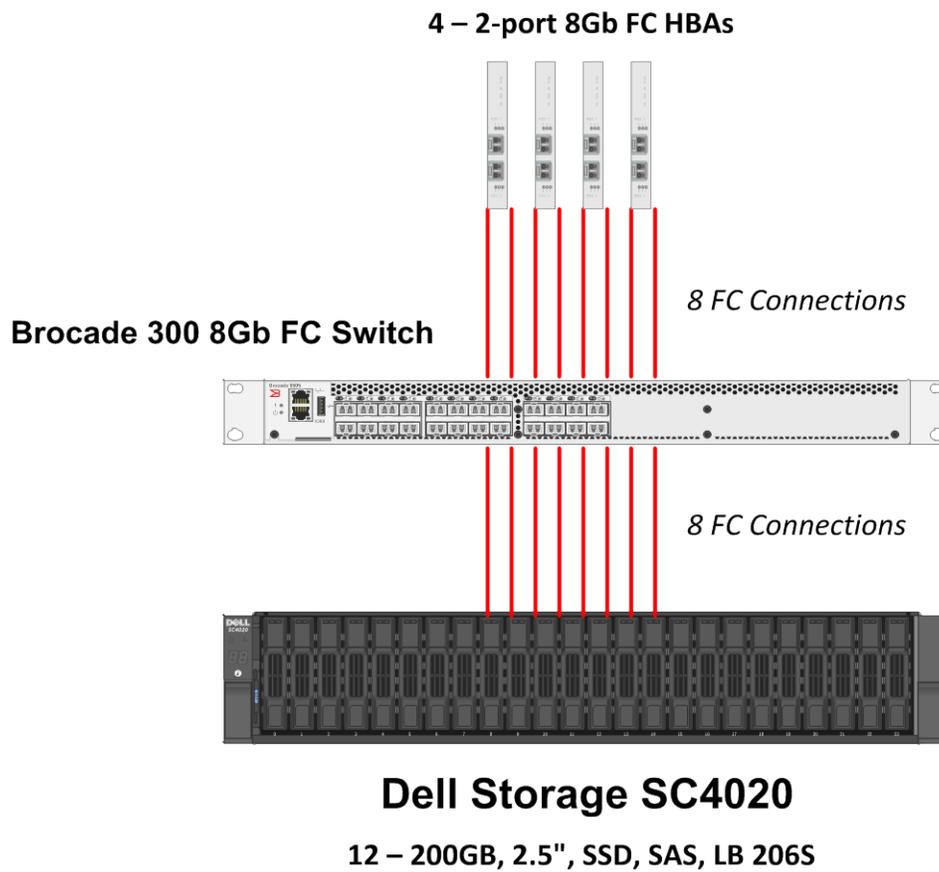
The above pricing includes hardware maintenance and software support for three years, 7 days per week, 24 hours per day. The hardware maintenance and software support provides the following:

- Acknowledgement of new and existing problems 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 Priced Storage Configuration that can be remedied by the repair or replacement of a Priced Storage Configuration component.

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

A second Brocade 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



### 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)
<b>Dell Storage SC4020</b>
SC4020 Dual Controller 16 GB cache per controller (32 GB total)
2- QLogic 2564 Quad Port 8Gb FC Adapters (1 adapter per controller)
8 – front-end connections (4 connections per controller) (8 connections used)
4 – backend 6Gb SAS connections (2 connections per controller) (4 connections used)
12 – Dell 200GB 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 [20 \(Host System and Tested Storage Configuration Components\)](#).

### Benchmark Configuration/Tested Storage Configuration Diagram

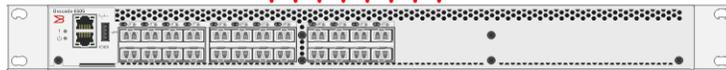
#### Dell PowerEdge R720 rack server

4 – 2-port 8Gb FC HBAs

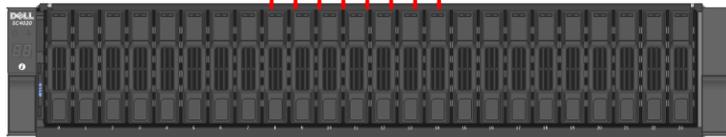


8 FC Connections

#### Brocade 300 8Gb FC Switch



8 FC Connections



#### Dell Storage SC4020

12 – 200GB, 2.5", SSD, SAS, LB 206S

### Host System and Tested Storage Configuration Components

<b>Host System</b>
<p><b>1 – Dell PowerEdge R720 rack server, with:</b></p> <ul style="list-style-type: none"> <li>2 – Intel® Xeon® 2.00 GHz E5-2650 processors 8 cores per processor and 20 MB Intel® Smart Cache</li> <li>64 GB main memory</li> <li>Windows Server 2008 R2 Enterprise with SP1</li> <li>PCIe 3.0</li> </ul>
<b>Tested Storage Configuration (TSC) Components</b>
<p>4 – QLogic QLE2562 Dual Port 8Gb FC HBAs</p>
<p>1 – Brocade 300 8Gb 12-24 port FC Switch (<i>16 ports/SFPs active</i>)</p>
<p><b>Dell Storage SC4020</b></p> <ul style="list-style-type: none"> <li>SC4020 Dual Controller 16 GB cache per controller (<i>32 GB total</i>)</li> <li>2- QLogic 2564 Quad Port 8Gb FC Adapters (<i>1 adapter per controller</i>)</li> <li>8 – front-end connections (<i>4 connections per controller</i>) (<i>8 connections used</i>)</li> <li>4 – backend 6Gb SAS connections (<i>2 connections per controller</i>) (<i>4 connections used</i>)</li> <li>12 – Dell 200GB 6Gb 2.5” SSDs</li> </ul>

## 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 64 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 65 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 92.

## 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 92.

## **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 [60](#) 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 2,400.715 GB distributed over 12 solid state drives (SSDs). There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 3.780 GB (0.16%) of the Physical Storage Capacity. There was 307.004 GB (12.81%) 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 1,198.468 GB of which 1,044.966 GB was utilized. The total Unused Storage capacity was 307.004 GB.

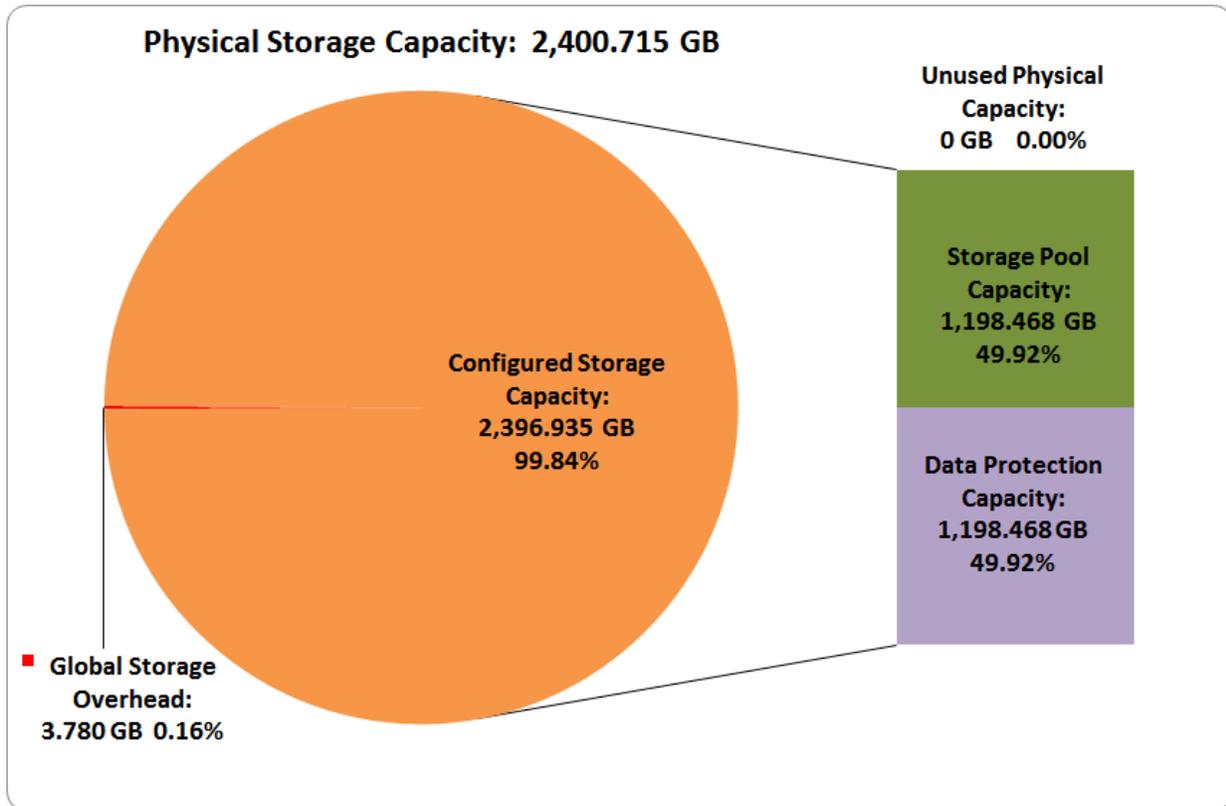
*Note: The configured Storage Devices may include additional storage capacity reserved for system overhead, which is not accessible for application use. That storage capacity may not be included in the value presented for Physical Storage Capacity.*

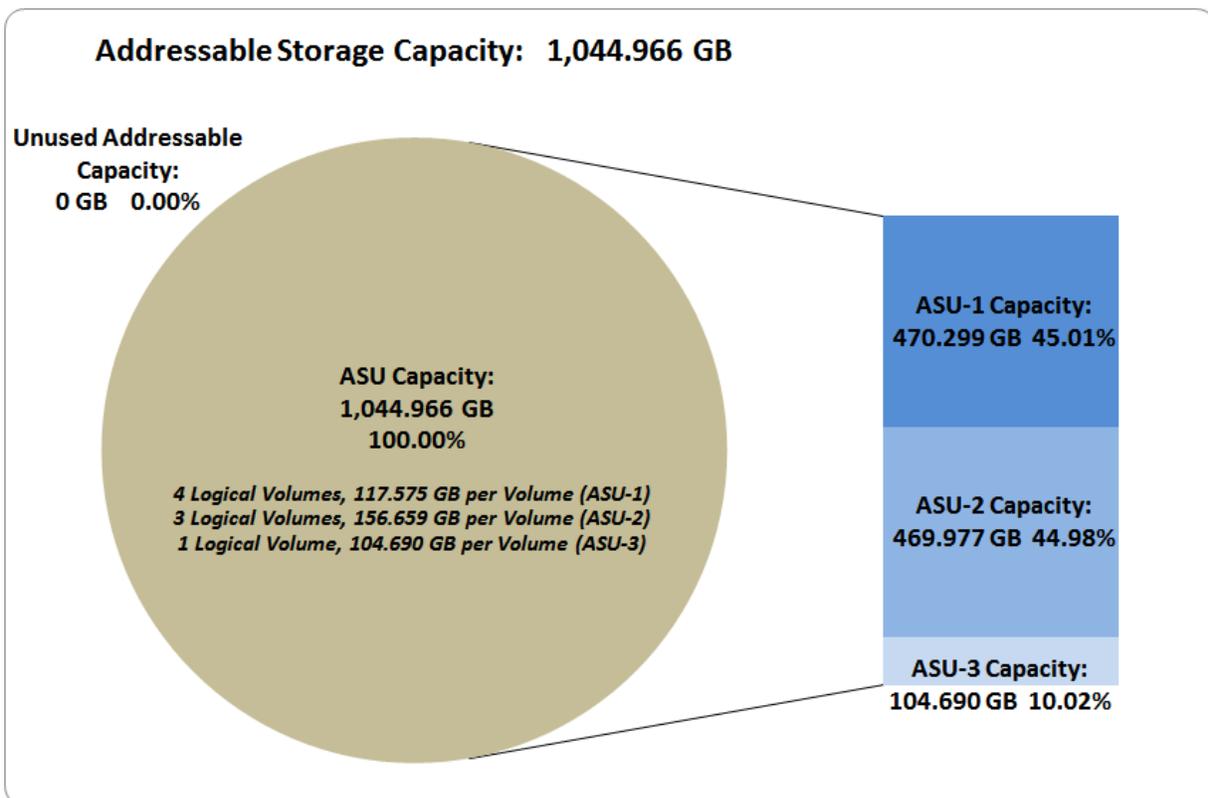
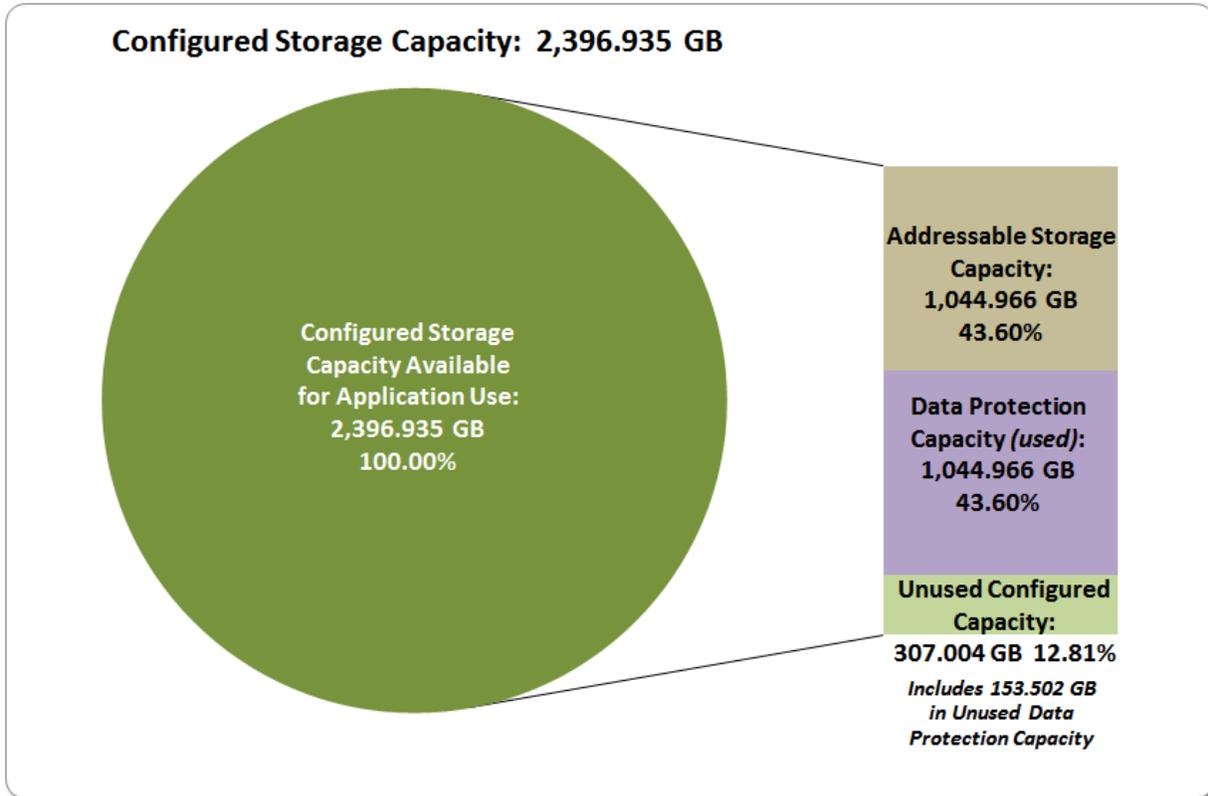
<b>SPC-1 Storage Capacities</b>		
<b>Storage Hierarchy Component</b>	<b>Units</b>	<b>Capacity</b>
Total ASU Capacity	Gigabytes (GB)	1,044.966
Addressable Storage Capacity	Gigabytes (GB)	1,044.966
Configured Storage Capacity	Gigabytes (GB)	2,396.935
Physical Storage Capacity	Gigabytes (GB)	2,400.715
Data Protection ( <i>Mirroring</i> )	Gigabytes (GB)	1,198.468
Required Storage ( <i>metadata/overhead/spares</i> )	Gigabytes (GB)	0.000
Global Storage Overhead	Gigabytes (GB)	3.780
Total Unused Storage	Gigabytes (GB)	307.004

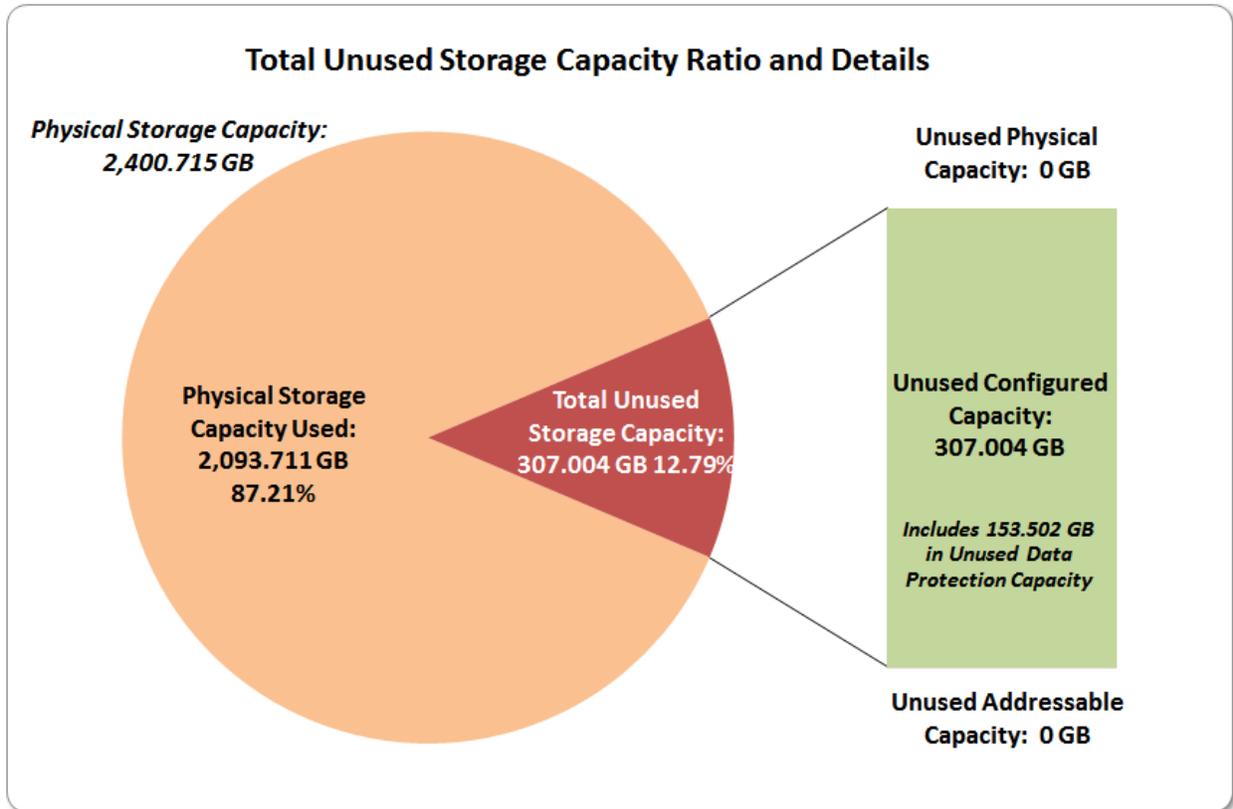
**SPC-1 Storage Hierarchy Ratios**

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	43.60%	43.53%
Required for Data Protection ( <i>Mirroring</i> )		50.00%	49.92%
Addressable Storage Capacity		43.60%	43.53%
Required Storage ( <i>spares, overhead</i> )		0.00%	0.00%
Configured Storage Capacity			99.84%
Global Storage Overhead			0.16%
Unused Storage:			
Addressable	0.00%		
Configured		12.81%	
Physical			0.00%

**SPC-1 Storage Capacity Charts**







## 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	43.53%
Protected Application Utilization	87.05%
Unused Storage Ratio	12.79%

### 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 (470.299 GB)	ASU-2 (469.977 GB)	ASU-3 (104.690 GB)
4 Logical Volumes 117.575 GB per Logical Volume (117.575 GB used per Logical Volume)	3 Logical Volumes 156.659 GB per Logical Volume (156.659 GB used per Logical Volume)	1 Logical Volume 104.690 GB per Logical Volume (104.690 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 60 contains definitions of terms specific to the SPC-1 Tests, Test Phases, and Test Runs.

### *Clause 5.4.3*

*The Tests must be executed in the following sequence: Primary Metrics, Repeatability, and Data Persistence. That required sequence must be uninterrupted from the start of Primary Metrics to the completion of Persistence Test Run 1. Uninterrupted means the Benchmark Configuration shall not be power cycled, restarted, disturbed, altered, or adjusted during the above measurement sequence. If the required sequence is interrupted other than for the Host System/TSC power cycle between the two Persistence Test Runs, the measurement is invalid.*

## **SPC-1 Tests, Test Phases, and Test Runs**

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

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

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

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

## “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 93.

### Sustainability Test Results File

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

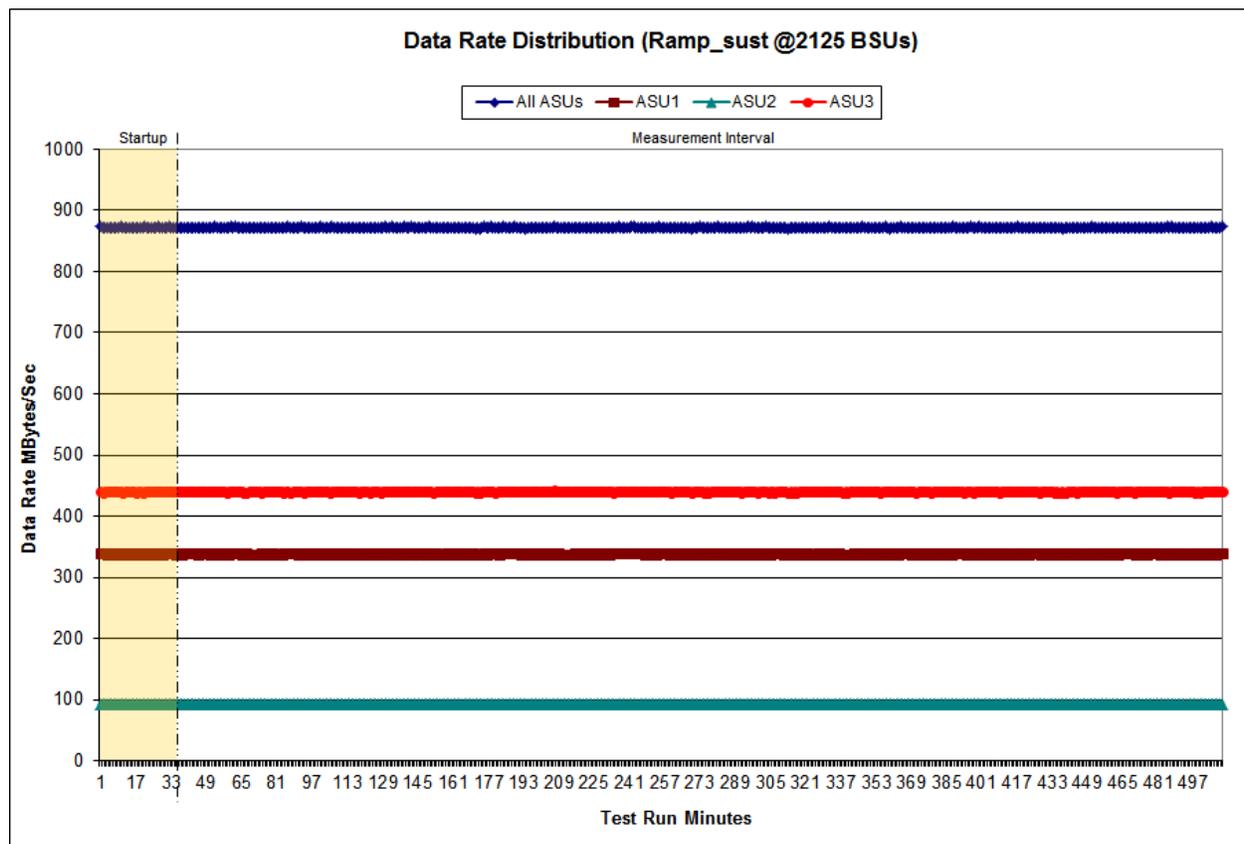
[Sustainability Test Results File](#)

