



SPC BENCHMARK 1™
FULL DISCLOSURE REPORT
NETWORK APPLIANCE, INC.
NETAPP FAS3040
(SNAPSHOT™ ENABLED)

SPC-1 V1.10.1

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AUDIT CERTIFICATION



Steve Daniel
Network Appliance, Inc.
7301 Kit Creek Road, Building 1
Research Triangle Park, NC 27709

January 29, 2008

The SPC Benchmark 1™ results listed below for the NetApp FAS3040 were produced in compliance with the SPC Benchmark 1™ V1.10.1 Onsite Audit requirements.

SPC Benchmark 1™ V1.10.1 Results	
Tested Storage Configuration (TSC) Name: NetApp FAS3040 (<i>Snapshot™ enabled</i>)	
Metric	Reported Result
SPC-1 IOPS™	29,958.60
SPC-1 Price-Performance	\$14.89/SPC-1 IOPS™
Total ASU Capacity	12,586.586 GB
Data Protection Level	Other Data Protection (<i>NetApp RAID DP™</i>)
Total TSC Price (including three-year maintenance)	\$446,210

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

- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository storage items were verified by physical inspection and information supplied by Network Appliance, Inc.:
 - ✓ Physical Storage Capacity and requirements.
 - ✓ Configured Storage Capacity and requirements.
 - ✓ Addressable Storage Capacity and requirements.
 - ✓ Capacity of each Logical Volume and requirements.
 - ✓ Capacity of each Application Storage Unit (ASU) and requirements.
- An appropriate diagram of the Benchmark Configuration (BC)/Tested Storage Configuration (TSC).
- Physical verification of the components to match the above diagram.

Storage Performance Council
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Redwood City, CA 94062
AuditService@storageperformance.org
650.556.9384

AUDIT CERTIFICATION (CONT.)

NetApp FAS3040 (*Snapshot™ enabled*)
SPC-1 Audit Certification

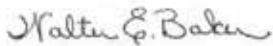
Page 2

- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters.
- Commands and parameters used to configure the SPC-1 Workload Generator.
- The following Host System requirements were verified by physical inspection and information supplied by Network Appliance, Inc.:
 - ✓ The type of Host System including the number of processors and main memory.
 - ✓ The presence and version number of the Workload Generator on the Host System.
 - ✓ The TSC boundary within the Host System.
- The execution of each Test, Test Phase, and Test Run was observed and found compliant with all of the requirements and constraints of Clauses 4 and 5 of the SPC-1 Benchmark Specification.
- The Test Results Files and resultant Summary Results Files received from Network Appliance, Inc. for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4 and 5 of the SPC-1 Benchmark Specification:
 - ✓ Data Persistence Test
 - ✓ Sustainability Test Phase
 - ✓ IOPS Test Phase
 - ✓ Response Time Ramp Test Phase
 - ✓ Repeatability Test
- There were no differences between the Tested Storage Configuration (TSC) used for the benchmark and Priced Storage Configuration.
- The submitted pricing information met all of the requirements and constraints of Clause 8 of the SPC-1 Benchmark Specification.
- The Full Disclosure Report (FDR) met all of the requirements in Clause 9 of the SPC-1 Benchmark Specification.
- This successfully audited SPC measurement is not subject to an SPC Confidential Review.

Audit Notes:

The use of NetApp's Snapshot™ during the benchmark measurements is accurately documented in Appendix F of the SPC-1 Full Disclosure Report for this result.

Respectfully,



Walter E. Baker
SPC Auditor

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LETTER OF GOOD FAITH

7 January, 2008

Walter Baker
Gradient Systems
643 Blair Island Road, Suite 103
Redwood City, CA 94063-2755

To: Walter Baker
Subject: SPC-1 Letter of Good Faith for the NetApp FAS3040

Network Appliance, Inc is the SPC-1 Test Sponsor for the above listed product. To the best of our knowledge and belief, the required SPC-1 benchmark results and materials we have submitted for that product are complete, accurate, and in full compliance with V1.10.1 of the SPC-1 benchmark specification.

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

Sincerely,

A handwritten signature in black ink, appearing to read 'Phil Brotherton'.

Phil Brotherton
Vice President
Enterprise Applications Business Unit

Network Appliance, Inc. 495 East Java Drive Sunnyvale, CA 94089 Telephone 408.822.6000 Fax 408.822.4501
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EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
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Auditor	Storage Performance Council – http://www.storageperformance.org Walter E. Baker – AuditService@StoragePerformance.org 643 Bair Island Road, Suite 103 Redwood City, CA 94063 Phone: (650) 556-9384 FAX: (650) 556-9385

Revision Information and Key Dates

Revision Information and Key Dates	
SPC-1 Specification revision number	V1.10.1
SPC-1 Workload Generator revision number	V2.00.04a
Date Results were first used publicly	January 29, 2008
Date the FDR was submitted to the SPC	January 29, 2008
Date revised FDR was submitted to the SPC Inclusion of omitted capacities diagram: page 12 Activation of hyperlinks to results files: various pages	January 31, 2008
Date the TSC is available for shipment to customers	March 18, 2008
Date the TSC completed audit certification	January 29, 2008

Tested Storage Product (TSP) Description

The NetApp FAS 3040 is the newest entry in the FAS3000 series of Enterprise Storage Systems. The NetApp FAS3000 series delivers outstanding value through excellent performance, best-in-class scalability, and proven lower TCO than other midrange storage systems.

These enterprise storage systems have the versatility to simultaneously meet diverse needs—SAN and NAS, primary and secondary storage—while providing high levels of availability. The FAS3040 system handles complex requirements in a way that actually simplifies the storage infrastructure and improves productivity.

The NetApp FAS3040 delivers excellent performance, whether the storage need is for SAN-based business applications, technical applications, or home directories. With large cache memory configurations, expandable high-performance I/O, 4-gigabit FC SAN support, and support for 10-Gigabit Ethernet, the FAS3040 delivers exceptional midrange systems performance

Summary of Results

SPC-1 Results	
Tested Storage Configuration (TSC) Name: NetApp FAS3040 (<i>Snapshot™ enabled</i>)	
Metric	Reported Result
SPC-1 IOPS™	29,958.60
SPC-1 Price-Performance	\$14.89/SPC-1 IOPS™
Total ASU Capacity	12,586.586GB
Data Protection Level	Other Data Protection
Total TSC Price (including three-year maintenance)	\$446,210

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

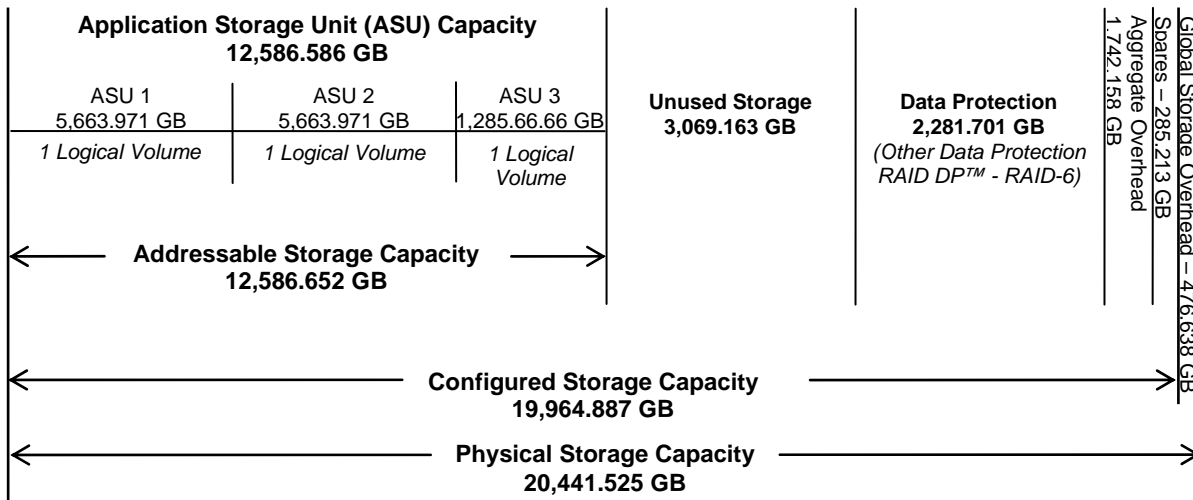
Total ASU (Application Storage Unit) Capacity represents the total storage capacity read and written in the course of executing the SPC-1 benchmark.

A **Data Protection Level** of “Other Protection Level” utilized NetApp’s RAID-DP™, a RAID 6 implementation, which provides double-parity RAID protection against data loss with negligible performance overhead and no cost penalty compared to single-parity RAID. Additional information is available at the following location:

<http://www.netapp.com/products/software/raid-dp.html>

Storage Capacities and Relationships

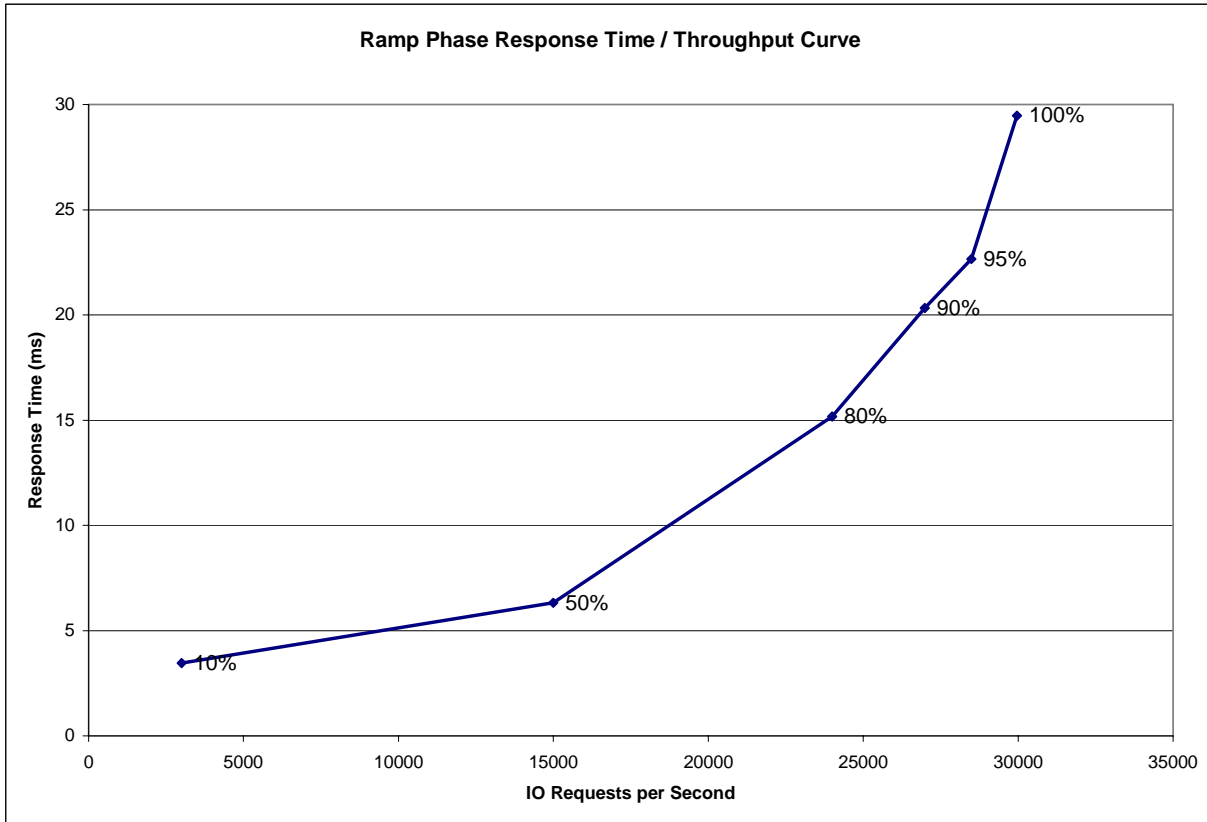
The following diagram documents the various storage capacities, used in this benchmark, and their relationships.



Response Time – Throughput Curve

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

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



Response Time – Throughput Data

	10% Load	50% Load	80% Load	90% Load	95% Load	100% Load
I/O Request Throughput	2,999.76	15,001.78	24,002.87	26,989.81	28,489.47	29,958.60
Average Response Time (ms):						
All ASUs	3.45	6.32	15.17	20.34	22.66	29.47
ASU-1	4.60	7.86	17.39	23.09	25.71	33.01
ASU-2	4.43	8.07	18.31	24.55	27.01	35.75
ASU-3	0.60	2.27	9.09	12.65	14.30	19.22
Reads	7.26	11.78	23.33	30.47	33.83	42.42
Writes	0.97	2.76	9.86	13.74	15.39	21.04

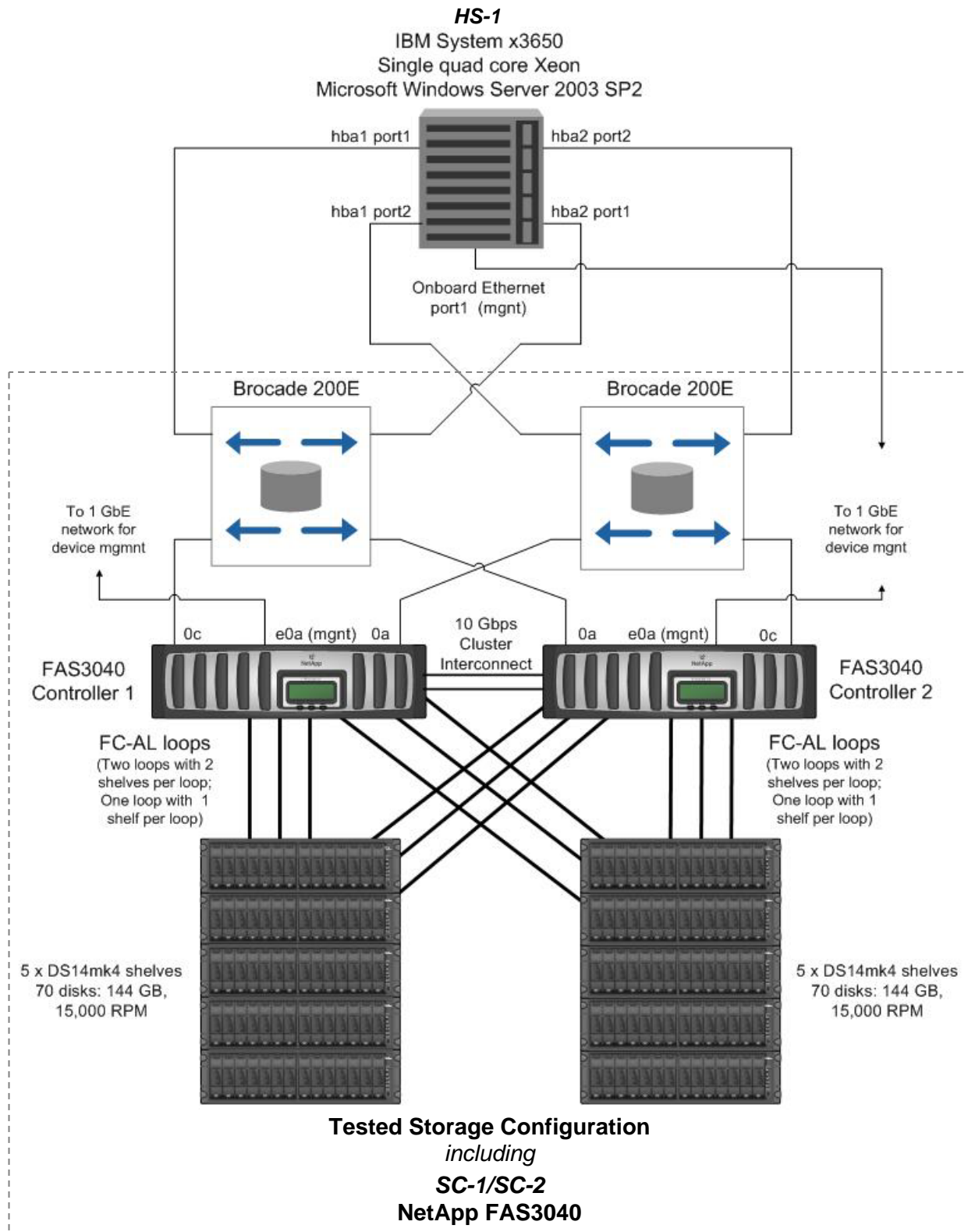
Tested Storage Configuration Pricing (Priced Storage Configuration)

