SPC BENCHMARK 1/ENERGY™
FULL DISCLOSURE REPORT

HEWLETT-PACKARD COMPANY
HP P6500 ENTERPRISE VIRTUAL ARRAY

SPC-1/E™ V1.12

Submitted for Review: February 17, 2012
Submission Identifier: AE00005

First Edition – February 2012

Trademarks

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AUDIT CERTIFICATION

Chuck Paridon
Hewlett-Packard Company
8000 Foothills Blvd
M/S 5785
Roseville, CA 95757-5785

February 16, 2012

The SPC Benchmark 1/Energy™ Reported Data listed below for the HP P6500 Enterprise Virtual Array were produced in compliance with the SPC Benchmark 1/Energy™ V1.12 Onsite Audit requirements.

SPC Benchmark 1/Energy™ V1.12 Reported Data	
Tested Storage Product (TSP) Name: HP P6500 Enterprise Virtual Array	
Metric	**Reported Result**
SPC-1 IOPS™	20,003.03
SPC-1 Price-Performance	$6.55/SPC-1 IOPS™
Total ASU Capacity	515.397 GB
Data Protection Level	Protected *(Mirroring)*
Total TSC Price (including three-year maintenance)	$130,982.94

Power Environment

Average RMS Voltage: 211.14 **Average Power Factor:** 0.809

Usage Profile

	Hours of Use per Day			Nominal	Nominal	Nominal	Nominal
	Heavy	Moderate	Idle	Power, W	Traffic, IOPS	IOPS/W	Heat, BTU/hr
Low Daily Usage:	0	8	16	227.85	3333.14	14.63	777.44
Medium Daily Usage:	4	14	6	231.49	8499.58	36.72	789.87
High Daily Usage:	18	6	0	235.84	14499.49	61.48	804.72
			Composite Metrics:	231.73	8,777.40	37.88	

Annual Energy Use, kWh: 2,029.93
Energy Cost, $/kWh: $ 0.12 **Annual Energy Cost, $:** $ 243.59

Storage Performance Council
643 Bair Island Road, Suite 103
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AUDIT CERTIFICATION *(CONT.)*

The following SPC Benchmark 1/Energy™ Onsite Audit requirements were reviewed and found compliant with V1.12 of the SPC Benchmark 1/Energy™ Specification:

- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository storage items were verified by information supplied by Hewlett-Packard Company:
  - ✓ 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/Tested Storage Configuration.
- Listings and commands to configure the Benchmark Configuration/Tested Storage Configuration, including customer tunable parameters that were changed from default values.
- SPC-1™ Workload Generator commands and parameters used for the audited SPC Test Runs.
- The following Host System requirements were verified by information supplied by Hewlett-Packard Company:
  - ✓ The type of Host System including the number of processors and main memory.
  - ✓ The presence and version number of the SPC-1™ Workload Generator on the Host System.
  - ✓ A valid SPC-1™ site license.
  - ✓ The TSC boundary within the Host System.
- The Test Results Files and resultant Summary Results Files received from Hewlett-Packard Company for each of following were authentic, accurate, and compliant with all of the requirements and constraints of Clauses 4, 5, and 11 of the SPC Benchmark 1/Energy™ Specification:
  - ✓ Idle Test
    - Conditioning Phase
    - Application Idle Phase
    - Recovery Phase
  - ✓ Primary Metrics Test:
    - Sustainability Test Phase
    - IOPS Test Phase
    - Response Time Ramp Test Phase
  - ✓ Repeatability Test
  - ✓ Data Persistence Test
- The Yokogawa WT230 Digital Power Meter, used to record power consumption, was verified as an SPC approved "Power Extension apparatus" with a current calibration certificate.
- All power supplies present in the Tested Storage Configuration were verified as active.

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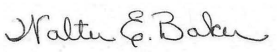
AUDIT CERTIFICATION *(CONT.)*

- Hewlett-Packard Company provided documentation of the following:
  - ✓ Voltage *(220)*, amperage *(30)*, and phase characteristics *(single)* of the AC inputs used for powering the Tested Storage Configuration.
  - ✓ The configured power supplies were configured for mutual failover.
- Concurrent power measurements were taken at each active AC input so that the total power requirement of the Tested Storage Configuration was recorded.
- The ambient temperature was recorded at the following times in near proximity to the Tested Storage configuration with a precision of at least ±0.1°C:
  - ✓ During the first one minute of the Idle Test *(Initial Energy Extension temperature)*.
  - ✓ During the last one minute of the Primary Metrics Test *(Final Energy Extension temperature)*.
- The Benchmark Configuration/Tested Storage Configuration diagram included the electrical metering, which illustrates the measurement apparatus used and the relationship between the active AC inputs and the associated measurement apparatus inputs.
- There were no differences between the Tested Storage Configuration and Priced Storage Configuration.
- The submitted pricing information met all of the requirements and constraints of Clause 8 of the SPC Benchmark 1/Energy™ Specification.
- The Full Disclosure Report *(FDR)* met all of the requirements in Clauses 9 and 11 of the SPC Benchmark 1/Energy™ Specification.
- This successfully audited SPC measurement is not subject to an SPC Confidential Review.

Audit Notes:

There were no audit notes or exceptions.

Respectfully,



Walter E. Baker
SPC Auditor

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LETTER OF GOOD FAITH

Hewlett-Packard Company
8000 Foothills Blvd.
Roseville, CA 95747

Date: January 12, 2012

From: Chuck Paridon, SET Performance Team; Hewlett-Packard Company

To: Walter E. Baker, SPC Auditor
Storage Performance Council (SPC)
643 Bair Island Road, Suite 103
Redwood City, CA 94063-2755

Subject: SPC-1E Letter of Good Faith for the HP StorageWorks P6500 Enterprise Virtual Array

Hewlett-Packard is the SPC-1E Test Sponsor for the above listed product. To the best of our knowledge and belief, the required SPC-1E benchmark results and materials we have submitted for that product are complete, accurate, and in full compliance with V1.13 of the SPC-1E benchmark specification.

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

Signed: _____ Date: 12/22/11

Neil MacDonald, Vice President, Data Center Development Unit, HP Storage

Date of Signature

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor Primary Contact	Hewlett-Packard Company – http://www.hp.com Chuck Paridon – chuck.paridon@hp.com 8000 Foothills Blvd. M/S 5785 Roseville, CA 95747-5785 Phone: (916) 785-5155 FAX: (916) 785-1648
Test Sponsor Alternate Contact	Hewlett-Packard Company – http://www.hp.com Joe Tarr – joseph.tarr@hp.com 8000 Foothills Blvd. M/S 5785 Roseville, CA 95747-5785 Phone: (916) 785.2967 FAX: (916) 785-1648
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	V1.12
SPC-1 Workload Generator revision number	V2.1.0
Date Results were first used publicly	February 17, 2012
Date the FDR was submitted to the SPC	February 17, 2012
Date the priced storage configuration is available for shipment to customers	currently available
Date the TSC completed audit certification	February 16, 2012

Tested Storage Product (TSP) Description

The HP P6000 Enterprise Virtual Array is an easy to use, capacity enhanced storage system with built-in virtualization letting you to consolidate storage and simplify your IT. The P6000 EVA also offers high performance, high availability, and robust data protection. Combined with your favorite database, email, ERP or other applications, the P6000 EVA provides an integrated end-to-end solution that helps drive your business.

See improved storage density with built-in Thin Provisioning and a smaller footprint in your data center with 2.5-inch form factor storage devices. The P6000 EVA offers multi-protocol support to your SAN with 8 Gb/s Fibre Channel, 1 Gb/s iSCSI, and 10 Gb/s iSCSI/FCoE options.

It provides a better business value by eliminating stranded capacity and maximizing performance. P6000 EVA uses all the disks to send and retrieve data and can dynamically expand virtual disks as data grows.

Summary of Results

SPC-1 Results	
Tested Storage Configuration (TSC) Name: HP P6500 Enterprise Virtual Array	
Metric	**Reported Result**
SPC-1 IOPS™	20,003.03
SPC-1 Price-Performance	$6.55/SPC-1 IOPS™
Total ASU Capacity	515.397 GB
Data Protection Level	Protected *(Mirroring)*
Total TSC Price (including three-year maintenance)	$130,982.94

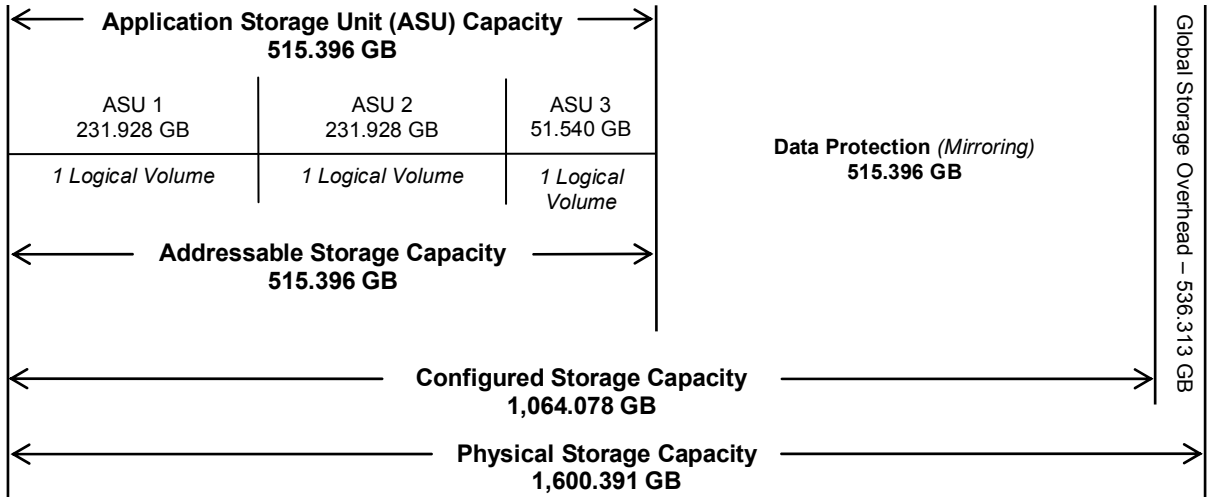
SPC-1 IOPS™ represents the maximum I/O Request Throughput at the 100% load point.

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

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

Storage Capacities, Relationships, and Utilization

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



SPC-1 Storage Capacity Utilization	
Application Utilization	32.20%
Protected Application Utilization	64.41%
Unused Storage Ratio	2.08%

Application Utilization: Total ASU Capacity *(515.396 GB)* divided by Physical Storage Capacity *(1600.391 GB)*.

Protected Application Utilization: Total ASU Capacity *(515.396 GB)* plus total Data Protection Capacity *(515.396 GB)* minus unused Data Protection Capacity *(0.000 GB)* divided by Physical Storage Capacity *(1600.391 GB)*.

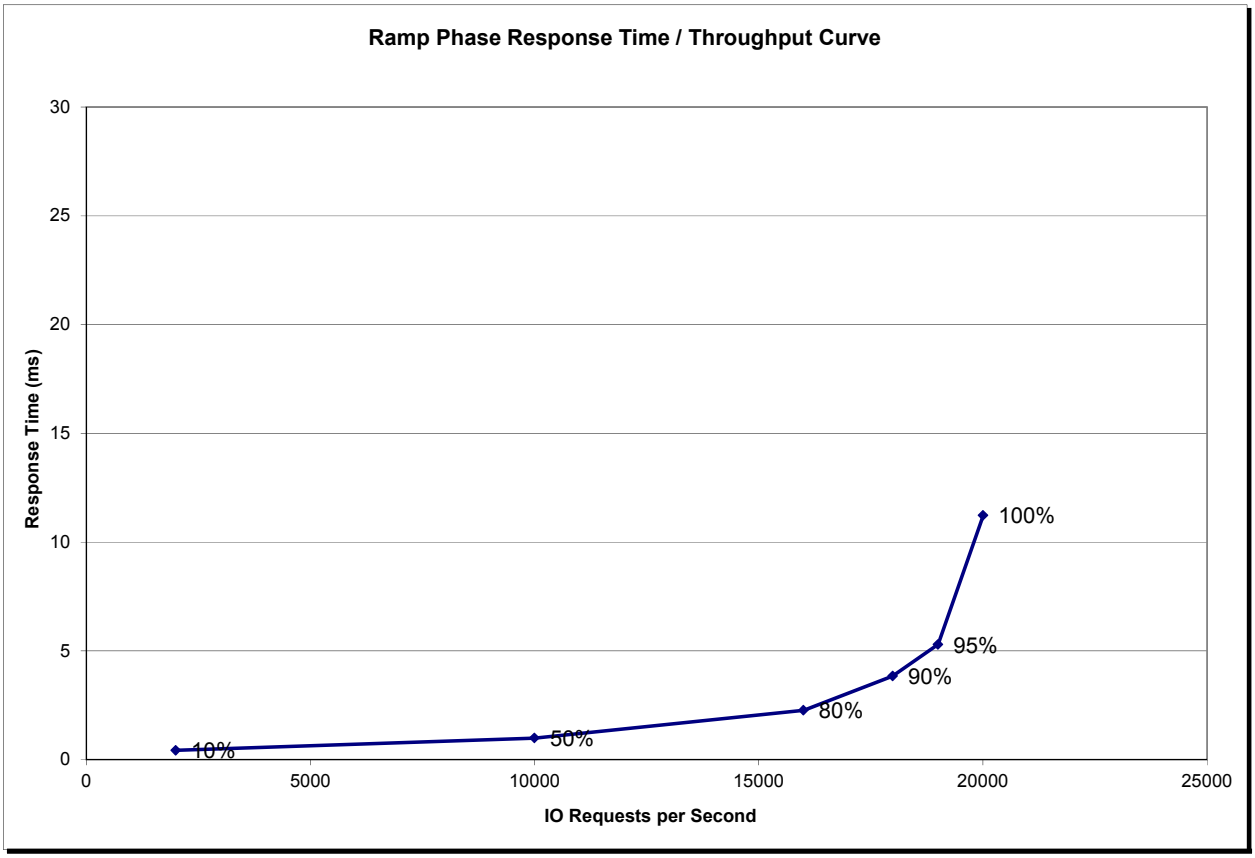
Unused Storage Ratio: Total unused capacity *(33.286 GB)* divided by Physical Storage Capacity *(1600.391 GB)*. The Unused Storage Ratio cannot exceed 45%.

Detailed information for the various storage capacities and utilizations is available on pages 26-27 in the Full Disclosure Report.

Response Time – Throughput Curve

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

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



Response Time – Throughput Data

	10% Load	50% Load	80% Load	90% Load	95% Load	100% Load
I/O Request Throughput	1,999.26	9,999.41	15,999.52	17,990.02	18,998.58	20,003.66
Average Response Time (ms):						
All ASUs	0.43	0.99	2.27	3.85	5.30	11.23
ASU-1	0.43	1.02	2.33	3.90	5.36	12.24
ASU-2	0.40	0.88	2.08	3.59	5.00	10.38
ASU-3	0.45	0.99	2.23	3.84	5.29	9.46
Reads	0.42	1.01	2.38	3.91	5.36	12.94
Writes	0.43	0.98	2.20	3.80	5.25	10.11

SPC-1/E Reported Data

The initial SPC-1/E energy extension temperature, recorded during the first one minute of the Idle Test was 81.50F. The final SPC-1/E energy extension temperature, recorded during the last one minute of the Primary Metrics Test was 82.64F.

Power Environment			
Average RMS Voltage:	211.14	Average Power Factor:	0.809

Usage Profile

	Hours of Use per Day			Nominal	Nominal	Nominal	Nominal
	Heavy	Moderate	Idle	Power, W	Traffic, IOPS	IOPS/W	Heat, BTU/hr
Low Daily Usage:	0	8	16	227.85	3333.14	14.63	777.44
Medium Daily Usage:	4	14	6	231.49	8499.58	36.72	789.87
High Daily Usage:	18	6	0	235.84	14499.49	61.48	804.72
			Composite Metrics:	231.73	8,777.40	37.88	

Annual Energy Use, kWh:	2,029.93		
Energy Cost, $/kWh:	$ 0.12	Annual Energy Cost, $:	$ 243.59

The above usage profile describes conditions in environments that respectively impose light ("low"), moderate ("medium"), and extensive ("high") demands on the Tested Storage Configuration (TSC).

HEAVY SPC-1 Workload: 236.96W at 80% of maximum reported performance *(15,999.52 SPC-1 IOPS)*.

MODERATE SPC-1 Workload: 232.48W at 50% of maximum reported performance *(9,999.41 SPC-1 IOPS)*.

IDLE SPC-1 Workload: 225.53W at 0% of maximum reported performance *(0.00 SPC-1 IOPS)*.

AVERAGE RMS VOLTAGE: The average supply voltage applied to the Tested Storage Product (TSP) as measured during the Measurement Intervals of the SPC-1/E Tests.

AVERAGE POWER FACTOR: The ratio of average real power, in watts, to the average apparent power, in volt-amps flowing into the Tested Storage Product (TSP) during the Measurement Intervals of the SPC-1/E Tests.

NOMINAL POWER, W: The average power consumption over the course of a day *(24 hours)*, taking into account hourly load variations.