### 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

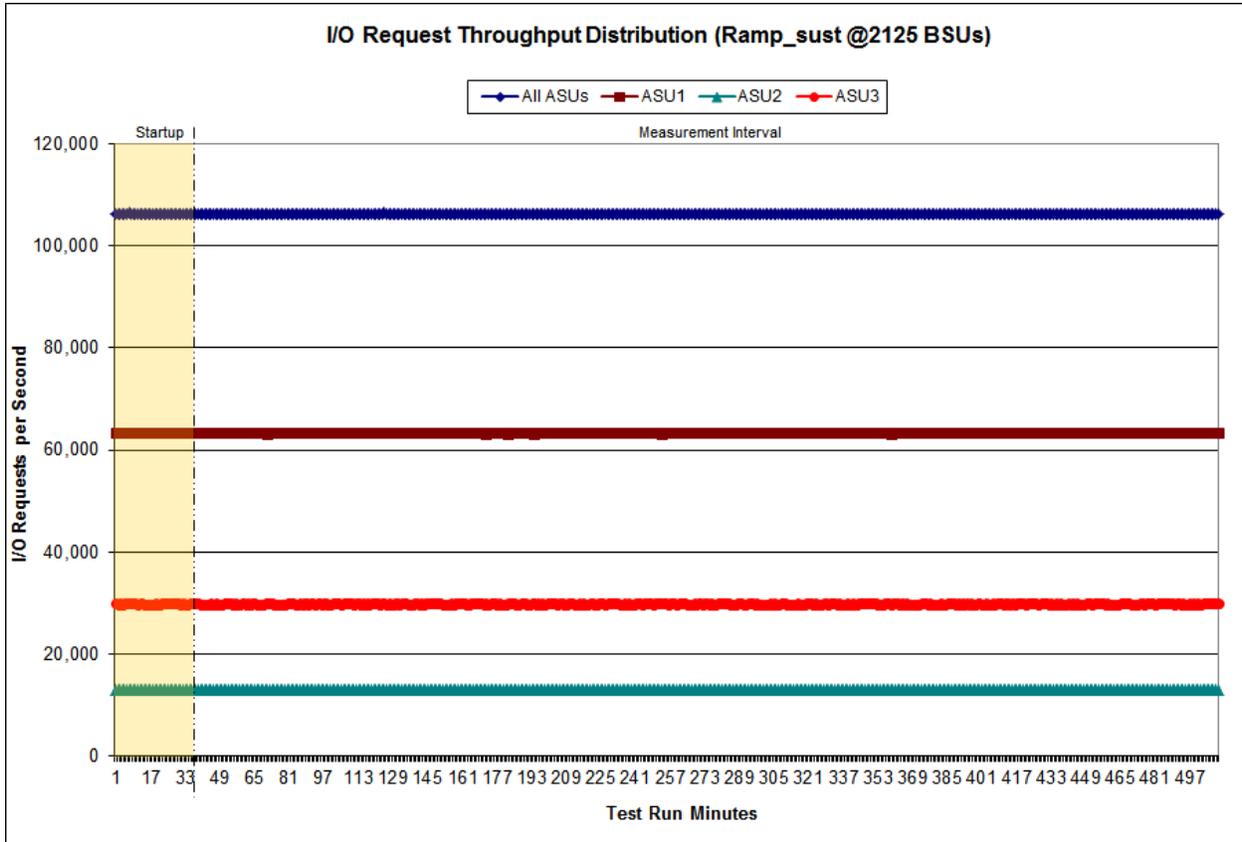


### Sustainability – I/O Request Throughput Distribution Data

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

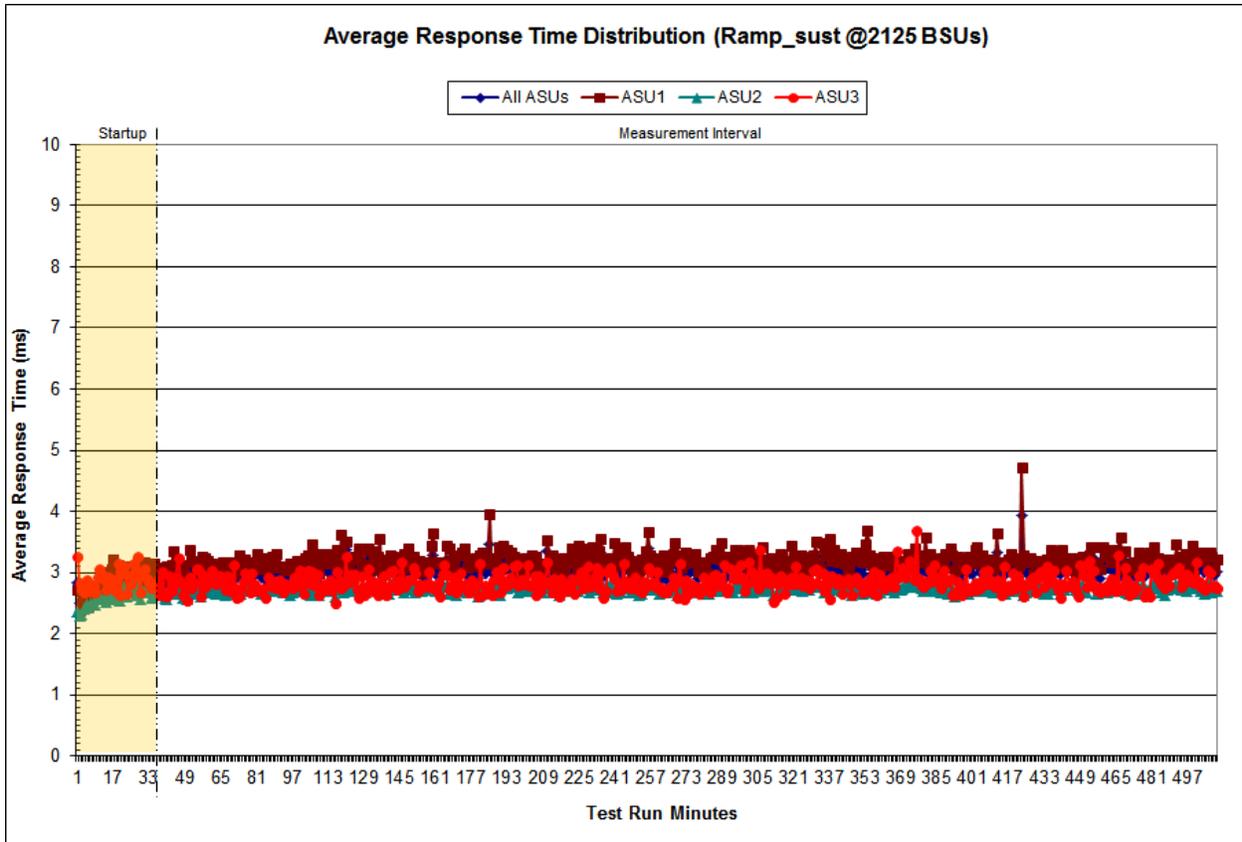


### Sustainability – Average Response Time (ms) Distribution Data

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](#)

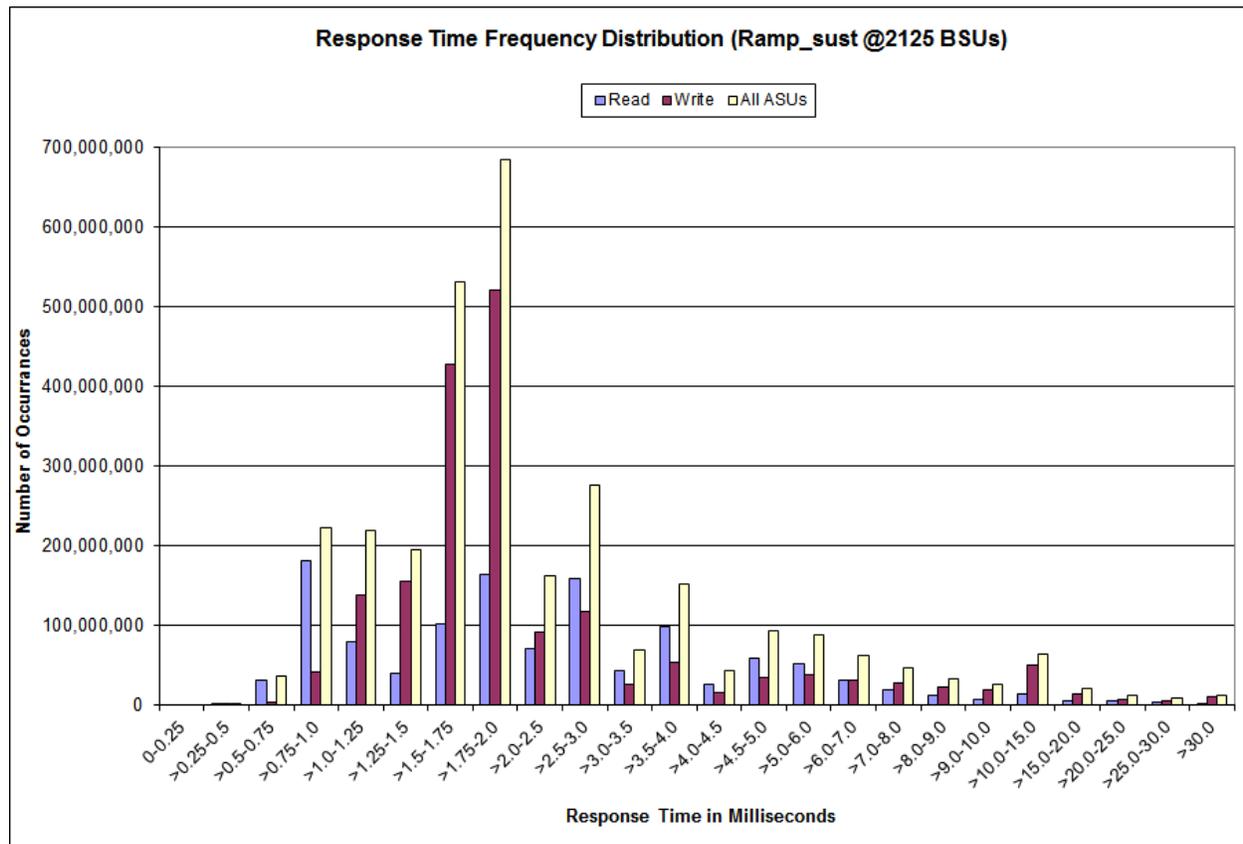
### Sustainability – Average Response Time (ms) Distribution Graph



**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	0	111,326	31,928,145	180,420,058	79,910,181	39,375,976	102,008,904	164,426,500
Write	0	15,988	3,884,261	42,433,832	138,441,465	154,959,177	428,075,079	520,288,273
All ASUs	0	127,314	35,812,406	222,853,890	218,351,646	194,335,153	530,083,983	684,714,773
ASU1	0	69,599	25,159,089	160,179,831	115,072,634	88,682,386	258,194,177	358,349,667
ASU2	0	43,408	7,125,869	35,940,173	44,342,330	30,867,305	59,901,007	64,512,515
ASU3	0	14,307	3,527,448	26,733,886	58,936,682	74,785,462	211,988,799	261,852,591
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	70,620,162	159,541,827	43,132,396	97,876,152	26,519,655	59,058,046	51,496,783	31,072,397
Write	92,003,545	116,796,562	26,377,609	53,896,539	16,367,869	35,046,205	37,511,357	30,797,469
All ASUs	162,623,707	276,338,389	69,510,005	151,772,691	42,887,524	94,104,251	89,008,140	61,869,866
ASU1	101,372,183	203,244,071	52,230,551	116,757,016	31,666,736	70,797,741	63,995,436	41,675,722
ASU2	16,313,900	31,412,207	8,856,171	18,713,837	5,468,345	11,473,286	10,713,929	7,441,583
ASU3	44,937,624	41,682,111	8,423,283	16,301,838	5,752,443	11,833,224	14,298,775	12,752,561
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	18,954,445	11,866,288	7,639,550	14,773,831	5,753,548	4,854,338	3,332,087	2,166,823
Write	28,146,476	22,022,651	18,604,148	49,570,345	14,778,071	6,957,650	5,993,982	10,083,900
All ASUs	47,100,921	33,888,939	26,243,698	64,344,176	20,531,619	11,811,988	9,326,069	12,250,723
ASU1	29,079,950	21,063,801	15,793,325	35,118,100	11,999,122	8,972,788	6,707,339	7,547,913
ASU2	8,163,923	4,870,130	2,431,630	3,924,892	1,188,348	851,155	749,434	1,057,540
ASU3	9,857,048	7,955,008	8,018,743	25,301,184	7,344,149	1,988,045	1,869,296	3,645,270

**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
<b>IM</b>	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 [93](#).

## IOPS Test Results File

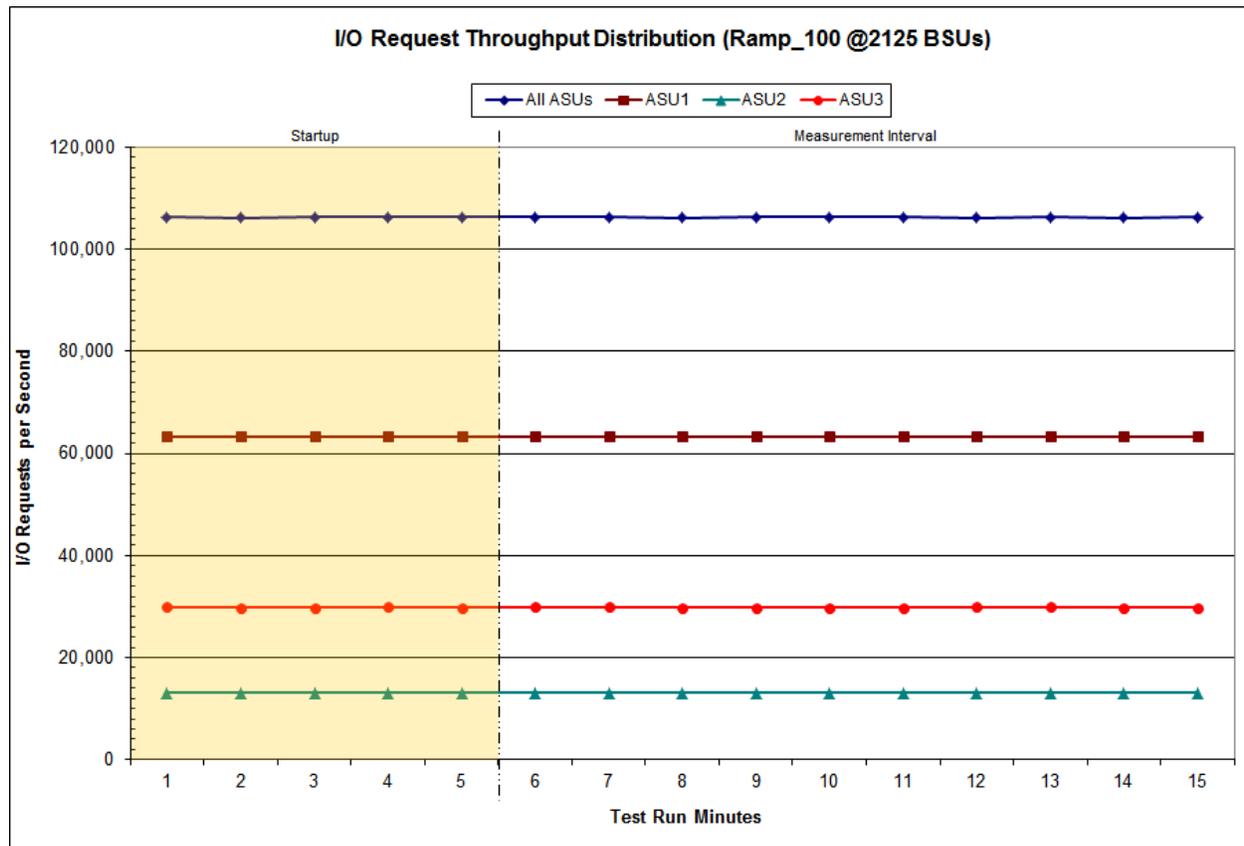
A link to the test results file generated from the IOPS Test Run is listed below.

[IOPS Test Results File](#)

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

2,125 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	1:16:14	1:21:15	0-4	0:05:01
<i>Measurement Interval</i>	1:21:15	1:31:15	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	106,287.83	63,327.65	13,084.97	29,875.22
1	106,174.43	63,279.78	13,061.35	29,833.30
2	106,219.08	63,294.47	13,083.80	29,840.82
3	106,230.03	63,291.27	13,080.03	29,858.73
4	106,245.25	63,342.48	13,059.78	29,842.98
5	106,283.10	63,317.87	13,086.07	29,879.17
6	106,256.02	63,310.82	13,077.55	29,867.65
7	106,202.98	63,306.82	13,062.13	29,834.03
8	106,252.27	63,359.98	13,047.68	29,844.60
9	106,243.73	63,348.28	13,056.35	29,839.10
10	106,234.08	63,331.08	13,060.73	29,842.27
11	106,207.95	63,293.90	13,057.30	29,856.75
12	106,289.93	63,338.97	13,074.63	29,876.33
13	106,208.48	63,308.17	13,064.53	29,835.78
14	106,259.00	63,340.73	13,074.70	29,843.57
<b>Average</b>	<b>106,243.76</b>	<b>63,325.66</b>	<b>13,066.17</b>	<b>29,851.93</b>

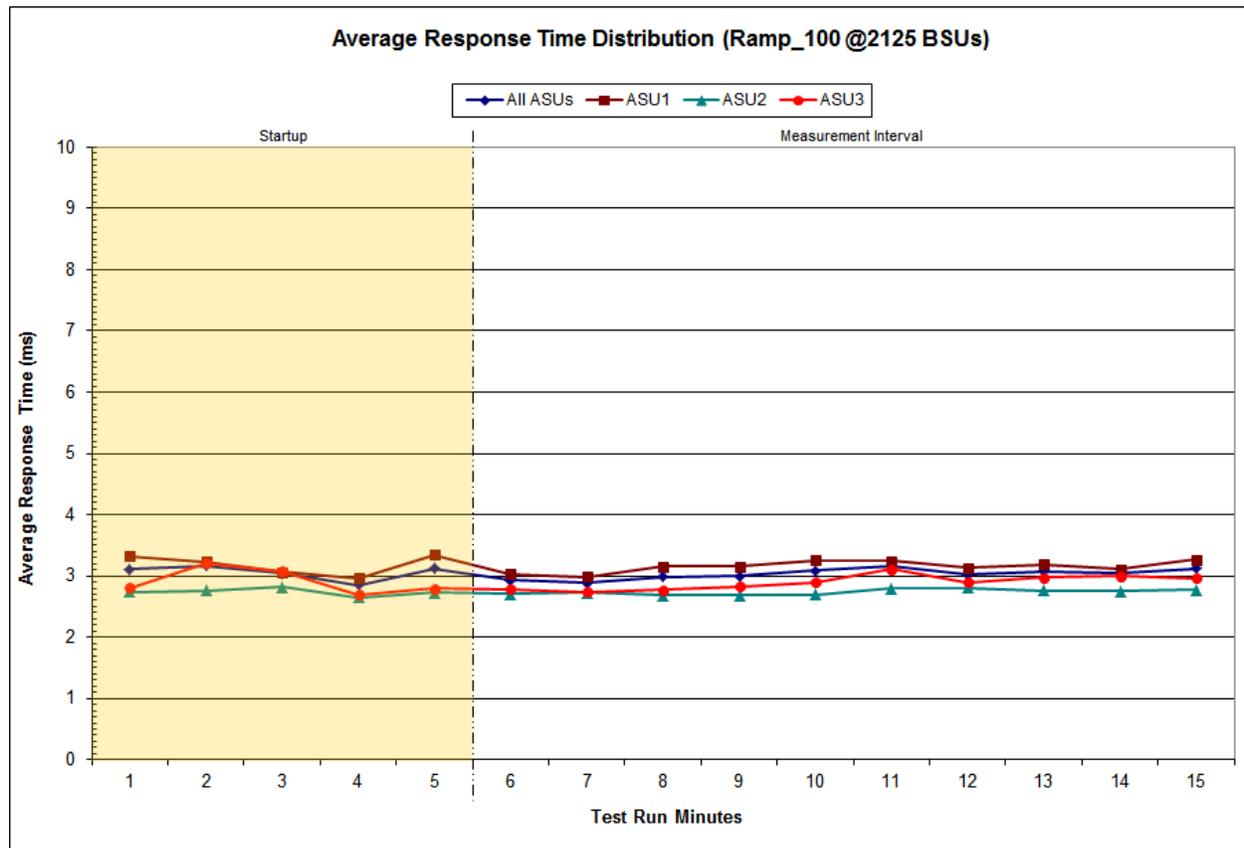
### IOPS Test Run – I/O Request Throughput Distribution Graph



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

2,125 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	1:16:14	1:21:15	0-4	0:05:01
<i>Measurement Interval</i>	1:21:15	1:31:15	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	3.11	3.32	2.74	2.81
1	3.17	3.23	2.76	3.22
2	3.04	3.07	2.82	3.08
3	2.85	2.96	2.65	2.69
4	3.12	3.35	2.73	2.80
5	2.93	3.04	2.71	2.79
6	2.89	2.99	2.73	2.74
7	2.99	3.15	2.68	2.78
8	3.00	3.15	2.68	2.83
9	3.09	3.25	2.70	2.90
10	3.15	3.25	2.79	3.11
11	3.03	3.13	2.81	2.90
12	3.08	3.19	2.76	2.97
13	3.04	3.11	2.75	3.00
14	3.12	3.27	2.77	2.97
<b>Average</b>	<b>3.03</b>	<b>3.15</b>	<b>2.74</b>	<b>2.90</b>

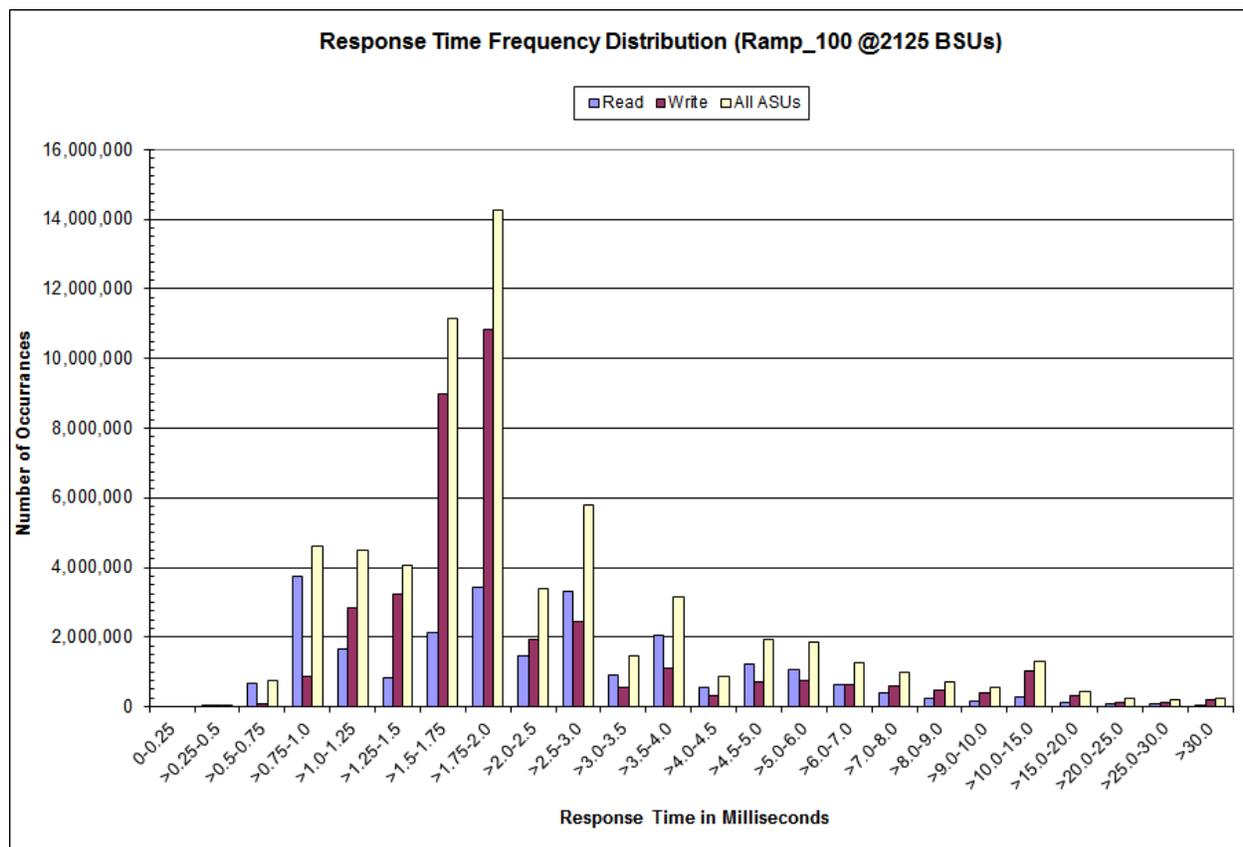
**IOPS Test Run – Average Response Time (ms) Distribution Graph**



**IOPS Test Run –Response Time Frequency Distribution Data**

Response Time (ms)	0-0.25	>0.25-0.5	>0.5-0.75	>0.75-1.0	>1.0-1.25	>1.25-1.5	>1.5-1.75	>1.75-2.0
Read	0	2,263	668,421	3,765,176	1,666,031	827,490	2,151,491	3,421,721
Write	0	296	78,640	865,958	2,837,399	3,226,350	8,982,929	10,837,997
All ASUs	0	2,559	747,061	4,631,134	4,503,430	4,053,840	11,134,420	14,259,718
ASU1	0	1,447	530,153	3,348,792	2,406,446	1,876,076	5,474,242	7,487,670
ASU2	0	839	145,807	736,741	905,830	642,443	1,258,860	1,346,180
ASU3	0	273	71,101	545,601	1,191,154	1,535,321	4,401,318	5,425,868
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	1,472,987	3,333,859	899,200	2,042,568	550,362	1,227,058	1,064,485	638,902
Write	1,925,710	2,446,255	551,337	1,128,321	335,509	715,889	774,336	640,427
All ASUs	3,398,697	5,780,114	1,450,537	3,170,889	885,871	1,942,947	1,838,821	1,279,329
ASU1	2,110,055	4,229,240	1,084,715	2,427,145	652,850	1,461,703	1,314,180	852,768
ASU2	340,191	658,464	185,259	393,080	113,320	238,759	223,311	156,284
ASU3	948,451	892,410	180,563	350,664	119,701	242,485	301,330	270,277
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	389,348	243,286	155,978	300,128	118,181	98,003	68,653	40,695
Write	589,314	463,705	385,937	1,018,347	319,589	143,811	122,618	209,024
All ASUs	978,662	706,991	541,915	1,318,475	437,770	241,814	191,271	249,719
ASU1	591,979	428,371	319,557	688,721	242,119	181,372	137,541	148,090
ASU2	174,417	106,179	50,394	83,815	24,690	17,761	15,448	21,600
ASU3	212,266	172,441	171,964	545,939	170,961	42,681	38,282	80,029