Storage System		Ext Qty	List Price	Disc %	Net Price	Ext Net Price
SES-SYSTEM	Support Edge Services Attach PN	1	\$0.00	0	\$0.00	\$0.00
X1941A-R6-C	Cable,Cluster 4X,Copper,5M,-C,R6	2	\$97.00	0	\$97.00	\$194.00
X2055A-R6-C	HBA,FC,2-Port,4Gb,Disk,Optical,PCIe,-C,R6	4	\$2,300.00	0	\$2,300.00	\$9,200.00
X505-R6-C	System Lift Handle,Detachable,-C,R6	2	\$0.00	0	\$0.00	\$0.00
X5515A-R6-C	Rackmount Kit,4N2,DS14-Middle,-C,R6	12	\$100.00	0	\$100.00	\$1,200.00
X6530-R6-C	Cable,Patch,FC SFP to SFP,0.5M,-C,R6	16	\$0.00	0	\$0.00	\$0.00
X6536-R6-C	Cable,Optical,50u,2GHz/KM/MM,LC/LC,5M,-C,R6	12	\$150.00	0	\$150.00	\$1,800.00
X6539-R6-C	SFP,Optical,4.25Gb,-C,R6	8	\$120.00	0	\$120.00	\$960.00
X800E-R6-C	Power Cable North America,-C,R6	24	\$0.00	0	\$0.00	\$0.00
DOC-3XXX-C	Documents,3XXX,-C	1	\$0.00	0	\$0.00	\$0.00
FAS3040AS-BASE-R5-C	FAS3040A,IB,ACT-ACT,SAN,OS,-C,R5	2	\$16,700.00	0	\$16,700.00	\$33,400.00
FCP	Onboard Target Ports,Quantity	4	\$0.00	0	\$0.00	\$0.00
LOOPS	Storage Loops Attached Quantity	4	\$0.00	0	\$0.00	\$0.00
MULTIPATH-C	Multipath configuration	1	\$0.00	0	\$0.00	\$0.00
X74015B-ESH4-R5-C	DS14MK4 SHLF,AC,14x144GB,15K,B,ESH4,-C,R5	10	\$27,418.00	0	\$27,418.00	\$274,180.00
SW-T4C-CLUSTERSAN-C	CFO Software,T4C,SAN Bndl	2	\$4,175.00	0	\$4,175.00	\$8,350.00
SW-T4C-FCPSAN-C	FCP Software,T4C,SAN Bndl	2	\$0.00	0	\$0.00	\$0.00
SW-T4C-ISCSISAN-C	iSCSI Software,T4C,SAN Bndl	2	\$0.00	0	\$0.00	\$0.00
SW-ONTAP4-3XXX	SW,DataONTAP4,3XXX	2	\$0.00	0	\$0.00	\$0.00
SW-T4C-SRESTORE-C	SnapRestore Software,T4C,-C	2	\$9,000.00	0	\$9,000.00	\$18,000.00
SVC-A-IN-NBR-Z	HW Support,Premium,4hr,z	Mths: 36	1 \$64,775.49	0	\$64,775.49	\$64,775.49
SW-SSP-A-IN-NBR-Z	SW Subs,Standard Replace,Inst,NBD,z	Mths: 36	1 \$9,486.00	0	\$9,486.00	\$9,486.00
Storage Subtotal						\$421,545.49
Host Attach Hardware and Software						
SW-DSM-MPIO-WINDOWS		1	\$0.00	0	\$0.00	\$0.00
X6518A-R6	Cable,Optical,LC/LC,5M,R6	4	\$150.00	0	\$150.00	\$600.00
X1089A-R6	HBA,QLogic QLE2462,2-Port,4Gb,PCIe,R6	2	\$2,615.00	0	\$2,615.00	\$5,230.00
SW-DSM-MPIO-WIN	Software,Data ONTAP DSM for Windows MPIO	1	\$1,000.00	0	\$1,000.00	\$1,000.00
SW-FAK-WIN	FCP Windows Host Utilities	1	\$75.00	0	\$75.00	\$75.00
SW-SSP-DSM-MPIO-WIN	SW Subs,Data ONTAP DSM for Windows MPIO	Mths: 36	1 \$360.00	0	\$360.00	\$360.00
X1611A-R5-C	Brocade 16-Port 200e FC Full Fab Switch,-C,R5	2	\$8,700.00	0	\$8,700.00	\$17,400.00
Host Subtotal						\$24,665.00
Total						\$446,210.49

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

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

Benchmark Configuration/Tested Storage Configuration Diagram



Benchmark Configuration/Tested Storage Configuration Components

Host System:	Tested Storage Configuration (TSC):
HS-1: IBM System x3650	2 – Qlogic QLE2462, 2-Port 4Gb PCIe, R6 HBAs (Host System)
Single quad core Xeon processor	4 – Qlogic QLE2462, 2-Port 4Gb PCIe, R6 HBAs (2 per FAS3040 controller)
2.33 GHz CPUs, 4096 KB cache per CPU	
16 GB main memory	2 – Brocade 16-Port 200e FC switches
Windows Server 2003 with SP2	SC-1/SC-2: NetApp FAS3040
Priced Host System Software: FCP Windows Host Utilities 3.0 for Native OS Data ONTAP® DSM 3.2 for Windows MPIO	2 – FAS3040 Storage Controllers each with:
PCIe	2 – AMD 2.5 GHz Opteron CPUs
WG	4 GB main memory
	512 KB L2 cache
	512 MB NVRAM
	2 FCP front-end connections
	6 FCP backend connections
	140 – 144 GB 15K RPM disk drives

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

CONFIGURATION INFORMATION

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

Clause 9.2.4.4.1

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

The Benchmark Configuration (BC)/Tested Storage Configuration (TSC) is illustrated on page 15 (*Benchmark Configuration/Tested Storage Configuration Diagram*).

Storage Network Configuration

Clause 9.2.4.4.1

...

5. *If the TSC contains network storage, the diagram will include the network configuration. If a single diagram is not sufficient to illustrate both the Benchmark Configuration and network configuration in sufficient detail, the Benchmark Configuration diagram will include a high-level network illustration as shown in Figure 9-8. In that case, a separate, detailed network configuration diagram will also be included as described in Clause 9.2.4.4.2.*

Clause 9.2.4.4.2

If a storage network was configured as a part of the Tested Storage Configuration and the Benchmark Configuration diagram described in Clause 9.2.4.4.1 contains a high-level illustration of the network configuration, the Executive Summary will contain a one page topology diagram of the storage network as illustrated in Figure 9-9.

The Benchmark Configuration (BC)/Tested Storage Configuration (TSC), including the network configuration, is illustrated on page 15 (*Benchmark Configuration/Tested Storage Configuration Diagram*).

Host System Configuration

Clause 9.2.4.4.3

The FDR shall minimally contain, for each Host System running the Workload Generator, a listing of the following:

1. *Number and type of CPUs.*
2. *Main memory capacity.*
3. *Cache memory capacity.*
4. *Number and type of disk controllers or Host Bus Adapters.*

The details of the Host System configuration may be found on page 15 (*Benchmark Configuration/Tested Storage Configuration Diagram*).

Customer Tunable Parameters and Options

Clause 9.2.4.5.1

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

“Appendix B: Customer Tunable Parameters and Options” on page 60 contains the customer tunable parameters and options that have been altered from their default values for this benchmark.

Tested Storage Configuration (TSC) Description

Clause 9.2.4.5.2

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

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

“Appendix C: Tested Storage Configuration (TSC) Creation” on page 61 contains the detailed information that describes how to create and configure the logical TSC.

SPC-1 Workload Generator Storage Configuration

Clause 9.2.4.5.3

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

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

SPC-1 DATA REPOSITORY

This portion of the Full Disclosure Report presents the detailed information that fully documents the various SPC-1 storage capacities and mappings used in the Tested Storage Configuration. “SPC-1 Data Repository Definitions” on page 56 contains definitions of terms specific to the SPC-1 Data Repository.

Storage Capacities and Relationships

Clause 9.2.4.6.1

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

SPC-1 Storage Capacities

SPC-1 Storage Capacities		
Storage Hierarchy Component	Units	Capacity
Total ASU Capacity	Gigabytes (GB)	12,586.586
Addressable Storage Capacity	Gigabytes (GB)	12,586.586
Configured Storage Capacity	Gigabytes (GB)	19,964.887
Physical Storage Capacity	Gigabytes (GB)	20,441.525
Data Protection (<i>Other Data Protection</i>)	Gigabytes (GB)	2,281.701
Required Storage (<i>spares/metadata</i>)	Gigabytes (GB)	2,027.370
Global Storage Overhead	Gigabytes (GB)	476.638
Total Unused Storage	Gigabytes (GB)	3,069.163

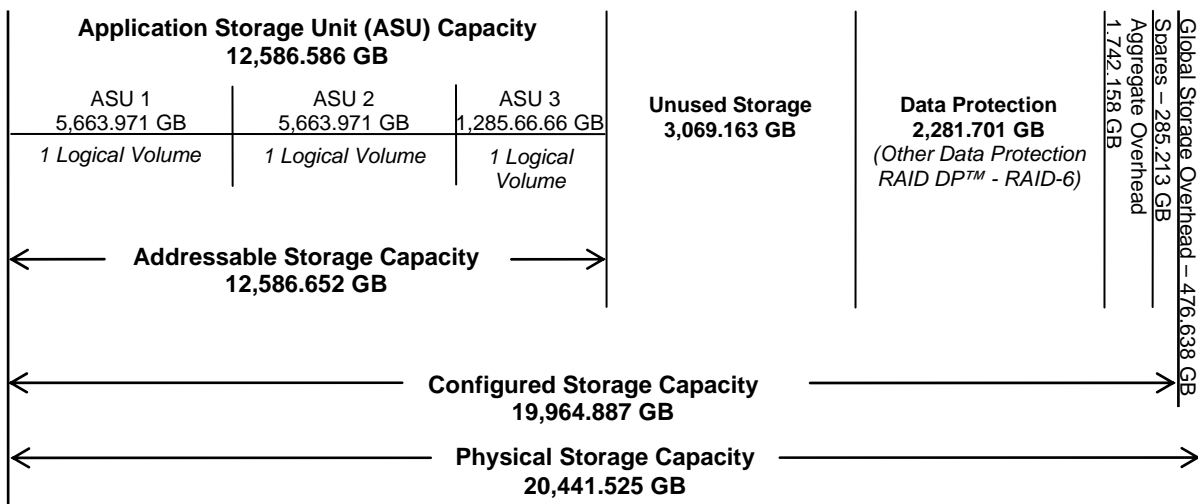
SPC-1 Storage Hierarchy Ratios

	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	63.04%	61.57%
Required for Data Protection (Other)		11.43%	11.16%
Addressable Storage Capacity		63.04%	61.57%
Required Storage		10.15%	9.92%
Configured Storage Capacity			97.67%
Global Storage Overhead			2.33%
Unused Storage:			
Addressable	0.00%		
Configured		15.37%	
Physical			0.00%

The Physical Storage Capacity consisted of 20,441.525 GB distributed over 140 disk drives each with a formatted capacity of 146.011 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 476.638 GB (2.33%) of Physical Storage Capacity. There was 3,069.163 GB (15.37%) 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.

SPC-1 Storage Capacities and Relationships Illustration

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



Logical Volume Capacity and ASU Mapping

Clause 9.2.4.6.2

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

Logical Volume Capacity and Mapping		
ASU-1 (5,663.971 GB)	ASU-2 (5,663.971 GB)	ASU-3 (1,258.664 GB)
1 Logical Volume 5,663.971 GB per Logical Volume (5,663.971 GB used per Logical Volume)	1 Logical Volume 5,663.971 GB per Logical Volume (5,663.971 GB used per Logical Volume)	1 Logical Volume 1,258.664 GB per Logical Volume (1,258.664 GB used per Logical Volume)

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

SPC-1 BENCHMARK EXECUTION RESULTS

This portion of the Full Disclosure Report documents the results of the various SPC-1 Tests, Test Phases, and Test Runs. “SPC-1 Test Execution Definitions” on page 57 contains definitions of terms specific to the SPC-1 Tests, Test Phases, and Test Runs.

Clause 5.4.3

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

SPC-1 Tests, Test Phases, and Test Runs

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

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

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

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

Primary Metrics Test – Sustainability Test Phase

Clause 5.4.4.1.1

The Sustainability Test Phase has exactly one Test Run and shall demonstrate the maximum sustainable I/O Request Throughput within at least a continuous three (3) hour Measurement Interval. This Test Phase also serves to insure that the TSC has reached Steady State prior to reporting the final maximum I/O Request Throughput result (SPC-1 IOPS™).

Clause 5.4.4.1.2

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

Clause 5.4.4.1.4

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

Clause 9.2.4.7.1

For the Sustainability Test Phase the FDR shall contain:

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

SPC-1 Workload Generator Input Parameters

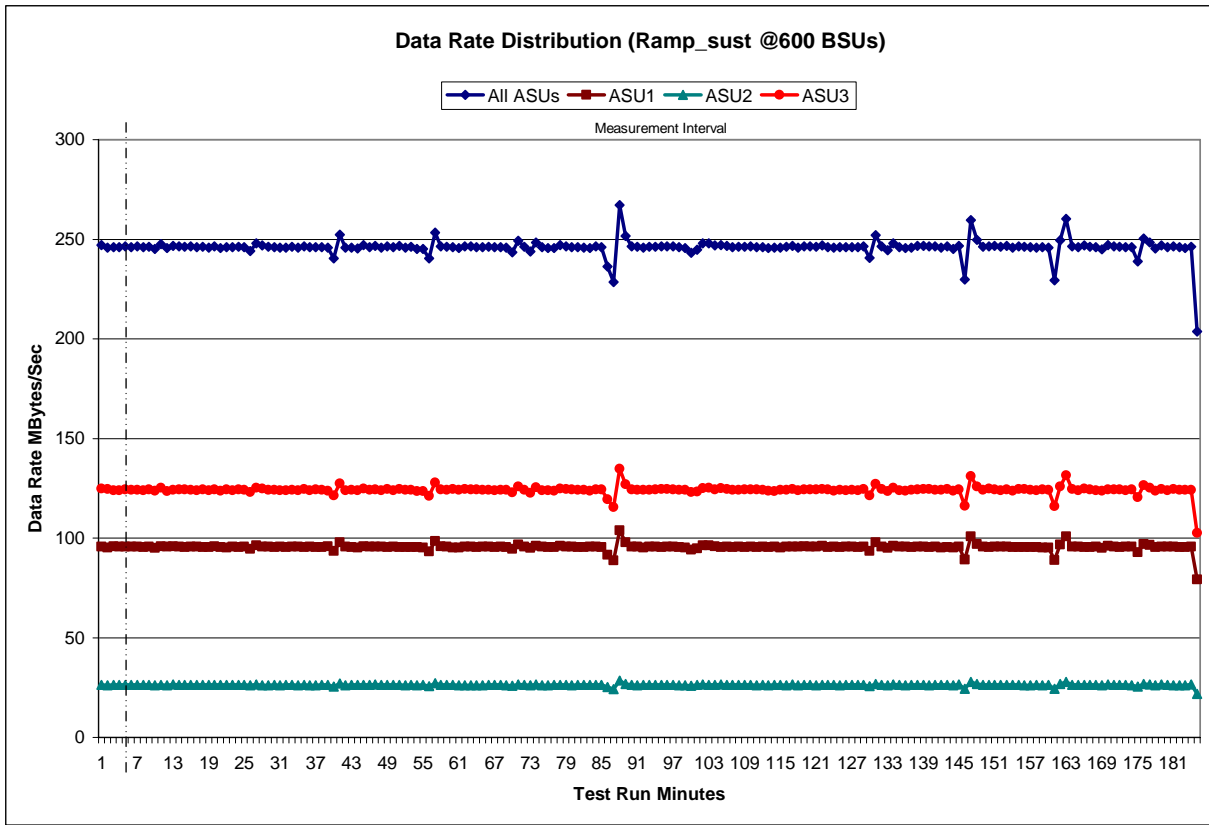
The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in “Appendix E: SPC-1 Workload Generator Input Parameters” on Page 71.

Sustainability Test Results File

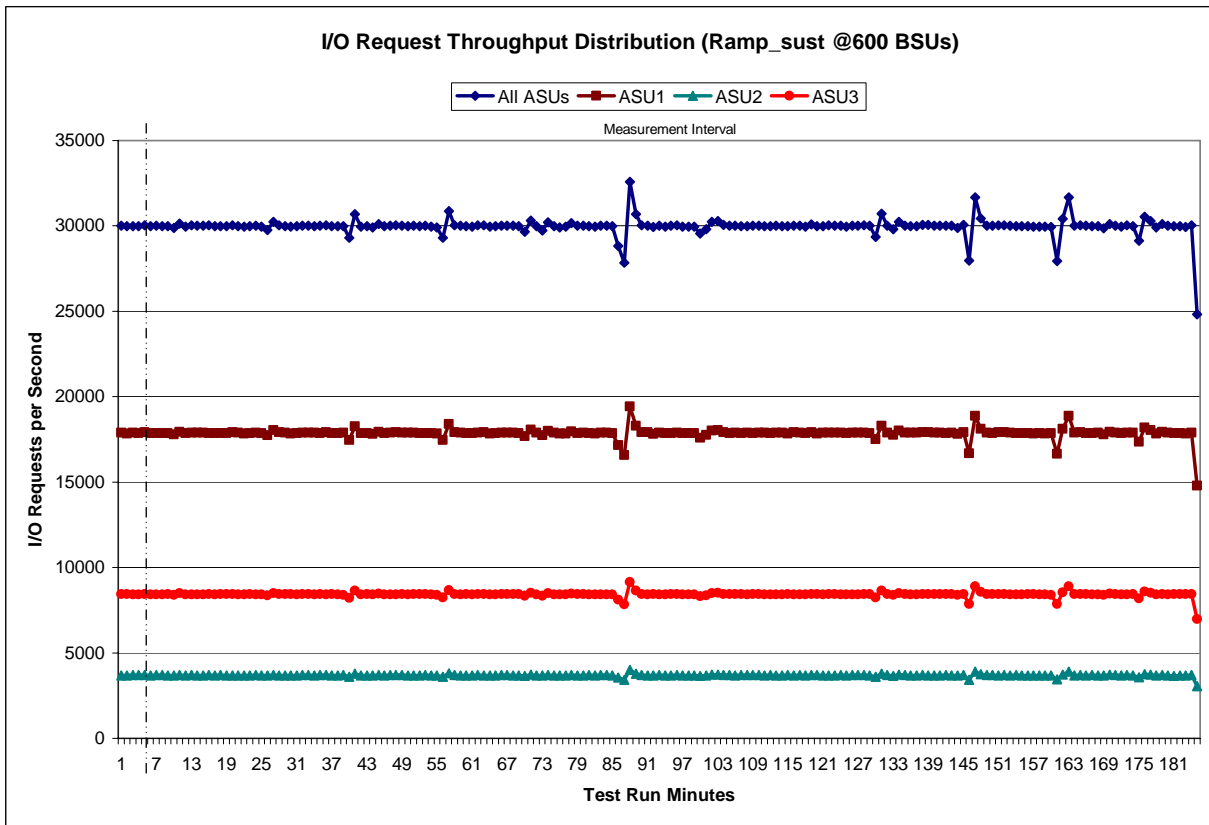
A link to the test results file generated from the Sustainability Test Run is listed below.