NOMINAL TRAFFIC, IOPS: The average level of I/O requests over the course of a day *(24 hours)*, taking into account hourly load variations.

NOMINAL IOPS/W: The overall efficiency with which I/O requests can be supported, reflected by the ratio of **NOMINAL TRAFFIC** versus the **NOMINAL POWER**.

NOMINAL HEAT, BTU/HR: The average amount of heat required to be dissipated over the course of a day *(24 hours)*, taking into account hourly load variations. *(1 watt = 3.412 BTU/hr)*

COMPOSITE METRICS: The aggregated **NOMINAL POWER**, **NOMINAL TRAFFIC**, and **NOMINAL IOPS/W** for all three environments: **LOW**, **MEDIUM**, and **HIGH DAILY USAGE**.

ANNUAL ENERGY USE, KWH: An estimate of the average energy use across the three environments over the course of a year and computed as (**NOMINAL POWER** * 24 *0.365).

ENERGY COST, $/KWH: A standardized energy cost per kilowatt hour.

ANNUAL ENERGY COST: An estimate of the annual energy use across the three environments over the course of a year and computed as (**ANNUAL ENERGY USE** * **ENERGY COST**).

SPC-1/E Power/Performance Profile

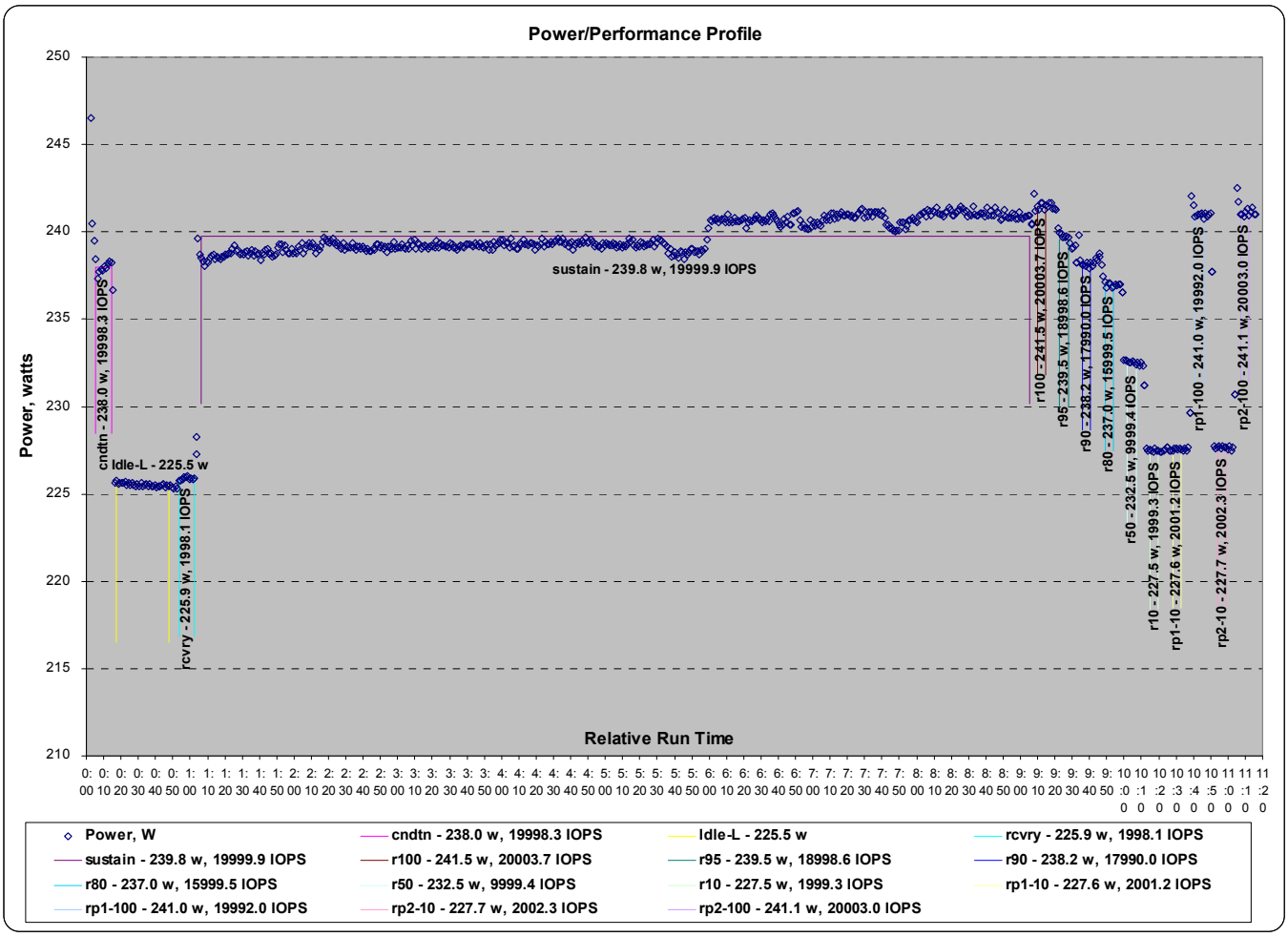
The SPC-1/E Power/Performance Profile table and chart provides a complete "at a glance" illustration and report for each SPC-1/E execution component. The power consumption in watts (W) for each execution component is reported and, where appropriate, the measured SPC-1 performance *(SPC-1 IOPS™)* is also reported.

The **Load Level** value in the table represents the percentage of the maximum, specified offered load that was used for a specific execution component. Each **Execution Component** entry includes the acronym, in parenthesis, which is used in the corresponding chart to identify the execution component.

SPC-1/E Power/Performance Profile Data

Execution Component	Load Level	SPC-1 IOPS™	Power (W)
Pre-Idle ***(cndtn)***	100%	19,998.32	237.98
Idle ***(Idle-L)***	0%	0.00	225.53
Post-Idle ***(rcvry)***	10%	1,998.11	225.88
Sustainability ***(sustain)***	100%	19,999.92	239.78
IOPS ***(r100)***	100%	20,003.66	241.49
Ramp95 ***(r95)***	95%	18,998.58	239.54
Ramp90 ***(r90)***	90%	17,990.02	238.18
Ramp80 ***(r80)***	80%	15,999.52	236.96
Ramp50 ***(r50)***	50%	9,999.41	232.48
Ramp10 ***(r19)***	10%	1,999.26	227.48
Repeat1 LRT ***(rp1-10)***	10%	2,001.16	227.56
Repeat1 IOPS ***(rp1-100)***	100%	19,991.99	240.97
Repeat2 LRT ***(rp2-10)***	10%	2,002.29	227.65
Repeat2 IOPS ***(rp2-100)***	100%	20,003.03	241.08

SPC-1/E Power/Performance Profile Chart



Priced Storage Configuration Pricing

Quan	Product Number		Description	List Price	Ext Price	Discount	Ext. Net Price
1	AF002A		HP Universal Rack 10642 G2 Shock Rack	1,489.00	1,489.00	27%	1,086.97
1	AF002A	001	Factory Express Base Racking	300.00	300.00	27%	219.00
1	AJ938A		HP P6500 EVA Dual Controller FC Array	18,500.00	18,500.00	27%	13,505.00
1	AJ938A	0D1	Factory integrated	-	-	27%	-
2	AJ840A		HP M6625 2.5-inch SAS Drive Enclosure	4,326.00	8,652.00	27%	6,315.96
2	AJ840A	0D1	Factory integrated	-	-	27%	-
8	QK757A		HP M5524 6G 200GB SAS SFF SSD	9,800.00	78,400.00	27%	57,232.00
8	QK757A	0D1	Factory integrated	-	-	27%	-
2	252663-D72		HP 24A High Voltage US/JP Modular PDU	299.00	598.00	27%	436.54
2	252663-D72	0D2	Factory horizontal mount of PDU	-	-	27%	-
1	AF062A		HP 10K G2 600mm Stabilizer Kit	229.00	229.00	27%	167.17
1	AF062A	B01	Include with complete system	-	-	27%	-
1	AF054A		HP 10642 G2 Sidepanel Kit	359.00	359.00	27%	262.07
1	AF054A	0D1	Factory integrated	-	-	27%	-
1	T5494GAE		HP P6000 CV V9.4 RSM V5.3 E-Media Kit	125.00	125.00	27%	91.25
1	TA811AAE		HP P6500 Command View SW E-LTU	22,200.00	22,200.00	27%	16,206.00
1	HK777A3		HP 3Y Critical Advantage L3 Service	-	-	27%	-
1	HK777A3	Q1Y	Command View P6500 EVA Unlimited SW Sup	8,030.00	8,030.00	27%	5,861.90
1	HK777A3	Q24	P6500 EVA Dual Controller Array JW Supp	8,524.00	8,524.00	27%	6,222.52
2	HK777A3	Q25	P6300/P6500 Drive Enclosure JW Supp	2,050.00	4,100.00	27%	2,993.00
8	HA104A3	WSK	P6300/P6500 SSD Support HW Supp	780.00	6,240.00	27%	4,555.20
2	456972	B21	HP BLc Emulex LPe1205 8Gb FC HBA Opt	849.00	1,698.00	12%	1,494.24
2	AJ716A		HP 8Gb Shortwave B-series FC SFP	199.00	398.00	12%	350.24
2	AJ821A		Brocade HPB series 8/24c Blade SAN Switch	9,285.00	18,570.00	27%	13,556.10
2	AJ836A		HP 5m Multi-mode OM3 LC/LC FC Cable	95.00	190.00	27%	138.70
4	AJ706A		HP EVA Loopback Connector	99.00	396.00	27%	289.08
			Totals		***178,998.00***		**130,982.94**

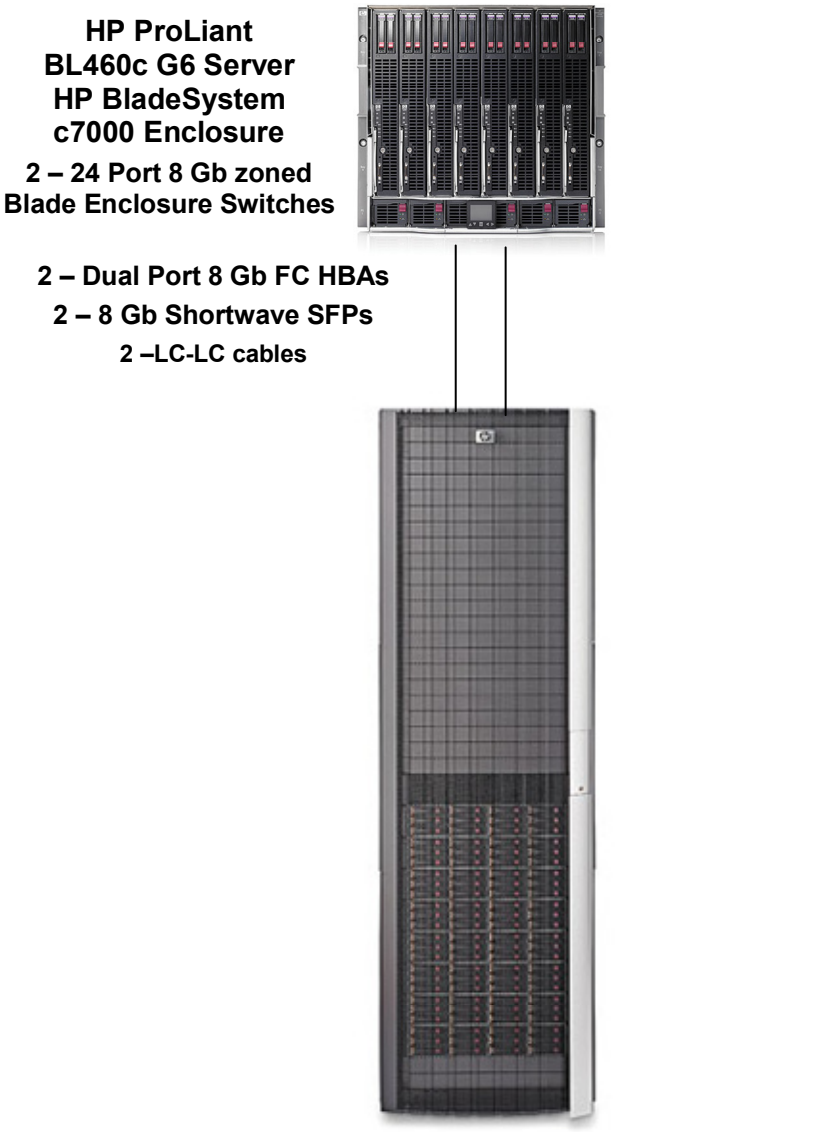
The above pricing includes hardware maintenance and software support for three years, 7 days per week, 24 hours per day. The hardware maintenance and software support provides the following:

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

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

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

Priced Storage Configuration Diagram



Priced Storage Configuration Components

Priced Storage Configuration:
2 – Dual Port 8 Gb FC HBAs
2 – 8 Gb Shortwave FC SFPs
2 –24 Port, 8 Gb zoned Blade Enclosure switches
HP P6500 Enterprise Virtual Array Dual Controllers with 8 GB cache/controller *(16 GB total)* dual power supplies for each controller *(4 total)* 2 – 8 Gb FC front-end physical connection, both used 2 – SAS backend physical connections, both used
1 – HP Universal Rack
2 – HP SAS Drive Enclosures dual power supplies for each drive enclosure *(4 total)*
8 –200 GB FC Solid State Devices *(SSDs)*
HP StorageWorks Command View EVA

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

CONFIGURATION INFORMATION

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

Clause 9.4.3.4.1

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

The Benchmark Configuration (BC)/Tested Storage Configuration (TSC) is illustrated on page 23 *(Benchmark Configuration/Tested Storage Configuration Diagram).*

Storage Network Configuration

Clause 9.4.3.4.1

…

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

Clause 9.4.3.4.2

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

The Tested Storage Configuration did not utilize network storage.

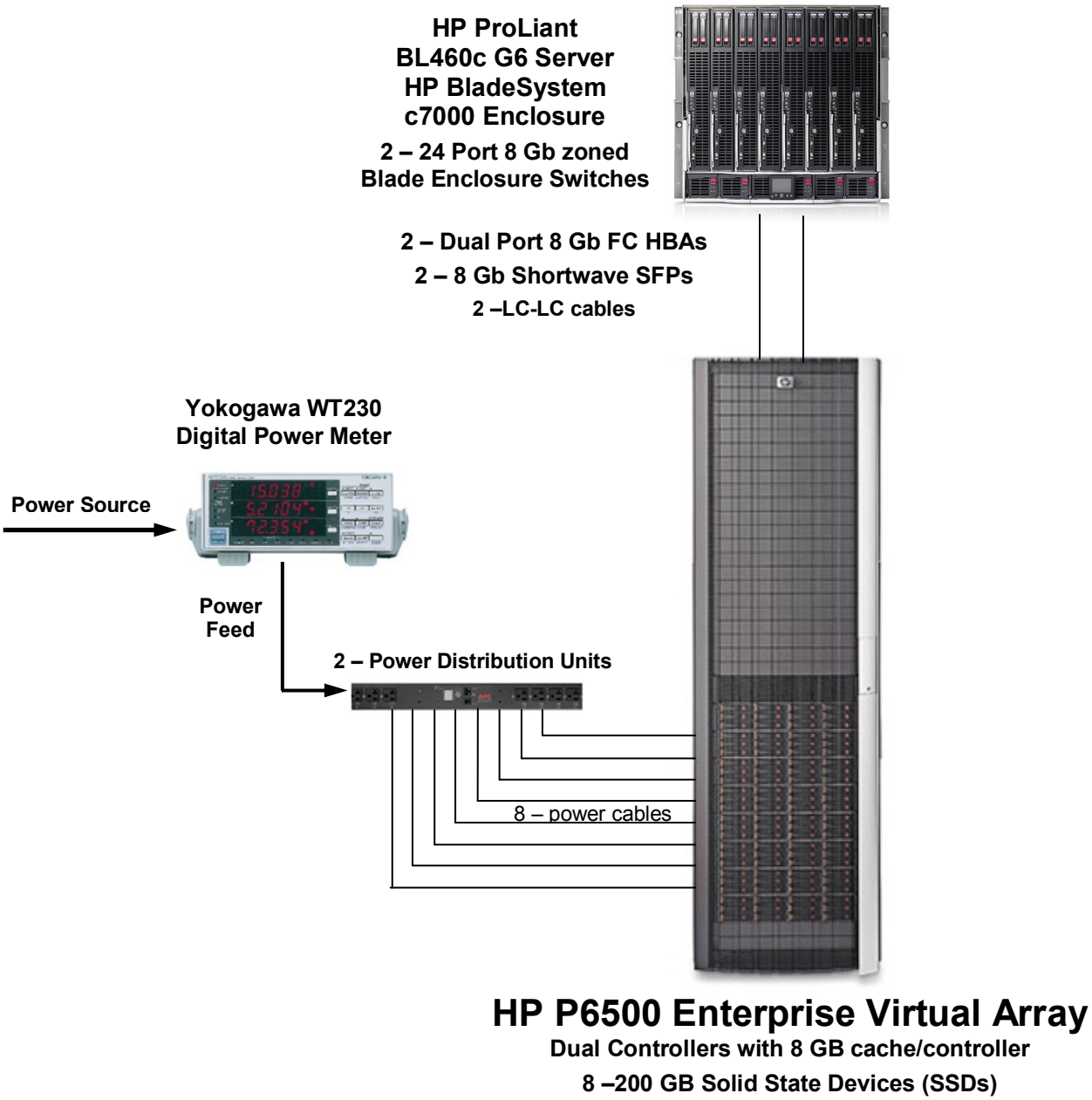
Host System and Tested Storage Configuration (TSC) Table of Components

Clause 9.4.3.4.3

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

The Host System and Tested Storage Configuration (TSC) table of components is appears on page 24 ***(****Host System and Tested Storage Configuration Components).*

Benchmark Configuration/Tested Storage Configuration Diagram



Host System and Tested Storage Configuration Components

Host System:	Tested Storage Configuration (TSC)
1 – HP ProLiant BL460c G6 Server **1 – HP BladeSystem c7000 Enclosure**	2 – Dual Port 8 Gb FC HBAs
	4 – 8 Gb Shortwave FC SFPs
2 – Intel® Xeon® 5500 series 2.27 GHz quad-core processors with 12 MB of Intel Smart Cache	2 –24 Port, 8 Gb zoned Blade Enclosure switches
79.9 GB main memory	**HP P6500 Enterprise Virtual Array** Dual Controllers with 8 GB cache/controller *(16 GB total)* dual power supplies for each controller *(4 total)* 2 – 8 Gb FC front-end physical connection, both used 2 – SAS backend physical connections, both used
Microsoft Windows Server 2003 R2 Enterprise x64	
Other BC components:	
1 – Yokogawa WT230 Digital Power Meter	1 – HP Universal Rack
2 – Power Distribution Units (PDUs)	2 – HP SAS Drive Enclosures with dual power supplies for each drive enclosure*(4 total)*
	HP StorageWorks Command View EVA

Customer Tunable Parameters and Options

Clause 9.4.3.5.1

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

"Appendix B: Customer Tunable Parameters and Options" on page 65 contains the customer tunable parameters and options that have been altered from their default values for this benchmark.