**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
63,745,984	63,496,265	249,719

### 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
<b>IM</b>	<b>0.0350</b>	<b>0.2810</b>	<b>0.0700</b>	<b>0.2100</b>	<b>0.0180</b>	<b>0.0700</b>	<b>0.0350</b>	<b>0.2810</b>
MIM	0.0350	0.2811	0.0700	0.2099	0.0180	0.0700	0.0350	0.2810
COV	0.002	0.001	0.002	0.001	0.002	0.001	0.003	0.000

## 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 [93](#).

## 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

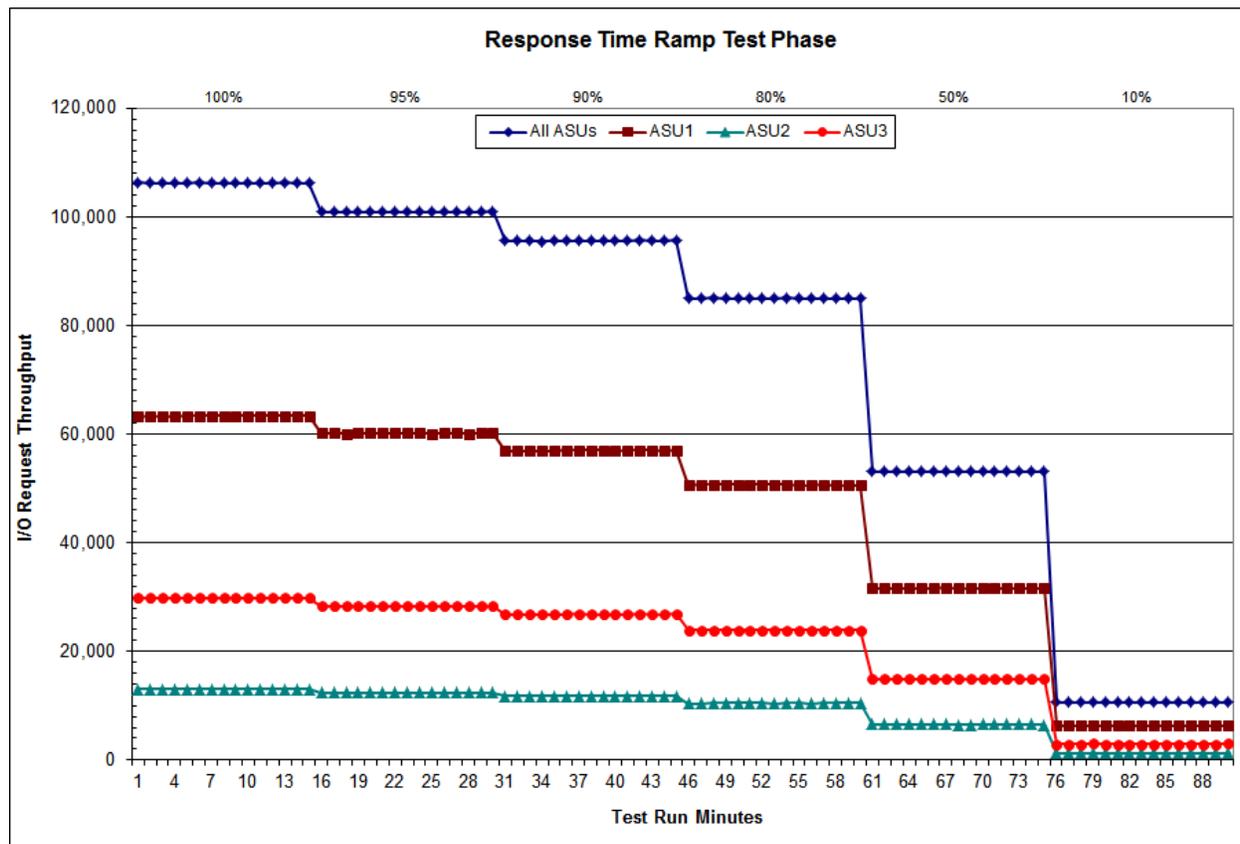
The five Test Runs that comprise the Response Time Ramp Phase are executed at 95%, 90%, 80%, 50%, and 10% of the Business Scaling Unit (BSU) load level used to produce the SPC-1 IOPS™ primary metric. The 100% BSU load level is included in the following Response Time Ramp data table and graph for completeness.

100% Load Level: 2,125 BSUs					95% Load Level: 2,018 BSUs				
	Start	Stop	Interval	Duration		Start	Stop	Interval	Duration
Start-Up/Ramp-Up	1:16:14	1:21:15	0-4	0:05:01	Start-Up/Ramp-Up	1:31:36	1:36:37	0-4	0:05:01
Measurement Interval	1:21:15	1:31:15	5-14	0:10:00	Measurement Interval	1:36:37	1:46:37	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	106,287.83	63,327.65	13,084.97	29,875.22	0	100,899.25	60,159.38	12,390.22	28,349.65
1	106,174.43	63,279.78	13,061.35	29,833.30	1	100,916.32	60,133.17	12,445.20	28,337.95
2	106,219.08	63,294.47	13,083.80	29,840.82	2	100,845.32	60,099.02	12,400.43	28,345.87
3	106,230.03	63,291.27	13,080.03	29,858.73	3	100,937.07	60,156.40	12,422.83	28,357.83
4	106,245.25	63,342.48	13,059.78	29,842.98	4	100,932.32	60,146.85	12,420.23	28,365.23
5	106,283.10	63,317.87	13,086.07	29,879.17	5	100,947.90	60,165.90	12,421.47	28,360.53
6	106,256.02	63,310.82	13,077.55	29,867.65	6	100,868.32	60,137.75	12,427.12	28,303.45
7	106,202.98	63,306.82	13,062.13	29,834.03	7	100,943.88	60,195.93	12,403.37	28,344.58
8	106,252.27	63,359.98	13,047.68	29,844.60	8	100,950.12	60,146.82	12,425.70	28,377.60
9	106,243.73	63,348.28	13,056.35	29,839.10	9	100,878.45	60,131.47	12,420.73	28,326.25
10	106,234.08	63,331.08	13,060.73	29,842.27	10	100,954.78	60,169.25	12,425.00	28,360.53
11	106,207.95	63,293.90	13,057.30	29,856.75	11	100,902.12	60,166.18	12,411.23	28,324.70
12	106,289.93	63,338.97	13,074.63	29,876.33	12	100,882.63	60,125.58	12,417.18	28,339.87
13	106,208.48	63,308.17	13,064.53	29,835.78	13	100,880.13	60,169.85	12,384.43	28,325.85
14	106,259.00	63,340.73	13,074.70	29,843.57	14	100,979.90	60,180.83	12,423.28	28,375.78
<b>Average</b>	<b>106,243.76</b>	<b>63,325.66</b>	<b>13,066.17</b>	<b>29,851.93</b>	<b>Average</b>	<b>100,918.82</b>	<b>60,158.96</b>	<b>12,415.95</b>	<b>28,343.92</b>
90% Load Level: 1,912 BSUs					80% Load Level: 1,700 BSUs				
	Start	Stop	Interval	Duration		Start	Stop	Interval	Duration
Start-Up/Ramp-Up	1:46:57	1:51:58	0-4	0:05:01	Start-Up/Ramp-Up	2:02:17	2:07:18	0-4	0:05:01
Measurement Interval	1:51:58	2:01:58	5-14	0:10:00	Measurement Interval	2:07:18	2:17:18	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	95,575.60	56,967.42	11,758.22	26,849.97	0	84,985.88	50,646.33	10,430.67	23,908.88
1	95,567.10	56,951.30	11,767.37	26,848.43	1	85,028.90	50,687.78	10,434.85	23,906.27
2	95,578.10	56,938.77	11,765.65	26,873.68	2	85,070.18	50,705.95	10,448.38	23,915.85
3	95,521.17	56,924.85	11,746.27	26,850.05	3	84,992.98	50,668.33	10,447.32	23,877.33
4	95,561.30	56,920.95	11,761.95	26,878.40	4	85,026.17	50,652.80	10,472.20	23,901.17
5	95,557.17	56,986.52	11,754.00	26,816.65	5	85,018.72	50,697.72	10,445.70	23,875.30
6	95,632.83	56,982.35	11,762.95	26,887.53	6	85,010.05	50,681.30	10,449.60	23,879.15
7	95,578.62	56,979.20	11,746.47	26,852.95	7	85,032.60	50,705.48	10,443.83	23,883.28
8	95,620.12	57,004.45	11,752.22	26,863.45	8	85,042.73	50,702.75	10,457.20	23,882.78
9	95,566.55	56,948.27	11,750.30	26,867.98	9	84,954.18	50,608.12	10,448.68	23,897.38
10	95,638.63	57,021.22	11,746.48	26,870.93	10	84,963.63	50,634.87	10,436.42	23,892.35
11	95,704.05	57,046.40	11,743.58	26,914.07	11	85,022.63	50,683.83	10,454.42	23,884.38
12	95,608.20	57,000.43	11,743.12	26,864.65	12	84,983.98	50,622.05	10,458.92	23,903.02
13	95,536.20	56,950.53	11,731.47	26,854.20	13	84,941.55	50,594.03	10,472.13	23,875.38
14	95,669.12	57,035.57	11,745.65	26,887.90	14	84,987.53	50,641.13	10,456.38	23,890.02
<b>Average</b>	<b>95,611.15</b>	<b>56,995.49</b>	<b>11,747.62</b>	<b>26,868.03</b>	<b>Average</b>	<b>84,995.76</b>	<b>50,657.13</b>	<b>10,452.33</b>	<b>23,886.31</b>

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

50% Load Level: 1,062 BSUs					10% Load Level: 212 BSUs				
Start-Up/Ramp-Up	Start	Stop	Interval	Duration	Start-Up/Ramp-Up	Start	Stop	Interval	Duration
Measurement Interval	2:17:33	2:22:34	0-4	0:05:01	Measurement Interval	2:32:43	2:37:44	0-4	0:05:01
(60 second intervals)	2:22:34	2:32:34	5-14	0:10:00	Measurement Interval	2:37:44	2:47:44	5-14	0:10:00
	All ASUs	ASU-1	ASU-2	ASU-3		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	53,122.20	31,670.08	6,540.40	14,911.72	0	10,595.92	6,320.90	1,294.23	2,980.78
1	53,079.42	31,630.32	6,525.13	14,923.97	1	10,608.07	6,312.80	1,311.72	2,983.55
2	53,096.08	31,623.77	6,537.10	14,935.22	2	10,605.27	6,318.83	1,302.52	2,983.92
3	53,114.57	31,627.87	6,536.48	14,950.22	3	10,624.70	6,325.63	1,308.52	2,990.55
4	53,147.17	31,664.65	6,531.82	14,950.70	4	10,612.22	6,334.98	1,301.68	2,975.55
5	53,133.95	31,654.60	6,538.87	14,940.48	5	10,607.83	6,323.52	1,304.48	2,979.83
6	53,141.48	31,693.47	6,524.98	14,923.03	6	10,601.12	6,319.30	1,300.15	2,981.67
7	53,108.48	31,668.63	6,513.80	14,926.05	7	10,574.50	6,299.03	1,303.57	2,971.90
8	53,112.75	31,660.35	6,519.10	14,933.30	8	10,597.50	6,324.13	1,303.03	2,970.33
9	53,102.03	31,653.88	6,530.77	14,917.38	9	10,605.90	6,321.82	1,302.73	2,981.35
10	53,074.07	31,626.03	6,538.88	14,909.15	10	10,582.27	6,315.03	1,300.72	2,966.52
11	53,135.07	31,657.17	6,533.73	14,944.17	11	10,598.78	6,319.85	1,298.08	2,980.85
12	<b>53,116.02</b>	<b>31,647.77</b>	<b>6,544.17</b>	<b>14,924.08</b>	12	<b>10,607.33</b>	<b>6,323.58</b>	<b>1,302.48</b>	<b>2,981.27</b>
13	<b>53,089.22</b>	<b>31,649.22</b>	<b>6,543.95</b>	<b>14,896.05</b>	13	<b>10,605.67</b>	<b>6,319.93</b>	<b>1,306.55</b>	<b>2,979.18</b>
14	<b>53,075.20</b>	<b>31,626.85</b>	<b>6,522.95</b>	<b>14,925.40</b>	14	<b>10,612.30</b>	<b>6,314.90</b>	<b>1,300.97</b>	<b>2,996.43</b>
Average	<b>53,108.83</b>	<b>31,653.80</b>	<b>6,531.12</b>	<b>14,923.91</b>	Average	<b>10,599.32</b>	<b>6,318.11</b>	<b>1,302.28</b>	<b>2,978.93</b>

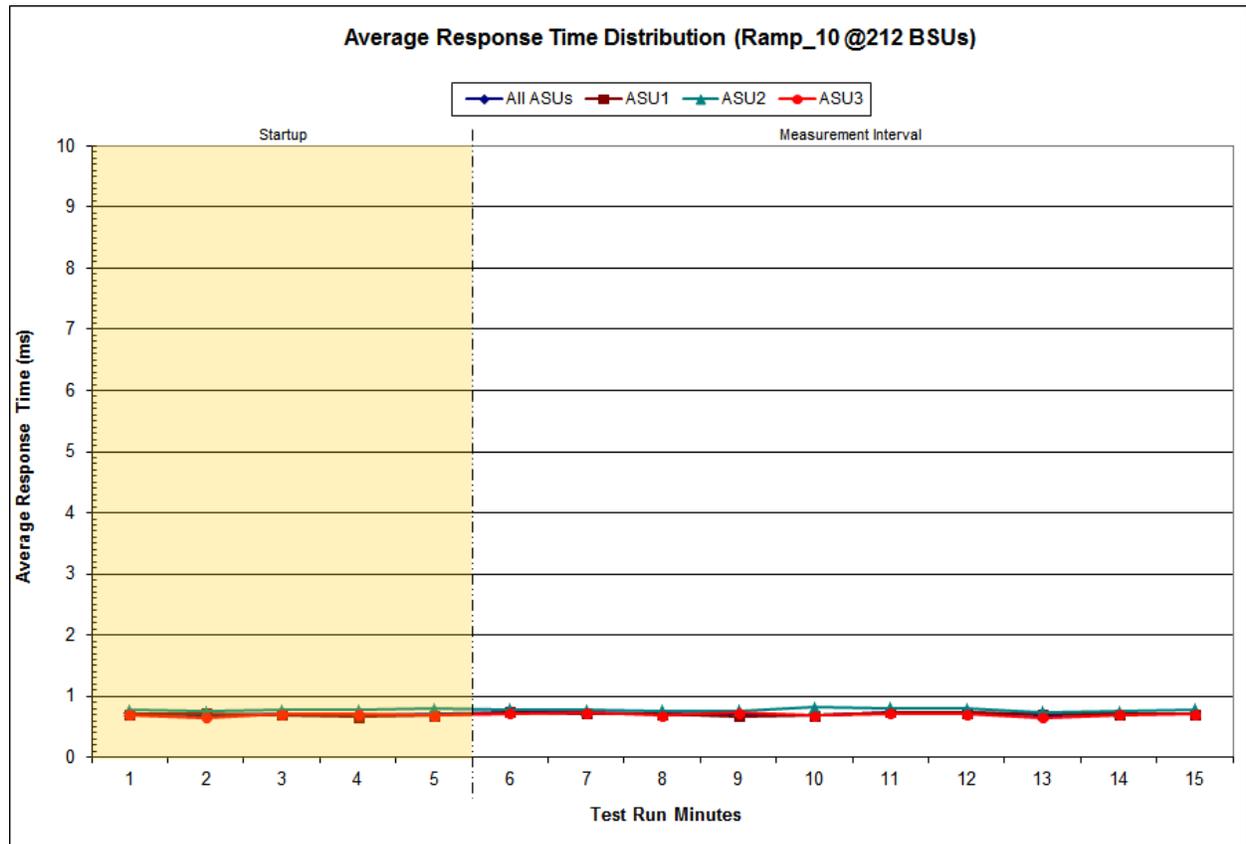
**Response Time Ramp Distribution (IOPS) Graph**



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

212 BSUs	Start	Stop	Interval	Duration
<b>Start-Up/Ramp-Up</b>	2:32:43	2:37:44	0-4	0:05:01
<b>Measurement Interval</b>	2:37:44	2:47:44	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	0.70	0.69	0.79	0.69
1	0.70	0.72	0.75	0.65
2	0.71	0.70	0.77	0.71
3	0.69	0.67	0.78	0.71
4	0.70	0.69	0.79	0.69
5	0.74	0.74	0.78	0.72
6	0.73	0.72	0.78	0.73
7	0.71	0.71	0.76	0.69
8	0.70	0.68	0.77	0.73
9	0.70	0.68	0.82	0.69
10	0.74	0.74	0.81	0.72
11	0.73	0.73	0.80	0.70
12	0.70	0.71	0.74	0.66
13	0.71	0.70	0.76	0.70
14	0.72	0.71	0.78	0.70
<b>Average</b>	<b>0.72</b>	<b>0.71</b>	<b>0.78</b>	<b>0.70</b>

**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	0.2810	0.0701	0.2099	0.0179	0.0700	0.0350	0.2810
COV	0.005	0.001	0.005	0.002	0.008	0.004	0.005	0.002

## Repeatability Test

### Clause 5.4.5

*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.*

### Clause 9.4.3.7.5

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

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

## SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in [Appendix E: SPC-1 Workload Generator Input Parameters](#) on Page 93.

**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.

	<b>SPC-1 IOPS™</b>
<b>Primary Metrics</b>	<b>106,243.76</b>
<b>Repeatability Test Phase 1</b>	106,241.85
<b>Repeatability Test Phase 2</b>	106.241.98

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

	<b>SPC-1 LRT™</b>
<b>Primary Metrics</b>	<b>0.72 ms</b>
<b>Repeatability Test Phase 1</b>	0.72 ms
<b>Repeatability Test Phase 2</b>	0.72 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).

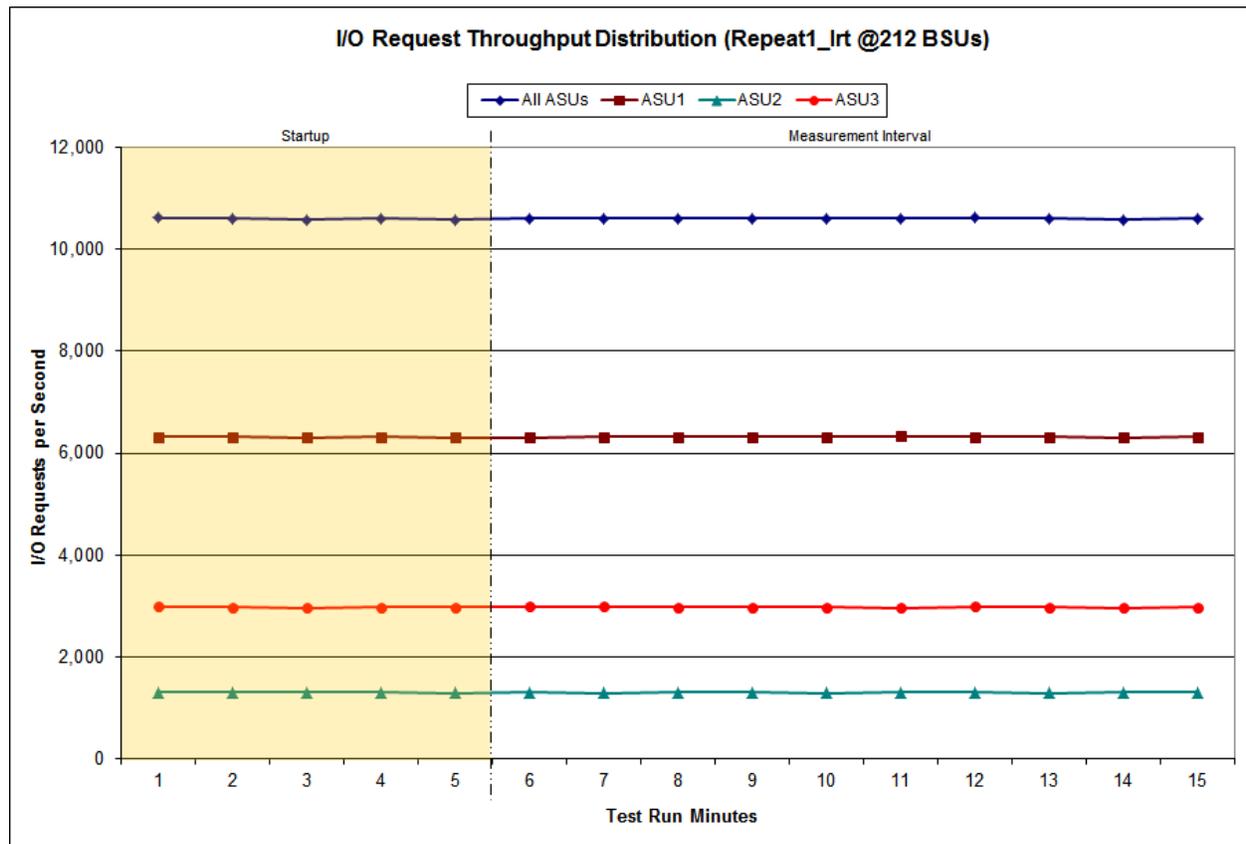
A link to the test result file generated from each Repeatability Test Run is listed below.

- [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**

212 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	2:47:59	2:52:59	0-4	0:05:00
<i>Measurement Interval</i>	2:52:59	3:02:59	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	10,612.75	6,324.38	1,301.55	2,986.82
1	10,602.70	6,317.87	1,304.82	2,980.02
2	10,568.48	6,298.42	1,302.88	2,967.18
3	10,603.80	6,318.68	1,304.45	2,980.67
4	10,577.13	6,301.78	1,296.32	2,979.03
5	10,597.38	6,301.00	1,303.42	2,992.97
6	10,599.50	6,315.32	1,297.50	2,986.68
7	10,605.50	6,316.83	1,306.98	2,981.68
8	10,596.97	6,316.17	1,309.25	2,971.55
9	10,599.08	6,319.30	1,298.72	2,981.07
10	10,601.22	6,328.18	1,304.50	2,968.53
11	10,615.45	6,324.73	1,302.13	2,988.58
12	10,598.98	6,316.22	1,298.13	2,984.63
13	10,578.92	6,308.85	1,302.18	2,967.88
14	10,602.33	6,317.48	1,306.27	2,978.58
<b>Average</b>	<b>10,599.53</b>	<b>6,316.41</b>	<b>1,302.91</b>	<b>2,980.22</b>

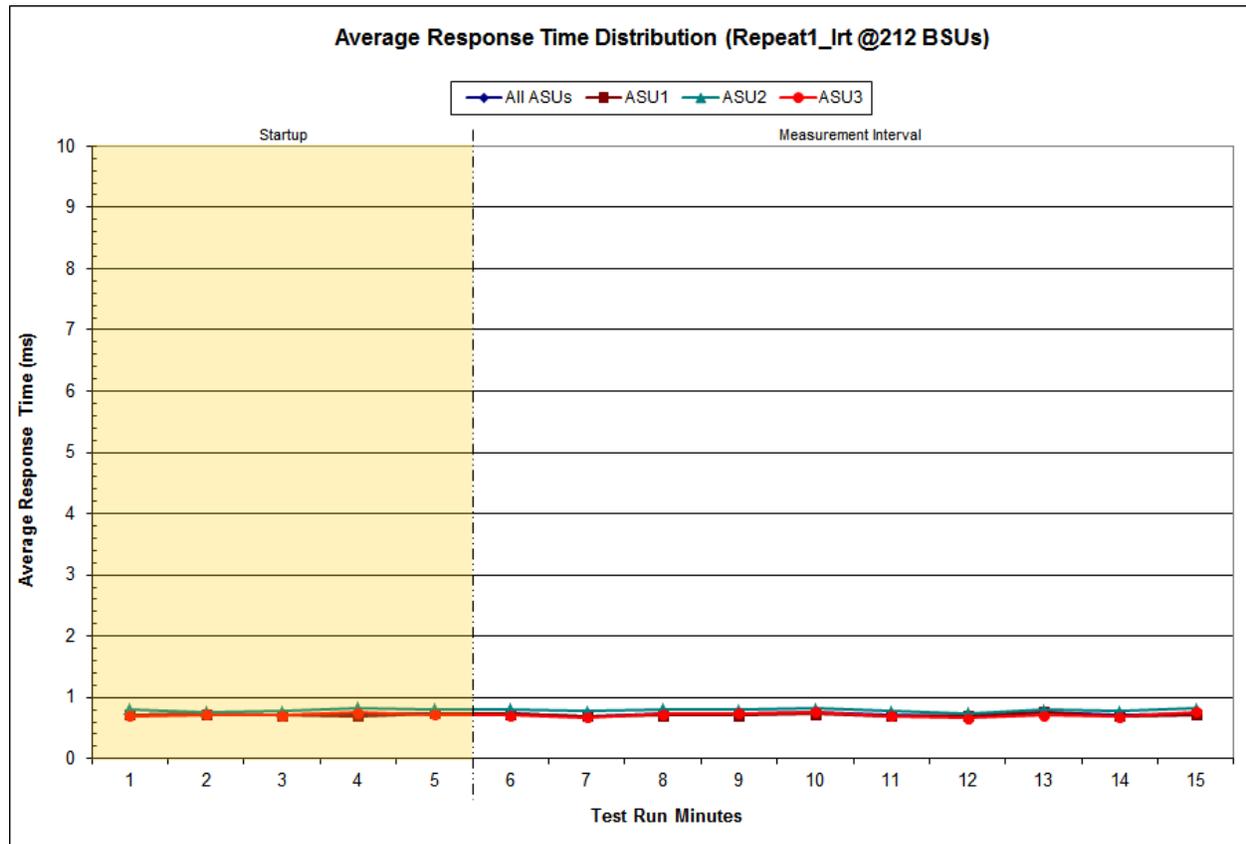
**Repeatability 1 LRT – I/O Request Throughput Distribution Graph**