[Sustainability Test Results File](#)

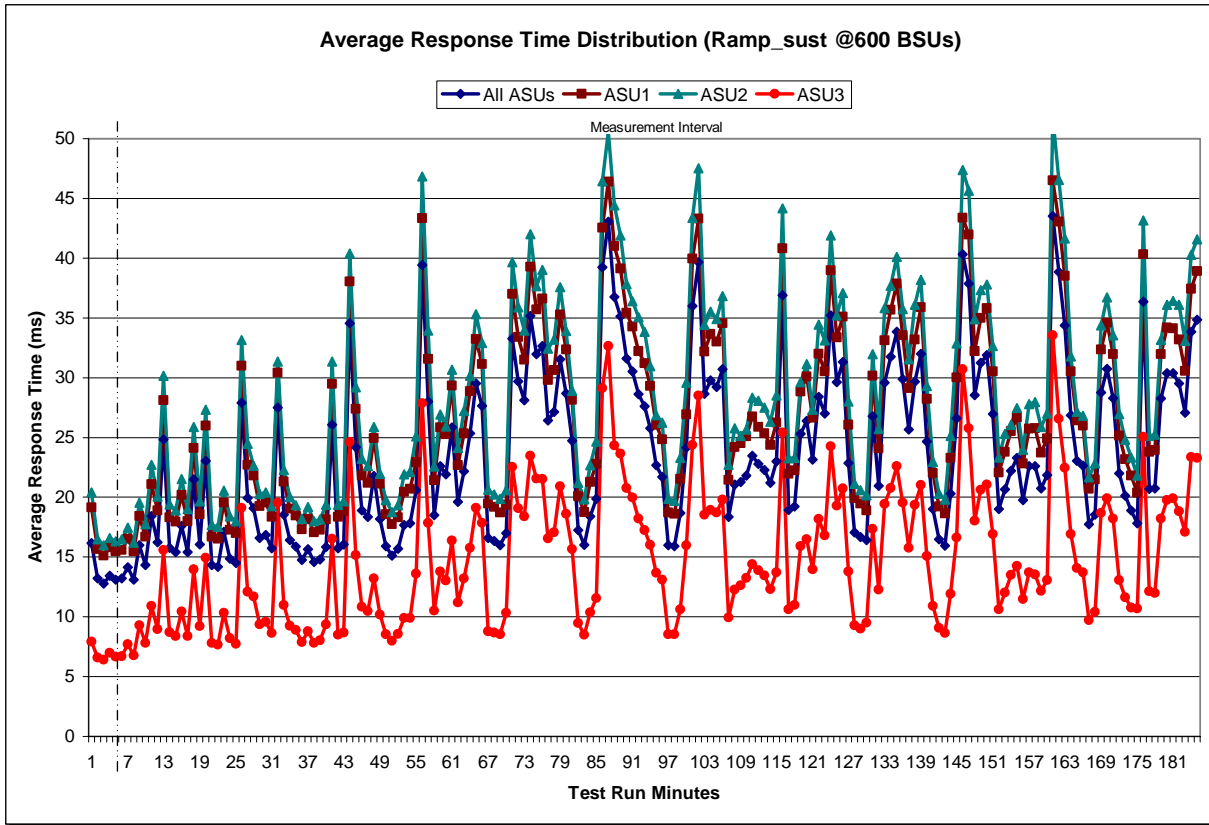
Sustainability – Data Rate Distribution Graph



Sustainability – I/O Request Throughput Distribution Graph



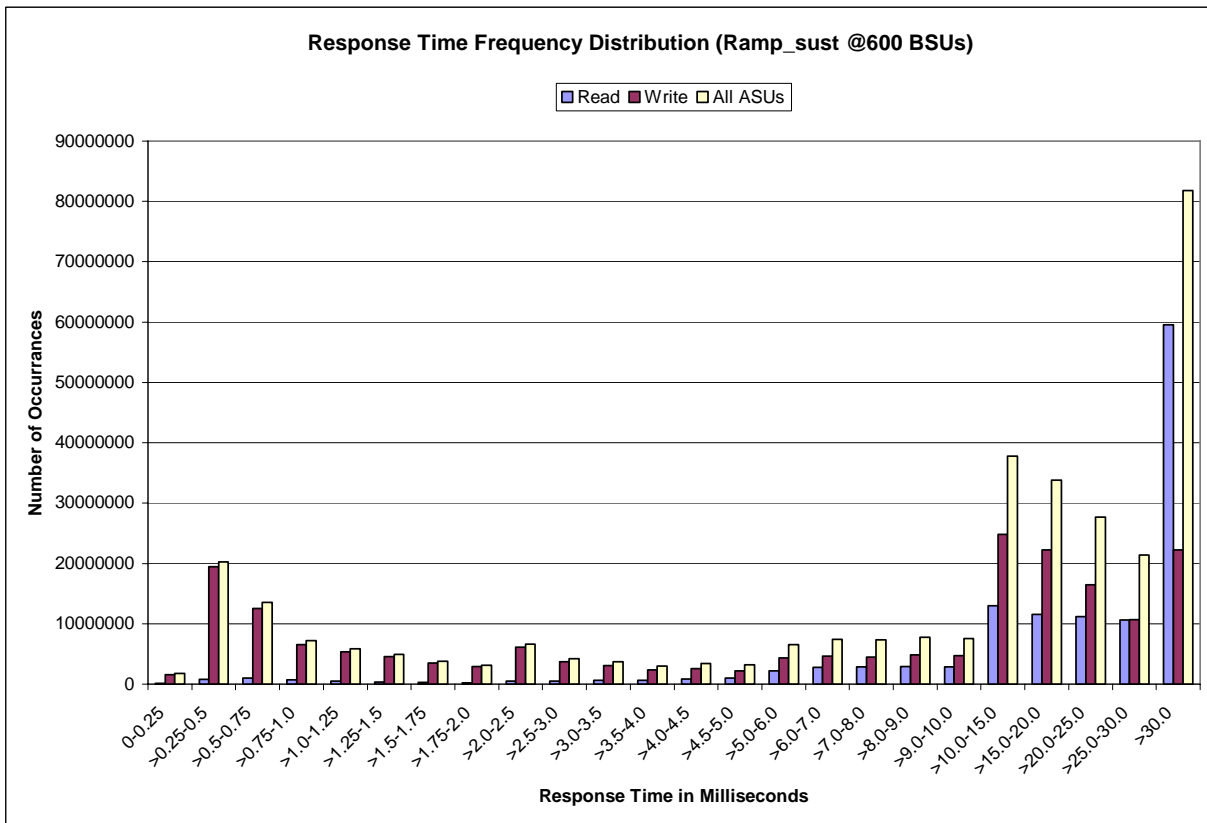
Sustainability – Average Response Time (ms) Distribution Graph



Sustainability – Response Time Frequency Distribution Data

Response Time (ms)	0-0.25	>0.25-0.5	>0.5-0.75	>0.75-1.0	>1.0-1.25	>1.25-1.5	>1.5-1.75	>1.75-2.0
Read	170,163	786,934	989,700	681,705	475,589	355,485	259,546	209,260
Write	1,579,365	19,434,325	12,574,278	6,543,698	5,373,788	4,575,246	3,520,555	2,932,235
All ASUs	1,749,528	20,221,259	13,563,978	7,225,403	5,849,377	4,930,731	3,780,101	3,141,495
ASU1	1,007,941	9,706,769	5,867,444	3,151,377	2,607,817	2,204,959	1,693,112	1,407,276
ASU2	175,951	1,962,344	1,280,017	700,755	567,240	470,552	358,647	297,093
ASU3	565,636	8,552,146	6,416,517	3,373,271	2,674,320	2,255,220	1,728,342	1,437,126
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	484,785	476,283	630,261	656,837	839,415	986,316	2,244,465	2,763,664
Write	6,141,816	3,703,779	3,069,630	2,359,447	2,594,697	2,203,973	4,319,962	4,626,715
All ASUs	6,626,601	4,180,062	3,699,891	3,016,284	3,434,112	3,190,289	6,564,427	7,390,379
ASU1	2,963,604	1,940,969	1,828,891	1,571,790	1,838,837	1,818,590	3,840,819	4,431,454
ASU2	625,237	409,077	382,099	315,573	361,289	343,068	723,705	832,311
ASU3	3,037,760	1,830,016	1,488,901	1,128,921	1,233,986	1,028,631	1,999,903	2,126,614
Response Time (ms)	>7.0-8.0	>8.0-9.0	>9.0-10.0	>10.0-15.0	>15.0-20.0	>20.0-25.0	>25.0-30.0	>30.0
Read	2,881,840	2,956,540	2,843,582	12,971,513	11,579,527	11,210,162	10,659,097	59,552,833
Write	4,474,767	4,829,366	4,691,002	24,798,172	22,227,920	16,458,901	10,719,927	22,260,715
All ASUs	7,356,607	7,785,906	7,534,584	37,769,685	33,807,447	27,669,063	21,379,024	81,813,548
ASU1	4,463,250	4,671,105	4,511,632	21,805,198	19,214,944	16,386,331	13,558,180	60,417,915
ASU2	845,934	890,446	853,956	4,256,711	3,851,583	3,300,937	2,723,200	13,287,767
ASU3	2,047,423	2,224,355	2,168,996	11,707,776	10,740,920	7,981,795	5,097,644	8,107,866

Sustainability – Response Time Frequency Distribution Graph



Sustainability – Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

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

Clauses 5.1.0 and 5.3.13.2

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

Clause 5.3.13.3

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

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

Primary Metrics Test – IOPS Test Phase

Clause 5.4.2.2

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

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

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

Clause 9.2.4.7.2

For the IOPS Test Phase the FDR shall contain:

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

SPC-1 Workload Generator Input Parameters

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

IOPS Test Results File

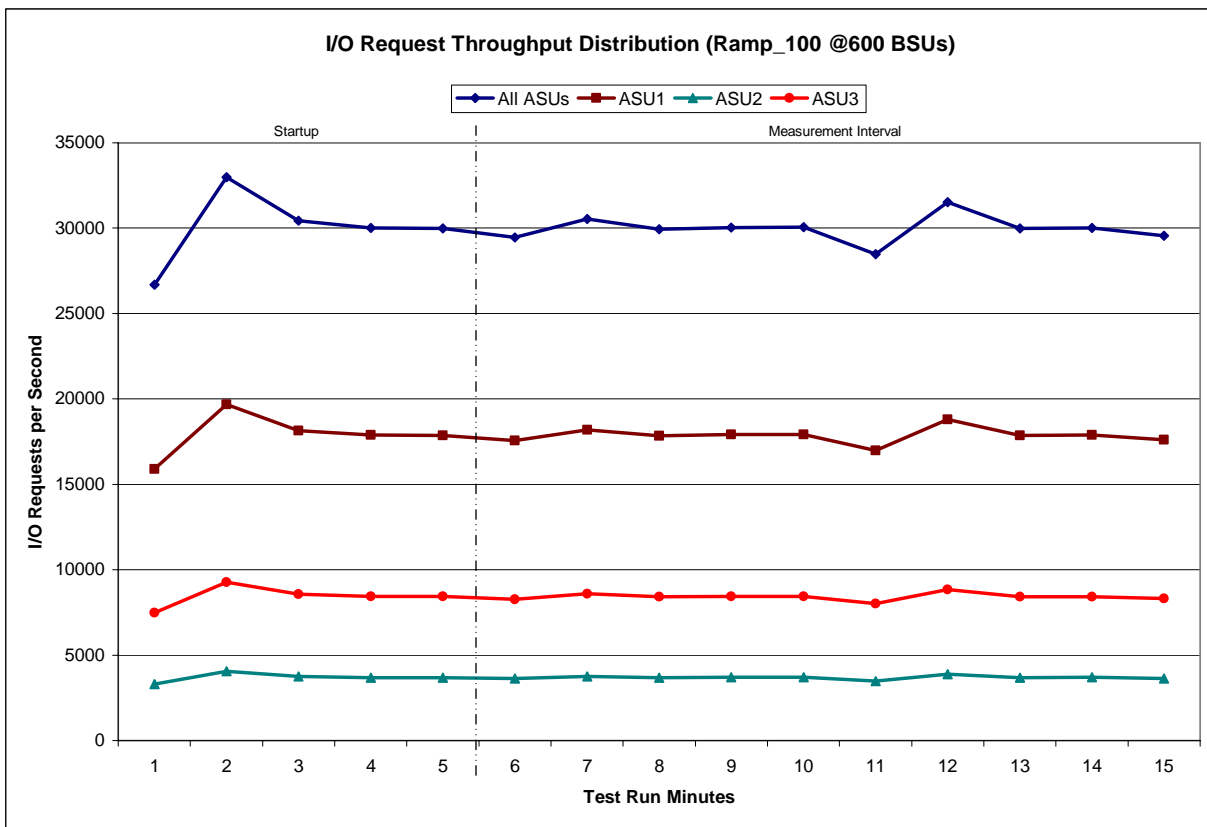
A link to the test results file generated from the IOPS Test Run is listed below.

[IOPS Test Results File](#)

IOPS Test Run – I/O Request Throughput Distribution Data

600 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	7:10:13	7:15:14	0-4	0:05:01
Measurement Interval	7:15:14	7:25:14	3-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	26,673.28	15,888.60	3,288.63	7,496.05
1	32,996.07	19,685.33	4,045.08	9,265.65
2	30,441.43	18,141.40	3,743.25	8,556.78
3	30,001.33	17,884.03	3,678.92	8,438.38
4	29,996.35	17,873.98	3,686.37	8,436.00
5	29,460.58	17,559.68	3,628.60	8,272.30
6	30,539.48	18,200.87	3,748.87	8,589.75
7	29,937.37	17,846.78	3,680.57	8,410.02
8	30,047.90	17,910.53	3,696.38	8,440.98
9	30,050.95	17,909.58	3,704.55	8,436.82
10	28,466.23	16,974.65	3,484.15	8,007.43
11	31,522.93	18,788.35	3,887.18	8,847.40
12	29,973.75	17,864.90	3,682.40	8,426.45
13	30,022.13	17,900.77	3,692.90	8,428.47
14	29,564.63	17,616.07	3,636.98	8,311.58
Average	29,958.60	17,857.22	3,684.26	8,417.12

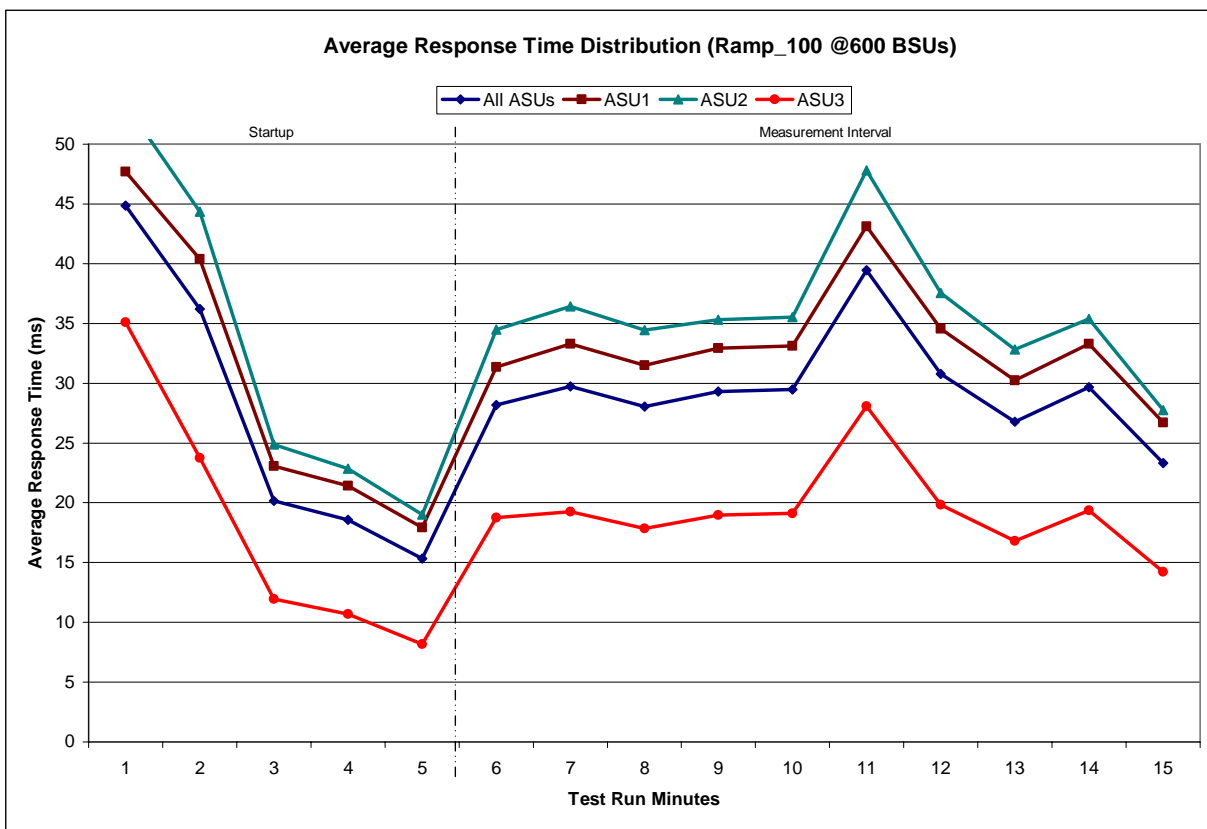
IOPS Test Run – I/O Request Throughput Distribution Graph



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

600 BSUs Start-Up/Ramp-Up Measurement Interval	Start 7:10:13 7:15:14	Stop 7:15:14 7:25:14	Interval 0-4 3-14	Duration 0:05:01 0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	44.85	47.70	53.34	35.09
1	36.20	40.38	44.35	23.76
2	20.17	23.08	24.87	11.96
3	18.59	21.44	22.84	10.69
4	15.32	17.92	19.01	8.18
5	28.19	31.34	34.48	18.75
6	29.73	33.29	36.41	19.27
7	28.02	31.50	34.45	17.84
8	29.31	32.93	35.31	18.99
9	29.48	33.12	35.51	19.12
10	39.47	43.13	47.81	28.08
11	30.79	34.56	37.54	19.82
12	26.78	30.24	32.84	16.79
13	29.65	33.31	35.39	19.37
14	23.32	26.70	27.74	14.21
Average	29.47	33.01	35.75	19.22