Tested Storage Configuration (TSC) Description

Clause 9.4.3.5.2

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

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

"Appendix C: Tested Storage Configuration (TSC) Creation" on page 66 contains the detailed information that describes how to create and configure the logical TSC.

SPC-1 Workload Generator Storage Configuration

Clause 9.4.3.5.3

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

The SPC-1 Workload Generator storage configuration commands and parameters for this measurement appear in "Appendix D: SPC-1 Workload Generator Storage Commands and Parameters" on page 74.

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

Storage Capacities and Relationships

Clause 9.4.3.6.1

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

SPC-1 Storage Capacities

SPC-1 Storage Capacities		
Storage Hierarchy Component	**Units**	**Capacity**
Total ASU Capacity	Gigabytes (GB)	515.396
Addressable Storage Capacity	Gigabytes (GB)	515.396
Configured Storage Capacity	Gigabytes (GB)	1,064.078
Physical Storage Capacity	Gigabytes (GB)	1,600.391
Data Protection *(Mirroring)*	Gigabytes (GB)	515.396
Required Storage	Gigabytes (GB)	0.00
Global Storage Overhead	Gigabytes (GB)	536.313
Total Unused Storage	Gigabytes (GB)	33.286

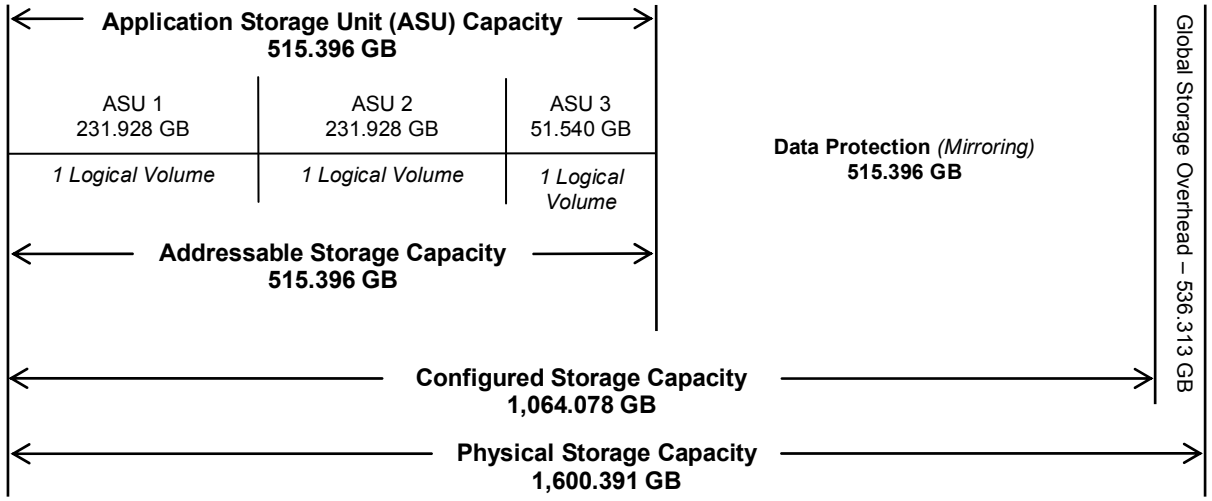
SPC-1 Storage Hierarchy Ratios

	Addressable Storage Capacity	**Configured Storage Capacity**	**Physical Storage Capacity**
Total ASU Capacity	100.00%	48.44%	32.20%
Required for Data Protection *(Mirrored)*		48.44%	32.20%
Addressable Storage Capacity		48.44%	32.20%
Required Storage		0.00%	0.00%
Configured Storage Capacity			66.49%
Global Storage Overhead			33.51%
Unused Storage:			
Addressable	0.00%		
Configured		3.13%	
Physical			0.00%

The Physical Storage Capacity consisted of 1,600.391 GB distributed over 8 solid state storage devices (SSDs) each with a formatted capacity of 200.049 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 536.313 GB (33.51%) of Physical Storage Capacity. There was 33.286 GB (3.13%) of Unused Storage within the Configured Storage Capacity. The Total ASU Capacity utilized 100.00% of the Addressable Storage Capacity resulting in 0.000 GB (0.00%) of Unused Storage within the Addressable Storage Capacity. The Data Protection *(Mirroring)* capacity was 515.396 GB of which 515.396 GB was utilized. The total Unused Storage was 33.286 GB.

SPC-1 Storage Capacities and Relationships Illustration

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



Logical Volume Capacity and ASU Mapping

Clause 9.4.3.6.3

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

Logical Volume Capacity and Mapping		
ASU-1 (231.928 GB)	**ASU-2 (231.928 GB)**	**ASU-3 (51.540 GB)**
9 Logical Volume 25.770 GB per Logical Volume (25.770 GB used per Logical Volume)	9 Logical Volume 25.770 GB per Logical Volume (25.770 GB used per Logical Volume)	2 Logical Volume 25.770 GB per Logical Volume (25.770 GB used per Logical Volume)

The Data Protection Level used for all Logical Volumes was "Mirrored" as described on page 12. See "ASU Configuration" in the **IOPS Test Results File** for more detailed configuration information.

Storage Capacity Utilization

Clause 9.4.3.6.2

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

Clause 2,8.1

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

Clause 2,8.2

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

Clause 2,8.3

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

SPC-1 Storage Capacity Utilization	
Application Utilization	32.20%
Protected Application Utilization	64.41%
Unused Storage Ratio	2.08%

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 62 contains definitions of terms specific to the SPC-1 Tests, Test Phases, and Test Runs.

Clause 5.4.3

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

SPC-1 Tests, Test Phases, and Test Runs

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

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

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

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

Primary Metrics Test – Sustainability Test Phase

Clause 5.4.4.1.1

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

Clause 5.4.4.1.2

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

Clause 5.4.4.1.4

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

Clause 9.4.3.7.1

For the Sustainability Test Phase the FDR shall contain:

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

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 75.