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

212 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	2:47:59	2:52:59	0-4	0:05:00
<i>Measurement Interval</i>	2:52:59	3:02:59	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	0.72	0.72	0.81	0.70
1	0.73	0.73	0.76	0.72
2	0.72	0.71	0.78	0.71
3	0.73	0.69	0.83	0.75
4	0.74	0.75	0.80	0.71
5	0.73	0.73	0.81	0.70
6	0.70	0.70	0.78	0.67
7	0.73	0.71	0.80	0.73
8	0.73	0.71	0.80	0.74
9	0.75	0.73	0.82	0.76
10	0.71	0.70	0.77	0.70
11	0.70	0.71	0.74	0.66
12	0.75	0.76	0.80	0.71
13	0.70	0.70	0.78	0.69
14	0.75	0.72	0.82	0.76
<b>Average</b>	<b>0.72</b>	<b>0.72</b>	<b>0.79</b>	<b>0.71</b>

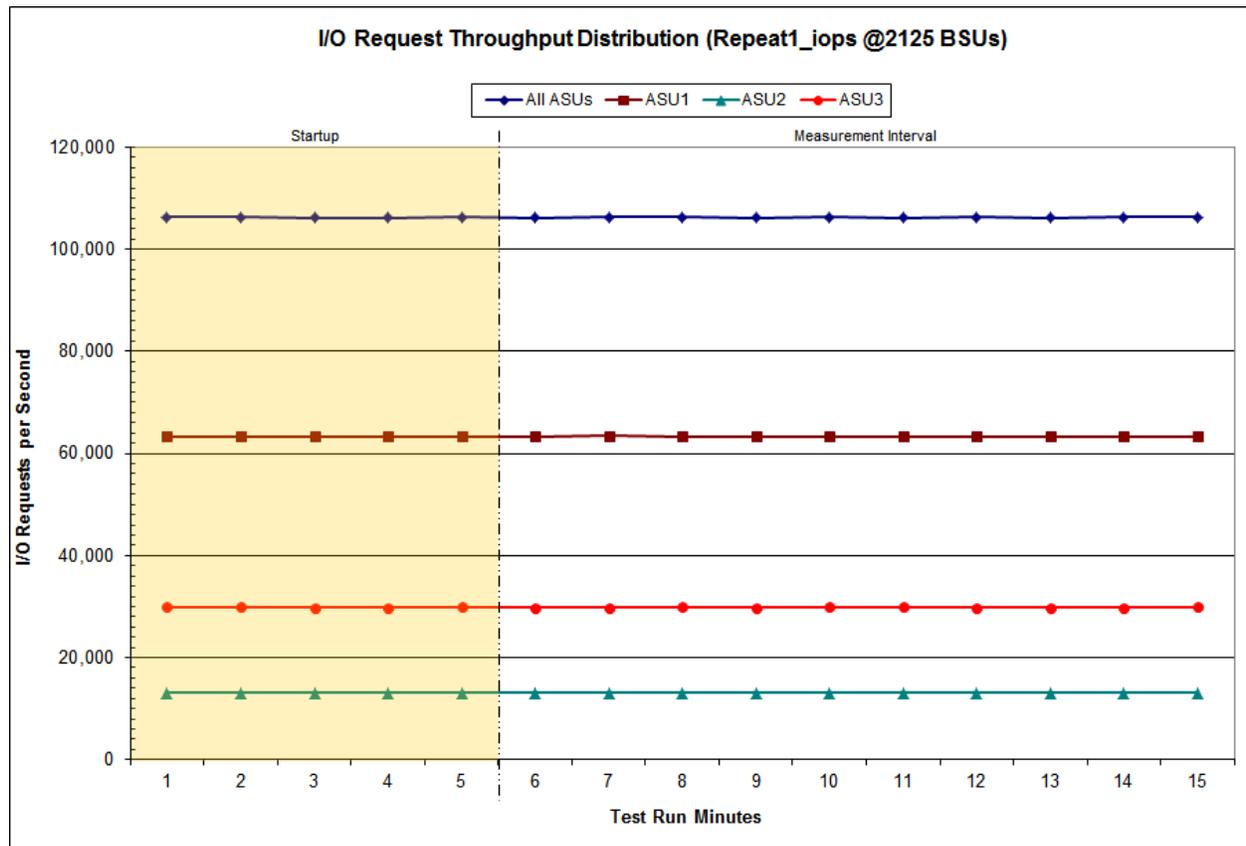
**Repeatability 1 LRT –Average Response Time (ms) Distribution Graph**



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

2,125 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	3:03:22	3:08:23	0-4	0:05:01
<i>Measurement Interval</i>	3:08:23	3:18:23	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	106,288.38	63,344.03	13,095.47	29,848.88
1	106,270.17	63,311.68	13,063.70	29,894.78
2	106,202.47	63,270.57	13,084.53	29,847.37
3	106,176.87	63,292.95	13,057.38	29,826.53
4	106,247.87	63,307.62	13,080.55	29,859.70
5	106,195.20	63,331.17	13,070.38	29,793.65
6	106,299.42	63,402.23	13,064.17	29,833.02
7	106,250.07	63,316.32	13,061.00	29,872.75
8	106,196.18	63,291.27	13,067.33	29,837.58
9	106,312.73	63,359.40	13,071.98	29,881.35
10	106,208.93	63,301.83	13,051.37	29,855.73
11	106,243.33	63,353.87	13,071.30	29,818.17
12	106,210.48	63,292.93	13,071.60	29,845.95
13	106,259.35	63,319.03	13,098.22	29,842.10
14	106,242.80	63,334.52	13,057.00	29,851.28
<b>Average</b>	<b>106,241.85</b>	<b>63,330.26</b>	<b>13,068.44</b>	<b>29,843.16</b>

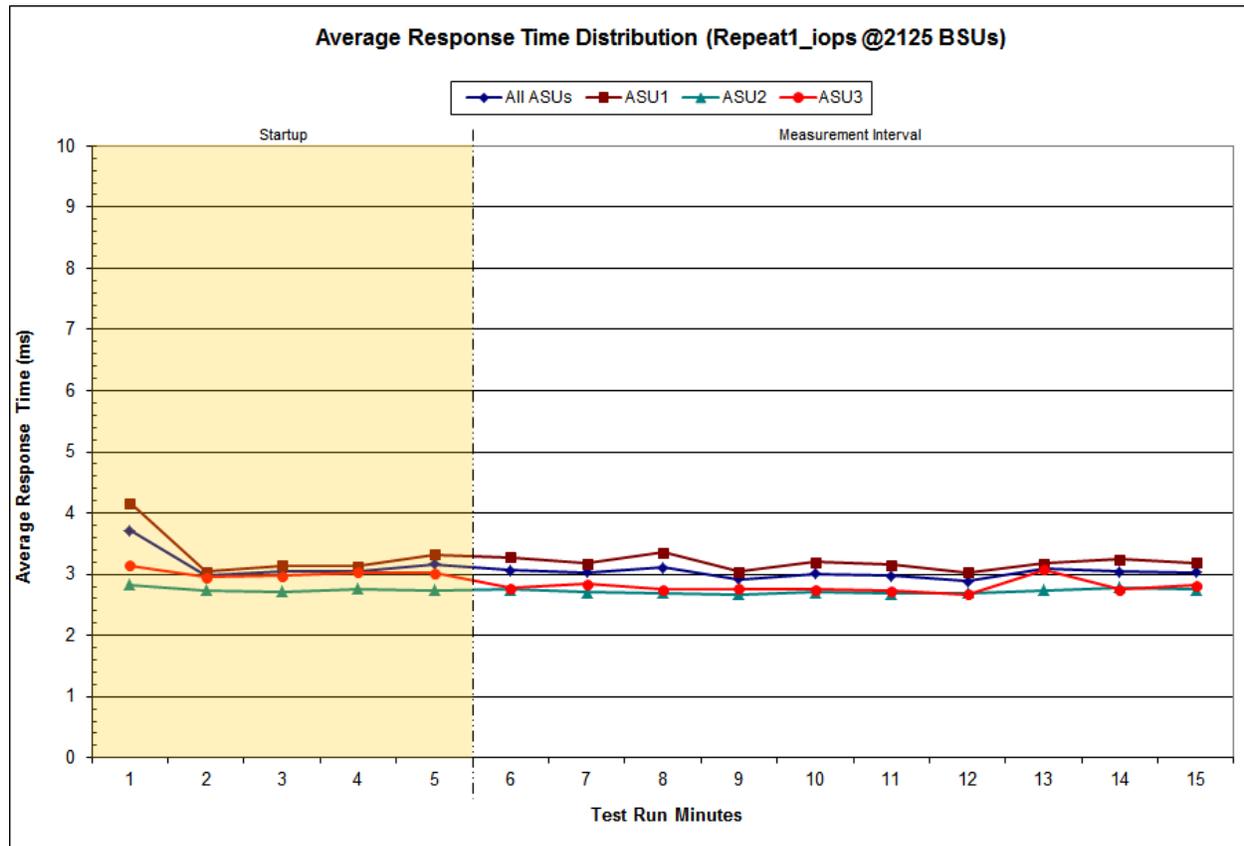
**Repeatability 1 IOPS – I/O Request Throughput Distribution Graph**



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

2,125 BSUs Start-Up/Ramp-Up Measurement Interval	Start	Stop	Interval	Duration
	3:03:22	3:08:23	0-4	0:05:01
	3:08:23	3:18:23	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	3.71	4.17	2.83	3.14
1	2.98	3.04	2.74	2.95
2	3.04	3.14	2.72	2.98
3	3.06	3.13	2.76	3.04
4	3.16	3.32	2.73	3.02
5	3.07	3.28	2.75	2.77
6	3.03	3.18	2.71	2.84
7	3.11	3.36	2.70	2.75
8	2.92	3.04	2.67	2.77
9	3.01	3.20	2.70	2.75
10	2.98	3.16	2.68	2.73
11	2.89	3.04	2.69	2.67
12	3.09	3.17	2.74	3.07
13	3.05	3.24	2.78	2.75
14	3.03	3.18	2.75	2.82
<b>Average</b>	<b>3.02</b>	<b>3.19</b>	<b>2.72</b>	<b>2.79</b>

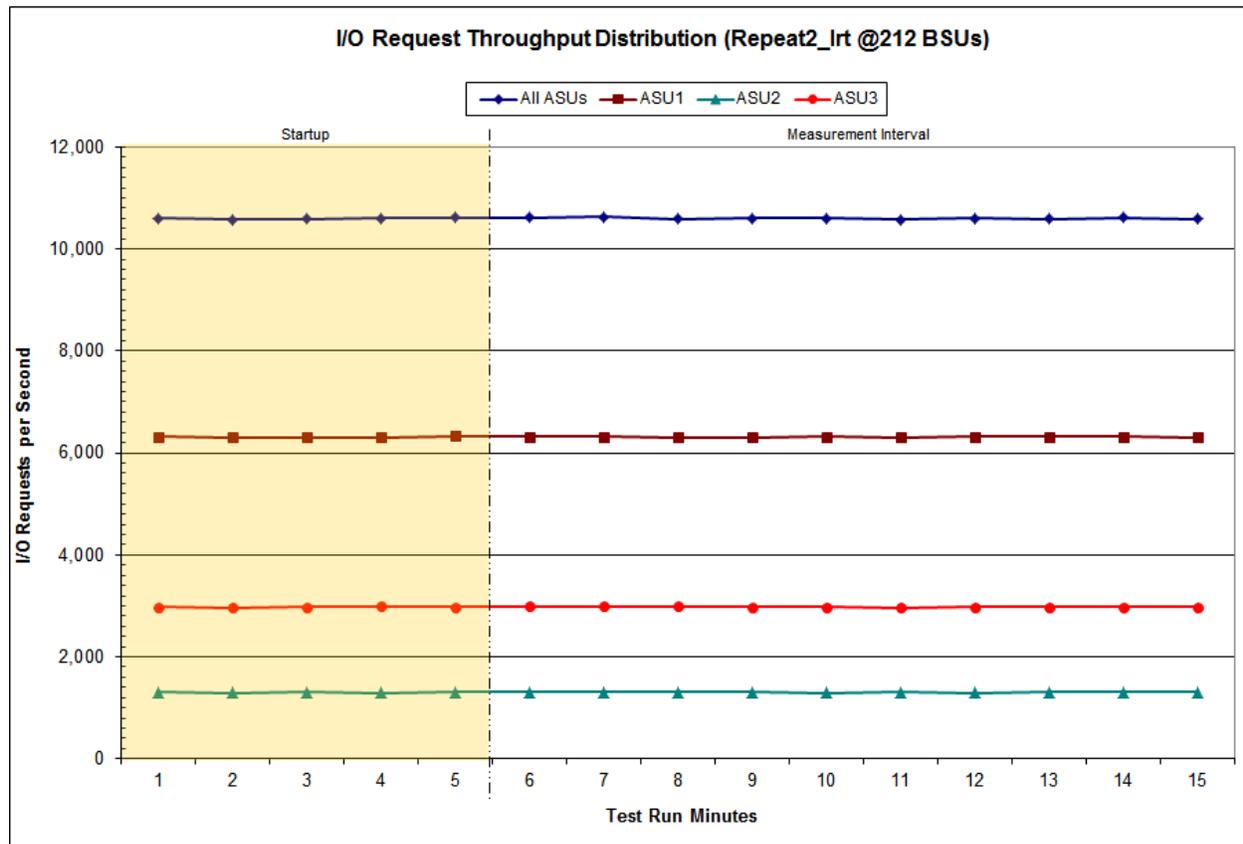
**Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph**



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

212 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	3:18:38	3:23:38	0-4	0:05:00
<i>Measurement Interval</i>	3:23:38	3:33:38	5-14	0:10:00
<b>60 second intervals</b>	<b>All ASUs</b>	<b>ASU1</b>	<b>ASU2</b>	<b>ASU3</b>
0	10,601.10	6,322.72	1,304.78	2,973.60
1	10,572.95	6,305.25	1,299.63	2,968.07
2	10,591.05	6,305.18	1,301.85	2,984.02
3	10,595.25	6,309.27	1,300.87	2,985.12
4	10,617.87	6,330.33	1,305.48	2,982.05
5	10,618.78	6,324.50	1,302.78	2,991.50
6	10,624.08	6,323.80	1,311.67	2,988.62
7	10,592.85	6,299.25	1,308.28	2,985.32
8	10,595.97	6,307.87	1,307.93	2,980.17
9	10,598.05	6,319.70	1,300.08	2,978.27
10	10,569.97	6,304.77	1,301.22	2,963.98
11	10,603.82	6,324.35	1,298.78	2,980.68
12	10,594.43	6,313.73	1,303.57	2,977.13
13	10,612.70	6,322.82	1,306.83	2,983.05
14	10,586.25	6,305.98	1,308.62	2,971.65
<b>Average</b>	<b>10,599.69</b>	<b>6,314.68</b>	<b>1,304.98</b>	<b>2,980.04</b>

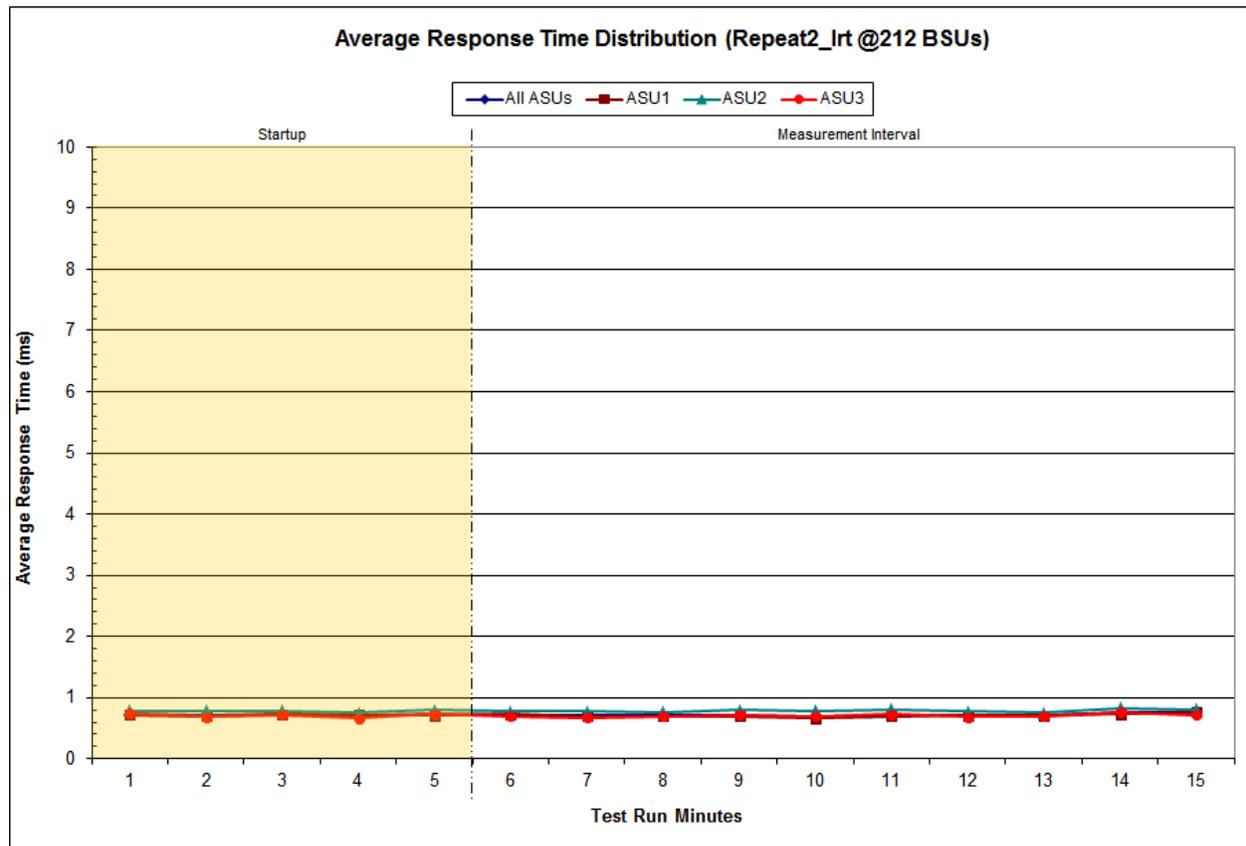
**Repeatability 2 LRT – I/O Request Throughput Distribution Graph**



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

212 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	3:18:38	3:23:38	0-4	0:05:00
<i>Measurement Interval</i>	3:23:38	3:33:38	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	0.73	0.72	0.79	0.75
1	0.71	0.70	0.79	0.69
2	0.74	0.74	0.79	0.72
3	0.71	0.72	0.75	0.67
4	0.73	0.71	0.80	0.73
5	0.72	0.73	0.78	0.70
6	0.70	0.70	0.77	0.68
7	0.71	0.70	0.76	0.69
8	0.72	0.70	0.80	0.71
9	0.69	0.66	0.78	0.70
10	0.72	0.70	0.81	0.73
11	0.71	0.70	0.78	0.68
12	0.71	0.71	0.76	0.70
13	0.76	0.74	0.83	0.77
14	0.76	0.77	0.81	0.72
<b>Average</b>	<b>0.72</b>	<b>0.71</b>	<b>0.79</b>	<b>0.71</b>

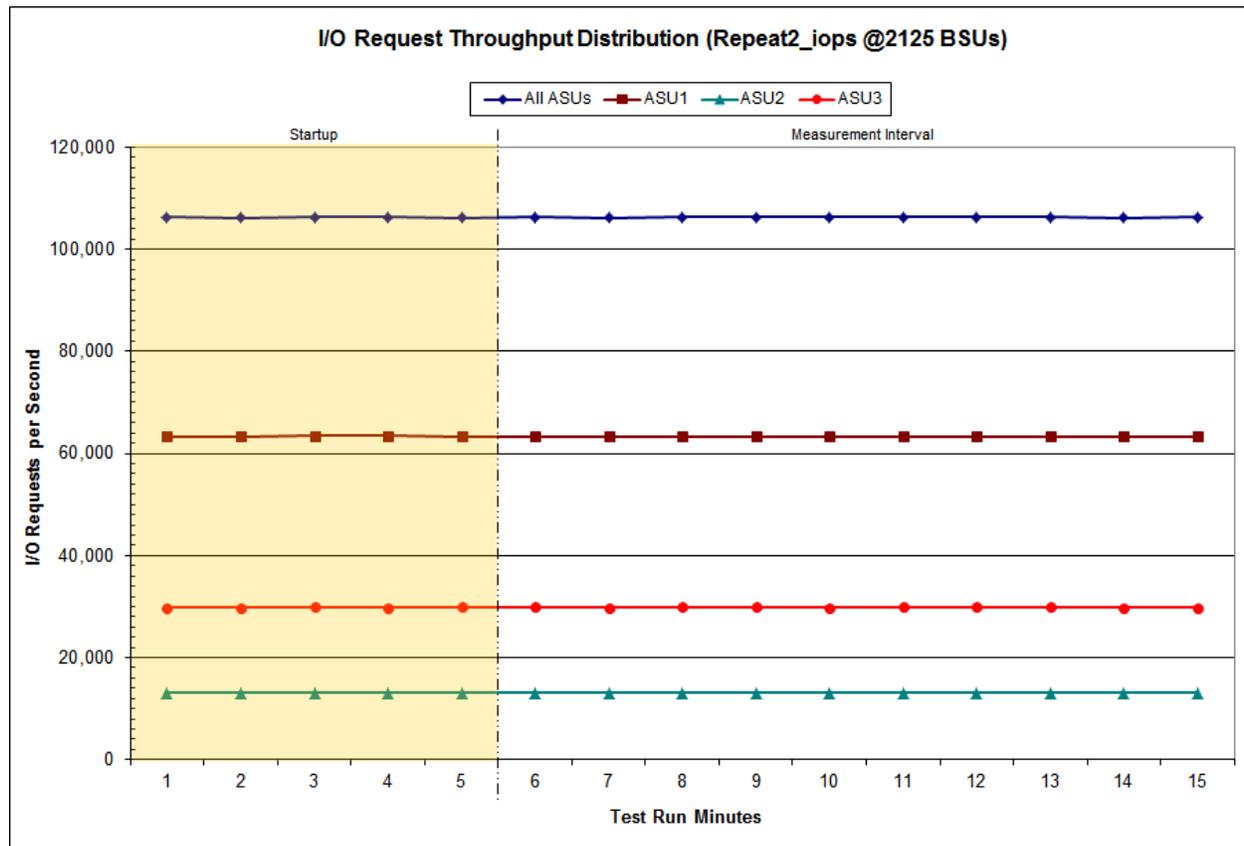
**Repeatability 2 LRT –Average Response Time (ms) Distribution Graph**



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

2,125 BSUs Start-Up/Ramp-Up Measurement Interval	Start	Stop	Interval	Duration
	3:34:00	3:39:01	0-4	0:05:01
	3:39:01	3:49:01	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	106,230.50	63,329.05	13,074.70	29,826.75
1	106,200.57	63,305.75	13,049.65	29,845.17
2	106,313.52	63,398.67	13,052.48	29,862.37
3	106,306.00	63,390.33	13,069.98	29,845.68
4	106,205.95	63,291.77	13,062.95	29,851.23
5	106,243.93	63,313.83	13,063.33	29,866.77
6	106,206.43	63,305.83	13,052.58	29,848.02
7	106,218.18	63,285.22	13,070.87	29,862.10
8	106,285.58	63,381.13	13,052.07	29,852.38
9	106,222.05	63,350.75	13,036.98	29,834.32
10	106,252.92	63,321.72	13,069.53	29,861.67
11	106,247.83	63,317.57	13,067.77	29,862.50
12	106,298.40	63,355.40	13,074.90	29,868.10
13	106,202.38	63,299.85	13,079.42	29,823.12
14	106,242.10	63,342.08	13,058.33	29,841.68
<b>Average</b>	<b>106,241.98</b>	<b>63,327.34</b>	<b>13,062.58</b>	<b>29,852.07</b>