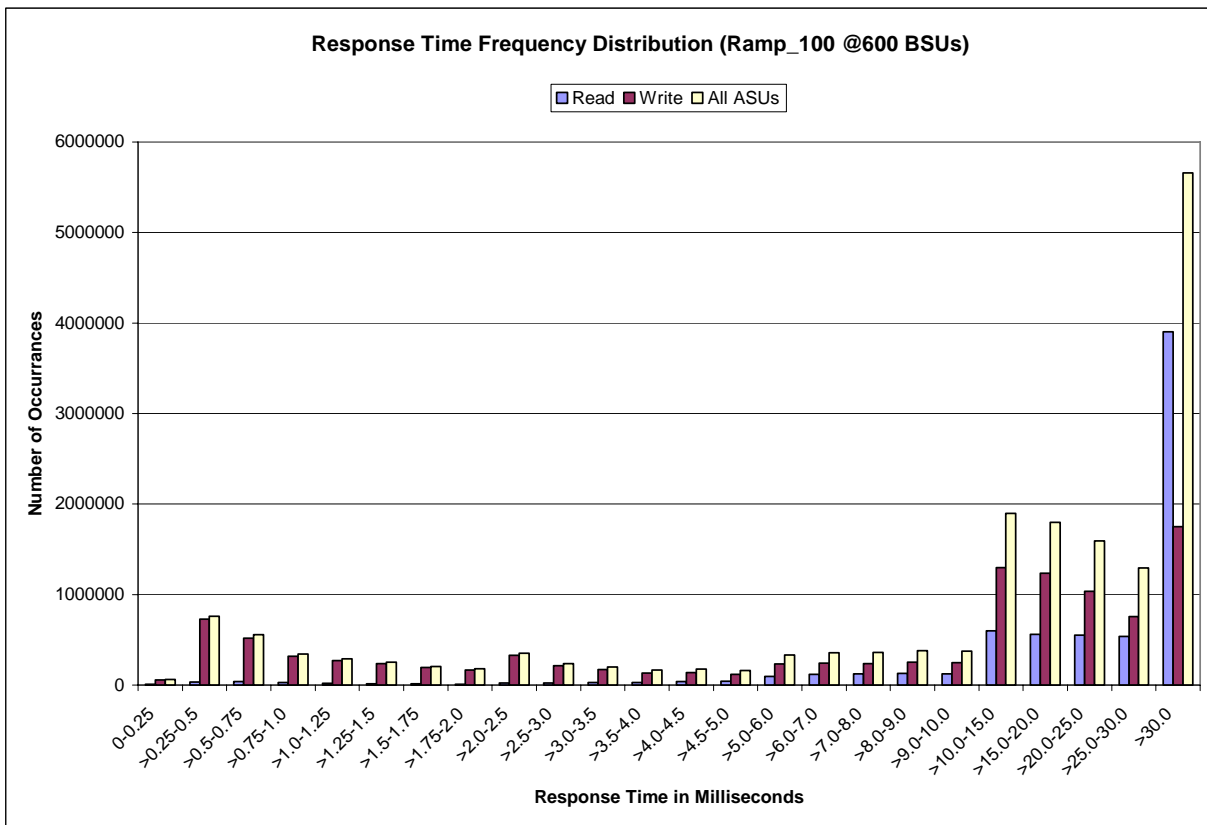
IOPS Test Run – Average Response Time (ms) Distribution Graph



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	7570	32,059	37,336	26,615	19,723	15,677	12,571	11,008
Write	54718	727,883	517,006	317,201	271,878	235,628	192,678	167,811
All ASUs	62288	759,942	554,342	343,816	291,601	251,305	205,249	178,819
ASU1	36612	366,415	243,453	152,710	130,826	112,725	92,701	80,632
ASU2	6110	73,191	51,540	32,001	27,420	23,452	19,080	16,566
ASU3	19566	320,336	259,349	159,105	133,355	115,128	93,468	81,621
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	23,533	22,984	28,614	30,419	37,277	42,134	96,590	116,698
Write	329,773	213,281	170,077	134,451	136,882	119,892	234,054	241,873
All ASUs	353,306	236,265	198,691	164,870	174,159	162,026	330,644	358,571
ASU1	158,845	108,971	95,939	83,290	90,917	88,892	185,575	206,905
ASU2	32,451	22,808	19,995	16,849	18,060	16,672	35,499	38,994
ASU3	162,010	104,486	82,757	64,731	65,182	56,462	109,570	112,672
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	123,651	127,472	125,503	599,338	560,947	552,303	537,388	3,904,416
Write	236,761	253,302	249,109	1,298,422	1,235,424	1,038,575	754,823	1,751,827
All ASUs	360,412	380,774	374,612	1,897,760	1,796,371	1,590,878	1,292,211	5,656,243
ASU1	210,342	220,847	216,985	1,073,266	998,631	900,446	771,358	4,087,047
ASU2	40,322	41,740	40,625	206,428	197,397	181,015	154,139	898,201
ASU3	109,748	118,187	117,002	618,066	600,343	509,417	366,714	670,995

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
17,975,155	12,318,912	5,656,243

IOPS Test Run – Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

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

Clauses 5.1.0 and 5.3.13.2

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

Clause 5.3.13.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
MIM	0.0350	0.2810	0.0699	0.2101	0.0180	0.0700	0.0350	0.2810
COV	0.003	0.001	0.003	0.002	0.006	0.004	0.004	0.001

Primary Metrics Test – Response Time Ramp Test Phase

Clause 5.4.2.3

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

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

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

Clause 9.2.4.7.3

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

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

SPC-1 Workload Generator Input Parameters

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

Response Time Ramp Test Results File

A link to each test result file generated from each Response Time Ramp Test Run list listed below.

[95% Load Level](#)

[90% Load Level](#)

[80% Load Level](#)

[50% Load Level](#)

[10% Load Level](#)

Response Time Ramp Distribution (IOPS) Data

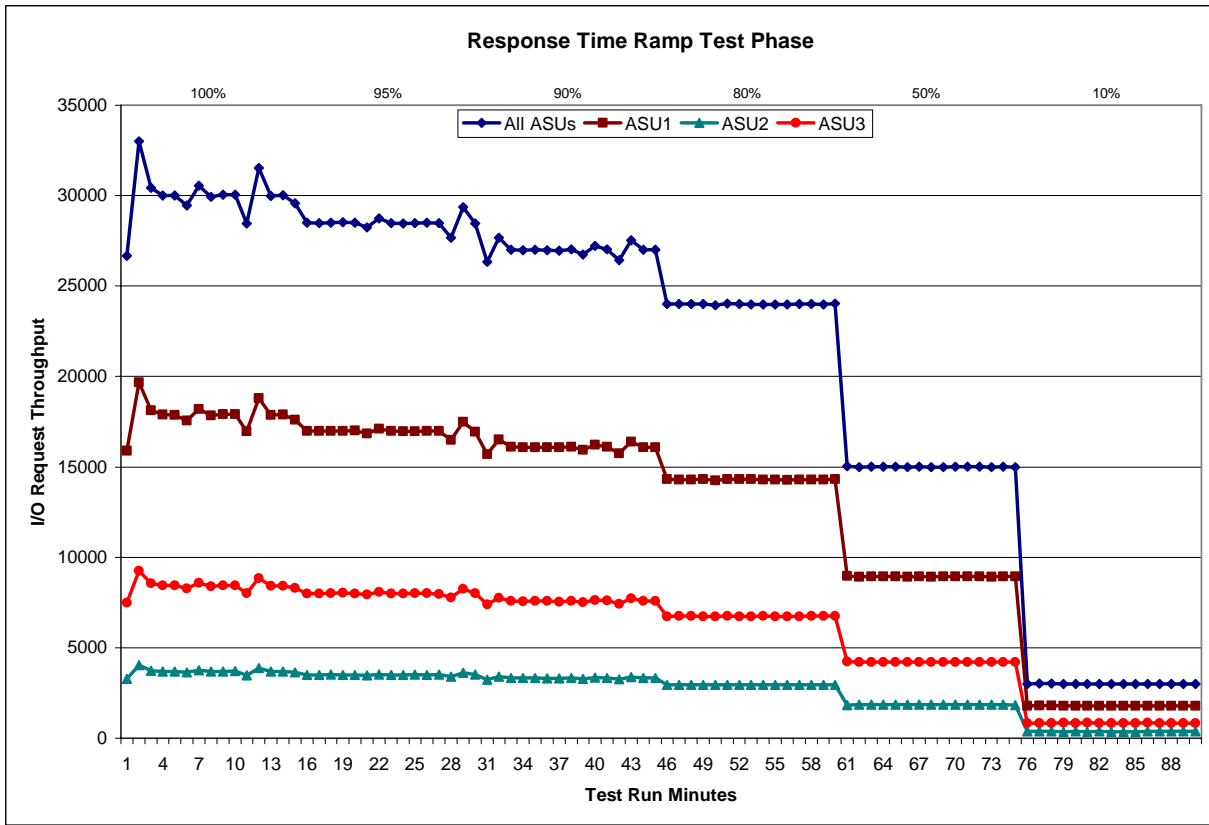
The five Test Runs that comprise the Response Time Ramp Phase are executed at 95%, 90%, 80%, 50%, and 10% of the Business Scaling Unit (BSU) load level used to produce the SPC-1 IOPS™ primary metric. The 100% BSU load level is included in the following Response Time Ramp data tables and graphs for completeness.

100% Load Level - 600 BSUs					95% Load Level - 570 BSUs				
Start-Up/Ramp-Up	Start	Stop	Interval	Duration	Start-Up/Ramp-Up	Start	Stop	Interval	Duration
Measurement Interval	7:10:13	7:15:14	0-4	0:05:01	Measurement Interval	7:25:17	7:30:18	0-4	0:05:01
(60 second intervals)	7:15:14	7:25:14	5-14	0:10:00	(60 second intervals)	7:30:18	7:40:18	5-14	0:10:00
All ASUs	ASU-1	ASU-2	ASU-3		All ASUs	ASU-1	ASU-2	ASU-3	
0	26,673.28	15,888.60	3,288.63	7,496.05	0	28,501.10	16,997.80	3,499.08	8,004.22
1	32,996.07	19,685.33	4,045.08	9,265.65	1	28,490.63	16,990.37	3,503.23	7,997.03
2	30,441.43	18,141.40	3,743.25	8,556.78	2	28,507.08	16,982.77	3,510.90	8,013.42
3	30,001.33	17,884.03	3,678.92	8,438.38	3	28,524.12	16,981.38	3,503.52	8,039.22
4	29,996.35	17,873.98	3,686.37	8,436.00	4	28,504.35	17,005.00	3,495.35	8,004.00
5	29,460.58	17,559.68	3,628.60	8,272.30	5	28,252.23	16,838.07	3,463.05	7,951.12
6	30,539.48	18,200.87	3,748.87	8,589.75	6	28,730.50	17,108.65	3,531.88	8,089.97
7	29,937.37	17,846.78	3,680.57	8,410.02	7	28,482.48	16,986.90	3,494.22	8,001.37
8	30,047.90	17,910.53	3,696.38	8,440.98	8	28,463.15	16,968.35	3,496.43	7,998.37
9	30,050.95	17,909.58	3,704.55	8,436.82	9	28,492.27	16,968.83	3,514.13	8,009.30
10	28,466.23	16,974.65	3,484.15	8,007.43	10	28,507.98	16,987.00	3,506.42	8,014.57
11	31,522.93	18,788.35	3,887.18	8,847.40	11	28,479.72	16,977.45	3,521.00	7,981.27
12	29,973.75	17,864.90	3,682.40	8,426.45	12	27,670.87	16,490.38	3,407.17	7,773.32
13	30,022.13	17,900.77	3,692.90	8,428.47	13	29,353.23	17,485.03	3,617.72	8,250.48
14	29,564.63	17,616.07	3,636.98	8,311.58	14	28,462.25	16,942.42	3,512.55	8,007.28
Average	29,958.60	17,857.22	3,684.26	8,417.12	Average	28,489.47	16,975.31	3,506.46	8,007.70

90% Load Level - 540 BSUs					80% Load Level - 480 BSUs				
Start-Up/Ramp-Up	Start	Stop	Interval	Duration	Start-Up/Ramp-Up	Start	Stop	Interval	Duration
Measurement Interval	7:40:21	7:45:22	0-4	0:05:01	Measurement Interval	7:55:25	8:00:26	0-4	0:05:01
(60 second intervals)	7:45:22	7:55:22	5-14	0:10:00	(60 second intervals)	8:00:26	8:10:26	5-14	0:10:00
All ASUs	ASU-1	ASU-2	ASU-3		All ASUs	ASU-1	ASU-2	ASU-3	
0	26,342.77	15,700.00	3,234.92	7,407.85	0	24,004.23	14,320.43	2,945.60	6,738.20
1	27,676.20	16,506.22	3,402.97	7,767.02	1	24,009.07	14,311.35	2,943.55	6,754.17
2	27,002.97	16,102.83	3,320.35	7,579.78	2	24,013.88	14,294.25	2,956.75	6,762.88
3	26,973.85	16,088.77	3,322.70	7,562.38	3	23,999.40	14,321.90	2,953.80	6,723.70
4	26,998.45	16,089.98	3,325.95	7,582.52	4	23,936.72	14,258.13	2,941.90	6,736.68
5	26,990.27	16,087.18	3,317.40	7,585.68	5	24,024.90	14,315.45	2,962.07	6,747.38
6	26,955.57	16,088.85	3,313.77	7,552.95	6	24,009.60	14,317.13	2,954.65	6,737.82
7	27,020.48	16,113.63	3,323.18	7,583.67	7	23,993.03	14,315.98	2,953.38	6,723.67
8	26,737.08	15,935.32	3,286.37	7,515.40	8	23,994.00	14,298.00	2,944.15	6,751.85
9	27,219.05	16,219.60	3,350.93	7,648.52	9	23,993.62	14,290.57	2,958.95	6,744.10
10	27,022.88	16,098.27	3,320.85	7,603.77	10	23,979.53	14,282.63	2,953.08	6,743.82
11	26,427.05	15,754.75	3,250.13	7,422.17	11	24,004.93	14,310.35	2,950.82	6,743.77
12	27,521.75	16,398.03	3,381.93	7,741.78	12	24,007.53	14,304.30	2,951.28	6,751.95
13	26,997.40	16,086.62	3,320.38	7,590.40	13	23,994.78	14,306.07	2,942.18	6,746.53
14	27,006.52	16,085.23	3,320.52	7,600.77	14	24,026.72	14,329.08	2,945.97	6,751.67
Average	26,989.81	16,086.75	3,318.55	7,584.51	Average	24,002.87	14,306.96	2,951.65	6,744.26

50% Load Level - 300 BSUs					10% Load Level - 60 BSUs				
Start-Up/Ramp-Up	Start	Stop	Interval	Duration	Start-Up/Ramp-Up	Start	Stop	Interval	Duration
Measurement Interval	8:10:29	8:15:30	0-4	0:05:01	Measurement Interval	8:25:33	8:30:34	0-4	0:05:01
(60 second intervals)	8:15:30	8:25:30	5-14	0:10:00	(60 second intervals)	8:30:34	8:40:34	5-14	0:10:00
All ASUs	ASU-1	ASU-2	ASU-3		All ASUs	ASU-1	ASU-2	ASU-3	
0	15,035.88	8,962.58	1,842.40	4,230.90	0	2,996.60	1,783.03	371.93	841.63
1	14,998.93	8,932.77	1,853.30	4,212.87	1	3,010.97	1,798.48	370.07	842.42
2	15,013.67	8,942.83	1,853.02	4,217.82	2	3,015.70	1,801.53	372.02	842.15
3	15,013.30	8,943.47	1,853.67	4,216.17	3	3,000.60	1,787.33	368.60	844.67
4	15,004.70	8,948.95	1,853.55	4,202.20	4	2,995.83	1,783.98	369.28	842.57
5	14,998.67	8,933.87	1,844.70	4,220.10	5	3,002.03	1,789.72	367.02	845.30
6	15,015.17	8,957.35	1,846.58	4,211.23	6	3,005.12	1,788.43	372.28	844.40
7	14,999.88	8,933.95	1,848.38	4,217.55	7	3,003.02	1,793.80	368.15	841.07
8	14,994.77	8,936.07	1,848.82	4,209.88	8	2,995.43	1,783.78	367.53	844.12
9	15,006.37	8,934.57	1,856.02	4,215.78	9	3,002.20	1,792.82	368.42	840.97
10	15,010.30	8,954.65	1,845.93	4,209.72	10	3,003.30	1,788.72	369.77	844.82
11	15,002.77	8,946.10	1,849.93	4,206.73	11	2,992.47	1,779.22	372.75	840.50
12	14,988.15	8,932.07	1,850.10	4,205.98	12	2,993.88	1,784.27	369.35	840.27
13	15,005.67	8,939.92	1,850.20	4,215.55	13	2,999.85	1,781.90	374.50	843.45
14	14,996.05	8,941.10	1,842.92	4,212.03	14	3,000.32	1,783.22	372.70	844.40
Average	15,001.78	8,940.96	1,848.36	4,212.46	Average	2,999.76	1,786.59	370.25	842.93