Sustainability Test Results File

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

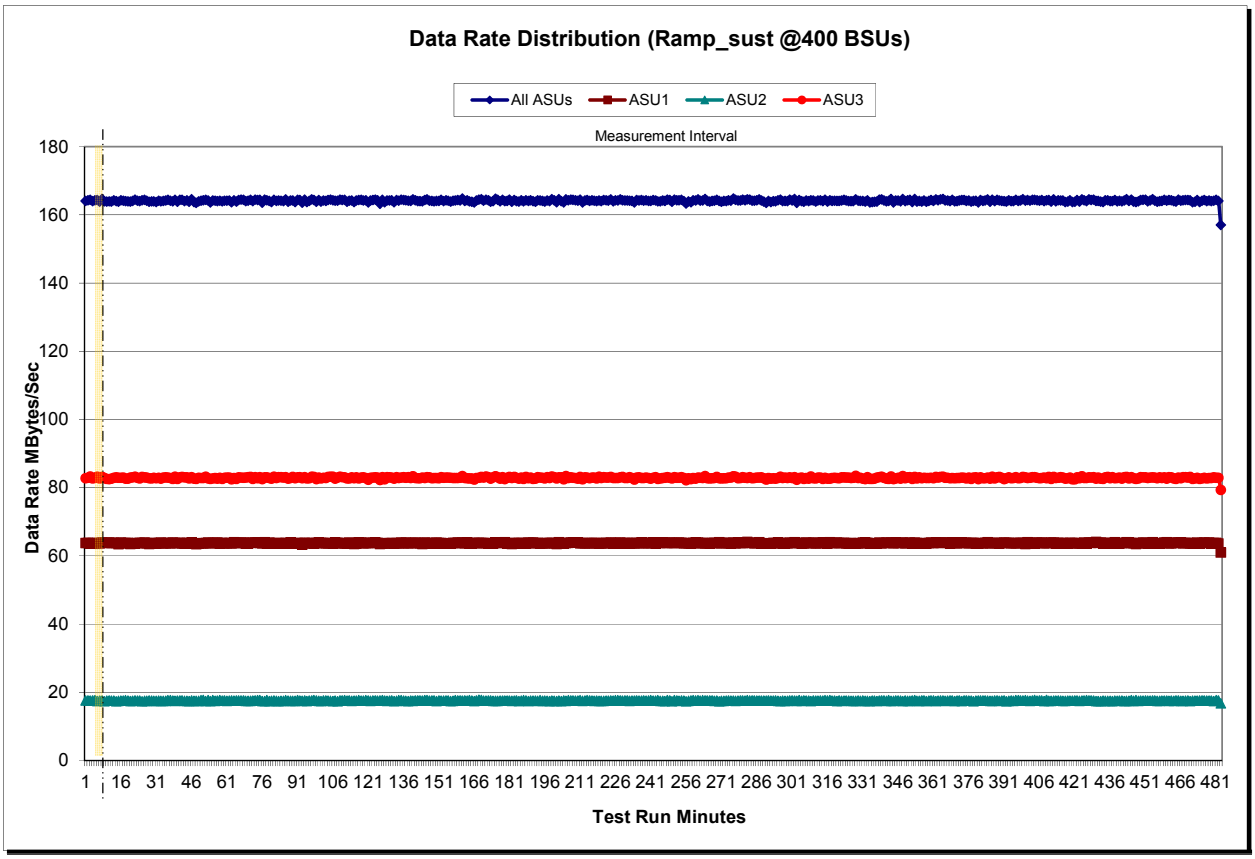
Sustainability Test Results File

Sustainability – Data Rate Distribution Data *(MB/second)*

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

Sustainability Data Tables

Sustainability – Data Rate Distribution Graph

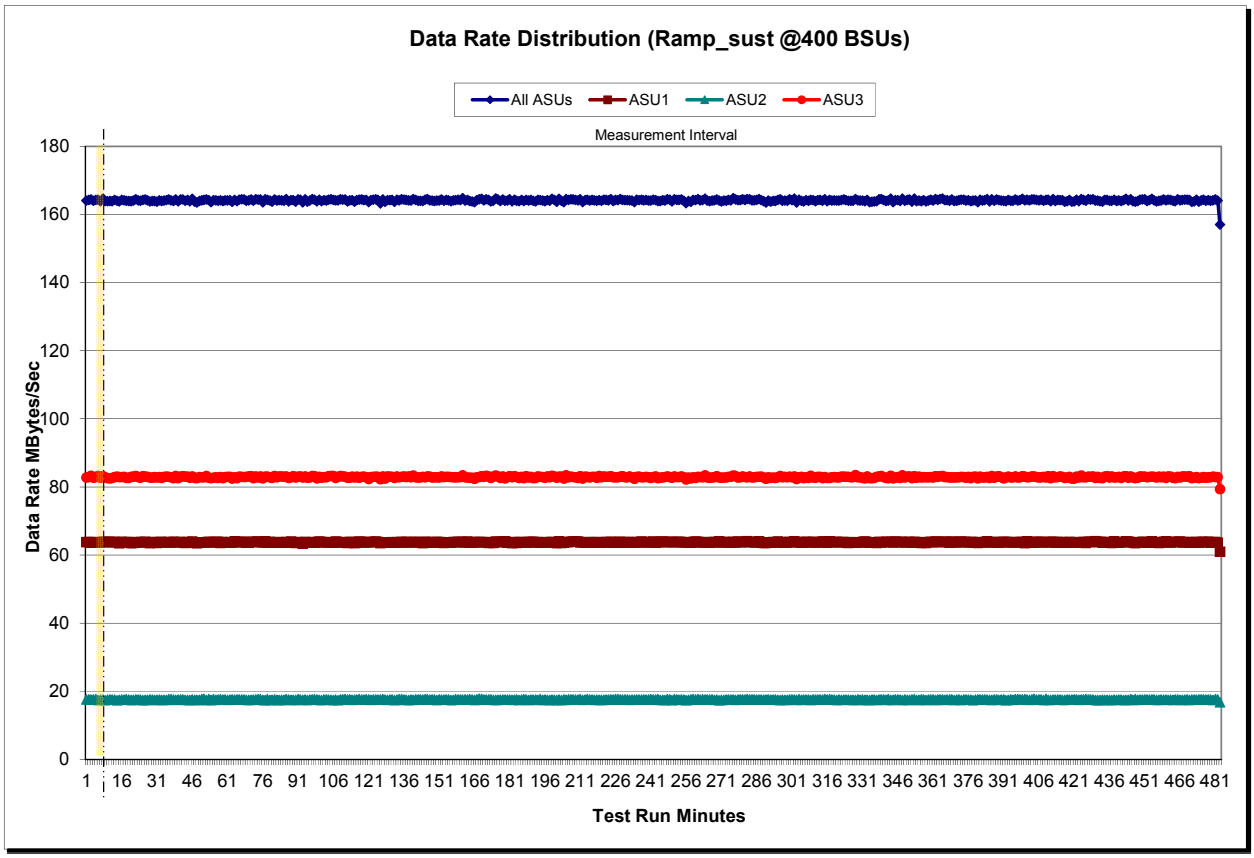


Sustainability – I/O Request Throughput Distribution Data

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

Sustainability Data Tables

Sustainability – I/O Request Throughput Distribution Graph

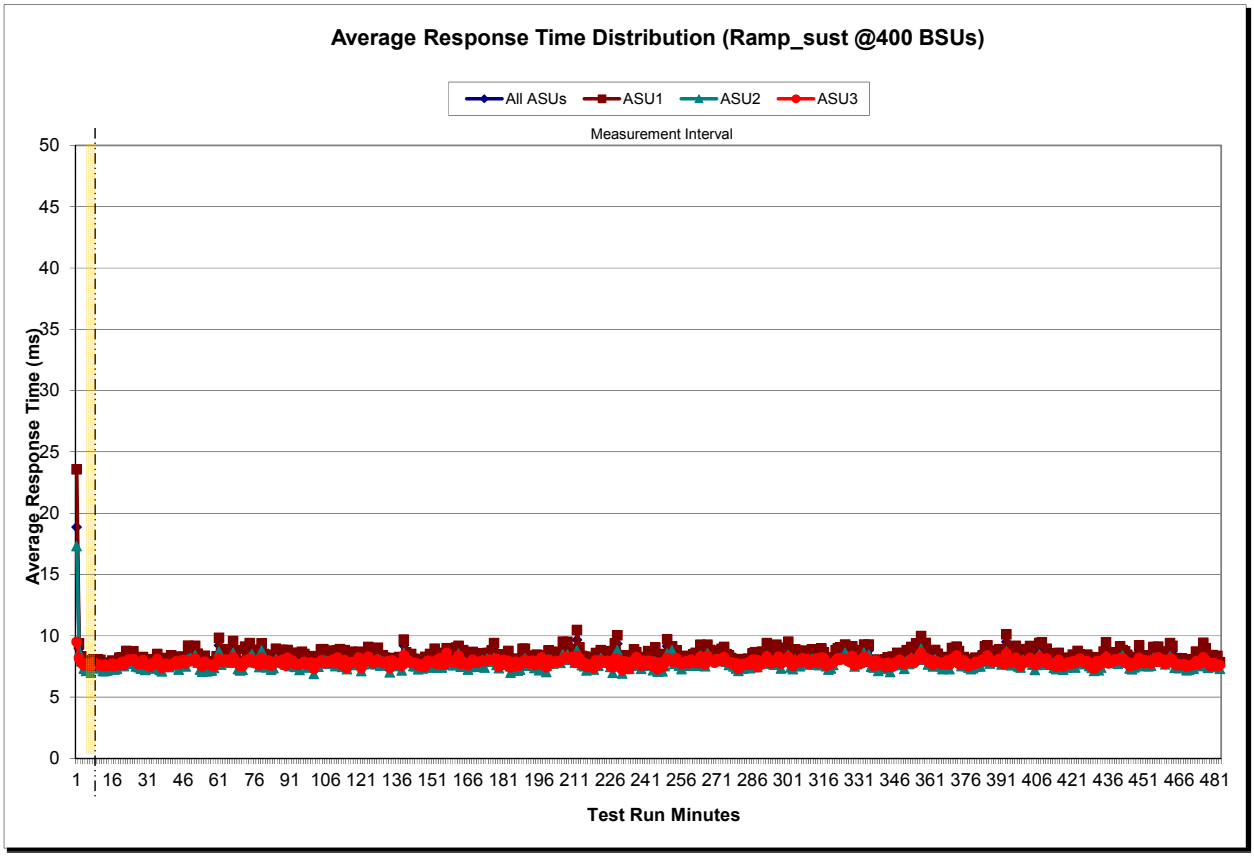


Sustainability – Average Response Time (ms) Distribution Data

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

Sustainability Data Tables

Sustainability – Average Response Time (ms) Distribution Graph



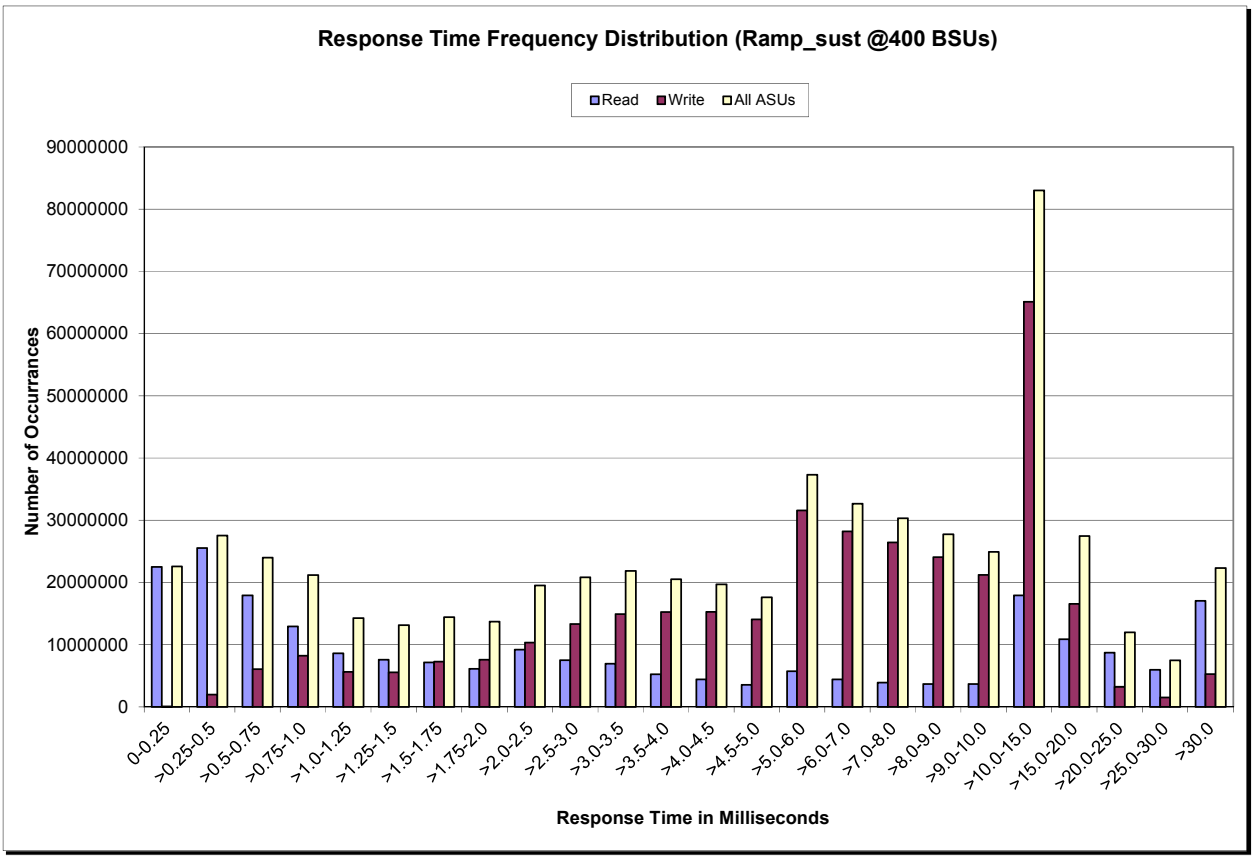
Sustainability – Response Time Frequency Distribution Data

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	22,495,213	25,532,875	17,924,812	12,944,351	8,619,906	7,582,123	7,172,563	6,115,209
Write	88,196	1,981,707	6,056,793	8,232,690	5,650,100	5,560,689	7,260,209	7,593,304
All ASUs	22,583,409	27,514,582	23,981,605	21,177,041	14,270,006	13,142,812	14,432,772	13,708,513
ASU1	17,094,505	22,573,543	17,578,924	14,275,132	9,546,641	8,713,712	9,144,964	8,463,677
ASU2	5,450,999	4,033,873	3,566,845	3,081,564	2,133,082	1,898,614	1,947,329	1,778,624
ASU3	37,905	907,166	2,835,836	3,820,345	2,590,283	2,530,486	3,340,479	3,466,212

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	9,195,887	7,508,792	6,934,279	5,251,525	4,419,523	3,556,214	5,722,787	4,436,268
Write	10,334,605	13,334,457	14,909,503	15,251,578	15,279,216	14,063,404	31,578,283	28,218,546
All ASUs	19,530,492	20,843,249	21,843,782	20,503,103	19,698,739	17,619,618	37,301,070	32,654,814
ASU1	12,367,151	12,338,532	12,516,892	11,317,639	10,688,009	9,428,608	18,977,658	16,256,658
ASU2	2,529,689	2,472,895	2,517,783	2,267,683	2,131,516	1,866,049	3,904,174	3,381,829
ASU3	4,633,652	6,031,822	6,809,107	6,917,781	6,879,214	6,324,961	14,419,238	13,016,327

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	3,903,351	3,676,943	3,676,356	17,911,262	10,892,766	8,734,174	5,945,817	17,043,904
Write	26,418,763	24,061,345	21,233,589	65,105,161	16,550,545	3,240,270	1,518,955	5,278,753
All ASUs	30,322,114	27,738,288	24,909,945	83,016,423	27,443,311	11,974,444	7,464,772	22,322,657
ASU1	14,927,098	13,644,465	12,308,809	42,679,043	16,089,454	9,057,063	5,835,390	17,476,715
ASU2	3,127,738	2,848,296	2,575,128	8,816,286	3,115,591	1,419,936	1,003,604	2,983,266
ASU3	12,267,278	11,245,527	10,026,008	31,521,094	8,238,266	1,497,445	625,778	1,862,676

Sustainability – Response Time Frequency Distribution Graph



Sustainability – Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.13.2

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

Clause 5.3.13.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0..0350	0.2810	0.0700	0.2100	0.0180	0.0700	0.3050	0.2810
COV	0.005	0.001	0.003	0.002	0.007	0.003	0.005	0.001

Primary Metrics Test – IOPS Test Phase

Clause 5.4.4.2

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

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

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

Clause 9.4.3.7.2

For the IOPS Test Phase the FDR shall contain:

1. *I/O Request Throughput Distribution (data and graph).*
2. *A Response Time Frequency Distribution.*
3. *An Average Response Time Distribution.*
4. *The human readable Test Run Results File produced by the Workload Generator.*
5. *A listing or screen image of all input parameters supplied t 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 75.

IOPS Test Results File

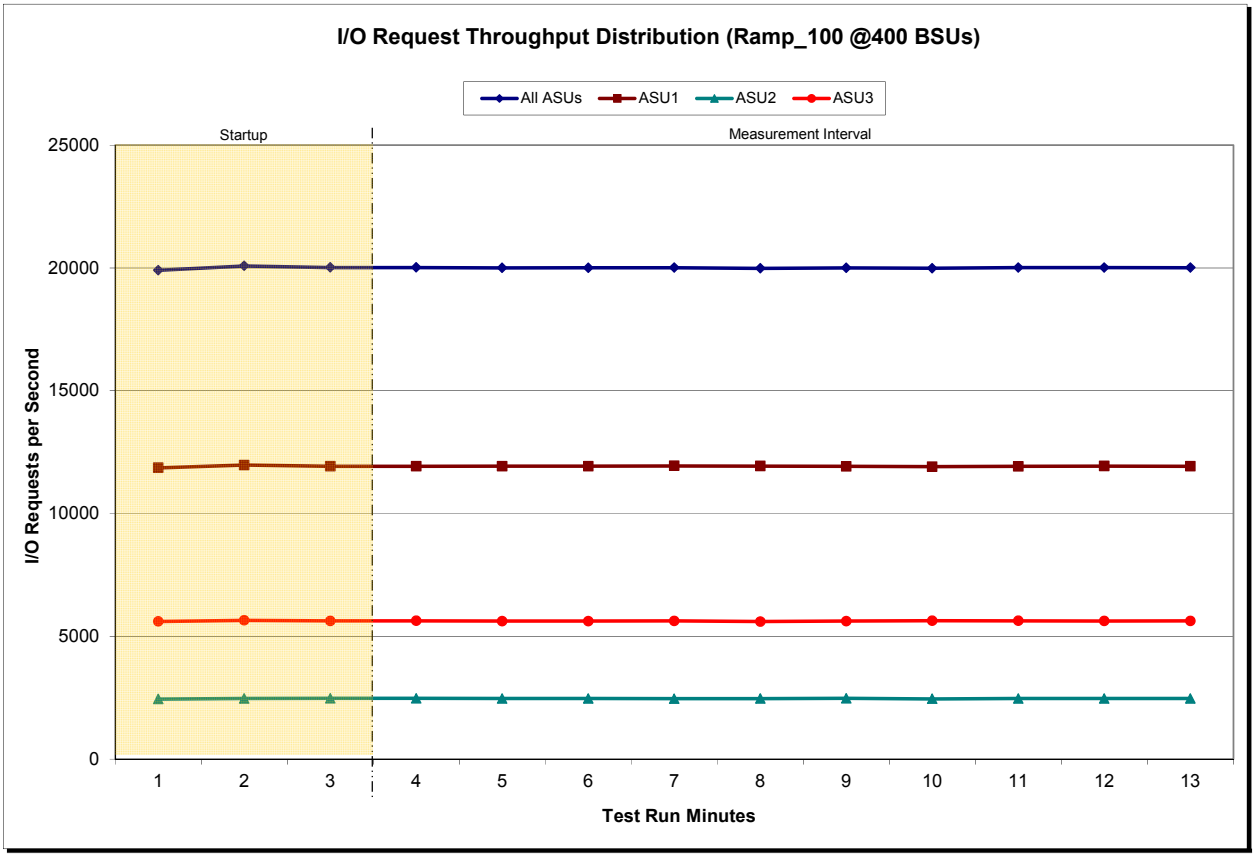
A link to the test results file generated from the IOPS Test Run is listed below.

IOPS Test Results File

IOPS Test Run – I/O Request Throughput Distribution Data

400 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:36:39	19:39:40	0-2	0:03:01
Measurement Interval	19:39:40	19:49:40	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	19,901.47	11,859.63	2,440.60	5,601.23
1	20,078.57	11,970.62	2,462.37	5,645.58
2	20,016.60	11,922.63	2,471.17	5,622.80
3	20,018.95	11,919.40	2,470.28	5,629.27
4	20,000.10	11,923.20	2,460.98	5,615.92
5	20,003.52	11,924.97	2,462.60	5,615.95
6	20,010.40	11,936.88	2,452.03	5,621.48
7	19,980.83	11,927.68	2,456.57	5,596.58
8	20,001.50	11,918.00	2,471.20	5,612.30
9	19,987.58	11,907.15	2,448.57	5,631.87
10	20,011.35	11,918.30	2,463.75	5,629.30
11	20,013.63	11,929.52	2,463.53	5,620.58
12	20,008.75	11,920.30	2,463.37	5,625.08
Average	***20,003.66***	***11,922.54***	***2,461.29***	***5,619.83***

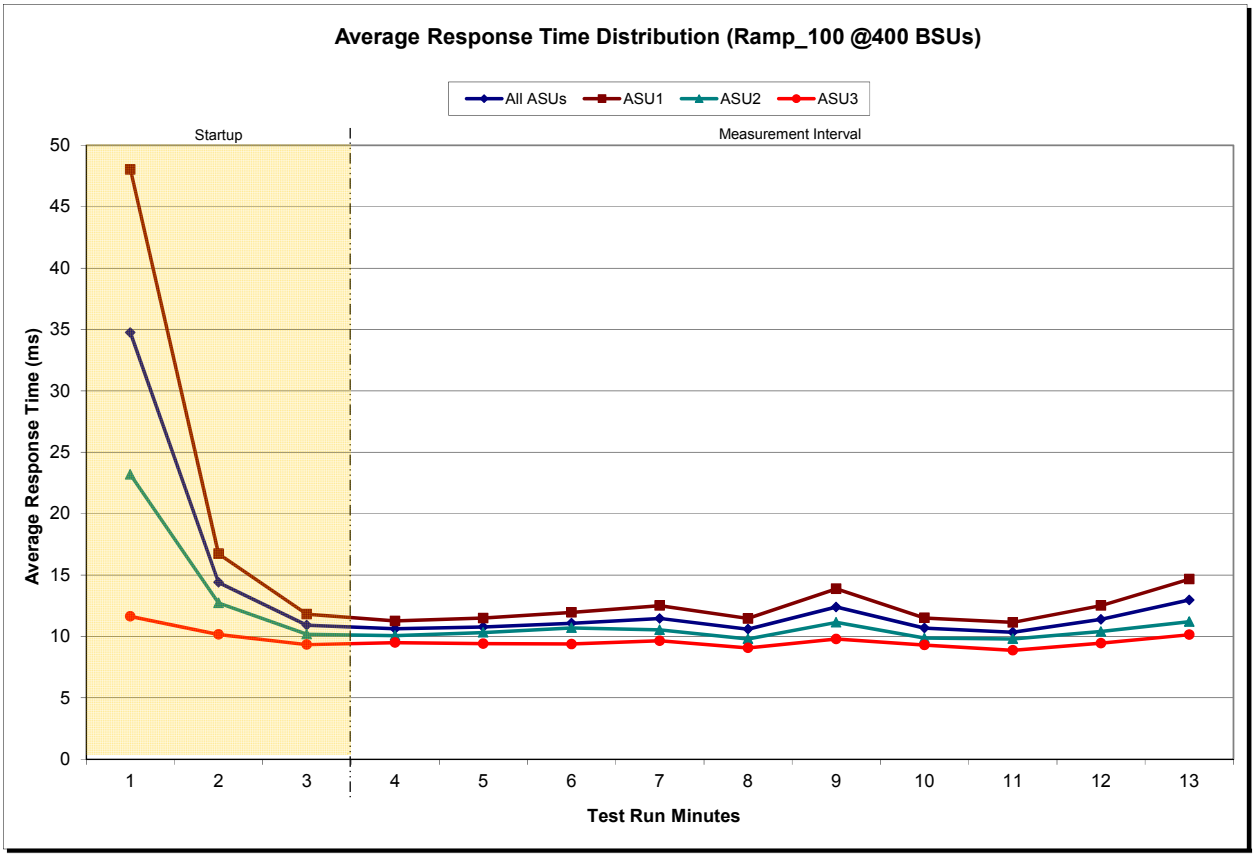
IOPS Test Run – I/O Request Throughput Distribution Graph



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

400 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:36:39	19:39:40	0-2	0:03:01
Measurement Interval	19:39:40	19:49:40	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	34.74	48.03	23.19	11.63
1	14.40	16.74	12.73	10.16
2	10.92	11.82	10.18	9.33
3	10.62	11.26	10.07	9.49
4	10.77	11.50	10.32	9.41
5	11.08	11.96	10.70	9.38
6	11.46	12.51	10.54	9.65
7	10.59	11.47	9.80	9.07
8	12.39	13.88	11.15	9.79
9	10.68	11.51	9.87	9.30
10	10.34	11.14	9.80	8.87
11	11.39	12.51	10.40	9.45
12	12.97	14.67	11.21	10.14
Average	***11.23***	***12.24***	***10.38***	***9.46***