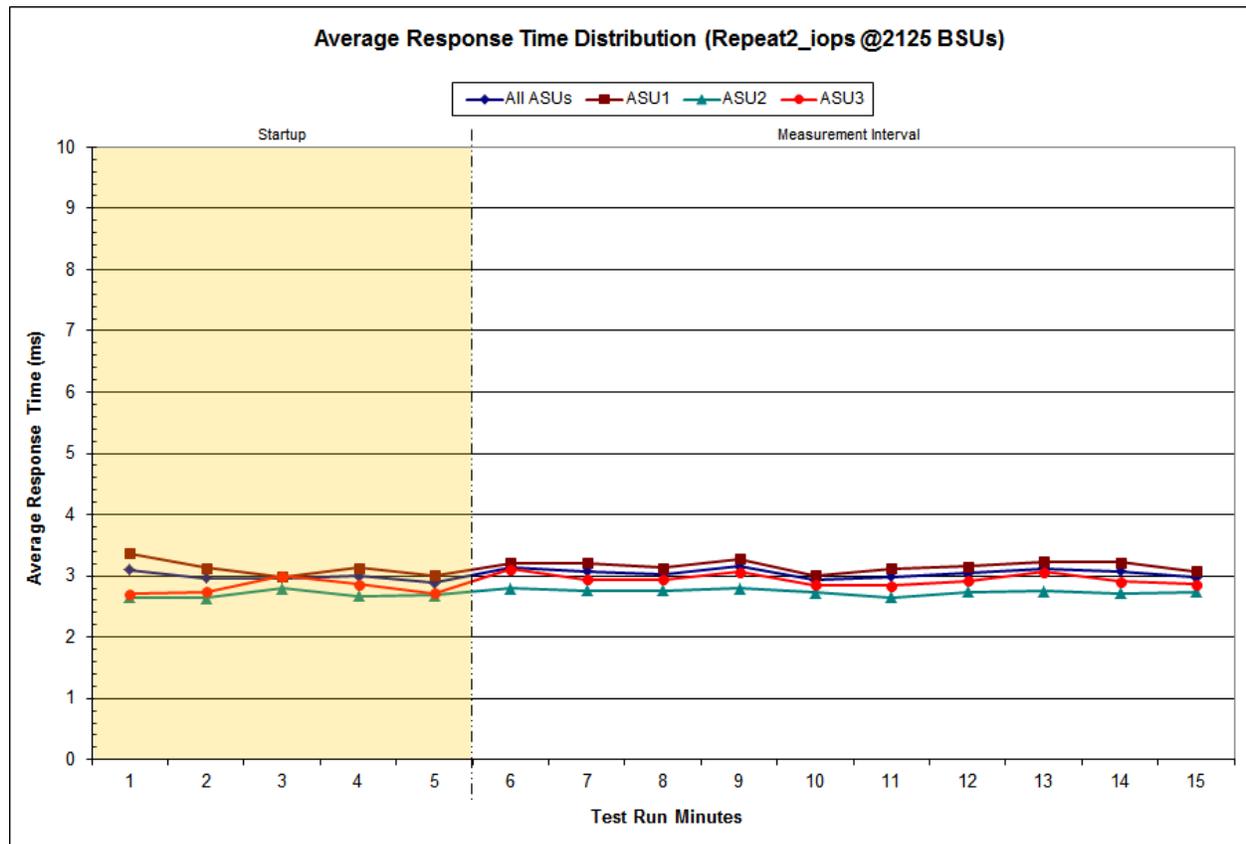
**Repeatability 2 IOPS – I/O Request Throughput Distribution Graph**



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

2,125 BSUs Start-Up/Ramp-Up Measurement Interval	Start	Stop	Interval	Duration
	3:34:00	3:39:01	0-4	0:05:01
	3:39:01	3:49:01	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	3.10	3.37	2.65	2.71
1	2.96	3.13	2.64	2.73
2	2.96	2.98	2.79	2.99
3	3.00	3.13	2.67	2.86
4	2.89	3.01	2.68	2.72
5	3.13	3.21	2.79	3.11
6	3.08	3.21	2.76	2.94
7	3.03	3.13	2.76	2.94
8	3.16	3.27	2.79	3.06
9	2.93	3.01	2.73	2.85
10	2.98	3.12	2.65	2.84
11	3.04	3.15	2.74	2.92
12	3.13	3.23	2.75	3.07
13	3.07	3.22	2.72	2.90
14	2.97	3.07	2.74	2.86
<b>Average</b>	<b>3.05</b>	<b>3.16</b>	<b>2.74</b>	<b>2.95</b>

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



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

*Clause 3.4.3*

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

*Clauses 5.1.10 and 5.3.15.2*

**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
<b>IM</b>	<b>0.0350</b>	<b>0.2810</b>	<b>0.0700</b>	<b>0.2100</b>	<b>0.0180</b>	<b>0.0700</b>	<b>0.0350</b>	<b>0.2810</b>
MIM	0.0350	0.2814	0.0699	0.2097	0.0180	0.0700	0.0349	0.2812
COV	0.005	0.001	0.006	0.001	0.009	0.004	0.007	0.003

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
<b>IM</b>	<b>0.0350</b>	<b>0.2810</b>	<b>0.0700</b>	<b>0.2100</b>	<b>0.0180</b>	<b>0.0700</b>	<b>0.0350</b>	<b>0.2810</b>
MIM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2809
COV	0.002	0.001	0.001	0.001	0.002	0.002	0.001	0.001

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
<b>IM</b>	<b>0.0350</b>	<b>0.2810</b>	<b>0.0700</b>	<b>0.2100</b>	<b>0.0180</b>	<b>0.0700</b>	<b>0.0350</b>	<b>0.2810</b>
MIM	0.0349	0.2812	0.0699	0.2098	0.0180	0.0702	0.0349	0.2811
COV	0.007	0.001	0.004	0.003	0.007	0.004	0.007	0.001

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
<i>IM</i>	<i>0.0350</i>	<i>0.2810</i>	<i>0.0700</i>	<i>0.2100</i>	<i>0.0180</i>	<i>0.0700</i>	<i>0.0350</i>	<i>0.2810</i>
MIM	0.0350	0.2810	0.0700	0.2101	0.0180	0.0700	0.0350	0.2810
COV	0.002	0.000	0.002	0.001	0.003	0.001	0.002	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 [93](#).

## Data Persistence Test Results File

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

[Persistence 1 Test Results File](#)

[Persistence 2 Test Results File](#)

### Data Persistence Test Results

<b>Data Persistence Test Results</b>	
Data Persistence Test Run Number: 1	
Total Number of Logical Blocks Written	254,717,776
Total Number of Logical Blocks Verified	109,658,128
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 gibibyte (GiB) is equal to 1,073,741,824 ( $2^{30}$ ) bytes.

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

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

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

## **SPC-1 Data Repository Definitions**

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

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

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

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

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

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

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

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

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

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

## SPC-1 Data Protection Levels

**Protected 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.

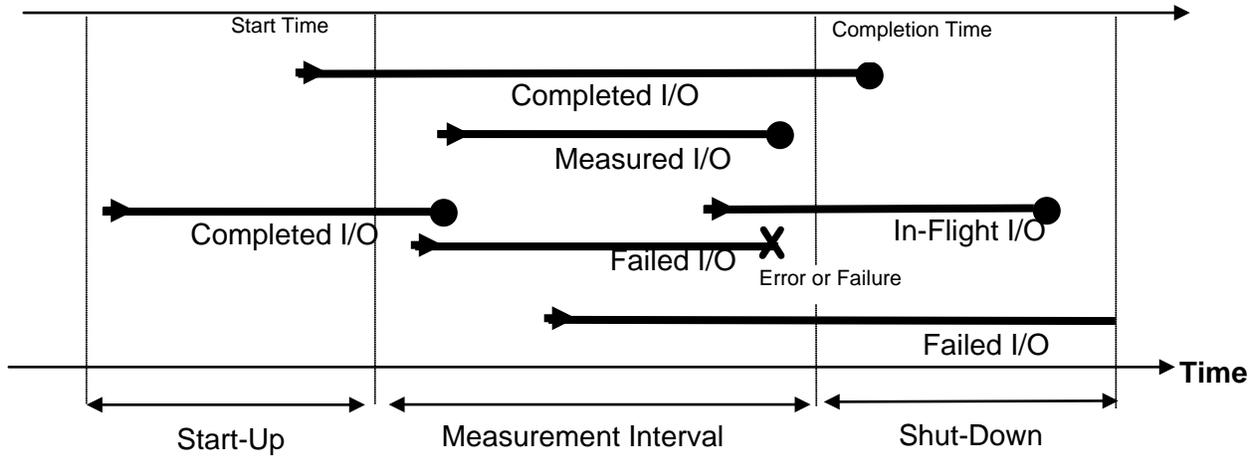
**Steady State:** The consistent and sustainable throughput of the TSC. During this period the load presented to the TSC by the Workload Generator is constant.

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

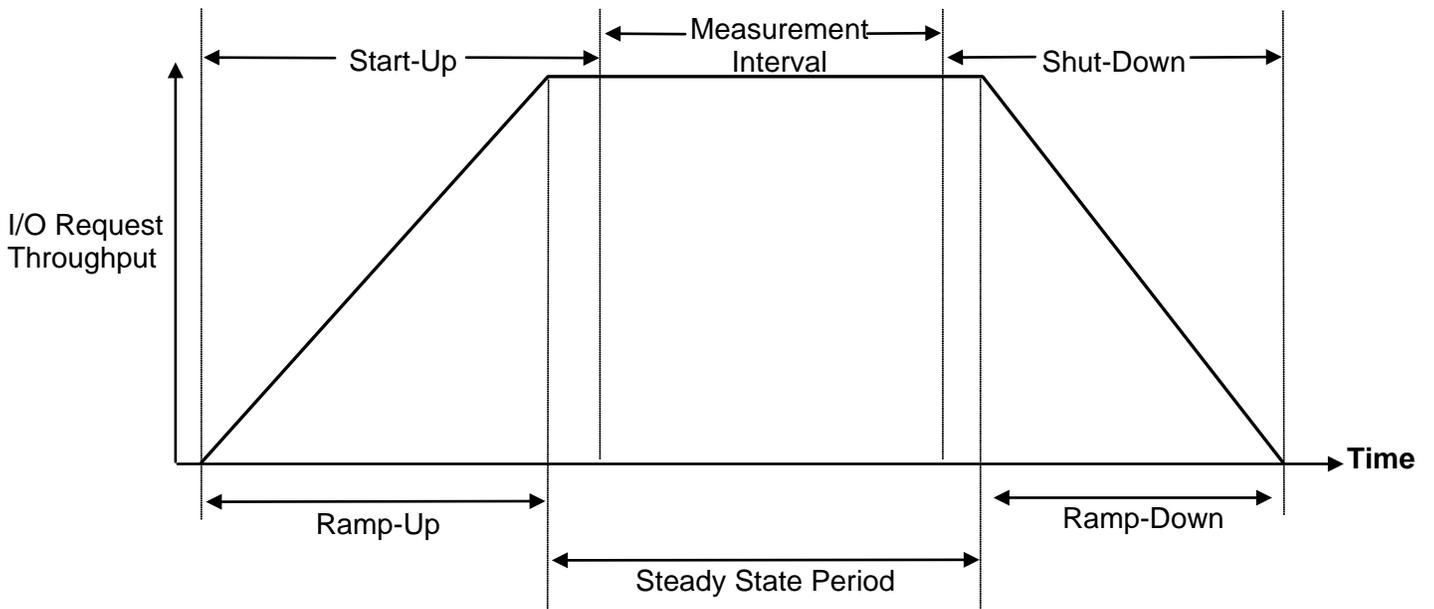
**Test Run:** The execution of SPC-1 for the purpose of producing or supporting an SPC-1 test result. SPC-1 Test Runs may have a finite and measured Ramp-Up period, Start-Up period, Shut-Down period, and Ramp-Down period as illustrated in the “SPC-1 Test Run Components” below. All SPC-1 Test Runs shall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



### SPC-1 Test Run Components



## **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 [70](#).

### **RAID Scrub**

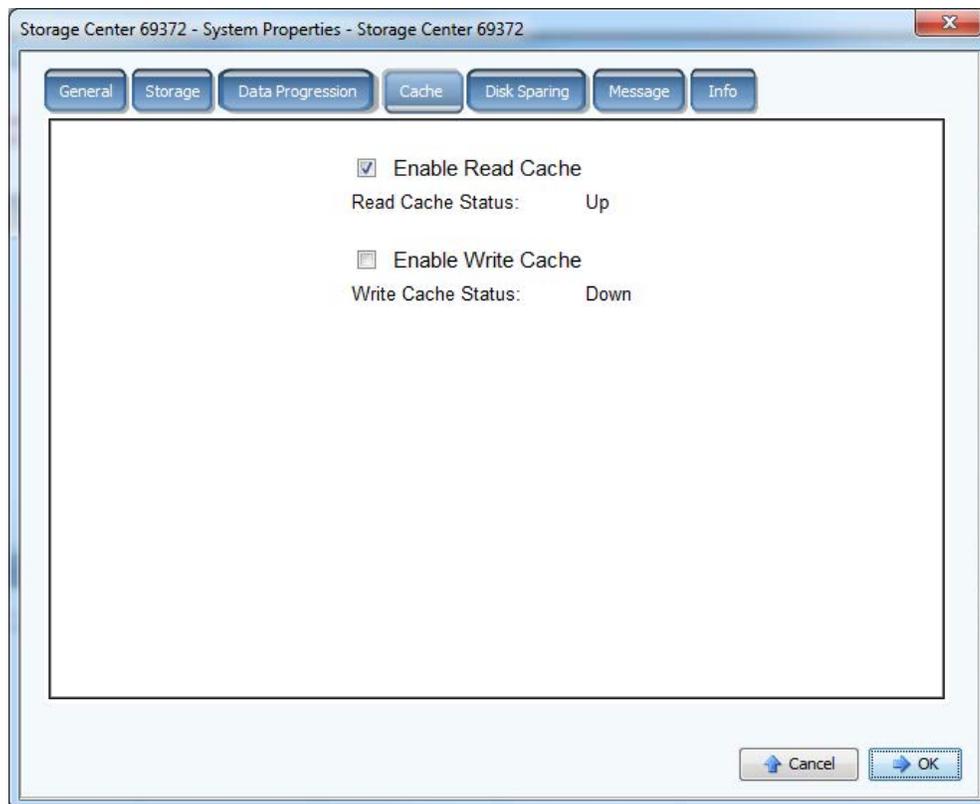
This process runs in the background at low priority. It ensures RAID stripe parity information is consistent with RAID stripe data and only executes if the RAID device has not been scrubbed for a week. Given that this process executes so infrequently, it was disabled for the benchmark measurements.

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

```
raid global set ScrubAdminStatus disable
```

### **System Write Cache**

The system write cache was disabled for the benchmark measurements because SSDs were used for Tier 1 storage. This parameter was disabled by clicking on System Properties in the main Storage Center screen. In the System Properties window, select the Cache tab and then unselect the Enable Write Cache option as illustrated below.

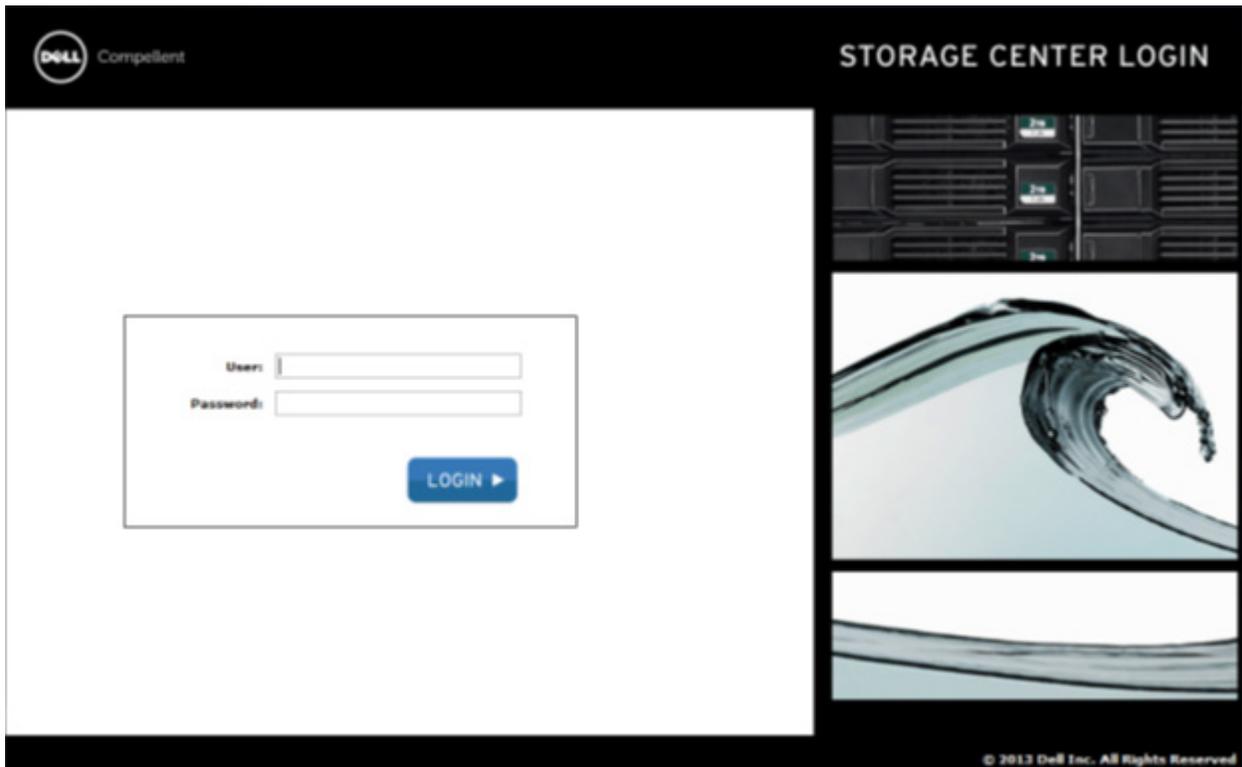


## APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

### Logon to the System Manager

Follow these steps to log on to System Manager:

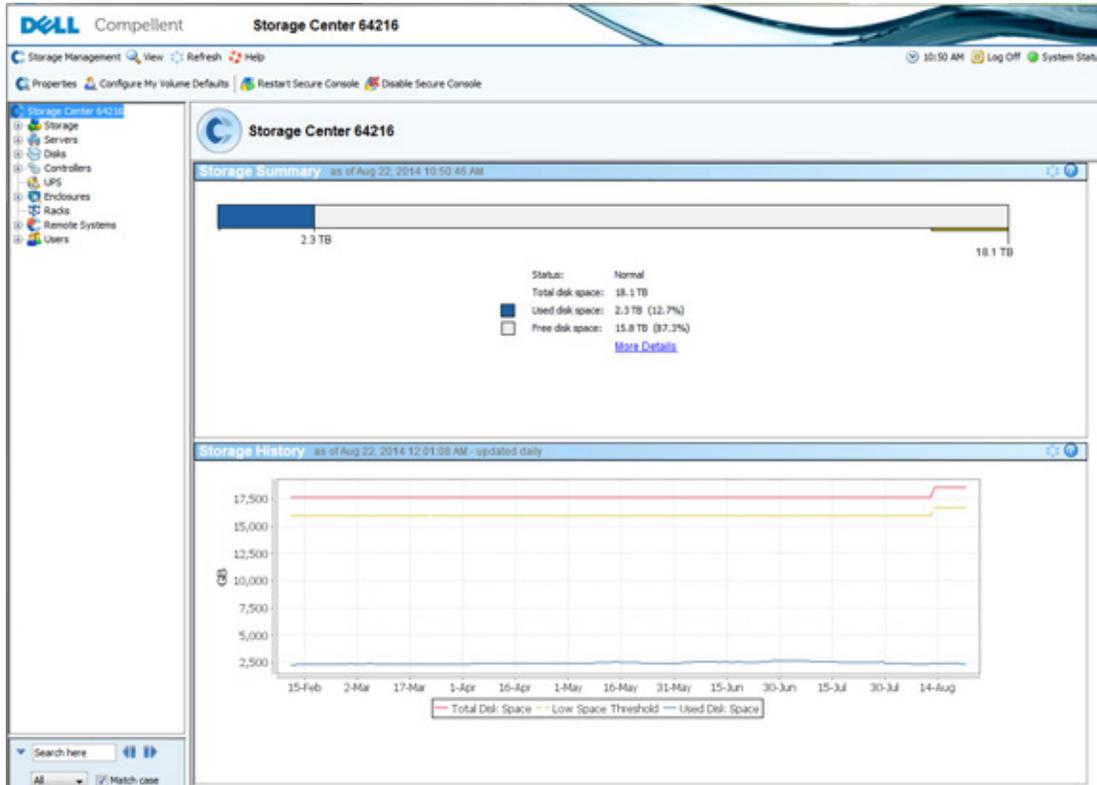
1. In the address bar of a web browser on the Host System, enter the IP address of the Management controller.
2. Click **Continue** to acknowledge the messages and alerts. The Storage Center Storage Center Login dialog box will appear.



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.