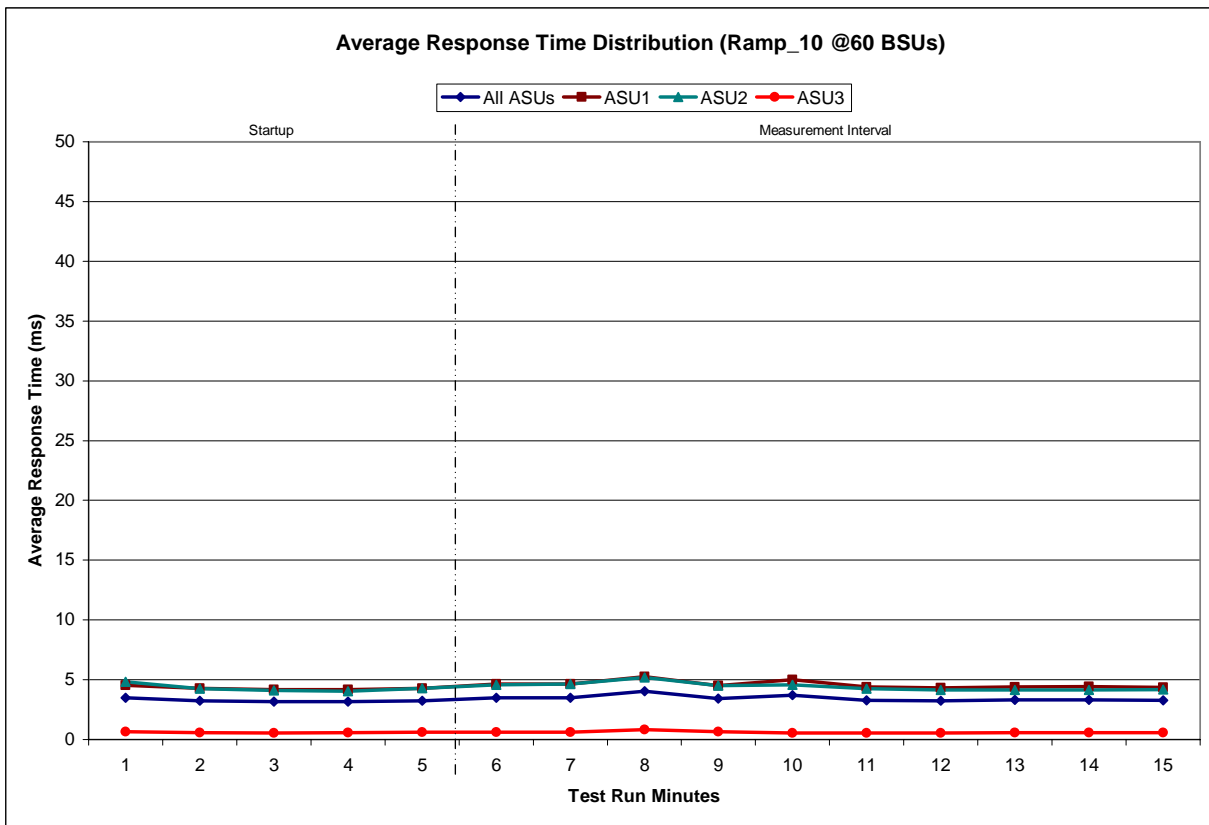
Response Time Ramp Distribution (IOPS) Graph



60 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	8:25:33	8:30:34	0-4	0:05:01
Measurement Interval	8:30:34	8:40:34	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	3.48	4.54	4.84	0.64
1	3.24	4.29	4.23	0.56
2	3.15	4.17	4.11	0.55
3	3.16	4.19	4.05	0.59
4	3.26	4.29	4.29	0.62
5	3.51	4.65	4.59	0.62
6	3.51	4.64	4.65	0.60
7	4.01	5.27	5.20	0.82
8	3.41	4.50	4.50	0.64
9	3.70	5.00	4.56	0.54
10	3.29	4.40	4.24	0.52
11	3.24	4.33	4.14	0.54
12	3.30	4.41	4.14	0.56
13	3.31	4.43	4.13	0.58
14	3.27	4.35	4.18	0.58
Average	3.45	4.60	4.43	0.60

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

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



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

Clause 3.4.3

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

Clauses 5.1.0 and 5.3.13.2

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

Clause 5.3.13.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
MIM	0.0352	0.2807	0.0696	0.2100	0.0180	0.0702	0.0353	0.2810
COV	0.017	0.004	0.005	0.003	0.018	0.010	0.014	0.002

Repeatability Test

Clause 5.4.5

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

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

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

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

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

Clause 9.2.4.7.4

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

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

SPC-1 Workload Generator Input Parameters

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

Repeatability Test Results File

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

	SPC-1 IOPS™	SPC-1 LRT™
<i>Primary Metrics</i>	29,958.60	3.45
Repeatability Test Phase 1	30,004.61	3.33
Repeatability Test Phase 2	29,998.98	3.37

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

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

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

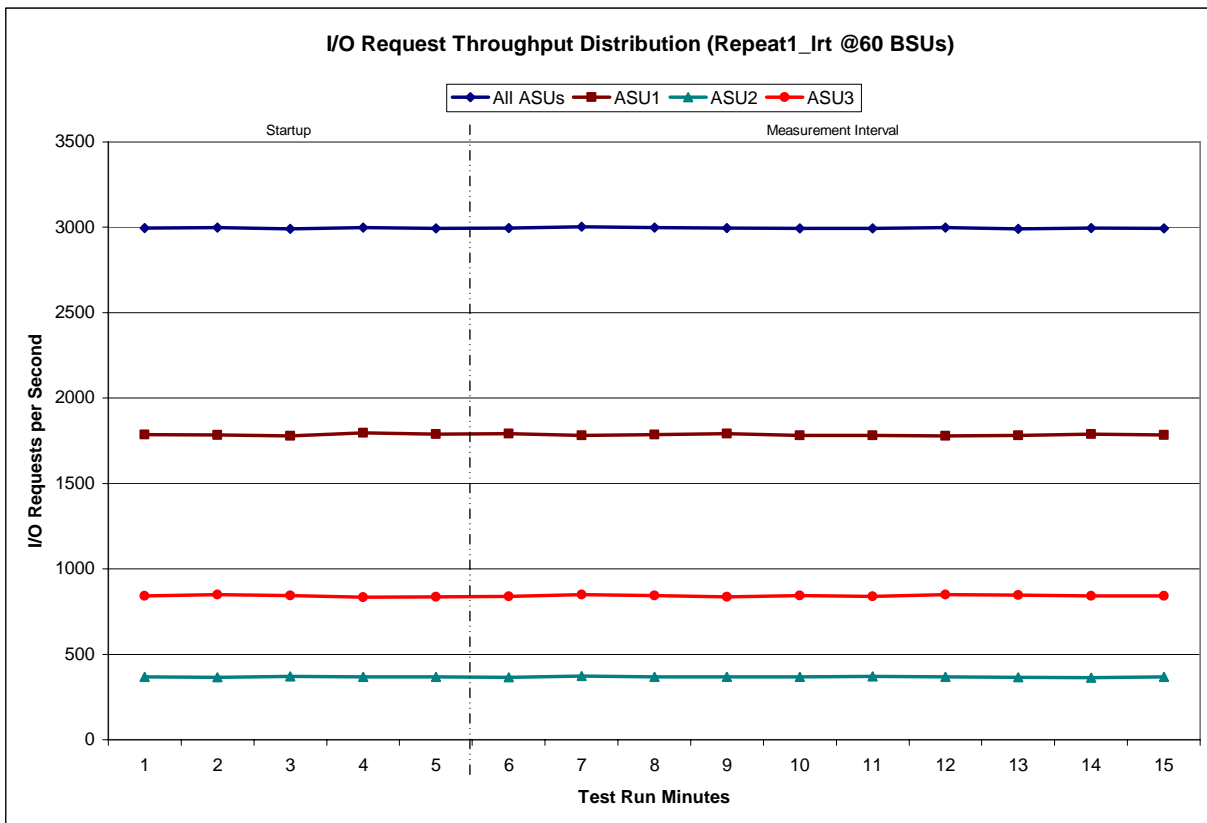
[Repeatability Test Phase 2, Test Run 1 \(LRT\)](#)

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

Repeatability 1 LRT - I/O Request Throughput Distribution Data

60 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	8:40:40	8:45:40	0-4	0:05:00
Measurement Interval	8:45:40	8:55:40	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	2,996.75	1,786.32	368.32	842.12
1	2,999.82	1,784.72	365.98	849.12
2	2,992.18	1,779.93	369.25	843.00
3	2,999.28	1,796.87	367.12	835.30
4	2,992.78	1,789.25	367.23	836.30
5	2,997.02	1,791.57	365.53	839.92
6	3,002.47	1,780.77	373.27	848.43
7	2,998.87	1,785.47	368.92	844.48
8	2,996.63	1,791.25	367.73	837.65
9	2,993.32	1,780.97	367.35	845.00
10	2,992.63	1,782.43	370.40	839.80
11	2,997.48	1,778.98	368.87	849.63
12	2,991.90	1,780.40	365.93	845.57
13	2,995.15	1,790.03	362.93	842.18
14	2,994.33	1,784.35	367.80	842.18
Average	2,995.98	1,784.62	367.87	843.49

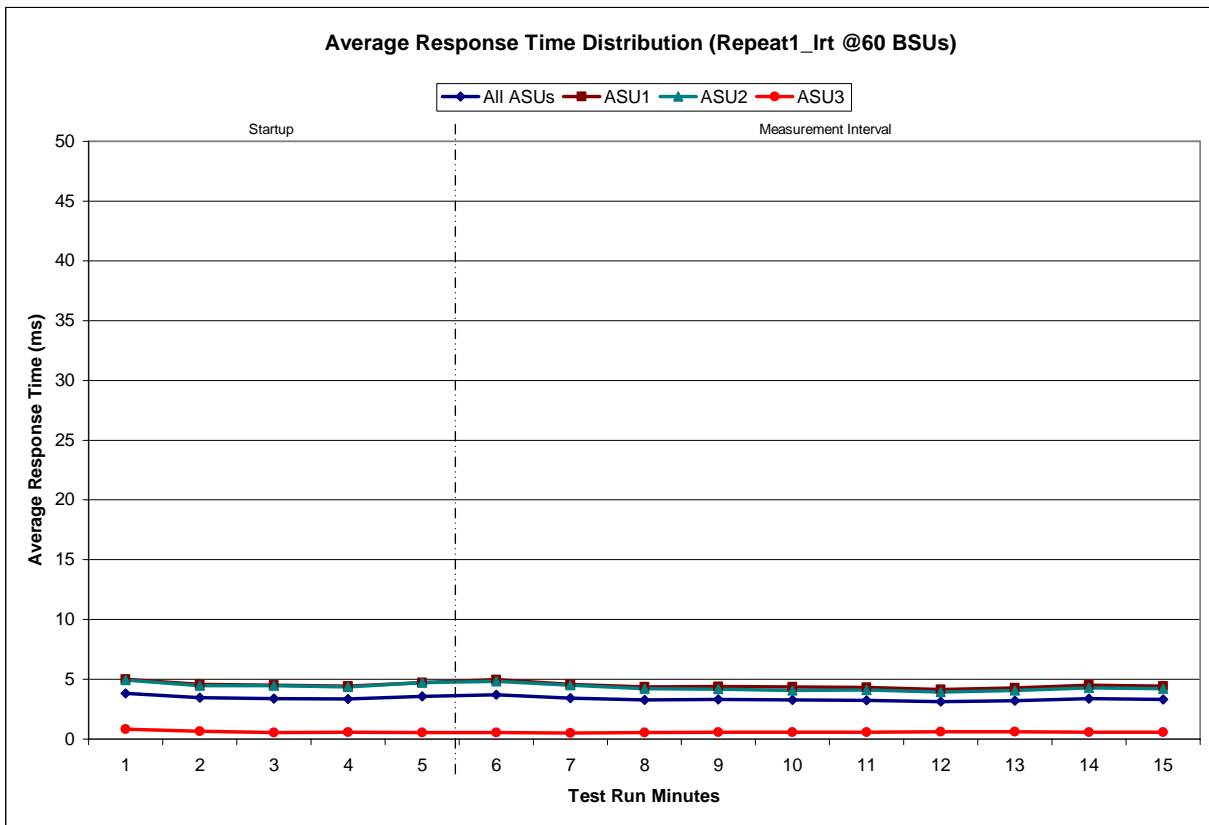
Repeatability 1 LRT - I/O Request Throughput Distribution Graph



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

60 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	8:40:40	8:45:40	0-4	0:05:00
Measurement Interval	8:45:40	8:55:40	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	3.83	5.01	4.94	0.81
1	3.45	4.58	4.45	0.64
2	3.38	4.49	4.45	0.56
3	3.36	4.44	4.37	0.59
4	3.56	4.72	4.71	0.55
5	3.72	4.98	4.82	0.55
6	3.42	4.58	4.51	0.52
7	3.28	4.36	4.23	0.56
8	3.29	4.38	4.17	0.59
9	3.26	4.37	4.06	0.57
10	3.25	4.33	4.11	0.57
11	3.12	4.16	3.94	0.60
12	3.21	4.27	4.06	0.63
13	3.38	4.51	4.28	0.59
14	3.33	4.44	4.21	0.59
Average	3.33	4.44	4.24	0.58

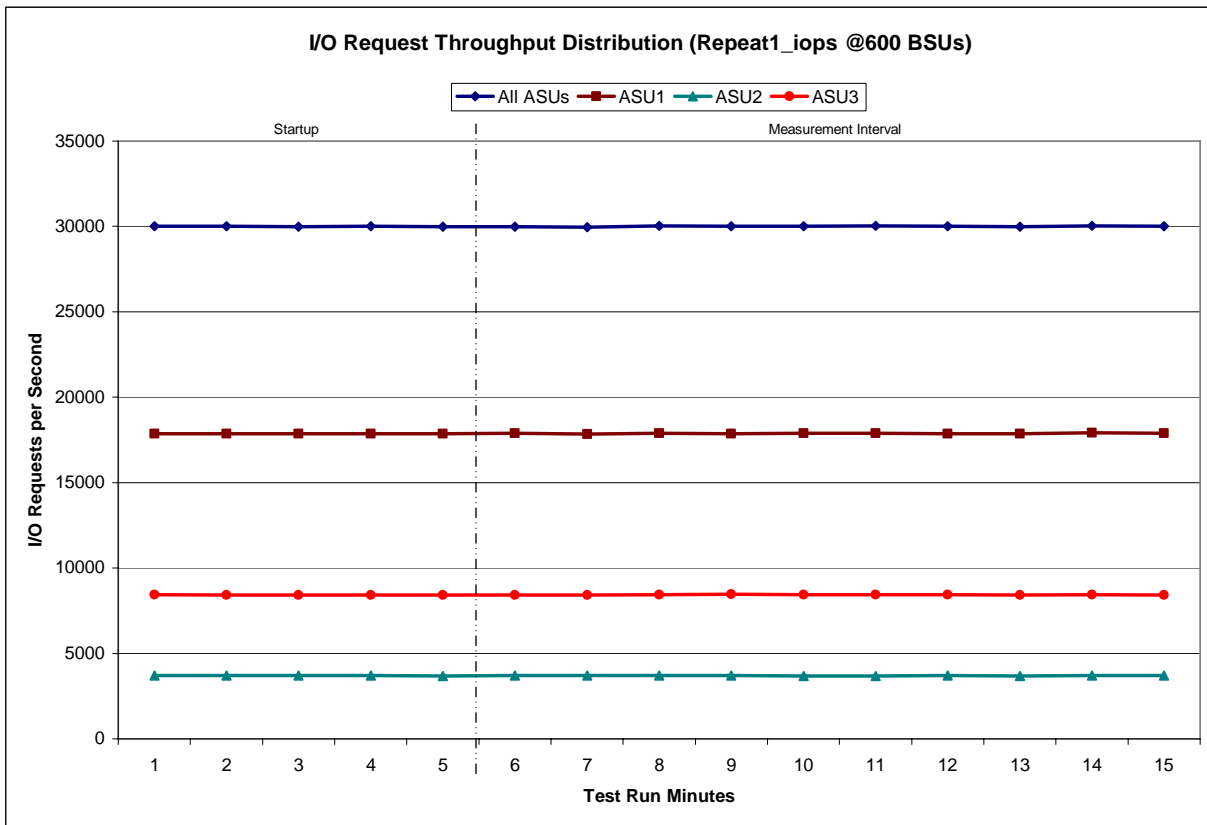
Repeatability 1 LRT –Average Response Time (ms) Distribution Graph



Repeatability 1 IOPS - I/O Request Throughput Distribution Data

600 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	8:55:44	9:00:45	0-4	0:05:01
<i>Measurement Interval</i>	9:00:45	9:10:45	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	30,003.92	17,875.90	3,692.10	8,435.92
1	30,002.67	17,877.97	3,697.35	8,427.35
2	29,978.55	17,867.00	3,693.00	8,418.55
3	29,998.23	17,876.57	3,693.25	8,428.42
4	29,982.72	17,874.22	3,688.40	8,420.10
5	29,985.37	17,882.92	3,691.60	8,410.85
6	29,962.02	17,843.60	3,692.18	8,426.23
7	30,032.98	17,896.78	3,698.82	8,437.38
8	30,019.42	17,870.75	3,694.42	8,454.25
9	29,998.73	17,888.68	3,681.17	8,428.88
10	30,025.97	17,895.10	3,689.58	8,441.28
11	30,000.08	17,872.88	3,692.12	8,435.08
12	29,977.63	17,859.82	3,691.25	8,426.57
13	30,042.25	17,909.83	3,700.52	8,431.90
14	30,001.65	17,891.58	3,694.15	8,415.92
Average	30,004.61	17,881.20	3,692.58	8,430.84