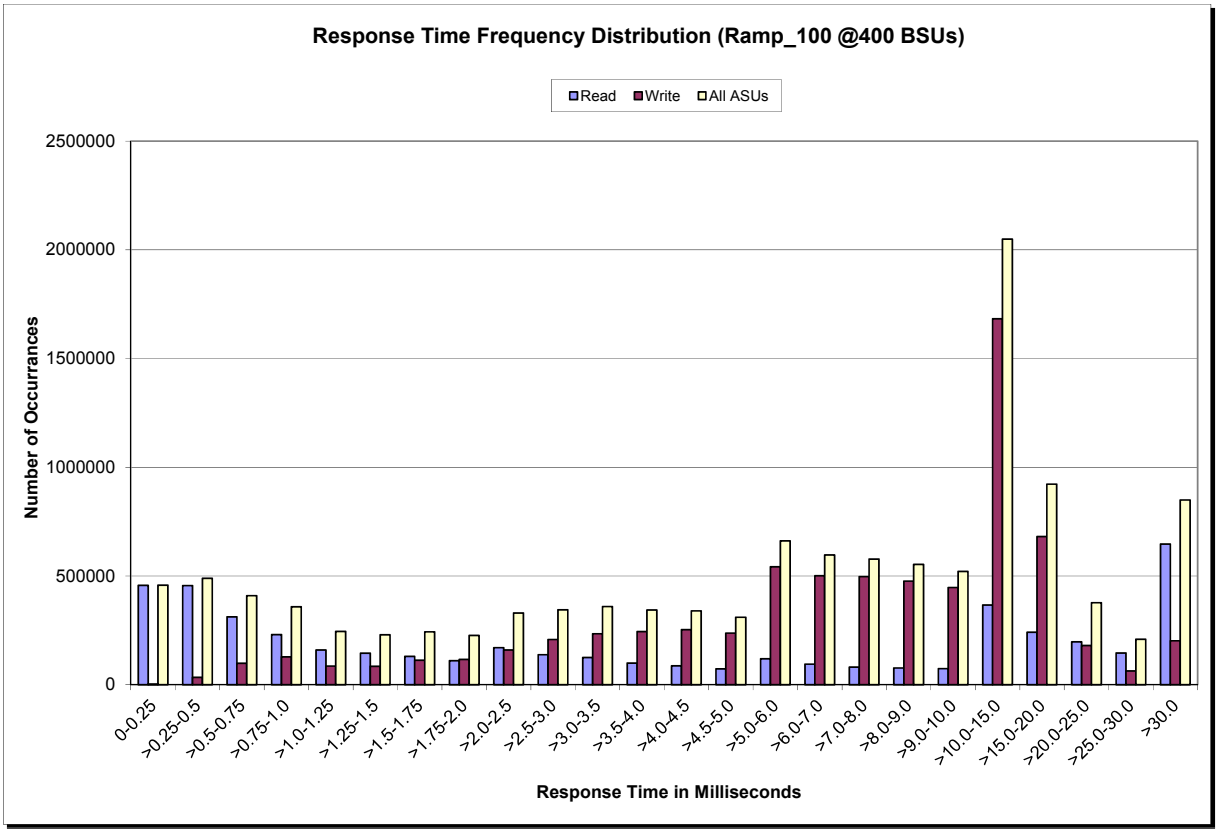
IOPS Test Run – Average Response Time (ms) Distribution Graph



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	456,283	455,987	311,557	230,618	159,688	144,307	130,387	109,774
Write	1,789	33,569	98,358	127,999	85,864	84,678	112,447	116,289
All ASUs	458,072	489,556	409,915	358,617	245,552	228,985	242,834	226,063
ASU1	348,427	402,079	300,079	243,929	167,055	153,994	155,159	140,786
ASU2	108,794	71,392	62,254	54,047	38,481	35,746	34,816	31,179
ASU3	851	16,085	47,582	60,641	40,016	39,245	52,859	54,098
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	169,915	137,541	125,210	99,228	86,486	72,605	118,780	94,752
Write	159,619	207,229	234,402	243,979	253,149	237,129	542,425	501,409
All ASUs	329,534	344,770	359,612	343,207	339,635	309,734	661,205	596,161
ASU1	210,820	206,392	208,523	192,240	188,223	169,068	341,703	303,208
ASU2	46,365	43,449	43,172	39,697	37,776	33,261	70,179	62,274
ASU3	72,349	94,929	107,917	111,270	113,636	107,405	249,323	230,679
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	81,011	76,550	73,898	366,179	241,218	197,244	145,523	646,752
Write	497,123	476,641	446,506	1,683,325	680,964	180,156	63,309	202,108
All ASUs	578,134	553,191	520,404	2,049,504	922,182	377,400	208,832	848,860
ASU1	288,588	275,681	258,751	1,029,315	477,048	241,430	151,863	699,031
ASU2	59,510	56,585	53,474	214,428	103,051	44,192	27,741	104,881
ASU3	230,036	220,925	208,179	805,761	342,083	91,778	29,228	44,948

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
12,001,959	11,13,099	848,860

IOPS Test Run – Measured Intensity Multiplier and Coefficient of Variation

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.13.2

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

Clause 5.3.13.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0352	0.2810	0.0700	0.2099	0.0180	0.0700	0.0350	0.2809
COV	0.005	0.001	0.005	0.001	0.009	0.003	0.005	0.002

Primary Metrics Test – Response Time Ramp Test Phase

Clause 5.4.4.3

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

The five Response Time Ramp Test Runs, in conjunction with the IOPS Test Run (100%), demonstrate the relationship between Average Response Time and I/O Request Throughput for the Tested Storage Configuration (TSC) as illustrated in the response time/throughput curve on page 14.

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

Clause 9.4.3.7.3

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

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

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 75.

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 - 400 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:36:39	19:39:40	0-2	0:03:01
Measurement Interval	19:39:40	19:49:40	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	19,901.47	11,859.63	2,440.60	5,601.23
1	20,078.57	11,970.62	2,462.37	5,645.58
2	20,016.60	11,922.63	2,471.17	5,622.80
3	20,018.95	11,919.40	2,470.28	5,629.27
4	20,000.10	11,923.20	2,460.98	5,615.92
5	20,003.52	11,924.97	2,462.60	5,615.95
6	20,010.40	11,936.88	2,452.03	5,621.48
7	19,980.83	11,927.68	2,456.57	5,596.58
8	20,001.50	11,918.00	2,471.20	5,612.30
9	19,987.58	11,907.15	2,448.57	5,631.87
10	20,011.35	11,918.30	2,463.75	5,629.30
11	20,013.63	11,929.52	2,463.53	5,620.58
12	20,008.75	11,920.30	2,463.37	5,625.08
Average	***20,003.66***	***11,922.54***	***2,461.29***	***5,619.83***

95% Load Level - 380 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	19:49:42	19:52:43	0-2	0:03:01
Measurement Interval	19:52:43	20:02:43	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	19,044.17	11,356.42	2,344.85	5,342.90
1	18,981.25	11,293.20	2,344.20	5,343.85
2	19,011.17	11,321.47	2,333.15	5,356.55
3	18,987.35	11,315.83	2,340.37	5,331.15
4	19,012.30	11,331.02	2,338.00	5,343.28
5	18,981.03	11,304.20	2,330.13	5,346.70
6	19,010.07	11,323.18	2,338.12	5,348.77
7	19,011.32	11,329.53	2,339.45	5,342.33
8	18,980.78	11,323.28	2,331.53	5,325.97
9	19,009.03	11,338.40	2,330.50	5,340.13
10	19,000.15	11,324.65	2,342.63	5,332.87
11	18,992.20	11,317.28	2,337.68	5,337.23
12	19,001.55	11,331.10	2,341.07	5,329.38
Average	***18,998.58***	***11,323.85***	***2,336.95***	***5,337.78***

90% Load Level - 360 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:02:45	20:05:46	0-2	0:03:01
Measurement Interval	20:05:46	20:15:46	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	17,989.52	10,724.72	2,207.68	5,057.12
1	17,987.53	10,722.02	2,206.02	5,059.50
2	17,989.13	10,708.23	2,215.20	5,065.70
3	17,992.30	10,721.75	2,216.23	5,054.32
4	17,990.12	10,713.72	2,223.00	5,053.40
5	17,992.92	10,727.30	2,217.27	5,048.35
6	18,007.88	10,743.53	2,210.35	5,054.00
7	17,968.03	10,700.85	2,212.73	5,054.45
8	17,976.47	10,706.47	2,208.53	5,061.47
9	18,000.03	10,714.58	2,210.47	5,074.98
10	17,993.65	10,718.40	2,211.63	5,063.62
11	17,979.52	10,719.75	2,212.10	5,047.67
12	17,999.28	10,724.10	2,216.77	5,058.42
Average	***17,990.02***	***10,719.05***	***2,213.91***	***5,057.07***

80% Load Level - 320 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:15:48	20:18:49	0-2	0:03:01
Measurement Interval	20:18:49	20:28:49	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	15,982.92	9,535.95	1,968.97	4,478.00
1	16,006.63	9,554.80	1,973.68	4,478.15
2	16,001.55	9,538.40	1,959.92	4,503.23
3	16,015.38	9,541.85	1,963.78	4,509.75
4	15,975.00	9,514.33	1,960.60	4,500.07
5	15,974.80	9,515.50	1,969.63	4,489.67
6	16,022.82	9,545.37	1,971.13	4,506.32
7	16,007.43	9,533.37	1,965.00	4,509.07
8	16,012.82	9,542.23	1,975.32	4,495.27
9	15,993.12	9,529.10	1,970.20	4,493.82
10	15,989.75	9,532.00	1,960.75	4,497.00
11	16,022.60	9,547.40	1,968.40	4,506.80
12	15,981.45	9,519.27	1,971.02	4,491.17
Average	***15,999.52***	***9,532.04***	***1,967.58***	***4,499.89***

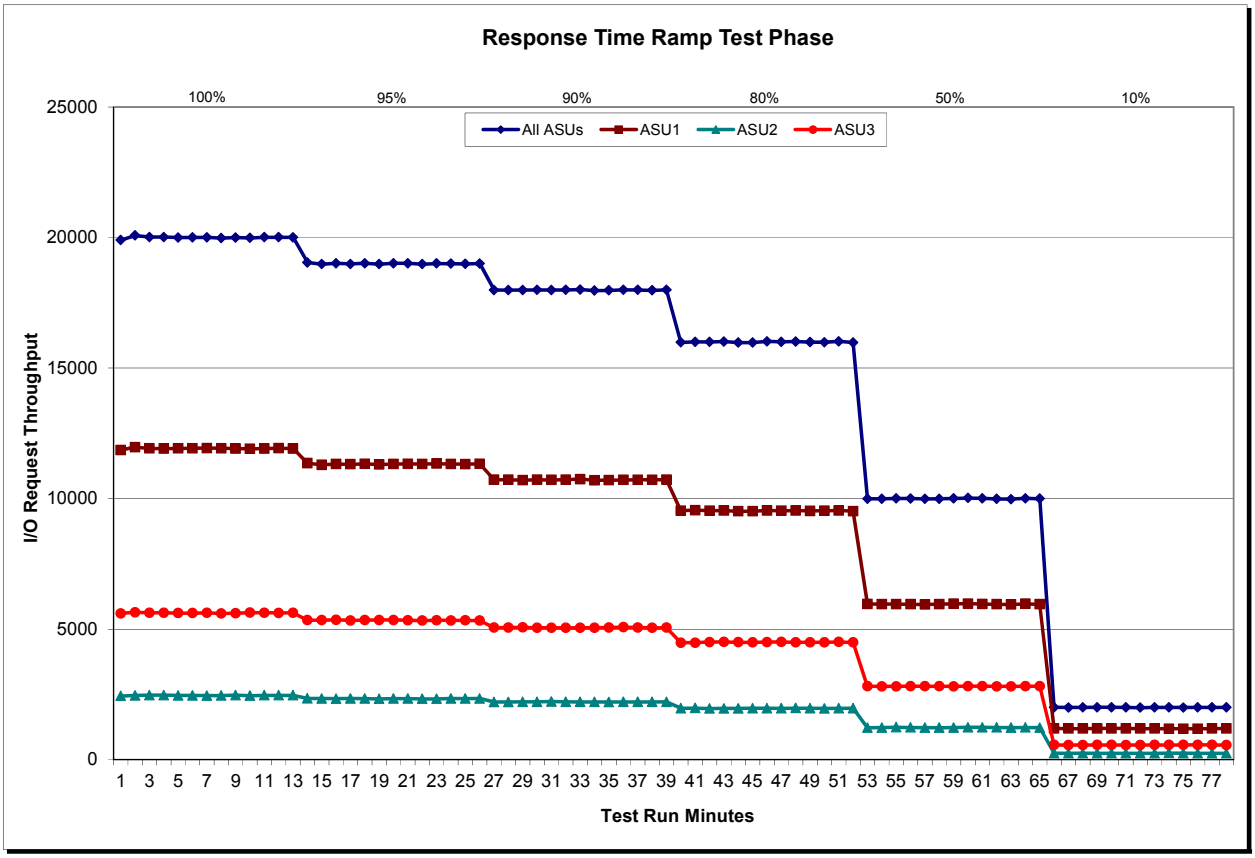
50% Load Level - 200 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:28:50	20:31:51	0-2	0:03:01
Measurement Interval	20:31:51	20:41:51	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	9,993.97	5,960.22	1,224.27	2,809.48
1	9,993.28	5,956.95	1,228.87	2,807.47
2	10,006.98	5,958.72	1,240.97	2,807.30
3	9,999.65	5,954.42	1,231.77	2,813.47
4	9,986.88	5,944.02	1,229.72	2,813.15
5	9,991.17	5,955.30	1,225.00	2,810.87
6	10,005.55	5,967.85	1,228.78	2,808.92
7	10,023.05	5,971.88	1,237.78	2,813.38
8	10,011.35	5,960.48	1,234.12	2,816.75
9	9,990.30	5,952.00	1,231.57	2,806.73
10	9,978.22	5,945.62	1,226.88	2,805.72
11	10,012.10	5,970.23	1,231.55	2,810.32
12	9,995.85	5,952.65	1,226.07	2,817.13
Average	***9,999.41***	***5,957.45***	***1,230.32***	***2,811.64***

10% Load Level - 40 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:41:52	20:44:53	0-2	0:03:01
Measurement Interval	20:44:53	20:54:53	3-12	0:10:00

(60 second intervals)	All ASUs	ASU-1	ASU-2	ASU-3
0	2,006.70	1,192.13	249.32	565.25
1	1,995.82	1,189.48	244.02	562.32
2	1,998.90	1,189.15	247.02	562.73
3	2,003.93	1,195.48	245.23	563.22
4	2,006.12	1,194.83	245.87	565.42
5	1,999.32	1,192.78	244.97	561.57
6	1,991.68	1,188.75	243.80	559.13
7	1,998.43	1,189.17	245.38	563.88
8	1,999.15	1,183.62	251.35	564.18
9	1,997.60	1,186.28	247.58	563.73
10	1,999.18	1,186.97	244.83	567.38
11	1,998.62	1,189.43	244.98	564.20
12	1,998.57	1,192.12	244.67	561.78
Average	***1,999.26***	***1,189.94***	***245.87***	***563.45***

Response Time Ramp Distribution (IOPS) Graph

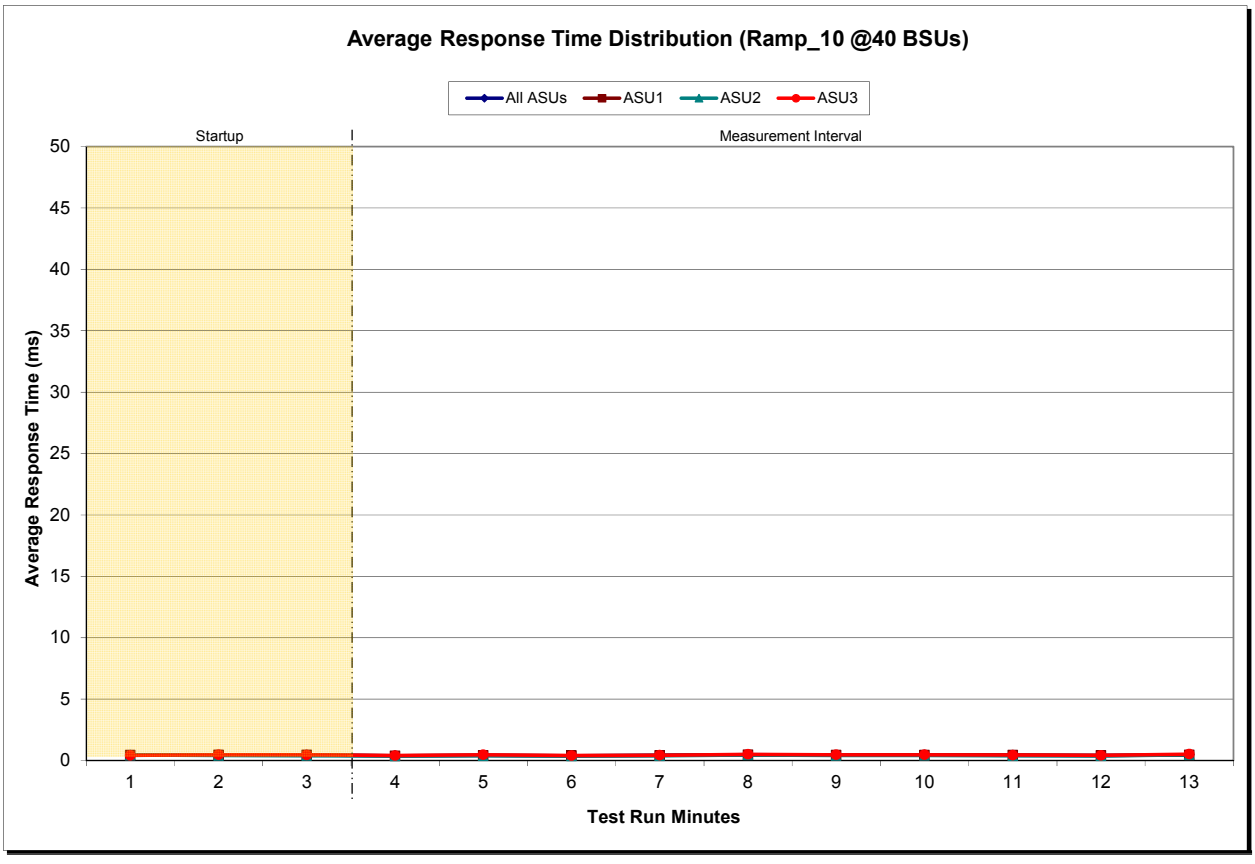


SPC-1 LRT™ Average Response Time (ms) Distribution Data

40 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:41:52	20:44:53	0-2	0:03:01
Measurement Interval	20:44:53	20:54:53	3-12	0:10:00