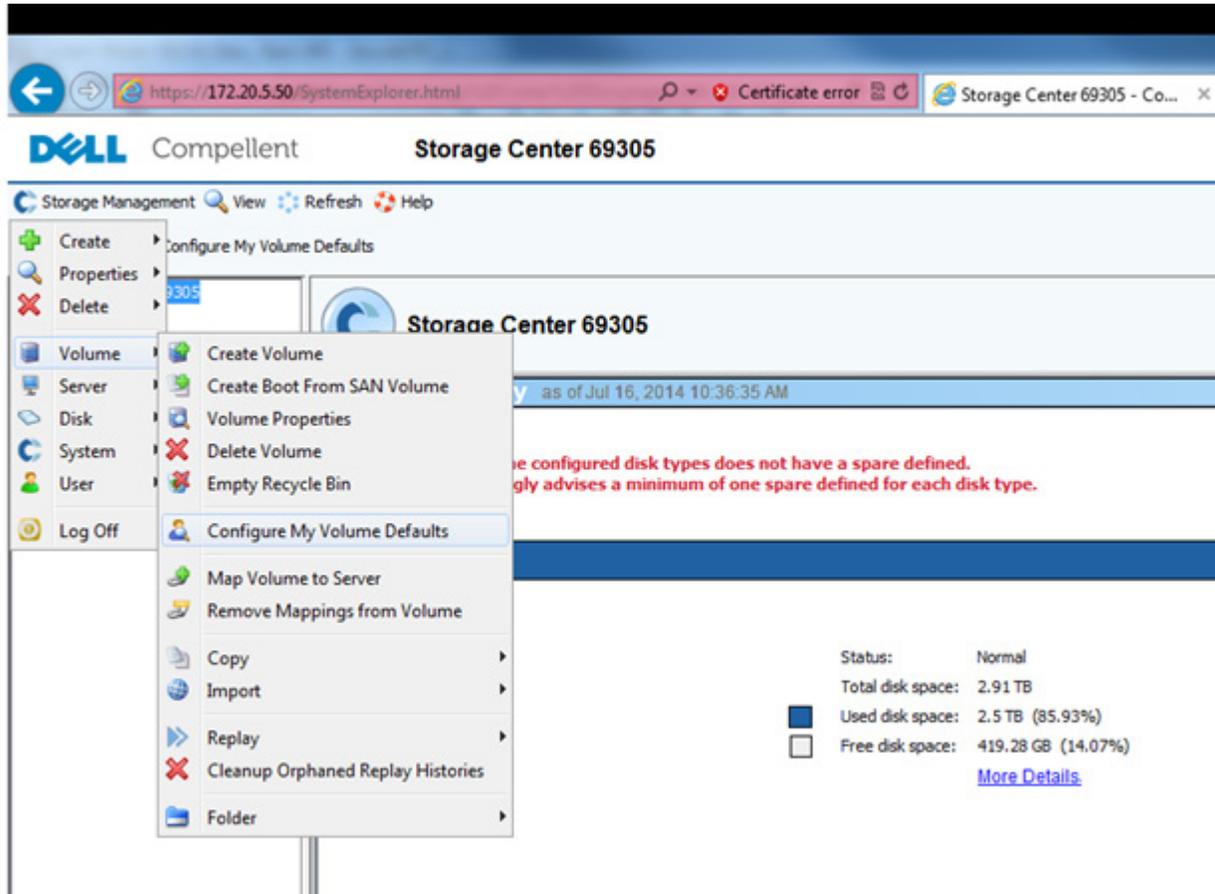
## View the System Dashboard

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

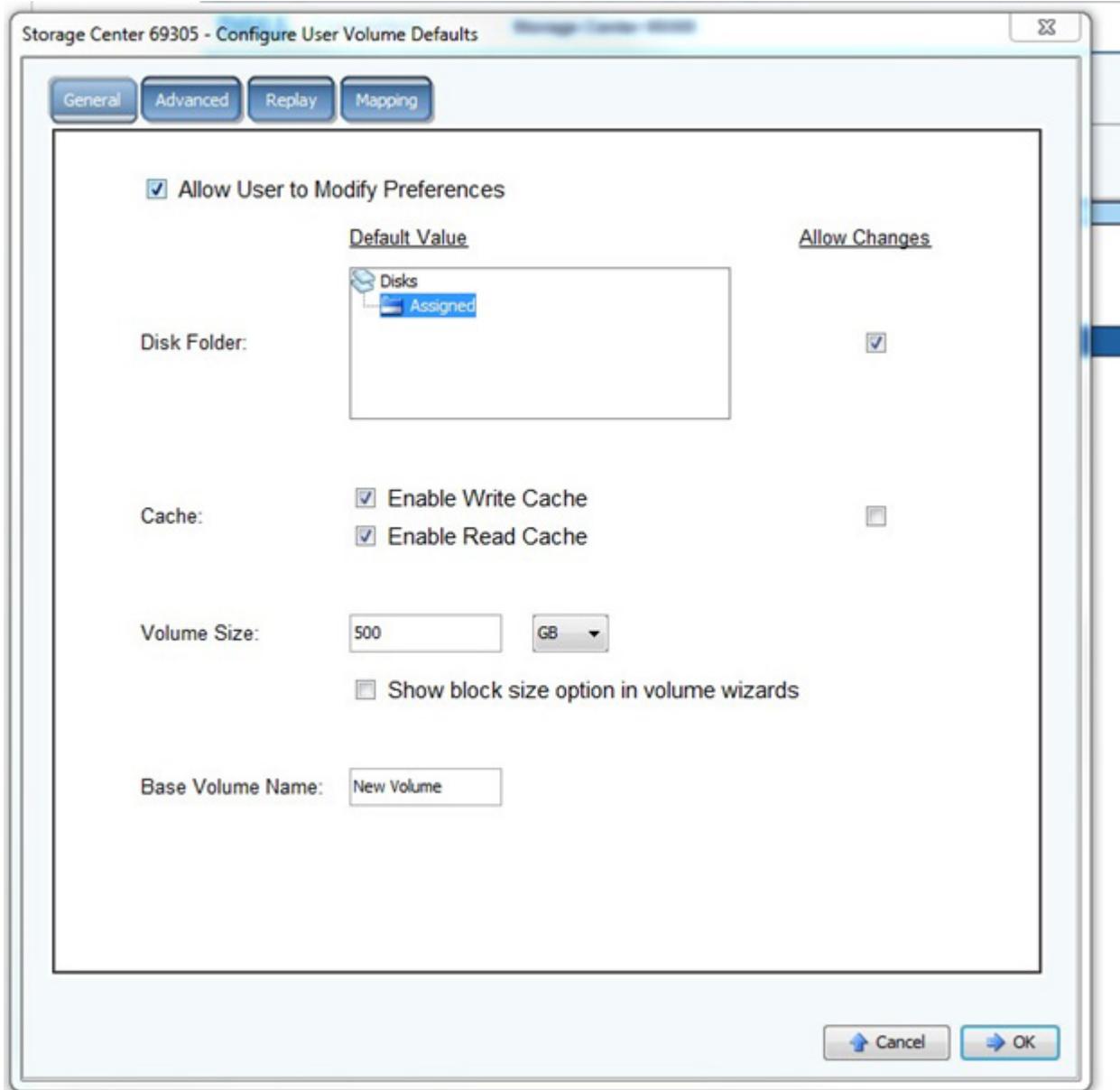


## Configure Volume Defaults

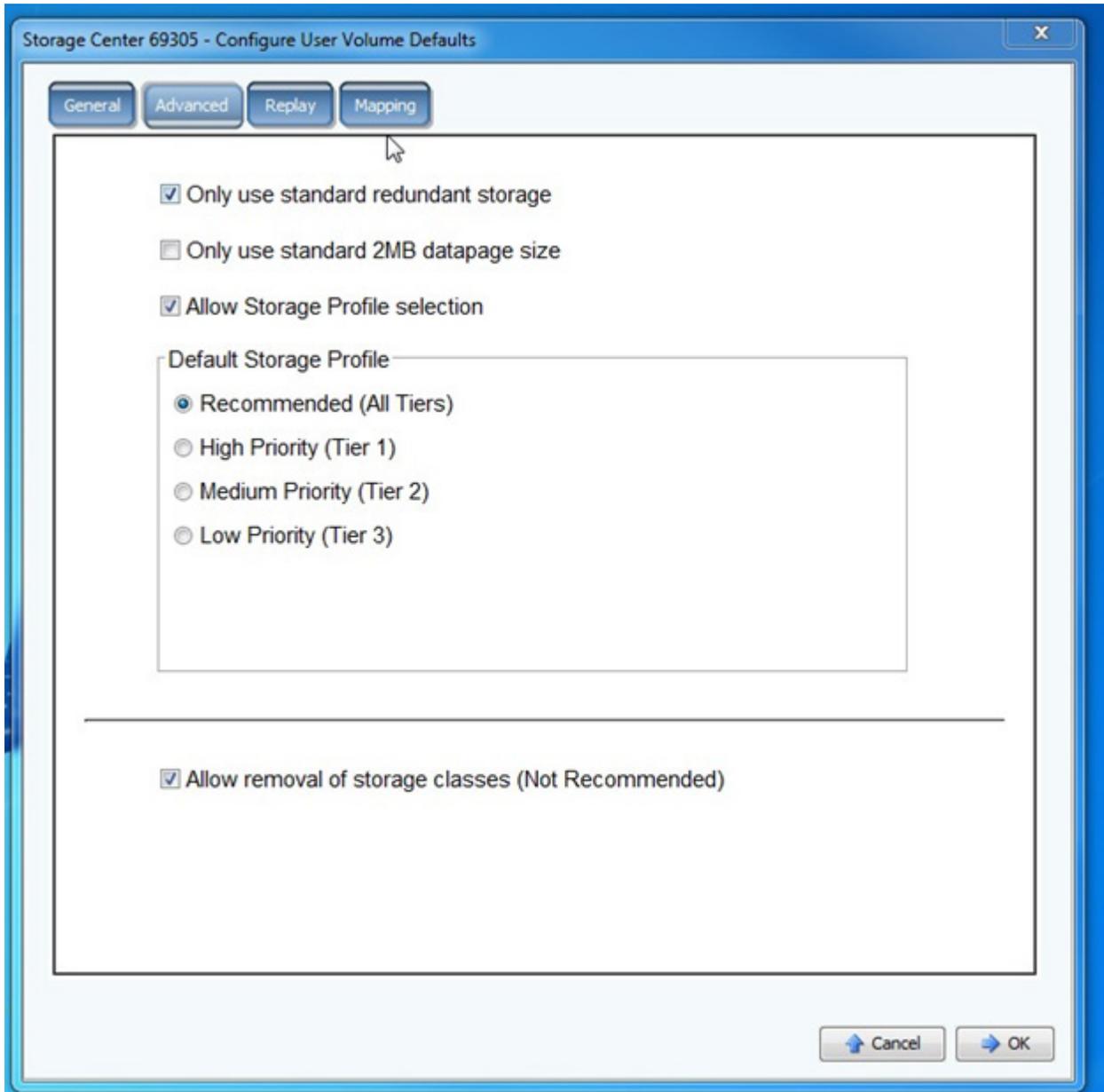
1. Select **Storage Management**, select **Volume** and then select **Configure My Volume Defaults**.



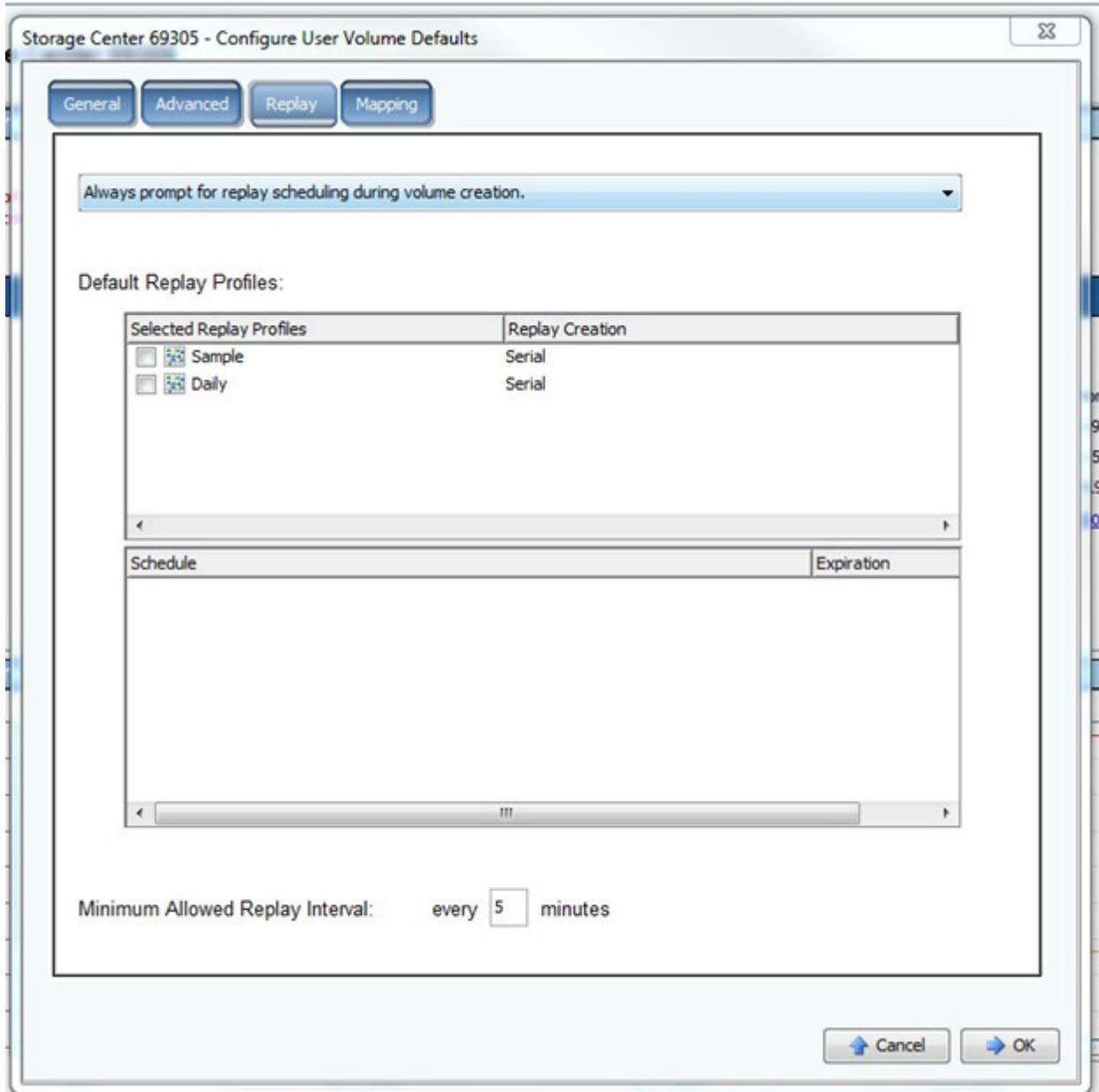
2. The **Configure User Volume Defaults** screen will be displayed. Select the **Advanced** tab.



3. Select the following on the **Advanced** screen:
  - **Only use standard redundant storage**
  - **Allow Storage Profile selection**
  - **Allow removal of storage classes**

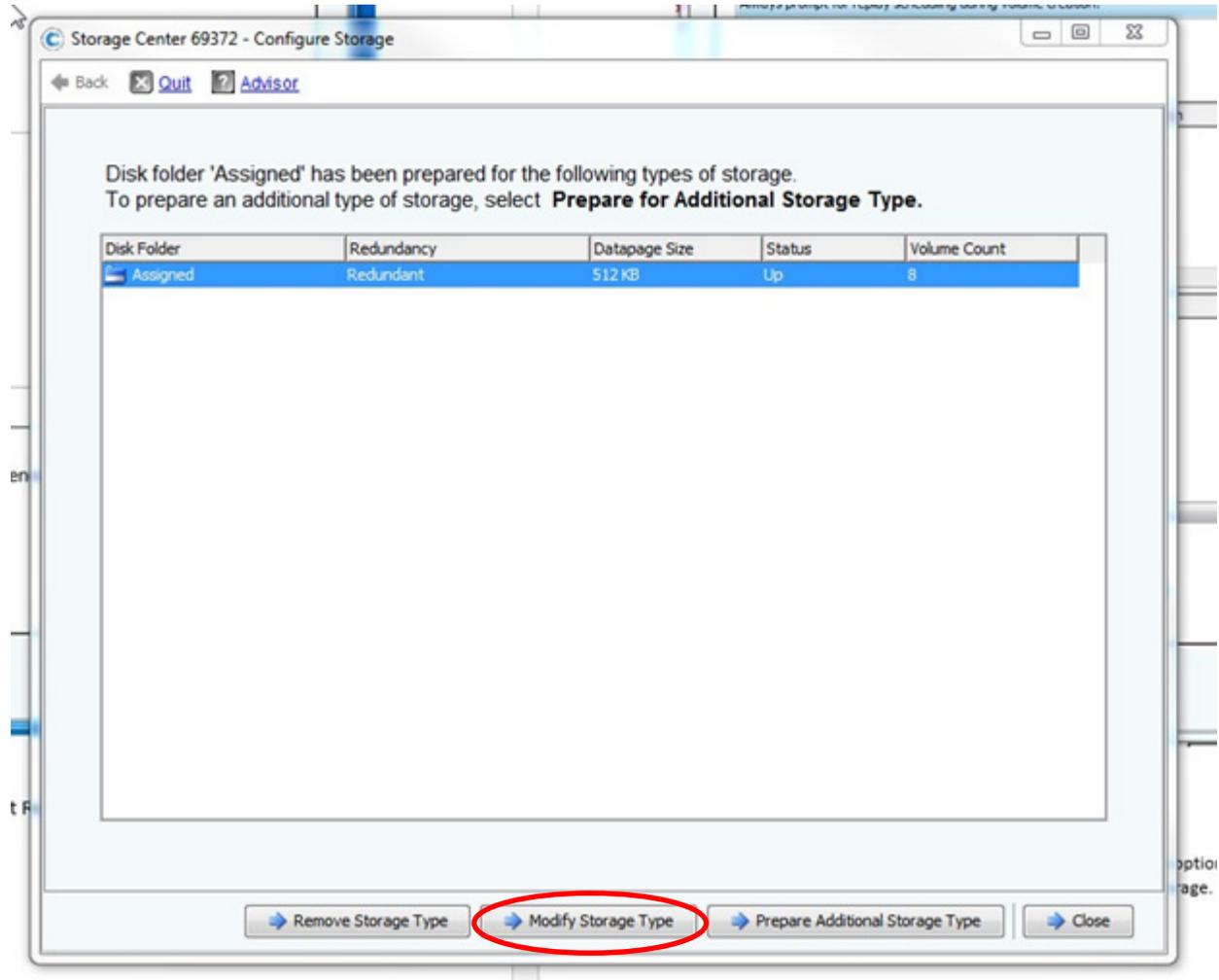


4. Select the **Replay** tab, clear the **Daily** checkbox in the **Default Replay Profiles** section.
5. Click **OK**.

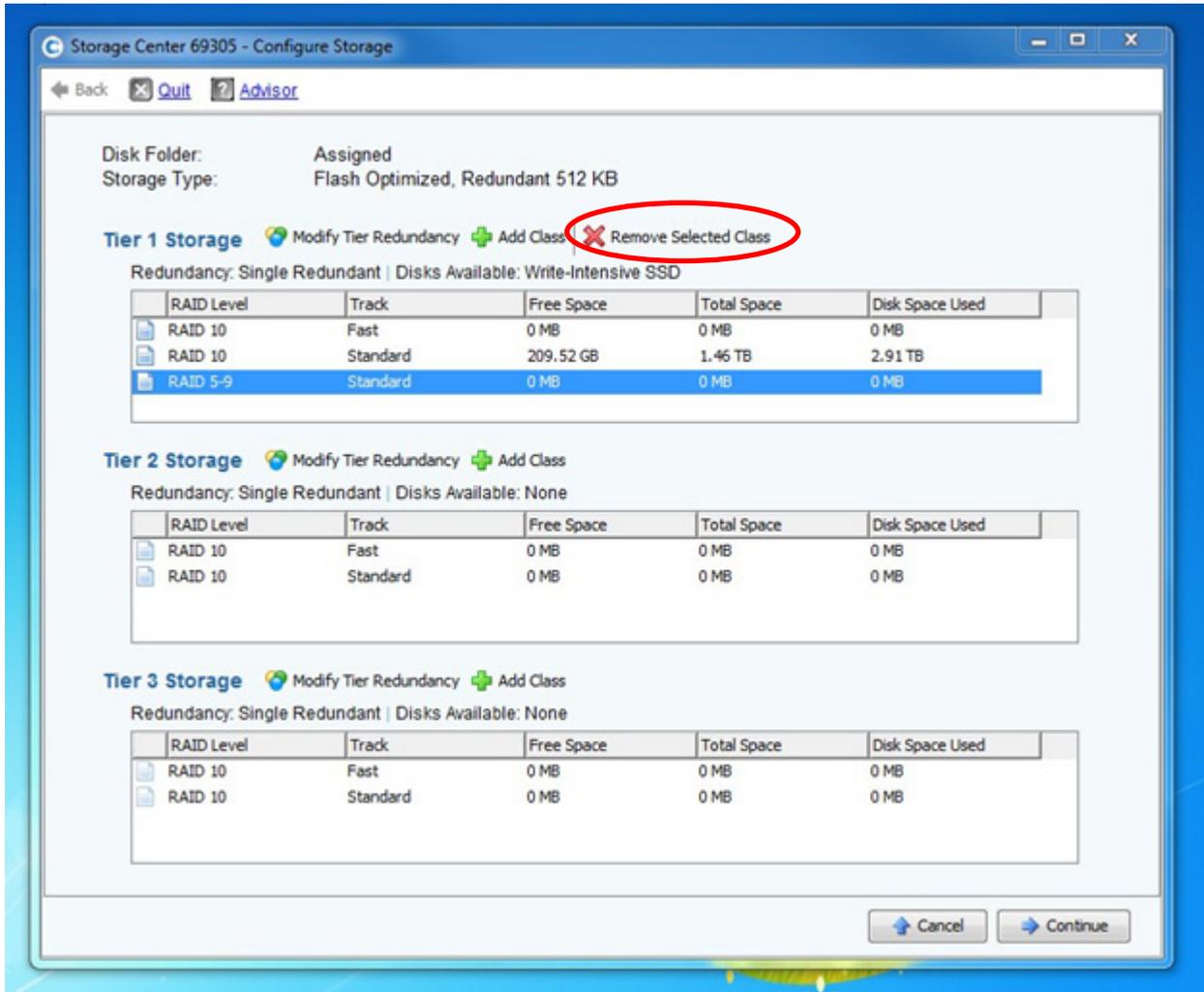


## Configure Storage

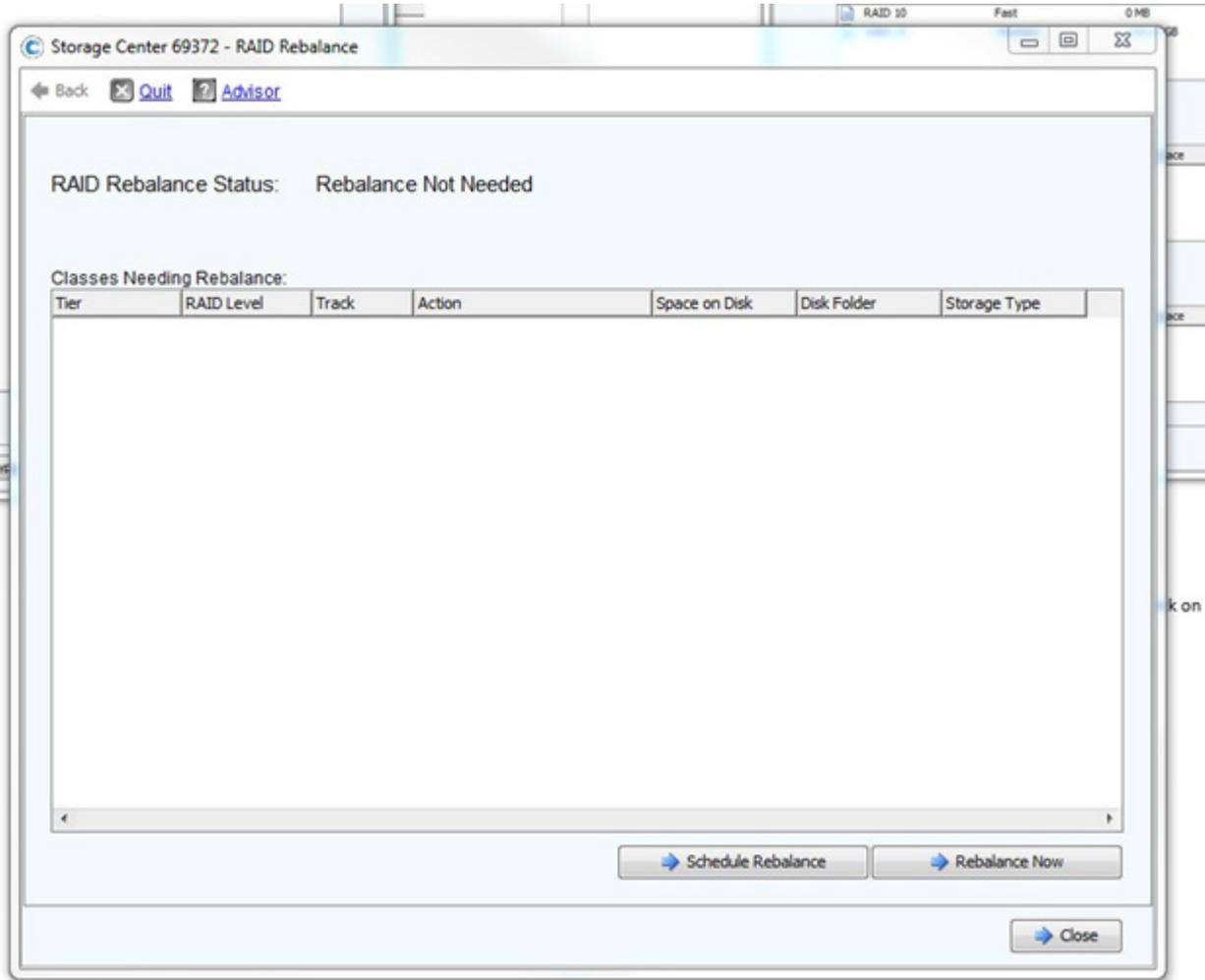
1. Select **Storage Management**, select **Disk** and then select **Configure Storage**.
2. Select **Modify Storage Type** on the **Configure Storage** screen.



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.



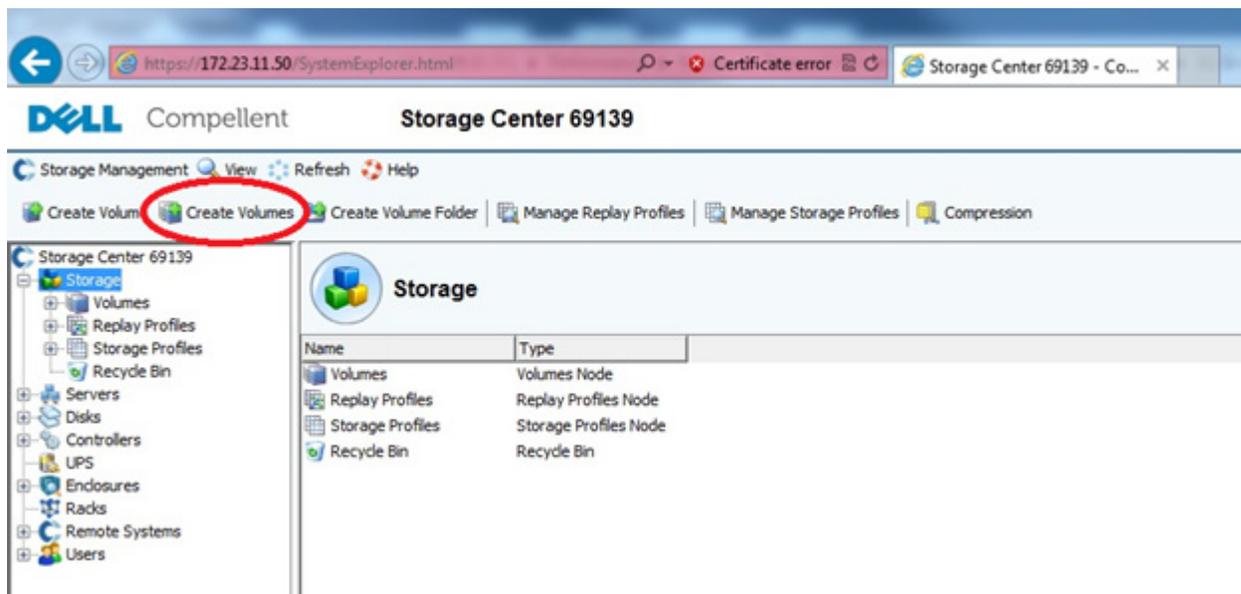
## Create Volumes

This section will create eight volumes with the follow capacities:

- Four volumes, each with a capacity of 109.5 GB
- Three volumes, each with a capacity of 145.9 GB
- One volume with a capacity of 97.5 GB

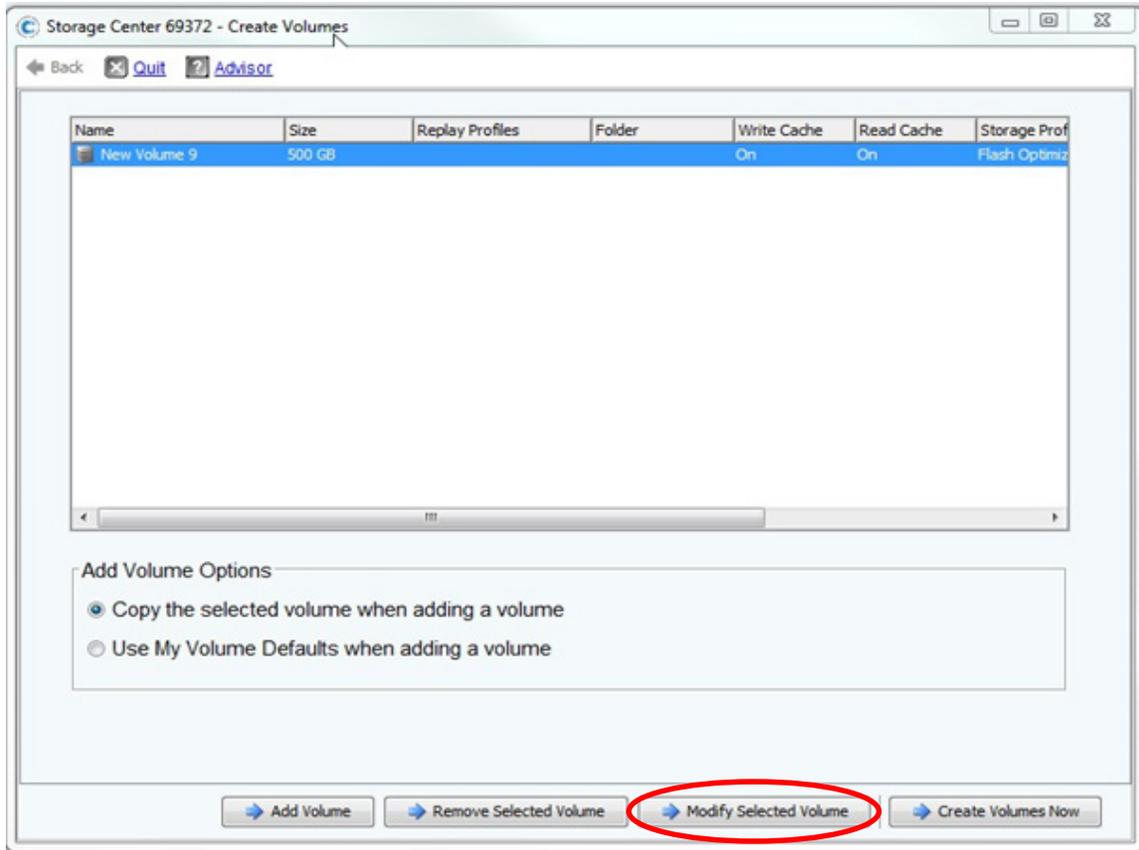
Initially, eight volumes, each with a capacity of 109.95 GB, will be created.