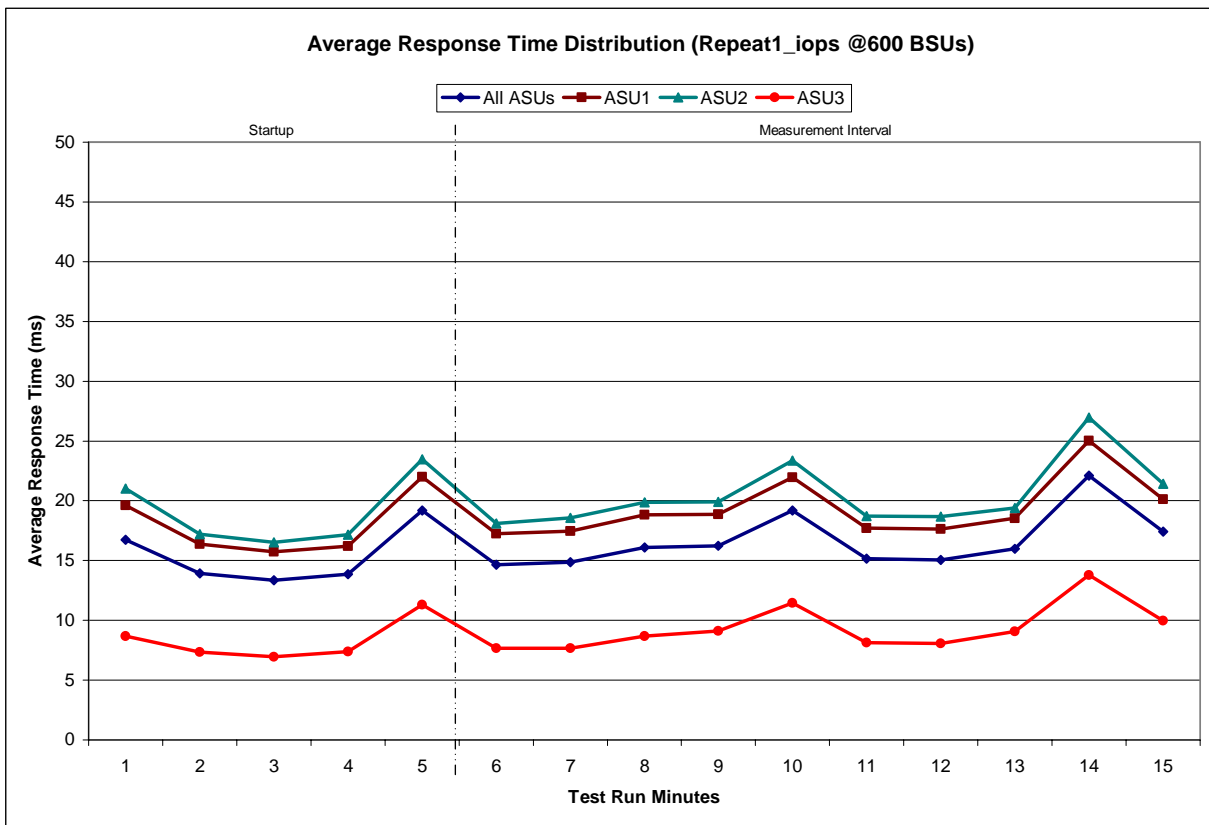
Repeatability 1 IOPS - I/O Request Throughput Distribution Graph



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

600 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	8:55:44	9:00:45	0-4	0:05:01
<i>Measurement Interval</i>	9:00:45	9:10:45	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	16.72	19.63	21.03	8.68
1	13.94	16.38	17.20	7.35
2	13.36	15.72	16.52	6.95
3	13.85	16.21	17.18	7.38
4	19.18	22.00	23.48	11.29
5	14.67	17.25	18.11	7.66
6	14.85	17.47	18.56	7.67
7	16.10	18.83	19.87	8.66
8	16.25	18.86	19.92	9.11
9	19.17	21.95	23.37	11.45
10	15.15	17.73	18.73	8.12
11	15.06	17.62	18.67	8.07
12	15.99	18.55	19.41	9.07
13	22.11	25.02	26.96	13.80
14	17.43	20.13	21.42	9.96
Average	16.68	19.34	20.50	9.36

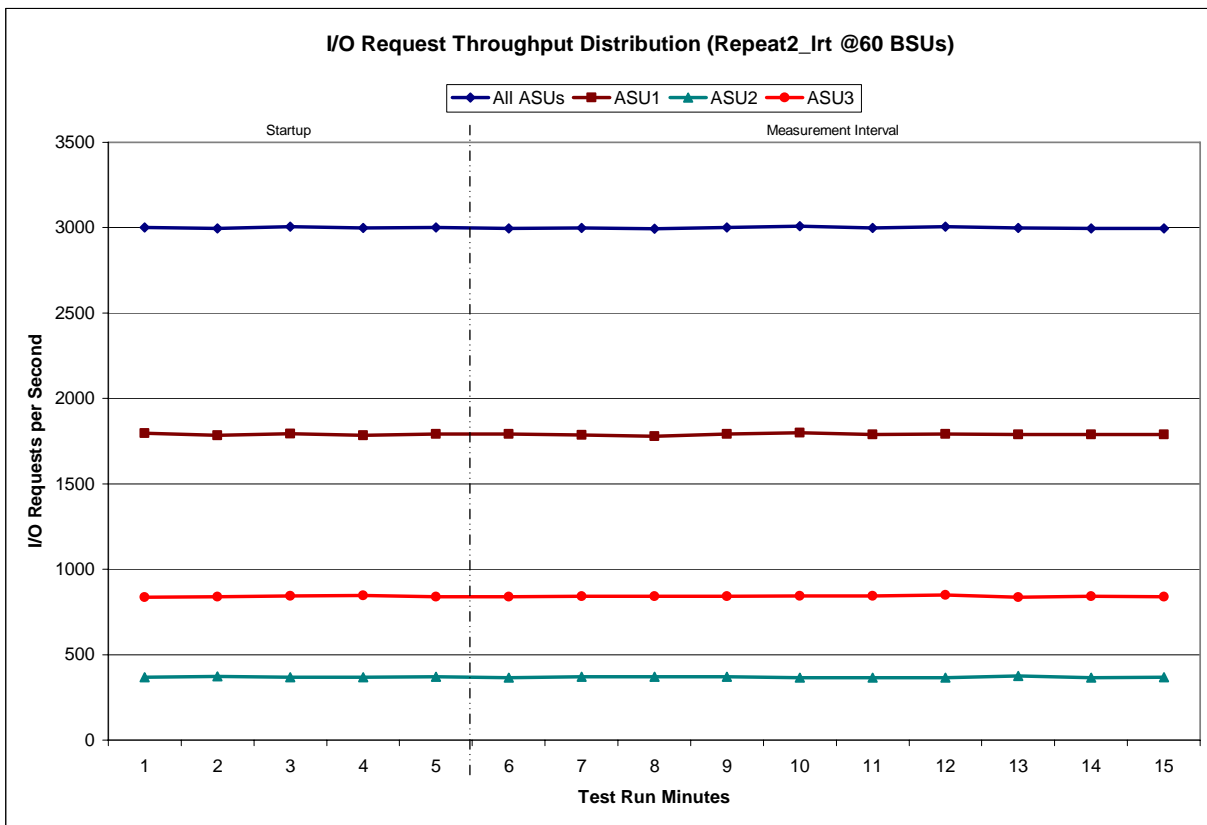
Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph



Repeatability 2 LRT - I/O Request Throughput Distribution Data

60 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	9:10:51	9:15:51	0-4	0:05:00
Measurement Interval	9:15:51	9:25:51	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	3,001.43	1,795.83	367.82	837.78
1	2,995.83	1,782.95	372.87	840.02
2	3,006.92	1,792.98	368.80	845.13
3	2,997.90	1,783.58	367.88	846.43
4	3,001.42	1,790.83	371.55	839.03
5	2,996.30	1,790.72	365.32	840.27
6	2,999.33	1,786.95	370.65	841.73
7	2,992.68	1,780.10	370.63	841.95
8	3,002.33	1,792.38	369.23	840.72
9	3,007.90	1,799.88	365.00	843.02
10	2,998.12	1,788.58	366.28	843.25
11	3,007.12	1,792.35	366.23	848.53
12	2,999.15	1,788.17	374.30	836.68
13	2,996.63	1,788.18	366.58	841.87
14	2,996.08	1,789.07	368.68	838.33
Average	2,999.57	1,789.64	368.29	841.64

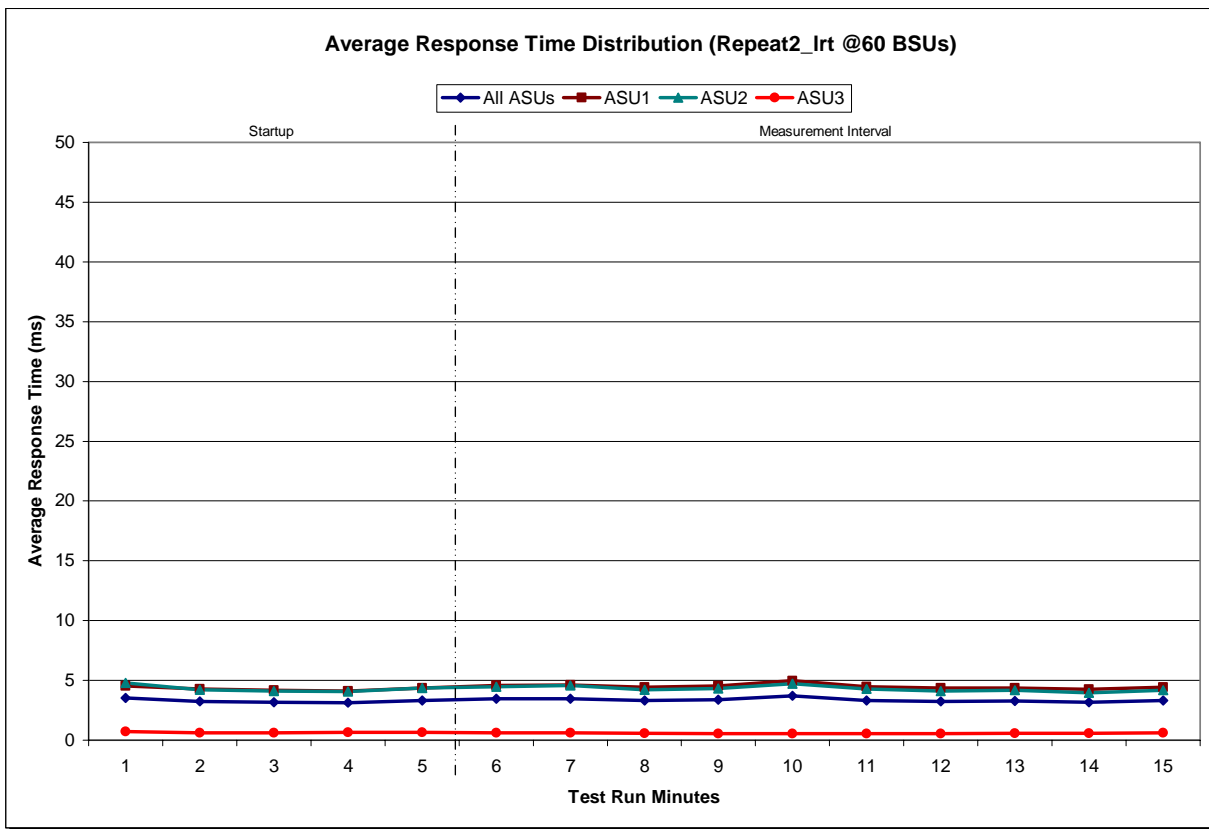
Repeatability 2 LRT - I/O Request Throughput Distribution Graph



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

60 BSUs	Start	Stop	Interval	Duration
<i>Start-Up/Ramp-Up</i>	9:10:51	9:15:51	0-4	0:05:00
<i>Measurement Interval</i>	9:15:51	9:25:51	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	3.51	4.55	4.81	0.71
1	3.23	4.27	4.19	0.61
2	3.17	4.18	4.10	0.60
3	3.12	4.10	4.06	0.65
4	3.32	4.36	4.37	0.63
5	3.44	4.56	4.48	0.61
6	3.47	4.59	4.57	0.59
7	3.32	4.43	4.22	0.57
8	3.38	4.52	4.33	0.53
9	3.70	4.98	4.73	0.53
10	3.33	4.45	4.27	0.52
11	3.25	4.36	4.11	0.54
12	3.27	4.34	4.16	0.57
13	3.18	4.25	3.96	0.58
14	3.32	4.41	4.16	0.61
Average	3.37	4.49	4.30	0.57

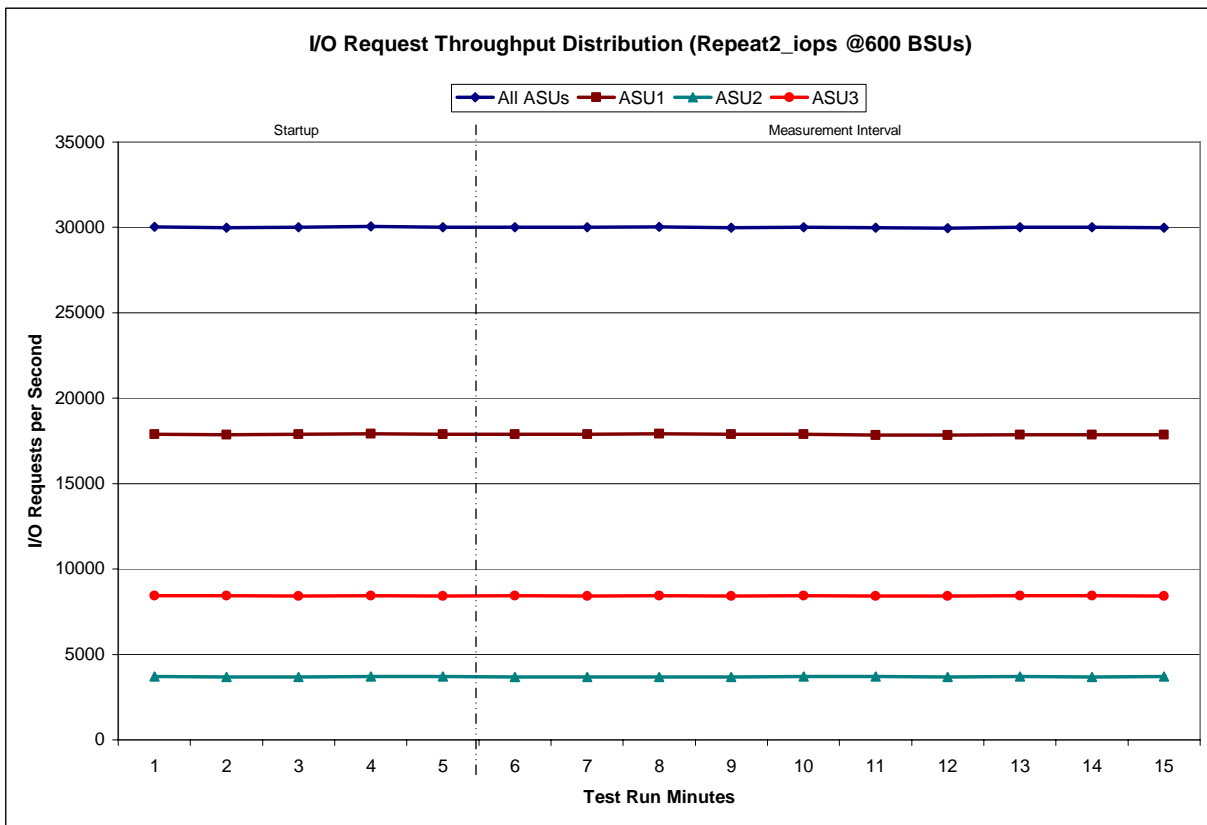
Repeatability 2 LRT –Average Response Time (ms) Distribution Graph



Repeatability 2 IOPS - I/O Request Throughput Distribution Data

600 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	9:25:55	9:30:56	0-4	0:05:01
Measurement Interval	9:30:56	9:40:56	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	30,034.83	17,901.45	3,698.48	8,434.90
1	29,994.47	17,865.85	3,688.28	8,440.33
2	30,002.05	17,889.95	3,686.72	8,425.38
3	30,050.10	17,910.67	3,696.58	8,442.85
4	30,013.83	17,895.70	3,697.08	8,421.05
5	30,017.53	17,894.72	3,688.05	8,434.77
6	30,008.78	17,892.57	3,688.43	8,427.78
7	30,027.82	17,907.68	3,681.30	8,438.83
8	29,974.63	17,894.45	3,676.22	8,403.97
9	30,011.77	17,885.25	3,696.25	8,430.27
10	29,983.67	17,848.40	3,707.32	8,427.95
11	29,959.42	17,845.25	3,687.33	8,426.83
12	30,005.65	17,876.72	3,691.68	8,437.25
13	30,011.27	17,872.23	3,687.90	8,451.13
14	29,989.25	17,875.07	3,692.23	8,421.95
Average	29,998.98	17,879.23	3,689.67	8,430.07