60 second intervals	All ASUs	ASU1	ASU2	ASU3
0	0.43	0.43	0.44	0.42
1	0.45	0.45	0.40	0.47
2	0.45	0.45	0.39	0.45
3	0.39	0.39	0.37	0.40
4	0.43	0.42	0.38	0.46
5	0.39	0.40	0.36	0.40
6	0.42	0.42	0.38	0.43
7	0.47	0.46	0.45	0.50
8	0.44	0.44	0.41	0.47
9	0.44	0.44	0.41	0.46
10	0.43	0.44	0.39	0.44
11	0.41	0.41	0.38	0.42
12	0.47	0.44	0.46	0.52
Average	***0.43***	***0.43***	***0.40***	***0.45***

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



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

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.13.2

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

Clause 5.3.13.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0352	0.2809	0.0695	0.2096	0.0180	0.0700	0.0349	0.2818
COV	0.015	0.004	0.008	0.004	0.023	0.010	0.016	0.003

Repeatability Test

Clause 5.4.5

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

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

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

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

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

Clause 9.4.3.7.4

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

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

SPC-1 Workload Generator Input Parameters

The SPC-1 Workload Generator input parameters for the Sustainability, IOPS, Response Time Ramp, Repeatability, and Persistence Test Runs are documented in "Appendix E: SPC-1 Workload Generator Input Parameters" on Page 75.

Repeatability Test Results File

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

	SPC-1 IOPS™
Primary Metrics	***20,003.66***
Repeatability Test Phase 1	19,991.92
Repeatability Test Phase 2	20,003.03

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

	SPC-1 LRT™
Primary Metrics	***0.43 ms***
Repeatability Test Phase 1	0.43 ms
Repeatability Test Phase 2	0.41 ms

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

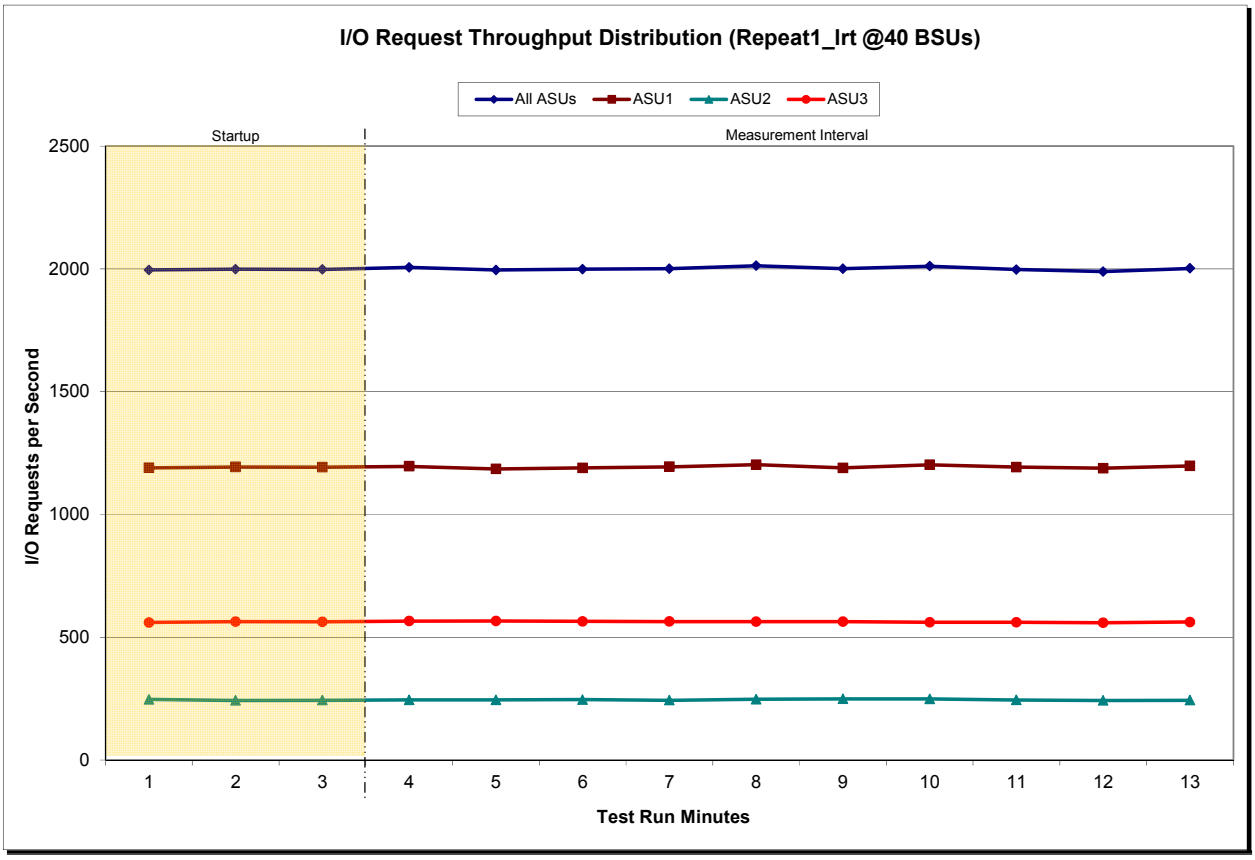
A link to the test result file generated from each Repeatability Test Run is listed below.

Repeatability Test Phase 1, Test Run 1 (LRT)
Repeatability Test Phase 1, Test Run 2 (IOPS)
Repeatability Test Phase 2, Test Run 1 (LRT)
Repeatability Test Phase 2, Test Run 2 (IOPS)

Repeatability 1 LRT – I/O Request Throughput Distribution Data

40 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:54:57	20:57:57	0-2	0:03:00
Measurement Interval	20:57:57	21:07:57	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	1,994.83	1,189.18	246.23	559.42
1	1,998.65	1,192.87	242.35	563.43
2	1,997.15	1,191.87	243.07	562.22
3	2,005.70	1,195.58	244.50	565.62
4	1,995.25	1,185.07	244.47	565.72
5	1,998.60	1,188.97	245.58	564.05
6	2,000.42	1,193.73	243.13	563.55
7	2,012.77	1,202.52	247.22	563.03
8	2,000.63	1,188.95	248.35	563.33
9	2,010.62	1,201.78	248.28	560.55
10	1,997.03	1,192.70	243.93	560.40
11	1,988.82	1,187.80	242.20	558.82
12	2,001.75	1,197.23	243.32	561.20
Average	***2,001.16***	***1,193.43***	***245.10***	***562.63***

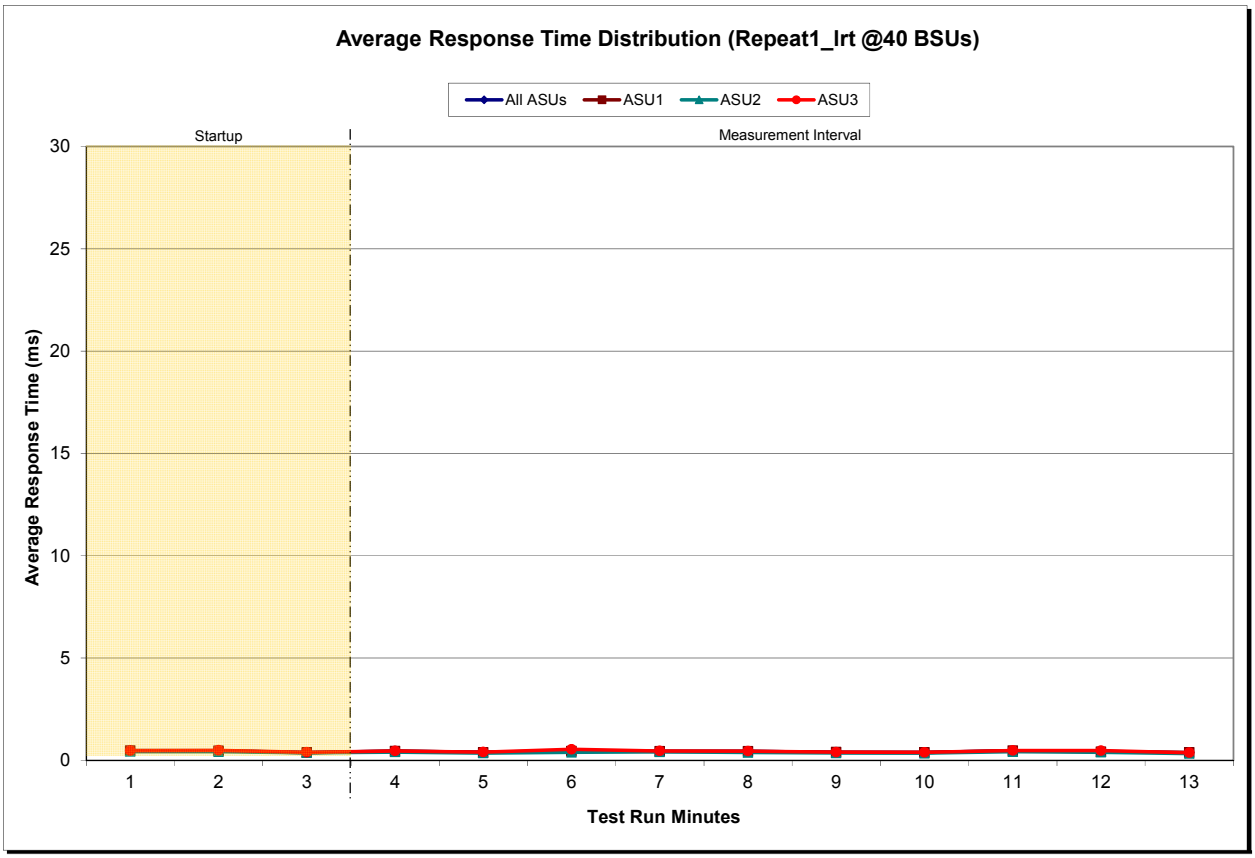
Repeatability 1 LRT – I/O Request Throughput Distribution Graph



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

40 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	20:54:57	20:57:57	0-2	0:03:00
Measurement Interval	20:57:57	21:07:57	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.47	0.48	0.43	0.47
1	0.47	0.46	0.42	0.50
2	0.38	0.37	0.37	0.40
3	0.45	0.46	0.41	0.46
4	0.39	0.39	0.36	0.41
5	0.47	0.45	0.39	0.54
6	0.44	0.44	0.41	0.46
7	0.44	0.44	0.38	0.45
8	0.40	0.40	0.36	0.40
9	0.38	0.38	0.35	0.39
10	0.47	0.47	0.42	0.49
11	0.44	0.43	0.40	0.48
12	0.38	0.39	0.34	0.38
Average	***0.43***	***0.42***	***0.38***	***0.45***

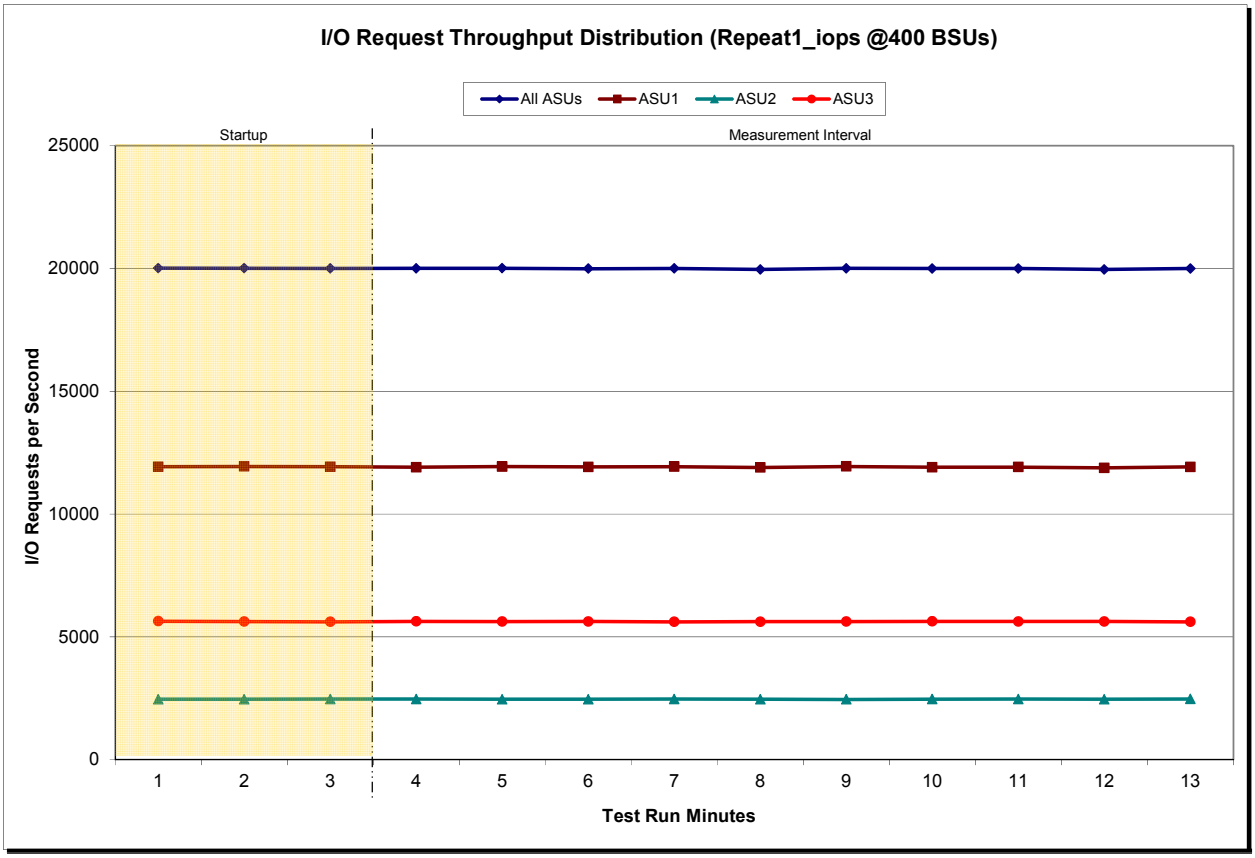
Repeatability 1 LRT –Average Response Time (ms) Distribution Graph



Repeatability 1 IOPS – I/O Request Throughput Distribution Data

400 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:07:59	21:11:00	0-2	0:03:01
Measurement Interval	21:11:00	21:21:00	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	20,014.88	11,923.12	2,456.27	5,635.50
1	20,008.00	11,937.67	2,452.60	5,617.73
2	19,999.12	11,923.80	2,464.42	5,610.90
3	20,003.10	11,909.25	2,464.92	5,628.93
4	20,010.85	11,933.98	2,456.25	5,620.62
5	19,992.80	11,915.30	2,453.63	5,623.87
6	19,999.23	11,928.20	2,461.45	5,609.58
7	19,960.00	11,892.18	2,454.32	5,613.50
8	20,006.53	11,937.63	2,451.95	5,616.95
9	19,993.88	11,906.80	2,459.87	5,627.22
10	19,996.05	11,909.58	2,462.12	5,624.35
11	19,961.35	11,881.33	2,454.85	5,625.17
12	19,996.12	11,914.90	2,469.48	5,611.73
Average	***19,991.99***	***11,912.92***	***2,458.88***	***5,620.19***