1. In the System Tree, select **Storage**
2. Click on **Create Volumes** to create the first volume

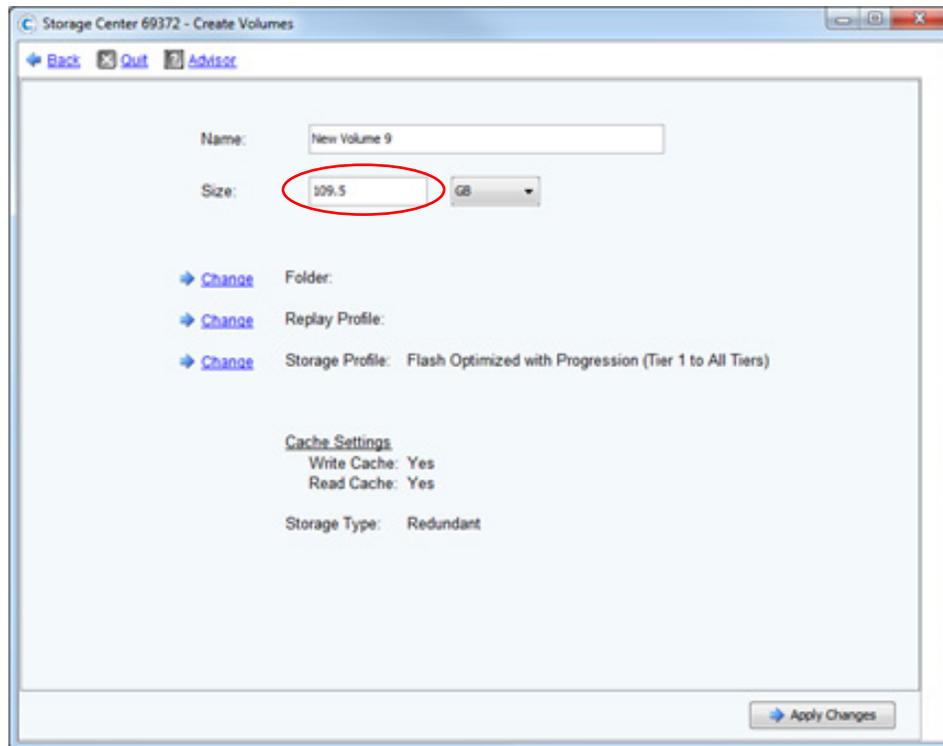


The Create Volumes wizard appears showing a default volume to create.

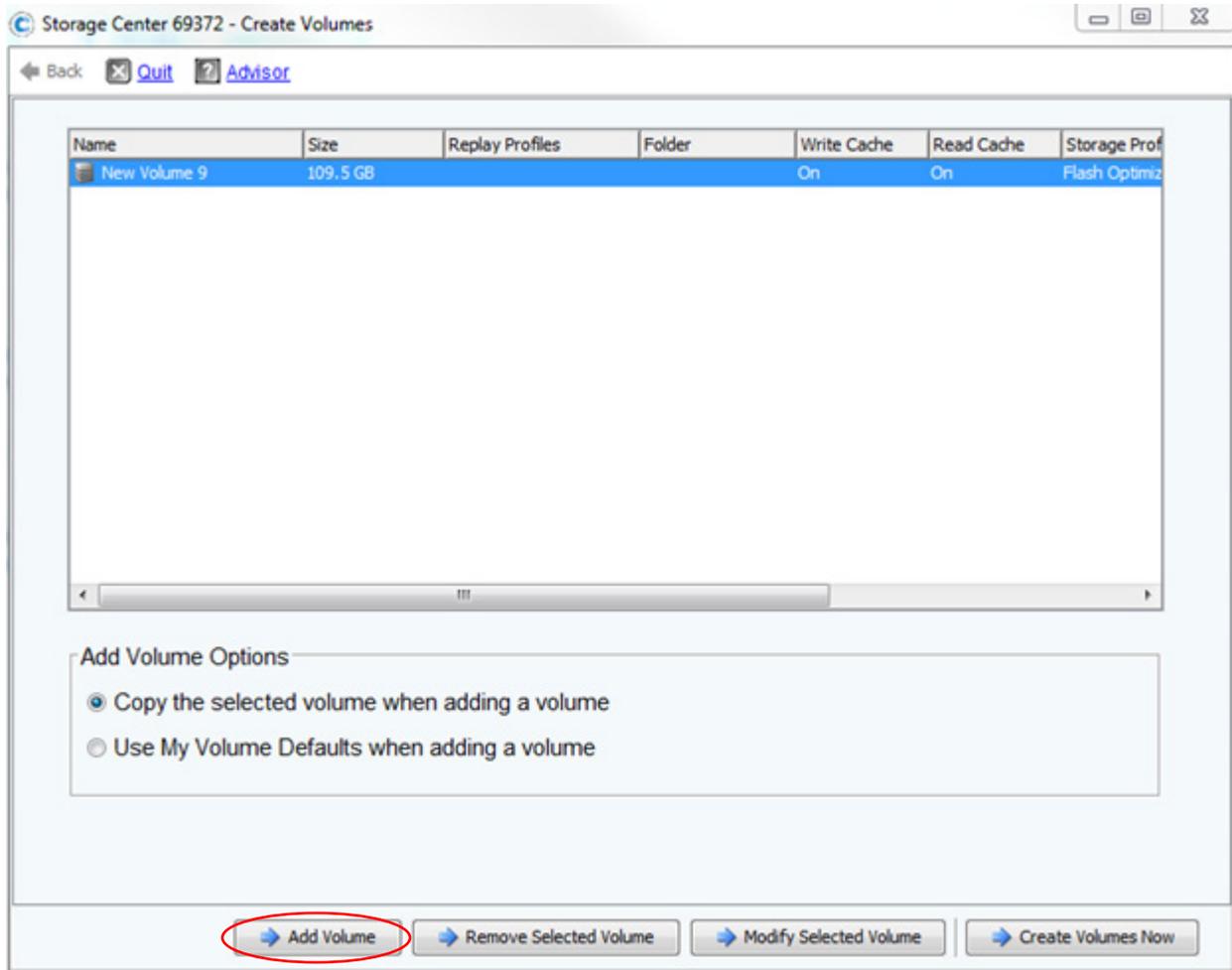
3. Select **Modify Selected Volume** on the Create Volumes screen.



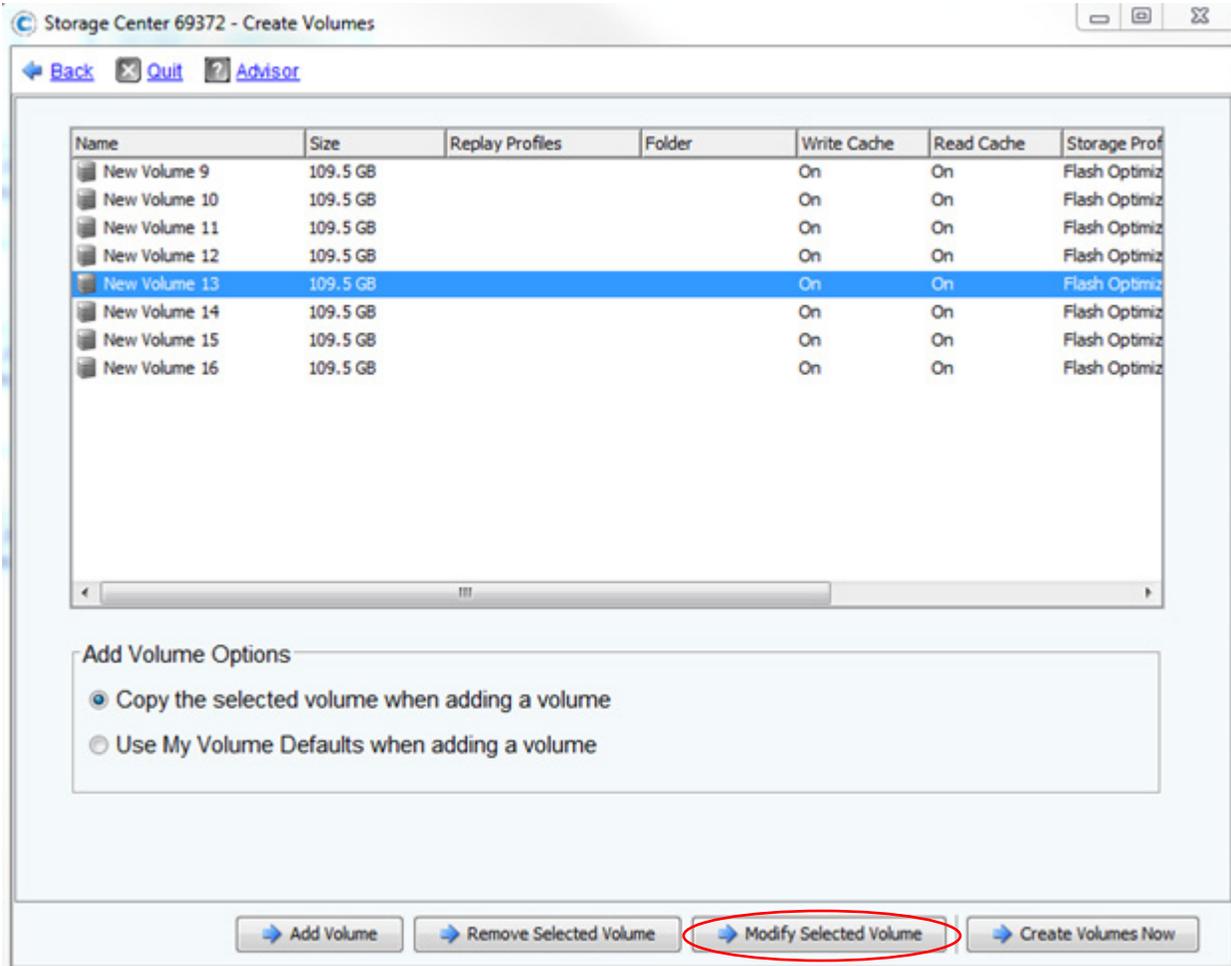
4. Change the value in the **Size** box to 109.5 and click **Apply Changes**.



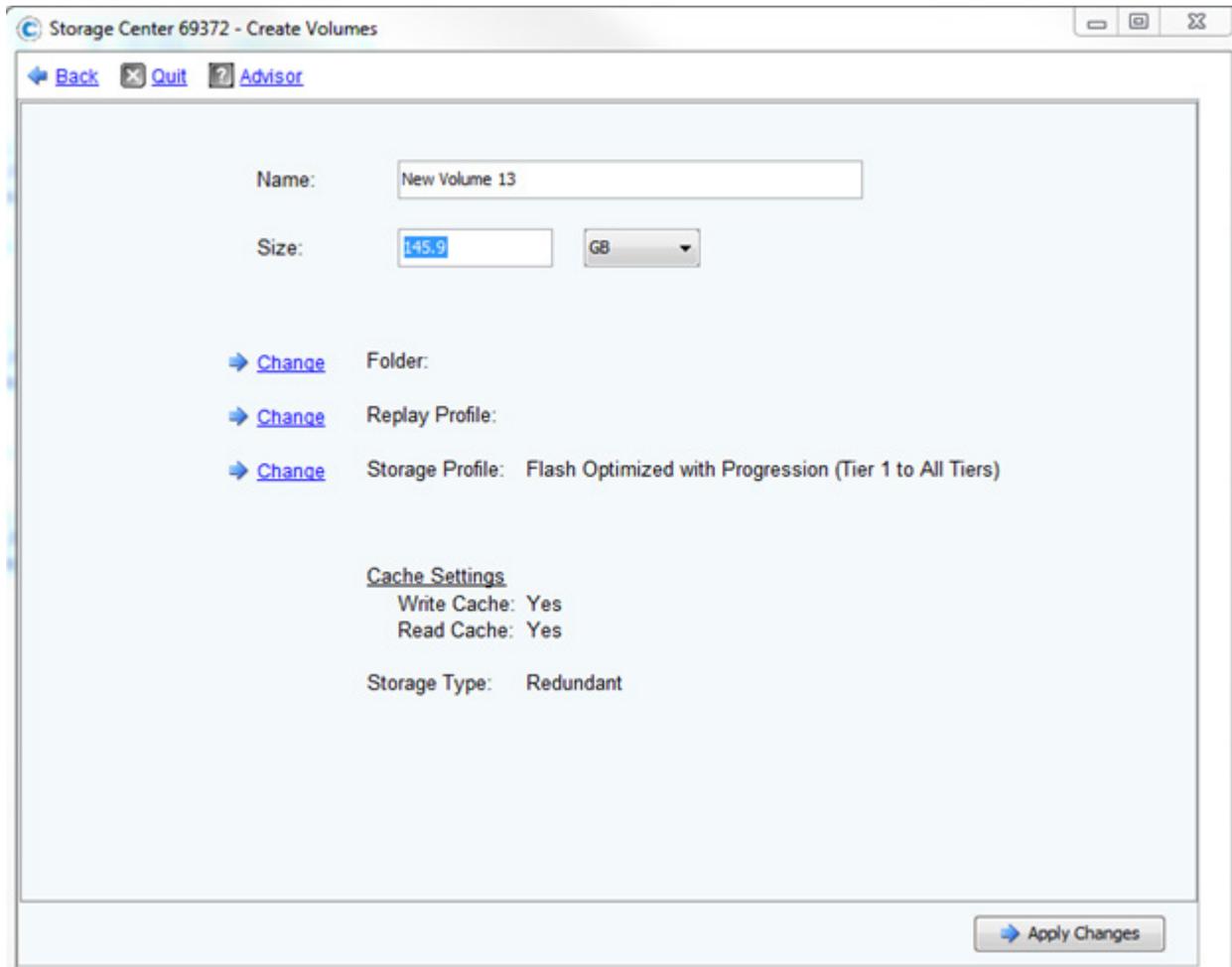
5. Create seven additional volume each with a capacity of 109.5 GB by clicking **Add Volume** seven times, once for each additional item.



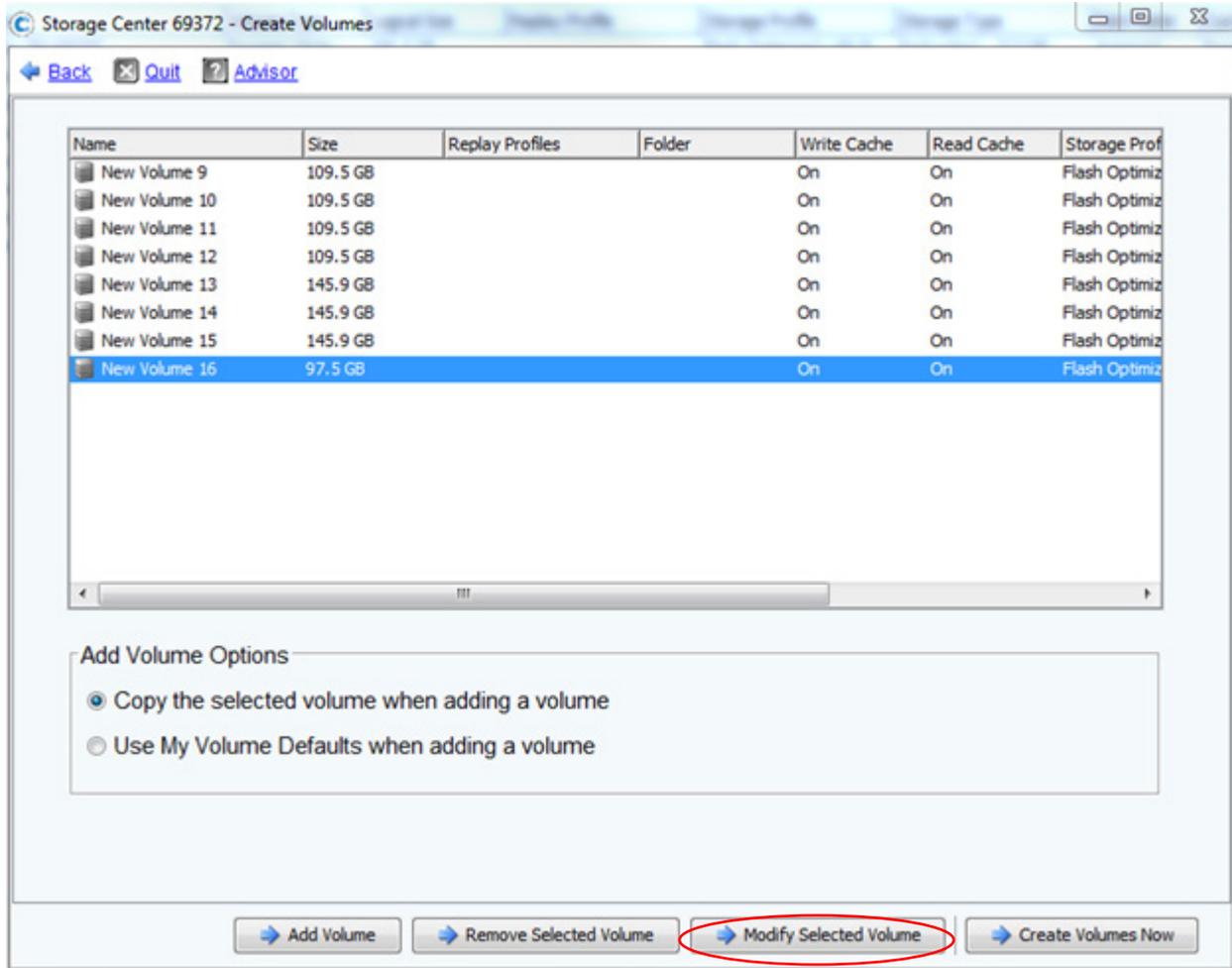
6. Select **New Volume 13** and click **Modify Selected Volume**.



7. Change the value in the **Size** box to 145.9 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 145.9 GB..



9. Select New Volume 16 and click **Modify Selected Volume**.



10. Change the value in the **Size** box to 97.5 and click **Apply Changes**.

Storage Center 69372 - Create Volumes

Back Quit Advisor

Name:

Size:

→ [Change](#) Folder:

→ [Change](#) Replay Profile:

→ [Change](#) Storage Profile: Flash Optimized with Progression (Tier 1 to All Tiers)

Cache Settings  
Write Cache: Yes  
Read Cache: Yes

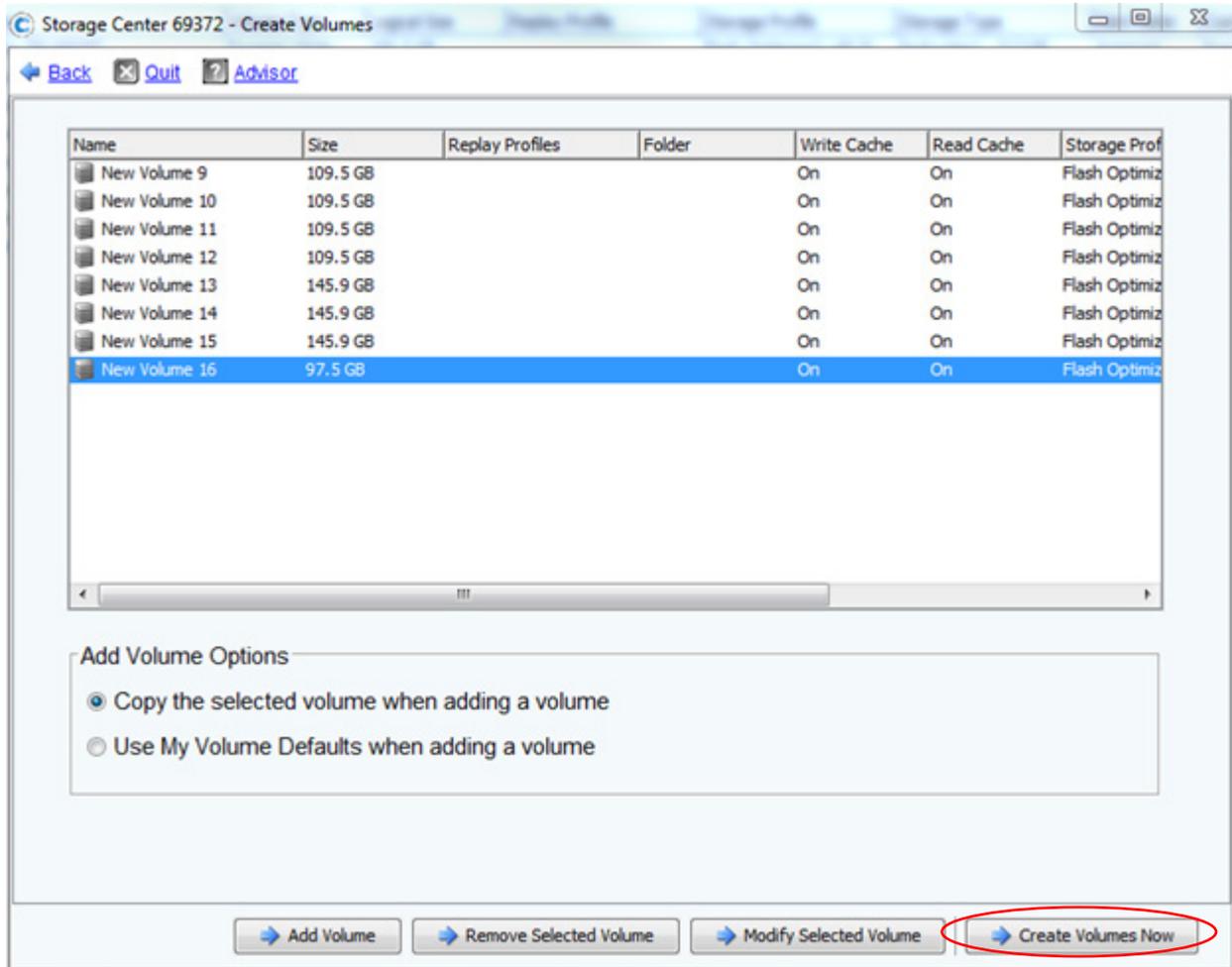
Storage Type: Redundant

→ Apply Changes

The Create Volumes screen should list eight volumes as follows:

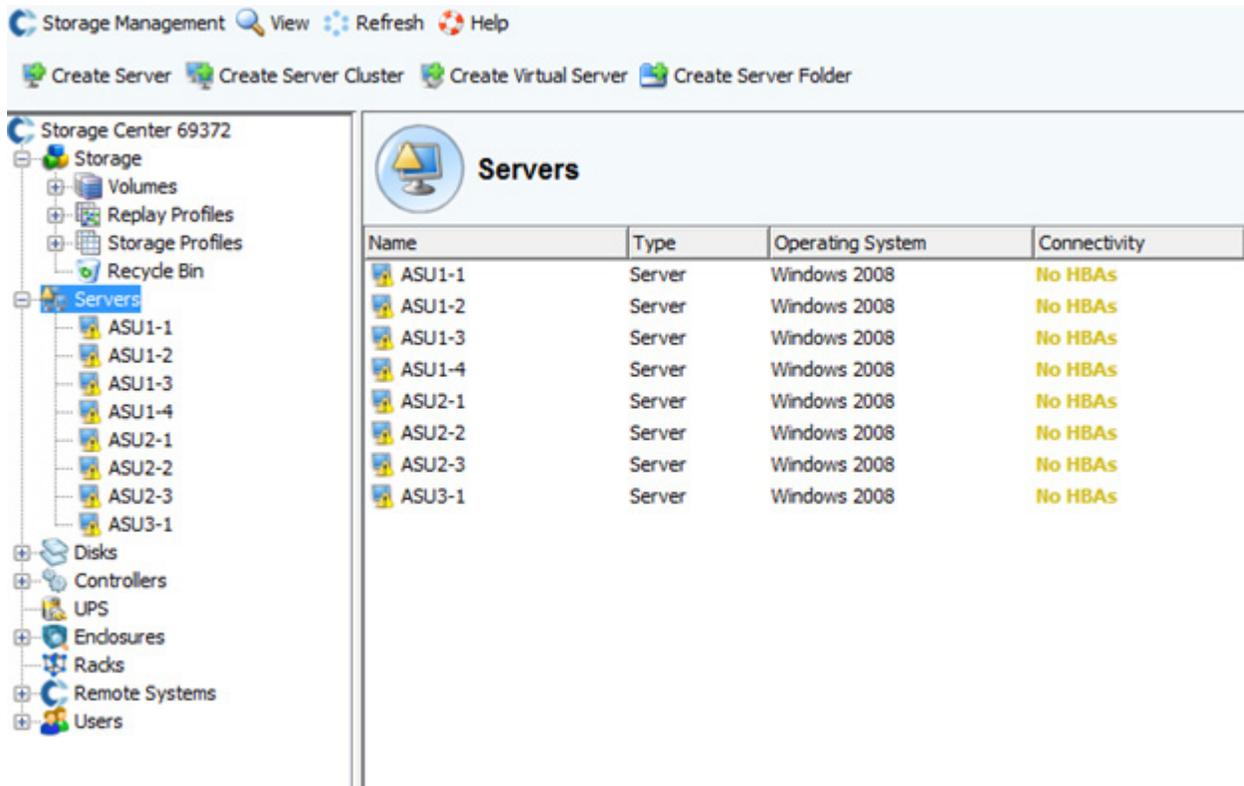
- Four volumes, each with a capacity of 109.5 GB
- Three volumes, each with a capacity of 145.9 GB
- One volume with a capacity of 97.5 GB