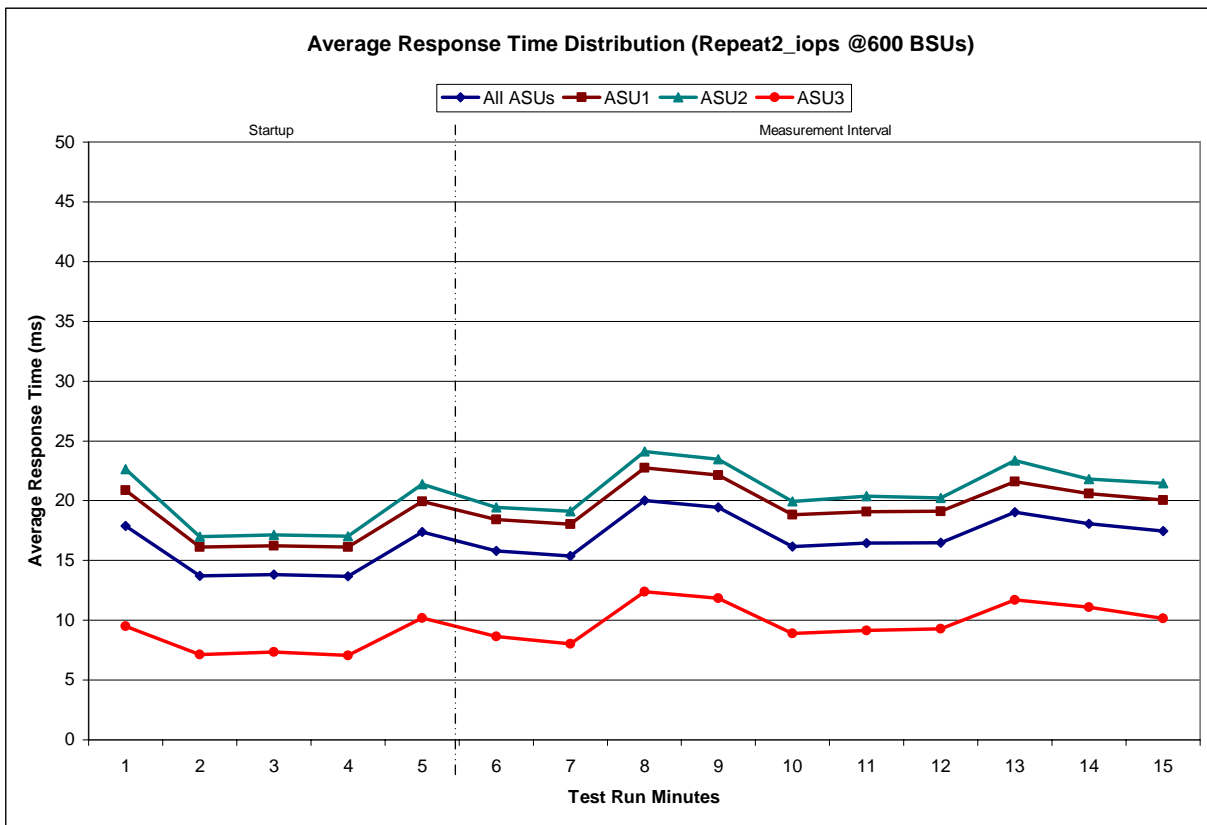
Repeatability 2 IOPS - I/O Request Throughput Distribution Graph



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

600 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	9:25:55	9:30:56	0-4	0:05:01
Measurement Interval	9:30:56	9:40:56	5-14	0:10:00
60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	17.89	20.87	22.63	9.51
1	13.71	16.14	16.99	7.13
2	13.84	16.23	17.13	7.34
3	13.69	16.13	17.01	7.06
4	17.38	19.95	21.37	10.19
5	15.81	18.43	19.45	8.63
6	15.36	18.05	19.11	8.02
7	20.01	22.77	24.13	12.38
8	19.42	22.15	23.47	11.85
9	16.17	18.81	19.95	8.89
10	16.44	19.06	20.36	9.16
11	16.48	19.10	20.25	9.28
12	19.04	21.61	23.35	11.69
13	18.06	20.58	21.83	11.09
14	17.44	20.06	21.45	10.14
Average	17.42	20.06	21.34	10.11

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



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

Clause 3.4.3

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

Clauses 5.1.0 and 5.3.13.2

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

Clause 5.3.13.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
MIM	0.0347	0.2811	0.0698	0.2101	0.0180	0.0698	0.0349	0.2815
COV	0.010	0.004	0.009	0.005	0.014	0.010	0.013	0.004

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
MIM	0.0350	0.2810	0.0700	0.2099	0.0180	0.0700	0.0350	0.2810
COV	0.003	0.001	0.003	0.001	0.007	0.002	0.003	0.001

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	0.0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.0350	0.2810
MIM	0.0351	0.2812	0.0702	0.2102	0.0181	0.0697	0.0350	0.2806
COV	0.013	0.004	0.008	0.006	0.021	0.012	0.010	0.003

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	0.2809	0.0700	0.2101	0.0180	0.0700	0.0350	0.2810
COV	0.003	0.001	0.004	0.002	0.005	0.003	0.004	0.001

Data Persistence Test

Clause 6

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

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

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

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

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

Clause 9.2.4.8

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

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

SPC-1 Workload Generator Input Parameters

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

Data Persistence Test Results File

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

[Persistence 1 Test Results File](#)

[Persistence 2 Test Results File](#)

Data Persistence Test Results

Data Persistence Test Results	
Data Persistence Test Run Number: 1	
Total Number of Logical Blocks Written	71,896,800
Total Number of Logical Blocks Verified	38,980,464
Total Number of Logical Blocks that Failed Verification	0
Time Duration for Writing Test Logical Blocks	10 minutes
Size in Bytes of each Logical Block	512
Number of Failed I/O Requests in the process of the Test	0

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

PRICED STORAGE CONFIGURATION AVAILABILITY DATE

Clause 9.2.4.9

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

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

The NetApp FAS3040 as documented in this Full Disclosure Report will become available for customer purchase and shipment on March 18, 2008.

PRICING INFORMATION

Clause 9.2.4.11

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

Clause 9.2.4.11.3

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

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

ANOMALIES OR IRREGULARITIES

Clause 9.2.4.10

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

There were no anomalies or irregularities encountered during the SPC-1 Onsite Audit of the NetApp FAS3040.

APPENDIX A: SPC-1 GLOSSARY

“Decimal” (*powers of ten*) Measurement Units

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

- A kilobyte (KB) is equal to 1,000 (10^3) bytes.
- A megabyte (MB) is equal to 1,000,000 (10^6) bytes.
- A gigabyte (GB) is equal to 1,000,000,000 (10^9) bytes.
- A terabyte (TB) is equal to 1,000,000,000,000 (10^{12}) bytes.
- A petabyte (PB) is equal to 1,000,000,000,000,000 (10^{15}) bytes
- An exabyte (EB) is equal to 1,000,000,000,000,000,000 (10^{18}) bytes

“Binary” (*powers of two*) Measurement Units

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

- A kibibyte (KiB) is equal to 1,024 (2^{10}) bytes.
- A mebibyte (MiB) is equal to 1,048,576 (2^{20}) bytes.
- A gibibyte (GiB) is equal to 1,073,741,824 (2^{30}) bytes.
- A tebibyte (TiB) is equal to 1,099,511,627,776 (2^{40}) bytes.
- A pebibyte (PiB) is equal to 1,125,899,906,842,624 (2^{50}) bytes.
- An exbibyte (EiB) is equal to 1,152,921,504,606,846,967 (2^{60}) bytes.

SPC-1 Data Repository Definitions

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

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

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

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

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

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

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

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

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

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

SPC-1 Data Protection Levels

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

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

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

Unprotected: There is no data protection provided.

SPC-1 Test Execution Definitions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

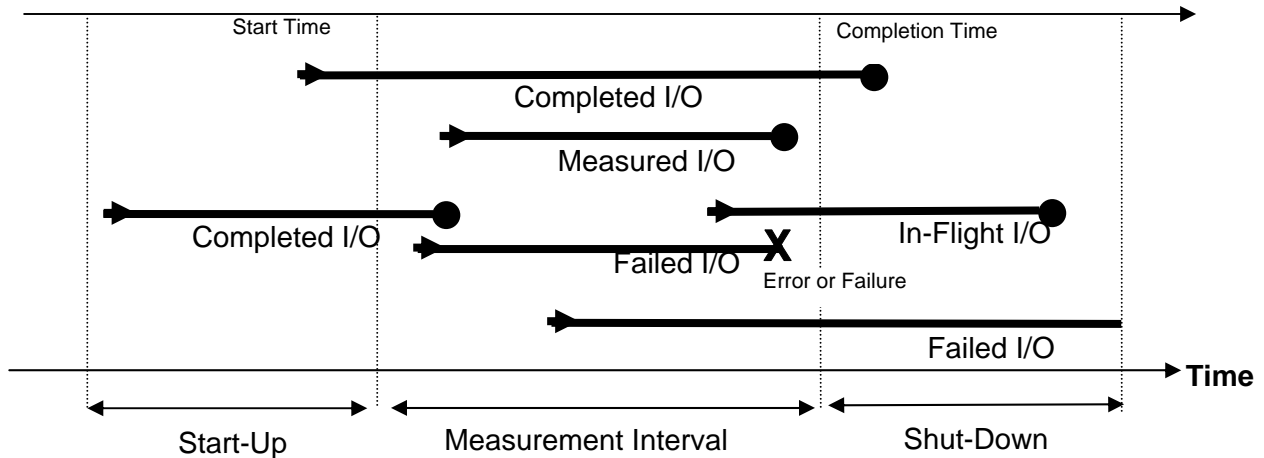
Test: A collection of Test Phases and or Test Runs sharing a common objective.

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

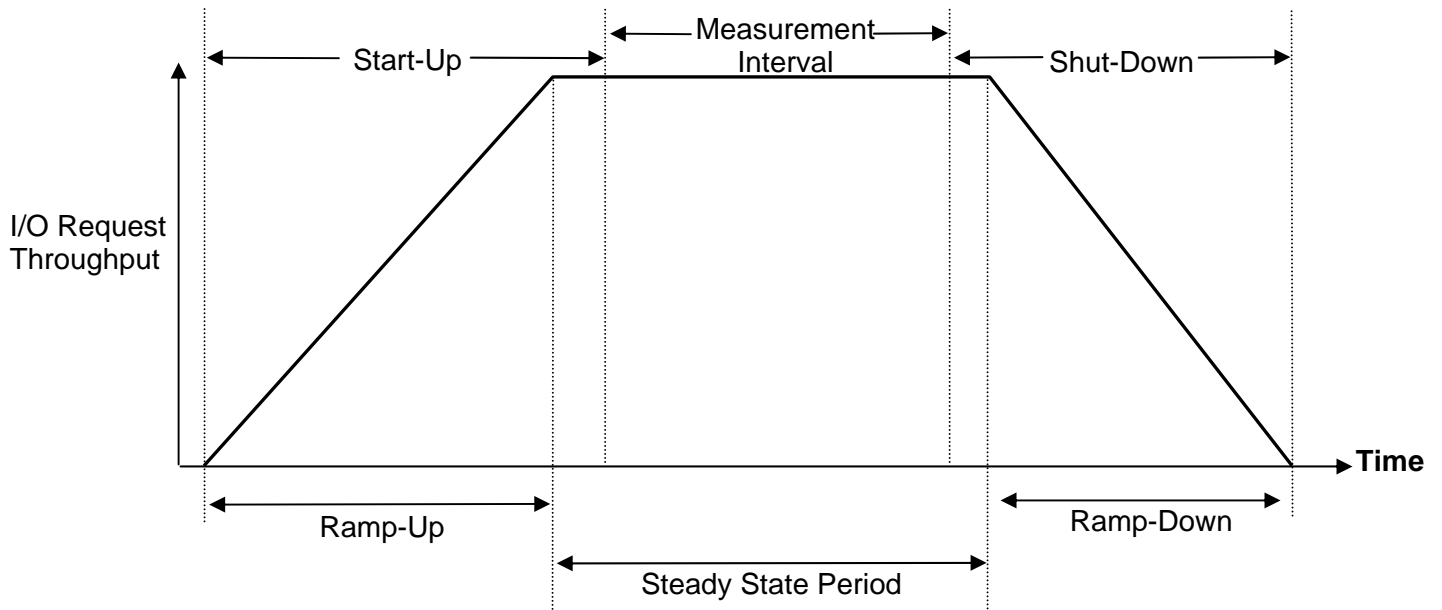
period, Shut-Down period, and Ramp-Down period as illustrated in the “SPC-1 Test Run Components” below. All SPC-1 Test Runs shall have a Steady State period and a Measurement Interval.

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

I/O Completion Types



SPC-1 Test Run Components



APPENDIX B: CUSTOMER TUNABLE PARAMETERS AND OPTIONS

Windows 2003 Server

For each HBA in the system, change the execution throttle (queue depth) from the default value of 16 to 256.

FAS3040 Storage Controllers

The following changes must be made on each controller:

- **LUN options:** Create the LUNs without space reservations. By default, the “lun create” command creates LUNs with space reservations. Instead of reserving space for the LUNs, the LUN create script pre-allocates space for all of the LUNs by overwriting every block of each LUN (see Appendix C), as required by the SPC-1 specification.
- **Volume Options (applied to vol0, the ONTAP root volume):**
 - Resize the volume from its default size of 100 GB to 30 GB.
 - Change the volume option “nosnap” from its default value of “off” to “on”. This disables the automatic creation of Snapshot copies.
- **Volume Options (applied to vol1, the SPC data set volume):**
 - Create the volumes with a space reservation requirement of “none” rather than the default value of “volume”. Because all of the LUNs in the volume are pre-allocated there is no need to reserve space in the volume.
 - Change the volume option “nosnap” from its default value of “off” to “on”. This disables the automatic creation of Snapshot™ copies.
- **Aggregate Options (applied to aggr0, the only aggregate in the system)**
 - Change the aggregate Snapshot reserve to 0 bytes.
 - Change the aggregate option “nosnap” from its default value of “off” to “on”.
These changes disable automatic Snapshot copies at the aggregate level.
- **System Flags:**
 - **waf_l_optimize_write_once:** change default value of 1 to 0. This flag affects the initial layout of data within a newly created aggregate. The default data layout favors applications which do not overwrite their data.
 - **waf_l_downgrade_target:** change default value of 1 to 0. This flag changes the run-time priority of the process that handles the SCSI protocol for incoming Fibre-Channel requests. For storage systems that are not also servicing NAS requests this change to the process priority is recommended.

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

Host System

- Install Microsoft Windows Server 2003 Service Pack 2.
- Install and setup two Qlogic 2462 HBAs using NetApp certified Qlogic driver.
- Install NetApp's FCP Windows® Host Utilities 3.0 for Native OS
- Install Qlogic SANsurfer HBA management software.
- Install Data ONTAP DSM 3.2 for Windows MPIO and set it up to use round robin load balancing policy.
- Set the "Execution Throttle" (also known as HBA queue depth) setting on each FCP port from default of 16 to 256 using SANsurfer HBA management software.

Brocade FCP Switches

Connect the physical connections from the Host System to the FAS3040 as illustrated on page 15 (*Benchmark Configuration/ Tested Storage Configuration Diagram*).

Storage Controllers

The following sections document how to set up the storage controllers and create the raid-groups, aggregates, volumes and LUNs that comprise the SPC-1 data repository.

Initializing Disk Ownership

The NetApp FAS3040 system consists of two storage controllers. Before the systems are installed the ownership of the individual disks must be established in the following fashion:

- Each controller should be setup with 3 active and 3 passive FCAL connections to the disk shelves
- Each controller should be setup with 5 active shelves (total 10 disk shelves between the two controllers). Each controller should own all disks in its 5 active shelves.

After the FCAL connections to disk shelves and disk ownership has been established, zero (initialize) all disks by executing the following steps on each NetApp controller:

1. Boot the NetApp controllers either by power cycling or typing "boot" at the "LOADER>" prompt on the console screen
2. Hit "CTRL C" during the boot process when prompted for the special boot menu on the console screen
3. Once at special boot menu, select option "4a" to zero (initialize) all disks and install a flexible root volume
4. After zeroing (initialization) of all disks are completed, follow the remaining prompts to complete the basic setup of NetApp controller.

After zeroing (initialization) of all disks and basic setup is completed, install NetApp Data ONTAP 7.3 by executing the following steps:

1. Download Data ONTAP 7.3 system files for FAS3040 platform from NetApp's NOW site to a directory location that can be accessed via an http URL
2. Login to NetApp controller as root and at the command prompt type:
`software install <http URL of Data ONTAP 7.3 system files>`
3. Once the installation of system files is completed, type "download" at the command prompt of NetApp controllers
4. Once "download" command completes, reboot the NetApp controller for changes to take effect.

Installing Licenses

The following licenses must be installed after NetApp ONTAP 7.3 system software installation has completed:

- cluster
- fcp
- snapstore

To install the licenses, execute the following command at NetApp controller's command prompt:

```
license add <license key>
```

Base Setup Script – FAS3040 Controllers

Once licenses are installed and both FAS3040 controllers rebooted, the perl script below should be run from the Host System to setup both FAS3040 controllers with appropriate storage sizes for SPC-1 ASUs. The script is invoked using the following syntax:

```
ntap_spc1_cfg.pl -f controller_a,controller_b -i wwpn_1,wwpn_2,wwpn_3,wwpn_4 -t timehost_ip_addr
```

The script does the following on each FAS3040 controller:

- modify /etc/rc file with the following setflags so these are persistent across reboots:
 - setflags waf_l_optimize_write_once 0
 - setflag waf_l_downgrade_target 0
- set timezone to EST5EDT
- sets the following setflags to appropriate settings:
 - waf_l_optimize_write_once 0
 - waf_l_downgrade_target 0
- create aggregate with the following configuration:
 - aggr0 settings, 4 rgs, rg sizes (1x18 + 3x17), 1 spare
 - aggr0 options:
 - nosnap=on

- set snap reserve = 0 on aggregate aggr0
- set snap sched to 0 0 0 on the aggregate aggr0
- Configure the flexible volumes within aggregate with the following configuration:
 - Root flexible volume (vol0)
 - resize root volume to 30GB
 - set volume options on root volume vol0
 - nosnap=on
 - nosnapdir=off
 - set snap reserve = 0 on vol0
 - set snap sched to 0 0 0 on vol0
 - spc1 data flexible volume (vol1):
 - create vol1 of size 8493820 MB
 - set volume options on vol1:
 - nosnap=on
 - nosnapdir=off
 - set snap reserve = 0 on vol1
 - set snap sched to 0 0 0 on vol1
 - set space reservation (guarantee) to “none”
- Create fcp portset to contain NetApp controller ports 0a and 0c. Then, create windows igroup which contains the wwpn of FCP HBAs initiators in the SPC-1 Windows driver system
- Create zeroed luns with no space reservation on each NetApp controller with the following sizes and then map them to the windows igroup created earlier assigning each lun a unique lun id.
 - 6 lun files for ASU1 of size 450100 MB each
 - 6 lun files for ASU2 of size 450100 MB each
 - 6 lun files for ASu3 of size 100022 MB each
- Verify fcp is started on both NetApp controllers.