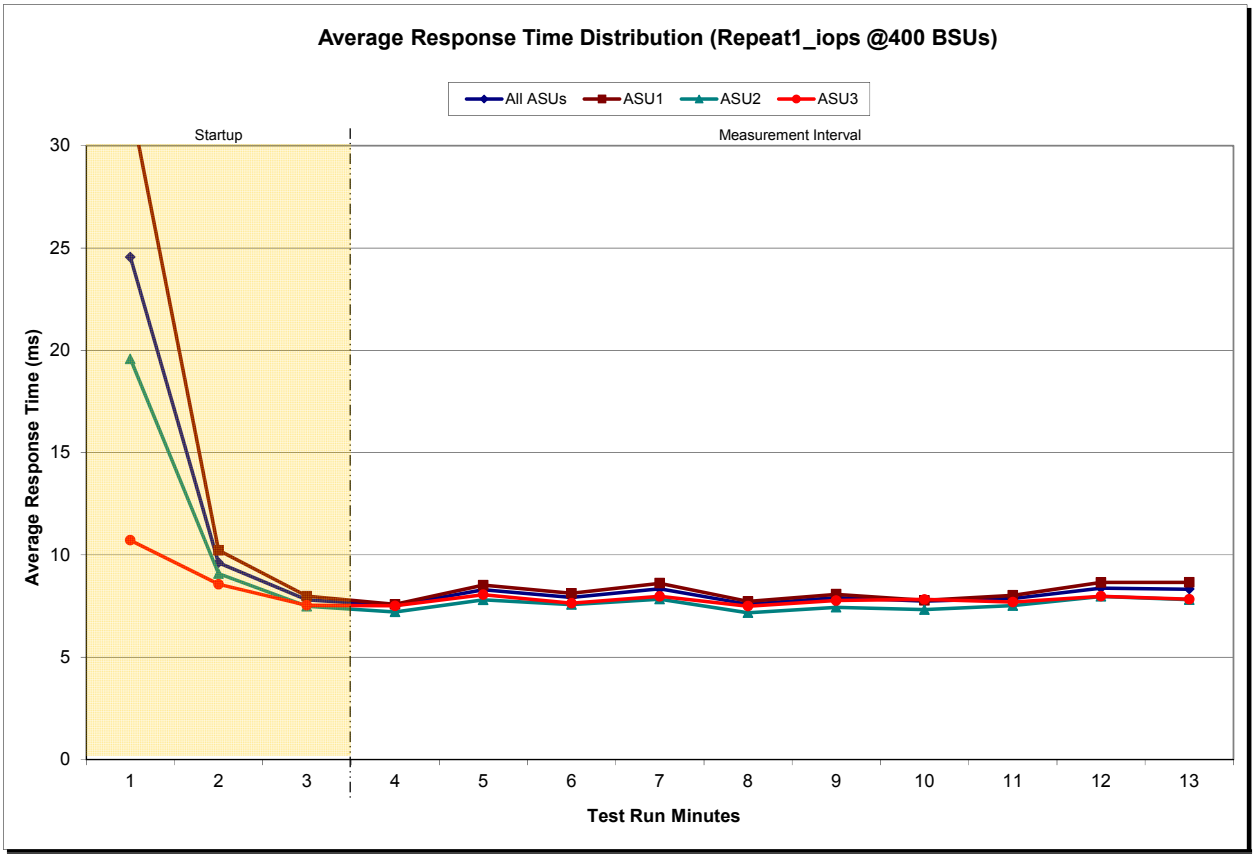
Repeatability 1 IOPS – I/O Request Throughput Distribution Graph



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

400 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:07:59	21:11:00	0-2	0:03:01
Measurement Interval	21:11:00	21:21:00	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	24.55	32.11	19.58	10.72
1	9.62	10.23	9.09	8.57
2	7.80	7.99	7.49	7.54
3	7.52	7.59	7.22	7.51
4	8.30	8.52	7.80	8.06
5	7.92	8.13	7.57	7.64
6	8.34	8.61	7.84	7.98
7	7.59	7.73	7.18	7.49
8	7.91	8.08	7.44	7.77
9	7.74	7.78	7.33	7.82
10	7.87	8.02	7.53	7.69
11	8.38	8.66	7.97	7.98
12	8.32	8.66	7.82	7.84
Average	***7.99***	***8.18***	***7.57***	***7.78***

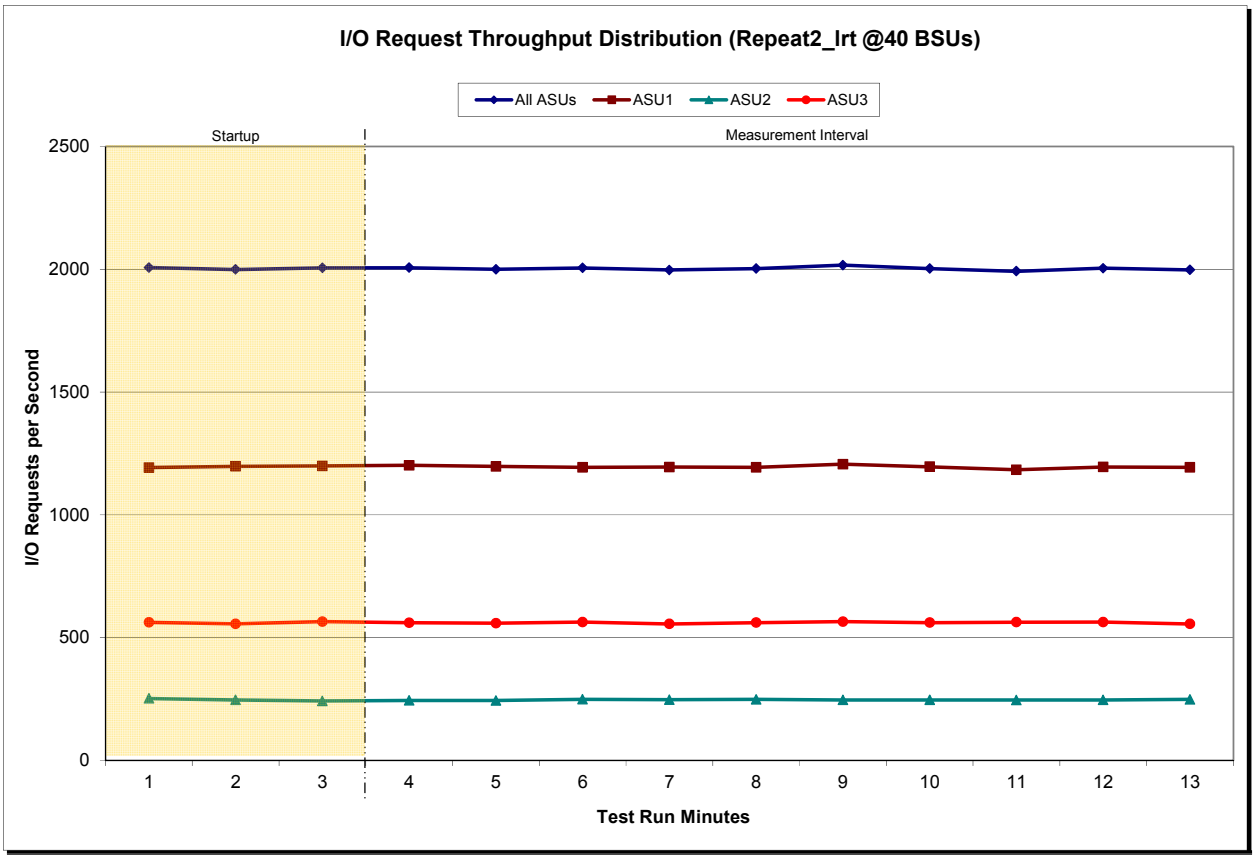
Repeatability 1 IOPS –Average Response Time (ms) Distribution Graph



Repeatability 2 LRT – I/O Request Throughput Distribution Data

40 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:21:04	21:24:04	0-2	0:03:00
Measurement Interval	21:24:04	21:34:04	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	2,006.58	1,192.62	252.03	561.93
1	1,999.27	1,197.43	245.67	556.17
2	2,005.68	1,198.83	242.00	564.85
3	2,006.13	1,201.43	244.17	560.53
4	1,999.42	1,196.97	243.78	558.67
5	2,005.58	1,193.48	248.68	563.42
6	1,996.93	1,194.25	247.17	555.52
7	2,002.58	1,193.18	248.30	561.10
8	2,016.80	1,205.93	245.70	565.17
9	2,002.58	1,195.70	245.77	561.12
10	1,991.72	1,183.48	245.48	562.75
11	2,003.90	1,194.73	246.05	563.12
12	1,997.23	1,193.38	248.30	555.55
Average	***2,002.29***	***1,195.26***	***246.34***	***560.69***

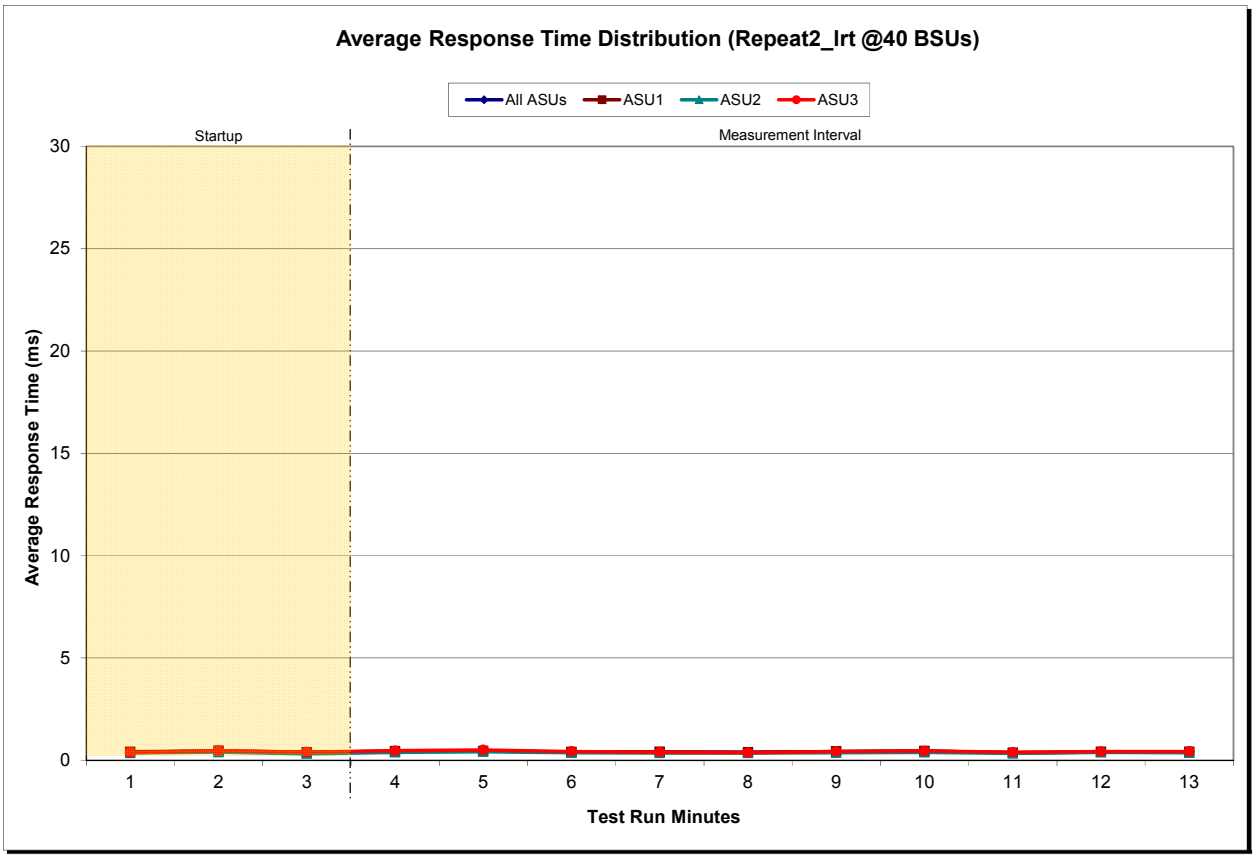
Repeatability 2 LRT – I/O Request Throughput Distribution Graph



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

40 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:21:04	21:24:04	0-2	0:03:00
Measurement Interval	21:24:04	21:34:04	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	0.40	0.41	0.36	0.38
1	0.46	0.46	0.40	0.47
2	0.39	0.39	0.32	0.40
3	0.44	0.44	0.39	0.47
4	0.46	0.45	0.42	0.51
5	0.40	0.40	0.37	0.43
6	0.40	0.41	0.36	0.40
7	0.38	0.39	0.35	0.37
8	0.42	0.43	0.37	0.43
9	0.45	0.45	0.39	0.46
10	0.37	0.37	0.34	0.39
11	0.41	0.41	0.39	0.43
12	0.41	0.41	0.37	0.43
Average	***0.41***	***0.42***	***0.37***	***0.43***

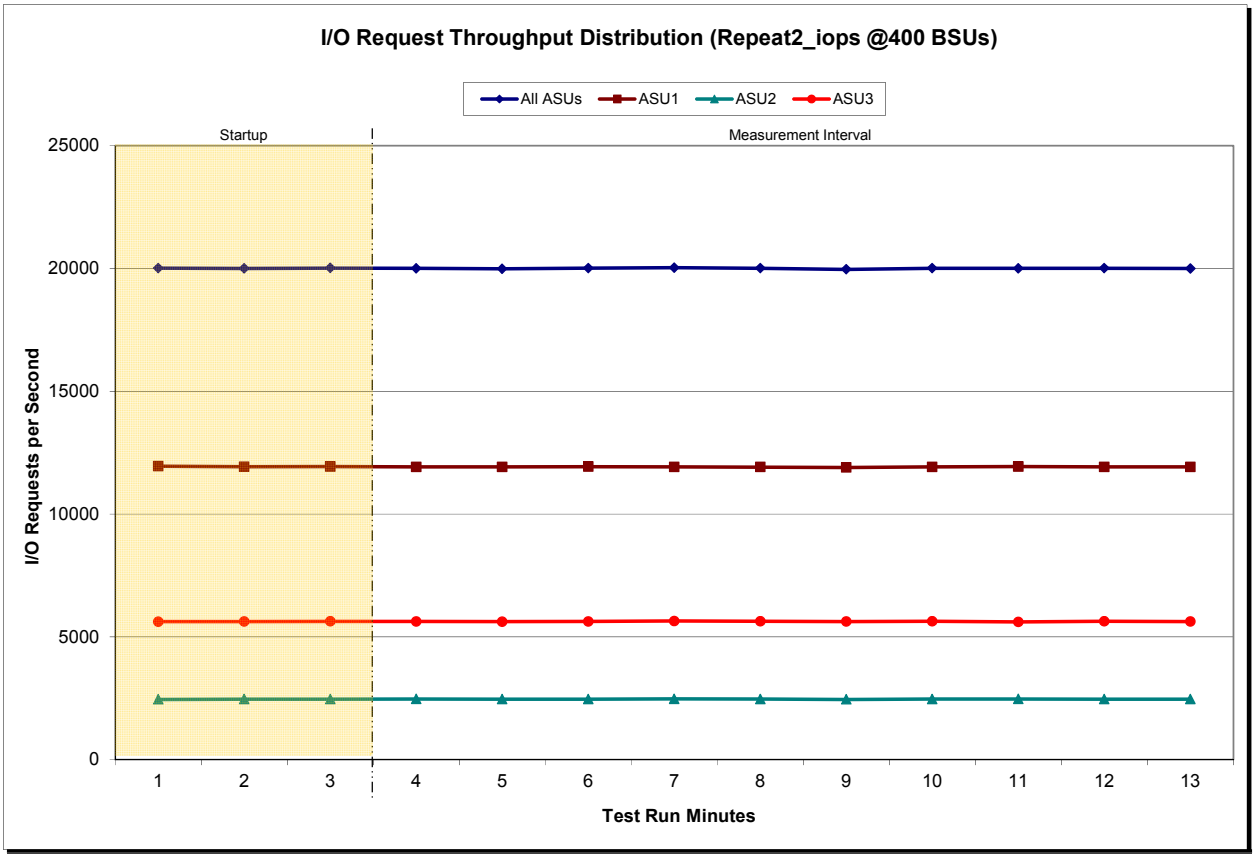
Repeatability 2 LRT –Average Response Time (ms) Distribution Graph



Repeatability 2 IOPS – I/O Request Throughput Distribution Data

400 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:34:06	21:37:07	0-2	0:03:01
Measurement Interval	21:37:07	21:47:07	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	20,013.47	11,947.37	2,450.17	5,615.93
1	19,999.13	11,922.90	2,458.27	5,617.97
2	20,018.17	11,933.48	2,458.95	5,625.73
3	20,005.13	11,916.97	2,466.43	5,621.73
4	19,988.70	11,915.93	2,459.77	5,613.00
5	20,013.85	11,931.70	2,457.38	5,624.77
6	20,029.82	11,914.30	2,472.32	5,643.20
7	20,009.55	11,912.37	2,464.30	5,632.88
8	19,963.42	11,895.55	2,448.57	5,619.30
9	20,011.05	11,918.15	2,462.20	5,630.70
10	20,005.12	11,932.28	2,469.60	5,603.23
11	20,008.92	11,916.35	2,460.18	5,632.38
12	19,994.75	11,916.97	2,458.18	5,619.60
Average	***20,003.03***	***11,917.06***	***2,461.89***	***5,624.08***