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



## Create Servers

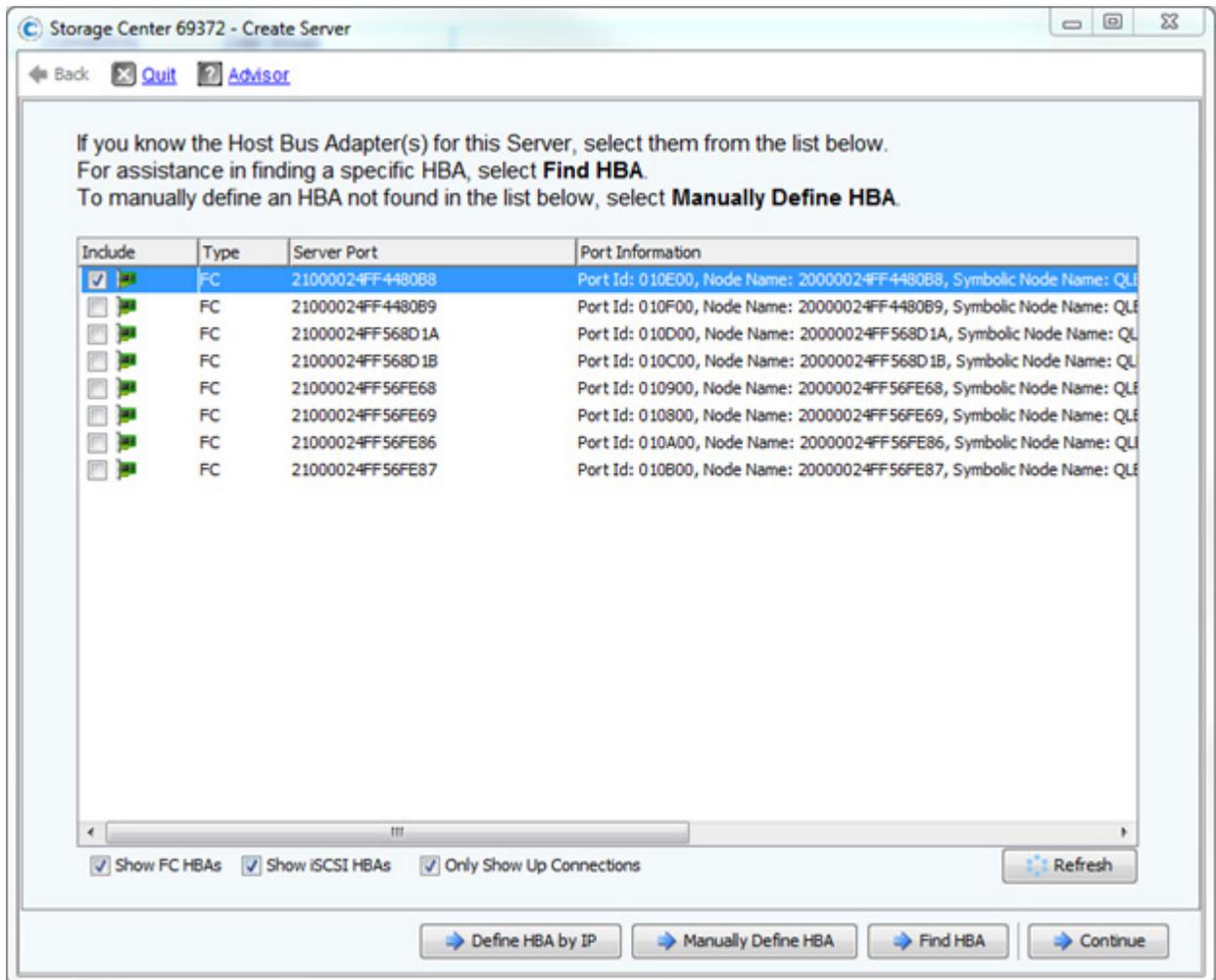
1. Select **Servers** and then click on **Create Server**.



The screenshot shows the Storage Management console interface. The top navigation bar includes 'Storage Management', 'View', 'Refresh', and 'Help'. Below this are buttons for 'Create Server', 'Create Server Cluster', 'Create Virtual Server', and 'Create Server Folder'. The left sidebar shows a tree view with 'Storage Center 69372' expanded to 'Storage', and 'Servers' selected. The main pane displays a table of servers.

Name	Type	Operating System	Connectivity
ASU1-1	Server	Windows 2008	No HBAs
ASU1-2	Server	Windows 2008	No HBAs
ASU1-3	Server	Windows 2008	No HBAs
ASU1-4	Server	Windows 2008	No HBAs
ASU2-1	Server	Windows 2008	No HBAs
ASU2-2	Server	Windows 2008	No HBAs
ASU2-3	Server	Windows 2008	No HBAs
ASU3-1	Server	Windows 2008	No HBAs

2. Select the first HBA port from the list and click **Continue**.

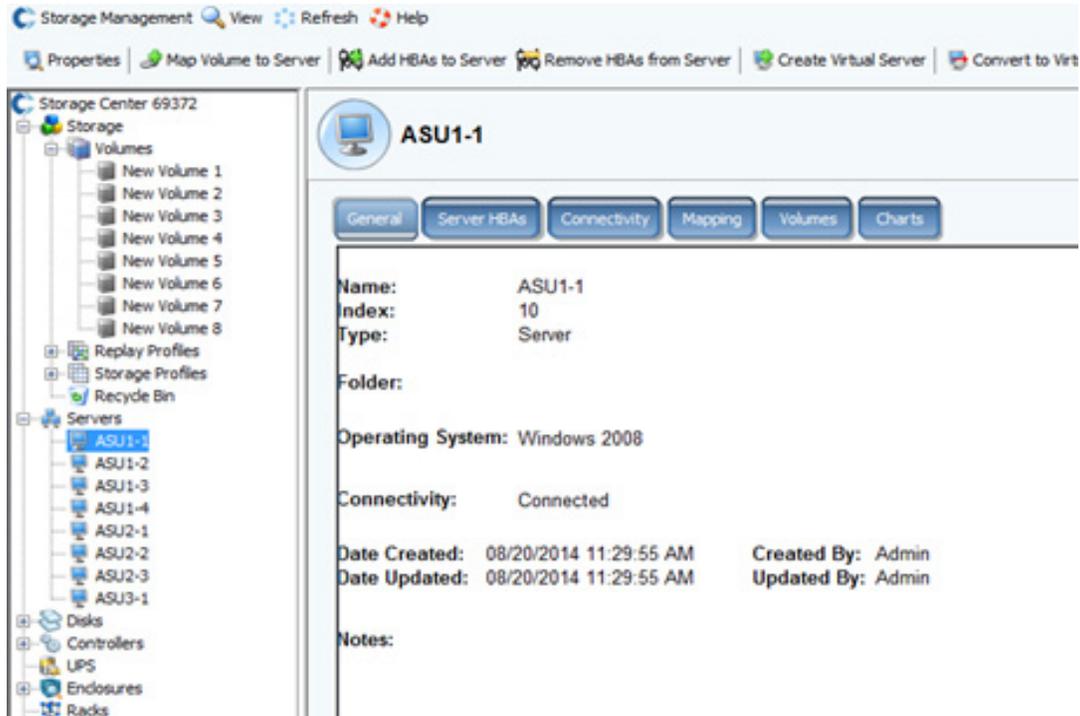


3. On the next page enter a name for the server.
4. Repeat steps #1-#3 to create servers for ASU1-2, ASU1-3, ASU1-4, ASU2-1, ASU2-2, ASU2-3, and ASU3-1.

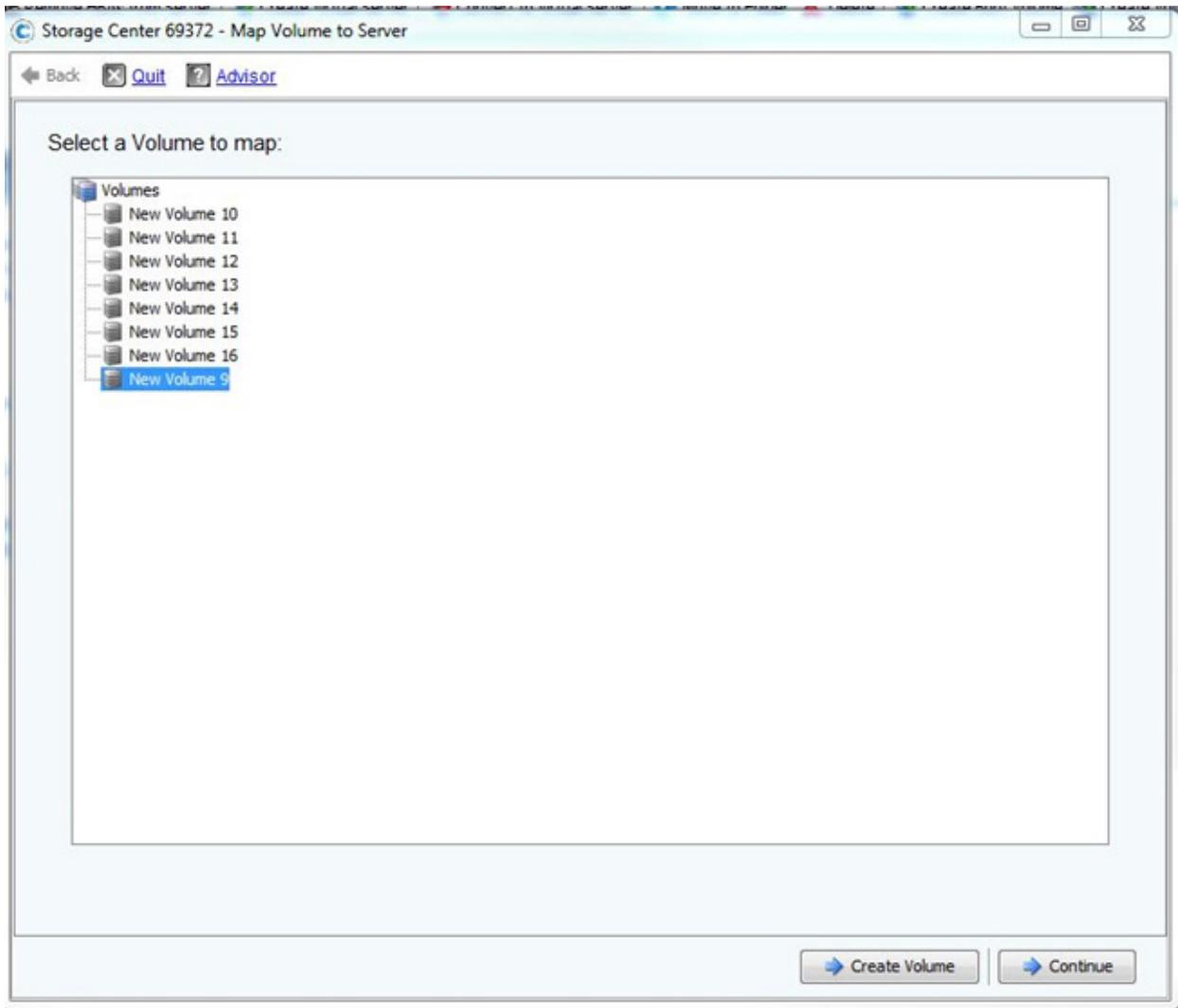
The screenshot shows a web-based interface for creating a server. The title bar reads "Storage Center 69372 - Create Server". At the top left, there are navigation links: "Back", "Quit", and "Advisor". The main content area is titled "Folder:" and contains a tree view with a folder named "Servers" selected. Below the folder view, there is a link "Create a New Folder". The "Name:" field contains the text "ASU1-1", which is circled in red. The "Operating System:" dropdown menu is set to "Windows 2008". The "Notes:" field is empty. At the bottom right, there is a "Continue" button.

## Volume to Server Mapping

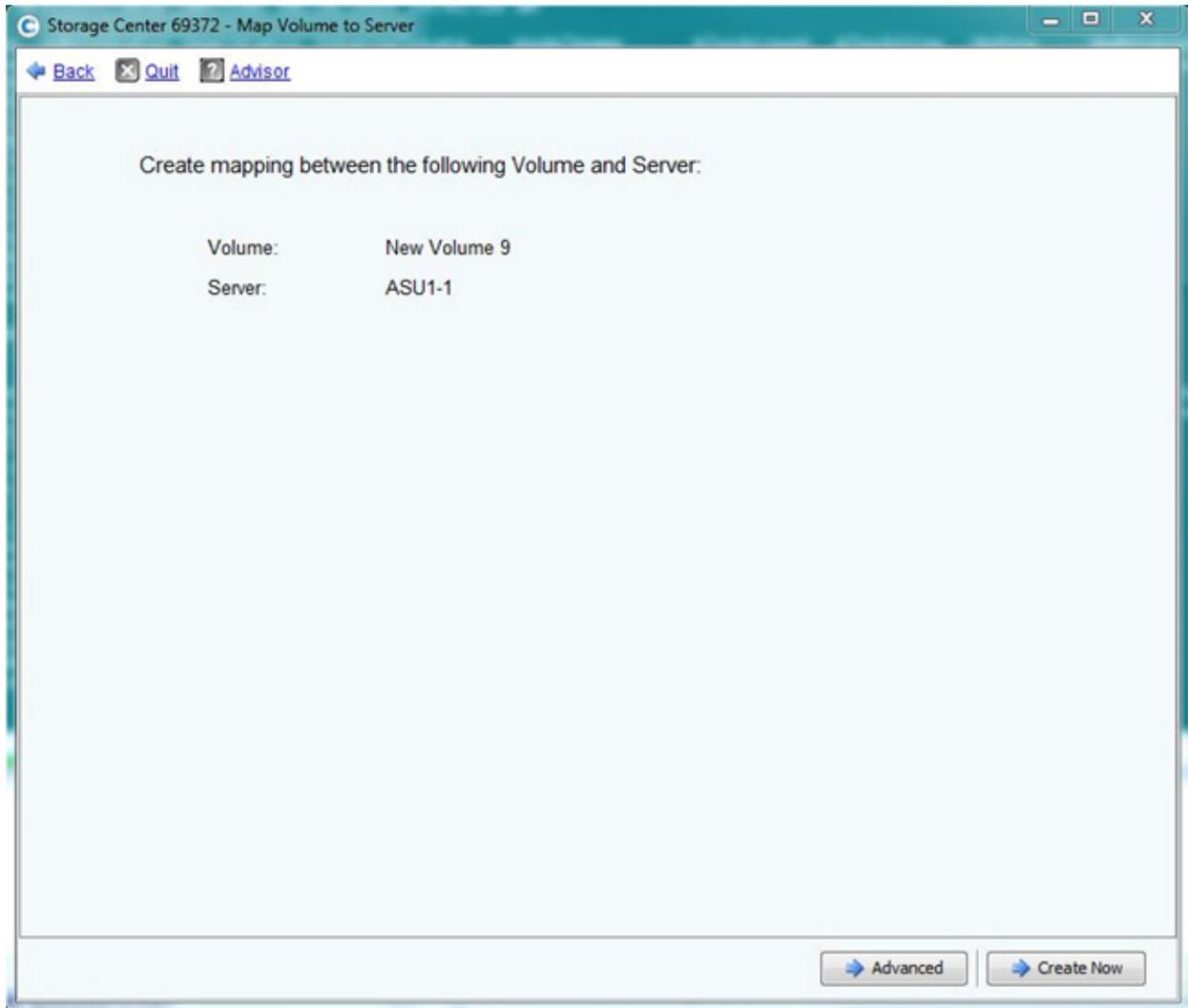
1. Select server **ASU1-1**, then click on **Map Volume to Server**.



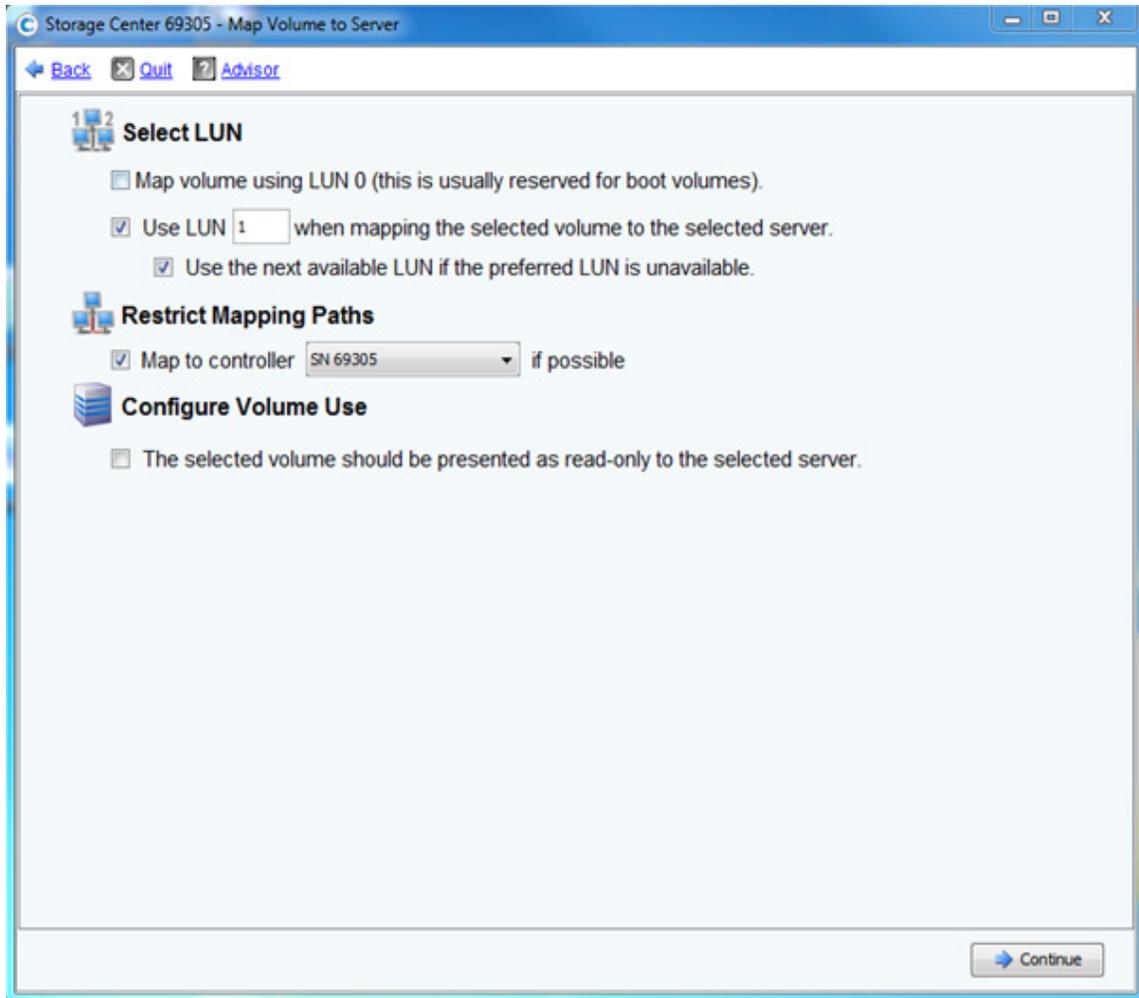
2. A list of volumes will be displayed. Select **New Volume 9** and click **Continue**.



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**

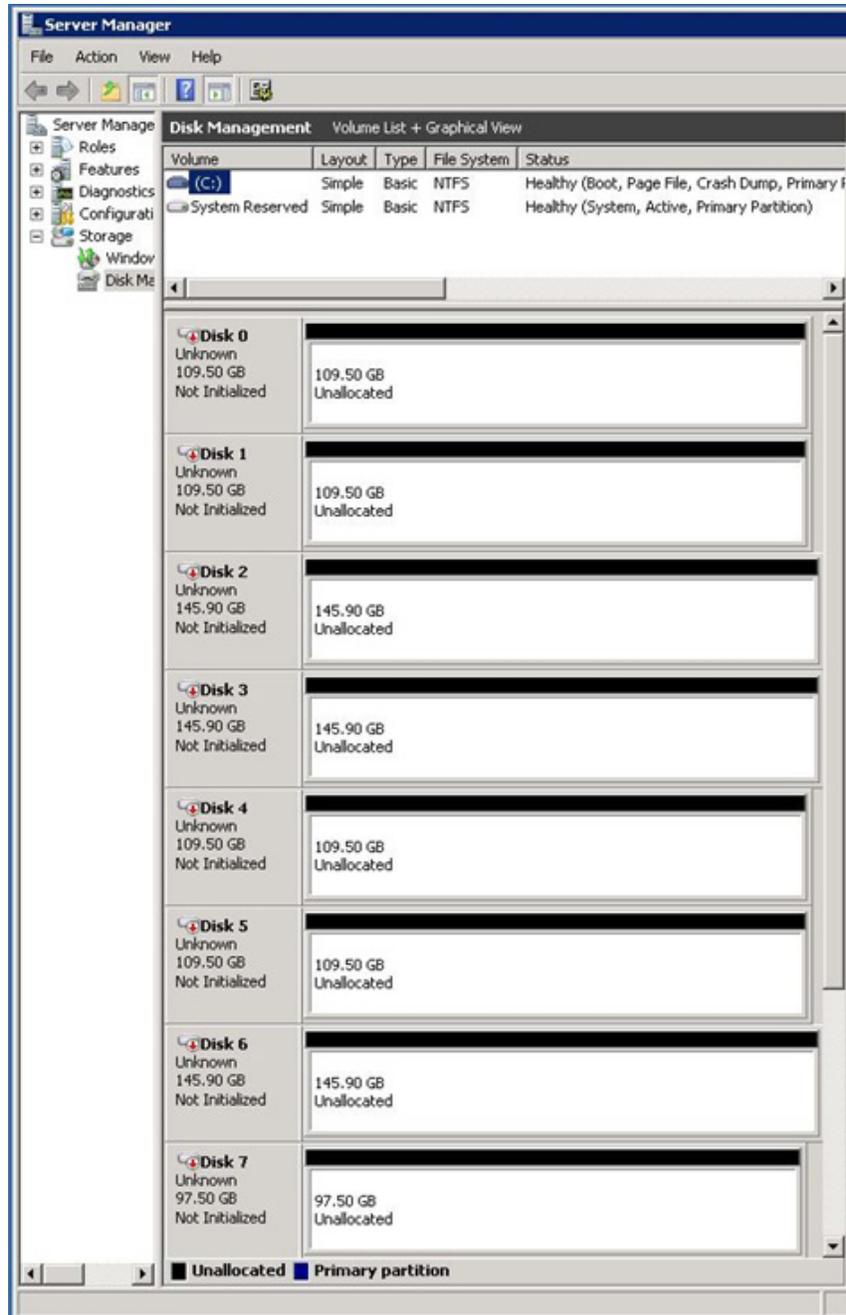


9. Repeat steps #1- #8 until the volume/server/controller mappings match the table below.

<b>Volume</b>	<b>Server</b>	<b>LUN</b>	<b>Controller</b>
New Volume 9	ASU1-1	1	SN 69372
New Volume 10	ASU1-2	2	SN 69373
New Volume 11	ASU1-3	3	SN 69372
New Volume 12	ASU1-4	4	SN 69373
New Volume 13	ASU2-1	5	SN 69372
New Volume 14	ASU2-2	6	SN 69373
New Volume 15	ASU2-3	7	SN 69372
New Volume 16	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 **Cancel**.
4. Reboot the Host System. The SPC-1 TSC creation/configuration process is complete.



## **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=asu1_1,lun=\\.\PhysicalDrive0
sd=asu1_2,lun=\\.\PhysicalDrive1
sd=asu2_5,lun=\\.\PhysicalDrive2
sd=asu2_6,lun=\\.\PhysicalDrive3
sd=asu1_3,lun=\\.\PhysicalDrive4
sd=asu1_4,lun=\\.\PhysicalDrive5
sd=asu2_7,lun=\\.\PhysicalDrive6
sd=asu3_8,lun=\\.\PhysicalDrive7
```

## **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 2125 -t 28800 -s 1800:300
java -cp C:\spc\spc1 repeat1 -b 2125 -s 300
java -cp C:\spc\spc1 repeat2 -b 2125 -s 300
java -cp C:\spc\spc1 -Xmx512m -Xss256k persist1 -b 2125

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.
```