Host Disk Stripe Setup

Once the ASU LUNs are visible on the Windows host, execute the following steps to stripe the appropriate ASU LUNs together and assign a drive letter:

- In Windows disk management MMC, initialize each disk associated with the ASU luns.
- Convert each of the same disks to dynamic disks
- Create three striped volumes for ASU1, ASU2, and ASU3.
 - Stripe each volume across all 12 luns associated with each respective ASU.
 - Assign drive letter “E” for ASU1
 - Assign drive letter “F” for ASU2
 - Assign drive letter “G” for ASU3

Setting Up Snapshot

Prior to setting up the snapshots and their schedules, there should not be any existing volume or aggregate snapshots. If volume or aggregate snapshot(s) exist(s), delete it/them.

Additionally, verify there is no "container block reclamation" scan process running on the both controllers prior to snapshots/schedule setup by issuing the following commands at the filer command prompt;

```
priv set advanced
waf1 scan status
```

To configure snapshots and their schedules after NetApp controller base setup script is executed successfully, no prior existence of snapshots and no block reclamation process running verified, execute the following commands on both NetApp controllers:

```
snap sched voll 0 0 0 3@0,15,30,45
```

The above command will setup the snapshots schedule on voll for snapshots to occur every 15 minutes and keep 3 latest snapshots

```
vol options voll nosnap off
```

The above command will turn on the snapshots on voll

ntap_spc1_cfg.pl

```
#!/usr/local/bin/perl
use Getopt::Std;

# ----- #
# Global Definition Section

# Set up some host-specific variables
$TEST=`VER 2>&l`;
$RSH="";
$TIME_CMD="";
$WINDOWS=0;
if ( $TEST eq "" ) {
    $RSH="/usr/bin/rsh -l root -n";
    $TIME_CMD="date";
} else {
    $WINDOWS=1;
    $RSH="rsh.exe";
    $TIME_CMD="time /T";
}

$INITIATOR_WWN_LIST="";
# controller-specific stuff
$LUN_TYPE = "windows";
$USE_WIN_RAW_DEVICES = 0;
$LUN_COUNT = 36;
$ASU1_2_LUN_SIZE = "450100m";
$ASU3_LUN_SIZE = "100022m";
$IGROUP_TYPE = "windows";
$TIMEHOST="";
$AGGR_NAME="aggr0";
```



```

$TARGET_VOL="voll";
@CONTROLLER_LIST=();

# ----- #
# Helper function definition section

sub usage {
    printf STDOUT "\
SPC-1 setup script for FAS3040 cluster:\
> %s [-h] [-r] -f controller_a,controller_b -t timehost_ip_addr [-i\
wnn_1,wnn_2,...,wnn_n]\
    Options                               Semantics\
    -h                                     Display help menu and exit\
\
    -r                                     Create setup for Windows raw devices\
                                     (default is to setup for Windows volume manager)
\
    -f controller_a,controller_b         Comma-separated list of controller hostnames or\
ip-addr\
                                     to setup for SPC-1 test.\
                                     *NOTE* We split lun creation evenly between\
controller_a\
                                     and controller_b, with controller_a getting the\
odd numbered\
                                     lun names (but even numbered lun ids) and\
controller_b\
                                     getting the even numbered lun names and odd\
number-\
                                     ed lun ids.\
\
    -i wwpn_1,wwpn_2,...,wwpn_n         Comma-separated list of WWPNS of client-side\
initiator ports.\
    -t timehost_ip_addr                 IP address of the timehost to synchronize\
controller times.\
", $0;
}
# Print msg with timestamp to STDOUT
sub log_msg {
    my $msg = shift(@_);
    $timestamp = `$_TIME_CMD`;
    chomp($timestamp);
    printf "%s -- %s\n", $timestamp, $msg;
}
# Small subroutine that sends an rsh command to $controller and returns the output
sub do_rsh($$) {
    my ($controller, $cmd) = @_;
    log_msg("Controller: ".$controller.": sending command \"priv set -q diag;\
\".$cmd.\"");

    if ($WINDOWS eq 1) {
        return(`$_RSH $controller -l root "priv set -q diag; $cmd`);
    } else {
        return(`$_RSH $controller "priv set -q diag; $cmd`);
    }
}

# ----- #
# Check options

getopts("rhf:i:t:");
if ($opt_h) {
    usage();
    exit 0;
}

```

```

}
if (!$opt_f) {
    printf STDERR "ERROR: Please provide comma-separated list of controller
hostnames or controller ip addresses!\n";
    usage();
    exit 1;
} else {
    $opt_f =~ s/\s+//;
    @CONTROLLER_LIST = split(",", $opt_f);
}
if ($opt_r) {
    $USE_WIN_RAW_DEVICES = 1;
    $LUN_TYPE = "linux";
    $LUN_COUNT=100;
    $ASU1_2_LUN_SIZE="135030m";
    $ASU3_SIZE="60013m";
}
if (!$opt_t) {
    printf STDERR "ERROR: Please provide a timehost ip to synchronize the
controller clocks!\n";
    usage();
    exit 1;
} else {
    $TIMEHOST = $opt_t;
}
if (!$opt_i) {
    printf STDERR "ERROR: Please provide a comma-separated list of host initiator
WWPNS!\n";
    usage();
    exit 1;
} else {
    $INITIATOR_WWN_LIST="";
    $opt_i =~ s/\s+//;
    @wwn_list = split(",", $opt_i);
    foreach $wwn (@wwn_list) {
        $INITIATOR_WWN_LIST .= $wwn.' ';
    }
}
# ----- #
# Functions for setting / configuring ONTAP options

# Routine for setting the two flags -- NOTE: Simply using setflag does not
guarantee persistence across reboots
sub do_setflags {
    foreach $controller (@CONTROLLER_LIST) {
        do_rsh($controller, "setflag wafld_optimize_write_once 0");
        do_rsh($controller, "setflag wafld_downgrade_target 0");
    }
}
# Routine for adding the 2 setflags and default gateway to each controller's rc
file so that they remain persistent across reboots
sub modify_rc_files {
    foreach $controller (@CONTROLLER_LIST) {
        do_rsh($controller, "wfile -a /etc/rc \\\\\"priv set -q diag; setflag
wafld_optimize_write_once 0\\\\");
        do_rsh($controller, "wfile -a /etc/rc \\\\\"priv set -q diag; setflag
wafld_downgrade_target 0\\\\");
    }
}
# Set timezone and rdate to timehost
sub set_timezone {
    foreach $controller (@CONTROLLER_LIST) {
        do_rsh($controller, "timezone EST5EDT");
    }
}

```

```
        do_rsh($controller, "rdate $TIMEHOST");
    }
}
# Routine for creating an aggregate with:
# - snapshots disabled
# - no snap reserve
# - 4 raid_dp raid groups:
#   - 1 x 18 disk raid group
#   - 3 x 17 disk raid group
sub create_aggrs {
    foreach $controller (@CONTROLLER_LIST) {
        # Disable aggregate snapshots
        do_rsh($controller, "aggr options $AGGR_NAME nosnap on");
        do_rsh($controller, "snap sched -A $AGGR_NAME 0 0 0");
        # Turn off snap reserve in the aggregate
        do_rsh($controller, "snap reserve -A $AGGR_NAME 0");
        # Create the first raidgroup of size 18
        do_rsh($controller, "aggr options $AGGR_NAME raidsize 18");
        do_rsh($controller, "aggr add $AGGR_NAME 15");
        sleep 30; # aggr add commands are async, so provide some sleep time
        # Now create the remaining 3 raid groups of size 17
        do_rsh($controller, "aggr options $AGGR_NAME raidsize 17");
        do_rsh($controller, "aggr add $AGGR_NAME 51");
        sleep 60; # aggr add commands are async, so provide some sleep time
    }
}
# Set options on root volume
sub do_root_vol_options {
    foreach $controller (@CONTROLLER_LIST) {
        # Resize vol to 30g
        do_rsh($controller, "vol size vol0 30g");
        sleep 30;
        # Disable snapshots
        do_rsh($controller, "vol options vol0 nosnap on");
        do_rsh($controller, "snap sched vol0 0 0 0");
        # Turn off snap reserve
        do_rsh($controller, "snap reserve vol0 0");
        do_rsh($controller, "vol options vol0 nosnapdir off");
    }
}
# Create a target flexible volume with snapshots off and snap reserve 0 that is 84%
of the containing aggregate
sub create_target_vols {
    foreach $controller (@CONTROLLER_LIST) {
        # Create a flexvol in $AGGR_NAME that is roughly 82% of all free space in
the aggr
        do_rsh($controller, "vol create $TARGET_VOL -s none $AGGR_NAME 8493820m");
        sleep 60; # vol create commands are async, so provide some time
        # Disable snapshots in target volume
        do_rsh($controller, "vol options $TARGET_VOL nosnap on");
        do_rsh($controller, "snap sched $TARGET_VOL 0 0 0");
        do_rsh($controller, "vol options $TARGET_VOL nosnapdir off");
        do_rsh($controller, "snap reserve $TARGET_VOL 0");
    }
}
# Setup FCP settings
sub setup_fcp {
    foreach $controller (@CONTROLLER_LIST) {
        do_rsh($controller, "cf enable");
        do_rsh($controller, "fcp start");
        # Set the cfmode to SSI
        do_rsh($controller, "fcp set cfmode -f single_image");
        # Configure targets
    }
}
```

```

do_rsh($controller, "fcp config 0a up");
do_rsh($controller, "fcp config 0c up");
do_rsh($controller, "fcp stop");
}
}
# Setup portsets
sub create_portsets {
    foreach $controller (@CONTROLLER_LIST) {
        do_rsh($controller, "portset create -f portset1 0a 0c");
    }
}
# Setup igroups
sub create_igroups {
    foreach $controller (@CONTROLLER_LIST) {
        do_rsh($controller, "igroup create -t $IGROUP_TYPE -a portset1 -f igroup1
$INITIATOR_WWN_LIST");
    }
}
# Routine for writing out zeroed luns sequentially on one partner controller
sub do_controller_luns {
    my ($controller, $file_count, $starting_index) = @_;
    my $file_index = $starting_index;
    my $asu_num = 1;
    my $file_size = $ASU1_2_LUN_SIZE;

    do_rsh($controller, 'exportfs -i -o anon=0 /vol/$TARGET_VOL');
    for ($i = 0; $i < $file_count; $i++) {
        # Check to see if it's time to switch to a new asu number
        if (($i == 20 && $LUN_COUNT == 100) || ($i == 6 && $LUN_COUNT == 36)) {
            $asu_num = 2;
        } elsif (($i == 40 && $LUN_COUNT == 100) || ($i == 12 && $LUN_COUNT == 36)) {
            $asu_num = 3;
            $file_size = $ASU3_LUN_SIZE;
        }

        $file_name = 'file-'. $file_index;
        do_rsh($controller, "mkfile $file_size /vol/$TARGET_VOL/$file_name");
        $file_index+=2;
    }
}
# This routine will fork off a child proc so that zeroed luns can be created in
parallel across both controllers
sub create_zeroed_luns {
    $pid = fork();

    if($pid == 0) {
        # Child proc -- Start odd-numbered lun creations on controller at index 0
        do_controller_lun(@CONTROLLER_LIST[0], $LUN_COUNT/2, 1);
        exit 0;
    } else {
        # Parent proc -- Start even-numbered lun creations on controller at index 1
        if (@CONTROLLER_LIST[1] ne "") {
            do_controller_luns(@CONTROLLER_LIST[1], $LUN_COUNT/2, 2);
        }
        waitpid($pid,0);
    }
}
# Routine that creates luns and maps them to igroup1
sub create_and_map_luns {
    my $lun_id = 0;
    my $controller = "";
    my $asu_num = 1;

```

```
my $file_index = 1;

for ($i = 0; $i < $LUN_COUNT; $i++) {
    # Alternate lun creation...
    $controller = @CONTROLLER_LIST[$i%2];

    # Check to see if it's time to switch to a new asu number
    if (($file_index == 41 && $LUN_COUNT == 100) || ($file_index == 13 &&
$LUN_COUNT == 36)) {
        $asu_num = 2;
    } elsif (($file_index == 81 && $LUN_COUNT == 100) || ($file_index == 25 &&
$LUN_COUNT == 36)) {
        $asu_num = 3;
    }

    $lun_name='asu'.$asu_num.'_'.$file_index;
    $lun_path='/vol/$TARGET_VOL/'.$lun_name;
    $file_name='/vol/$TARGET_VOL/file-'.$file_index;
    do_rsh($controller, "lun create -t $LUN_TYPE -f $file_name -o noreserve
$lun_path");
    sleep 1;
    do_rsh($controller, "lun map $lun_path igroup1 $lun_id");
    sleep 1;
    $lun_id++;
    $file_index++;
}
}
# Routine for executing the final batch of commands before leaving setup
sub final_tasks {
    foreach $controller (@CONTROLLER_LIST) {
        # Make sure fcp service is running before leaving
        do_rsh($controller, "fcp start");
    }
}
# ----- #
# Main execution entry point
# ----- #
log_msg("Starting setup on cluster: '@CONTROLLER_LIST[0].',
'@CONTROLLER_LIST[1].'");
modify_rc_files();
set_timezone();
do_setflags();
create_aggrs();
do_root_vol_options();
create_target_vols();
setup_fcp();
create_portsets();
create_igroups();
create_zeroed_luns();
create_and_map_luns();
final_tasks();
log_msg("Setup finished on cluster: '@CONTROLLER_LIST[0].',
'@CONTROLLER_LIST[1].'");
exit 0;
```

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

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

```
javaparms="-Xmx1024m -Xms512m -Xss256k"  
sd=asu1_1,lun=\\.\\E:  
sd=asu2_1,lun=\\.\\F:  
sd=asu3_1,lun=\\.\\G:
```

APPENDIX E: SPC-1 WORKLOAD GENERATOR INPUT PARAMETERS

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

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

```
REM metrics test
set
metstrtime="%date:~4,2%_date:~7,2%_date:~10,4%_time:~0,2%h%time:~3,2%m%time:~6,2%s"
java -Xmx1024m -Xms512m -Xss256k metrics -b 620 -s 300
c:\sleep.exe 30
```

```
REM repeatability1 test
set
replstrtime="%date:~4,2%_date:~7,2%_date:~10,4%_time:~0,2%h%time:~3,2%m%time:~6,2%s"
java -Xmx1024m -Xms512m -Xss256k repeat1 -b 620 -s 300
c:\sleep.exe 30
```

```
REM repeatability2 test
set
rep2strtime="%date:~4,2%_date:~7,2%_date:~10,4%_time:~0,2%h%time:~3,2%m%time:~6,2%s"
java -Xmx1024m -Xms512m -Xss256k repeat2 -b 620 -s 300
c:\sleep.exe 30
```

```
REM persistencel test
set
perlstrtime="%date:~4,2%_date:~7,2%_date:~10,4%_time:~0,2%h%time:~3,2%m%time:~6,2%s"
java -Xmx1024m -Xms512m -Xss256k persist1 -b 620
c:\sleep.exe 30
```

```
REM move the results directories to appropriate locations
mkdir 620.baseline.nosnap
c:\sleep.exe 30
```

```
move /Y metrics 620.baseline.nosnap\metrics.620.baseline.nosnap.%metstrtime%
c:\sleep.exe 30
```

```
move /Y repeatability1
620.baseline.nosnap\repeat1.620.baseline.nosnap.%replstrtime%
c:\sleep.exe 30
```

```
move /Y repeatability2
620.baseline.nosnap\repeat2.620.baseline.nosnap.%rep2strtime%
c:\sleep.exe 30
```

```
move /Y persistencel
620.baseline.nosnap\persist1.620.baseline.nosnap.%perlstrtime%
```

```
c:\sleep.exe 30
```

Persistence Test Run 2

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

```
REM persistence2 test
set
per2strtime="%date:~4,2%_date:~7,2%_date:~10,4%_time:~0,2%h%time:~3,2%m%t
ime:~6,2%s"
java -Xmx1024m -Xms512m -Xss256k persist2
c:\sleep.exe 30

REM move the results directories to appropriate locations
move /Y persistence2
620.baseline.nosnap\persist2.620.baseline.nosnap.%per2strtime%
c:\sleep.exe 30

move /Y SPCOut 620.baseline.nosnap\SPCOut.620.baseline.nosnap.%per2strtime%
c:\sleep.exe 30
```


APPENDIX F: USE OF NETAPP'S SNAPSHOT™

NetApp's Snapshot(tm) technology was enabled to provide multiple, point-in-time, space efficient copies of the SPC-1 data repository during the Primary Metrics and Repeatability Tests, as well as during Persistence Test Run 1.

A Snapshot copy was created at fifteen (15) minute intervals during the above measurements, retaining the most current three (3) Snapshot copies. The final Snapshot copy was completed after Persistence Test Run 1 terminated with no intervening activity.

Verification of the above Snapshot execution and accuracy of the Snapshot copy was accomplished using the Persistence Test as follows:

1. Persistence Test Run 1 writes specific content to randomly selected locations in the SPC-1 data repository, recording the locations selected and content written. After the storage system has been power cycled, Persistence Test Run 2 is executed to verify the correct content at the correct locations written by Persistence Test Run 1. See Clause 6 of the SPC-1 specification for the details of the Persistence Test.
2. Immediately after the completion of Persistence Test Run 1 and subsequent completion of the final Snapshot copy, the ASU data repository content was changed using the 'dd' utility.
3. Persistence Test Run 2 was then executed and failed because the activity in step #2 changed the content in the locations utilized by Persistence Test Run 1.
4. The final Snapshot copy was then used to return the SPC-1 data repository to the 'point in time' immediately after Persistence Test Run 1 successfully completed.
5. Persistence Test Run 2 was then executed and completed successfully, which verified application of the final Snapshot copy in step #4 returned the SPC-1 repository to the 'point in time' immediately after successful completion of Persistence Test Run 1.