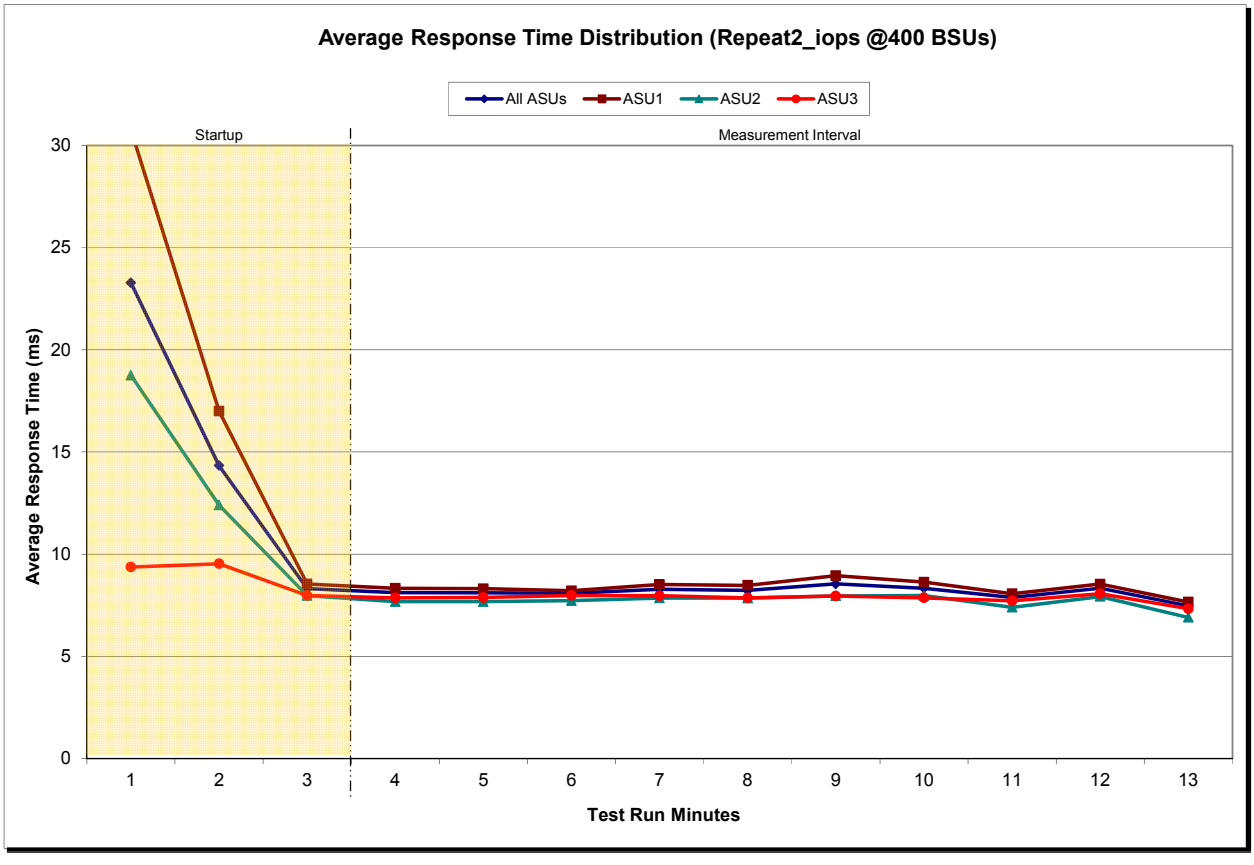
Repeatability 2 IOPS – I/O Request Throughput Distribution Graph



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

400 BSUs	Start	Stop	Interval	Duration
Start-Up/Ramp-Up	21:34:06	21:37:07	0-2	0:03:01
Measurement Interval	21:37:07	21:47:07	3-12	0:10:00
60 second intervals	**All ASUs**	**ASU1**	**ASU2**	**ASU3**
0	23.28	30.74	18.76	9.37
1	14.34	17.00	12.40	9.53
2	8.32	8.54	7.97	7.98
3	8.12	8.33	7.68	7.86
4	8.11	8.31	7.67	7.88
5	8.09	8.21	7.73	7.98
6	8.28	8.51	7.85	7.97
7	8.23	8.48	7.85	7.86
8	8.55	8.95	7.96	7.95
9	8.33	8.63	7.98	7.86
10	7.89	8.07	7.40	7.72
11	8.33	8.54	7.93	8.07
12	7.47	7.66	6.90	7.33
Average	***8.14***	***8.37***	***7.69***	***7.85***

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



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

Clause 3.4.3

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

Clauses 5.1.10 and 5.3.13.2

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

Clause 5.3.13.3

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2810	0.0699	0.2105	0.0180	0.0697	0.0347	0.2812
COV	0.012	0.005	0.010	0.004	0.010	0.010	0.015	0.005

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0351	0.2807	0.0699	0.2102	0.0180	0.0699	0.0351	02811
COV	0.006	0.001	0.003	0.002	0.008	0.003	0.006	0.001

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2820	0.0701	0.2098	0.0179	0.0700	0.0352	0.2800
COV	0.014	0.005	0.011	0.005	0.024	0.010	0.011	0.005

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

	ASU1-1	ASU1-2	ASU1-3	ASU1-4	ASU2-1	ASU2-2	ASU2-3	ASU3-1
IM	***0.0350***	***0.2810***	***0.0700***	***0.2100***	***0.0180***	***0.0700***	***0.0350***	***0.2810***
MIM	0.0350	0.2810	0.0700	0.2098	0.0180	0.0701	0.0350	0.2812
COV	0.005	0.001	0.004	0.002	0.005	0.003	0.004	0.002

Data Persistence Test

Clause 6

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

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

Execution of Persistence Test Run 1 will cause the SPC-1 Workload Generator to write a specific pattern at randomly selected locations throughout the Total ASU Capacity. The SPC-1 Workload Generator will retain the information necessary to later validate the pattern written at each location

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

Persistence Test Run 2, executed after the TSC has been restarted, will utilize the retained data from Persistence Test Run 1 to validate the patterns written at each location during Persistence Test Run 1.

Clause 9.4.3.8

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

1. *A listing or screen image of all input parameters supplied to the Workload Generator (may optionally be referenced in an appendix).*
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 9-16. 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 75.

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	47,987,296
Total Number of Logical Blocks Verified	33,482,736
Total Number of Logical Blocks that Failed Verification	0
Time Duration for Writing Test Logical Blocks	10 minutes
Size in Bytes of each Logical Block	512
Number of Failed I/O Requests in the process of the Test	0

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

PRICED STORAGE CONFIGURATION AVAILABILITY DATE

Clause 9.2.4.9

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

The HP P6500 Enterprise Virtual Array as documented in this Full Disclosure Report is currently available for customer purchase and shipment.

PRICING INFORMATION

Clause 9.4.3.3.6

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

Pricing information may found in the Priced Storage Configuration Pricing section on page 15.

TESTED STORAGE CONFIGURATION (TSC) AND PRICED STORAGE CONFIGURATION DIFFERENCES

Clause 9.4.3.3.7

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

A list of all differences between the Tested Storage Configuration (TSC) and Priced Storage Configuration may be found in the Executive Summary portion of this document on page 15.

ANOMALIES OR IRREGULARITIES

Clause 9.4.3.10

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

There were no anomalies or irregularities encountered during the SPC-1 Onsite Audit of the HP P6500 Enterprise Virtual Array .

APPENDIX A: SPC-1 GLOSSARY

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

SPC-1 Data Repository Definitions

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

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

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

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

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

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

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

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

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

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

SPC-1 Data Protection Levels

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

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

SPC-1 Test Execution Definitions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

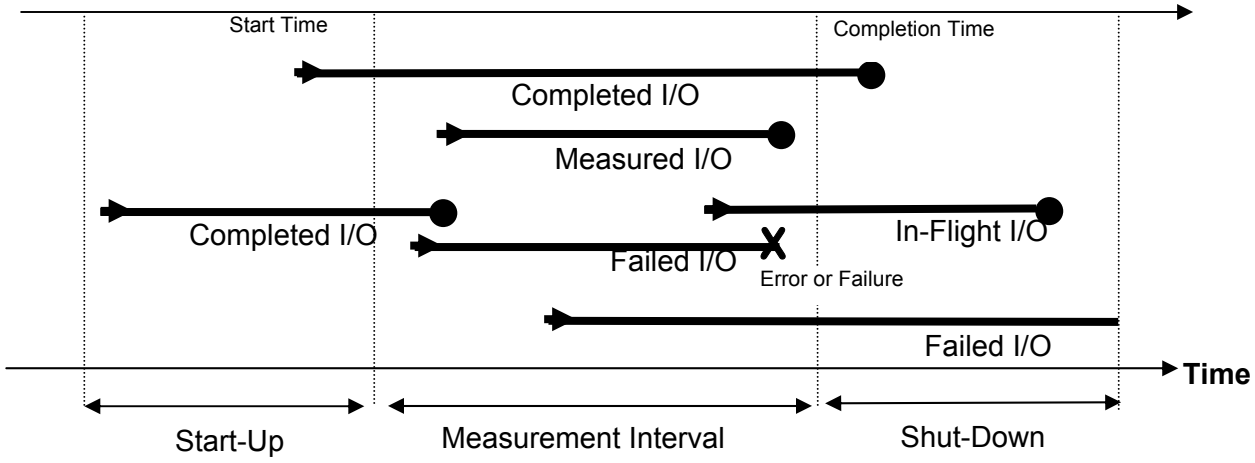
Test: A collection of Test Phases and or Test Runs sharing a common objective.

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

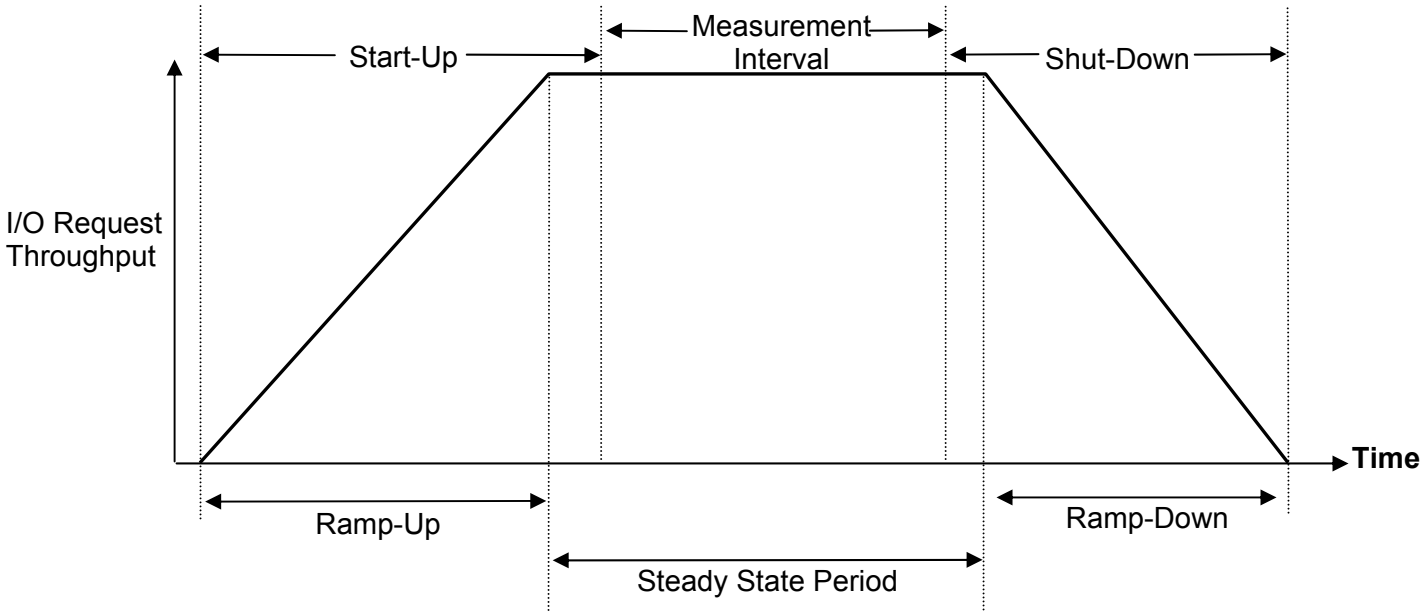
period, Shut-Down period, and Ramp-Down period as illustrated in the "SPC-1 Test Run Components" below. All SPC-1 Test Runs shall have a Steady State period and a Measurement Interval.

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

I/O Completion Types



SPC-1 Test Run Components



APPENDIX B: CUSTOMER TUNABLE PARAMETERS AND OPTIONS

The FC HBA **queuedepth** parameter was changed from a default of 32 to a value 254 for the benchmark measurements.

APPENDIX C: TESTED STORAGE CONFIGURATION (TSC) CREATION

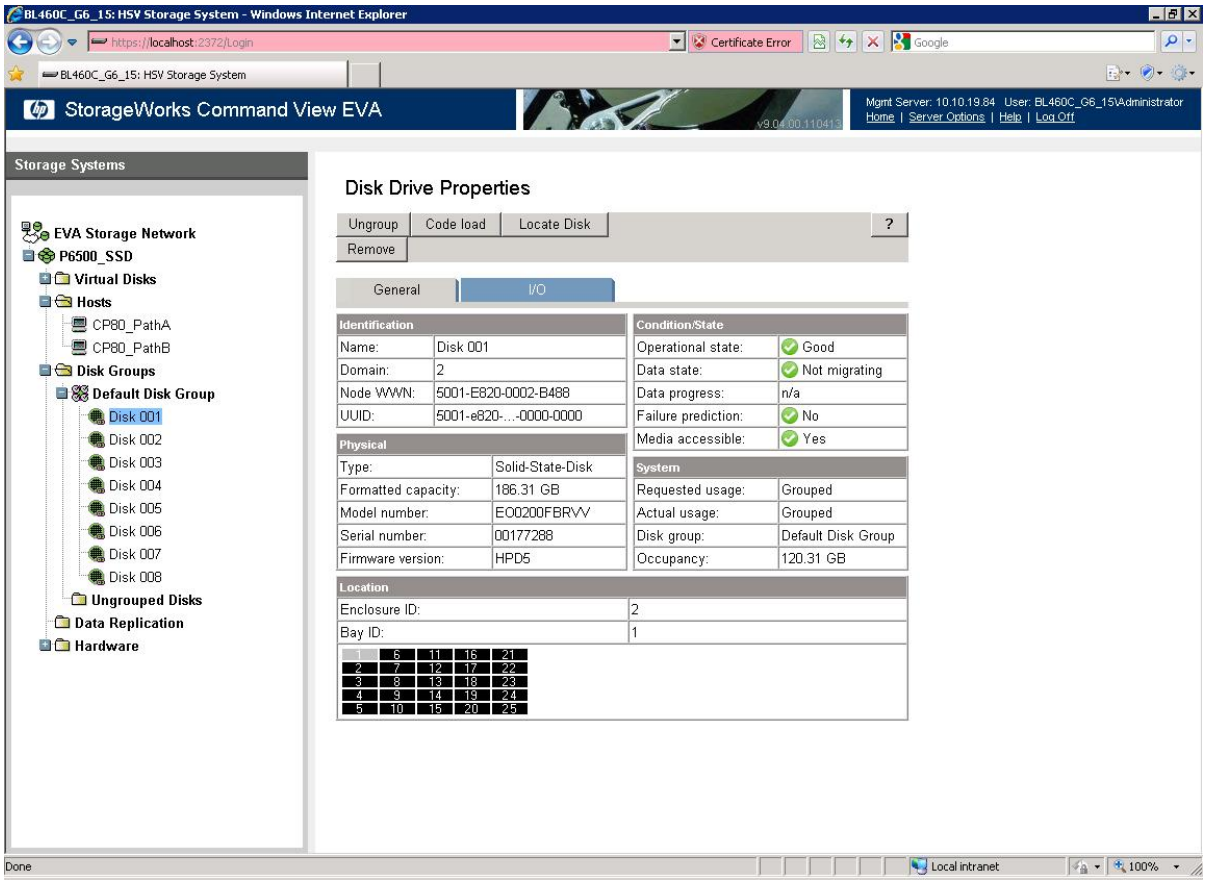
HP StorageWorks Command View EVA Software provides storage management for the HP P6500 Enterprise Virtual Array (EVA). The software was used, as described below, to create the SPC-1/E Application Storage Units (ASUs) used in the audited measurements.

Creation of those volumes consisted of the following steps:

- The grouping of available storage devices into a Disk Group.
- The creation of Virtual Disks *(Vdisks)* from that collection of storage devices.
- Define the two Host System ports, which comprise the paths by which the Vdisks will be presented the Host System.
- Presentation of the Vdisks to the Host System, defining the SPC-1/E Logical Volumes (LUNs), which comprise the SPC-1/E ASUs.

Properties for each configured storage device are listed in the **Disk Drive Properties** window and include formatted capacity, model, serial number and firmware revision for each device. The bottom of the window provides a graphical depiction of the enclosure and slot each device is located in.

The SPC-1/E Tested Storage Configuration (TSC) contained a total of 8 Solid State Devices (SSDs), each with a formatted capacity of 200.049 GB *(186.310 GiB)*. The "disk drive" properties for the first SSD are illustrated below.

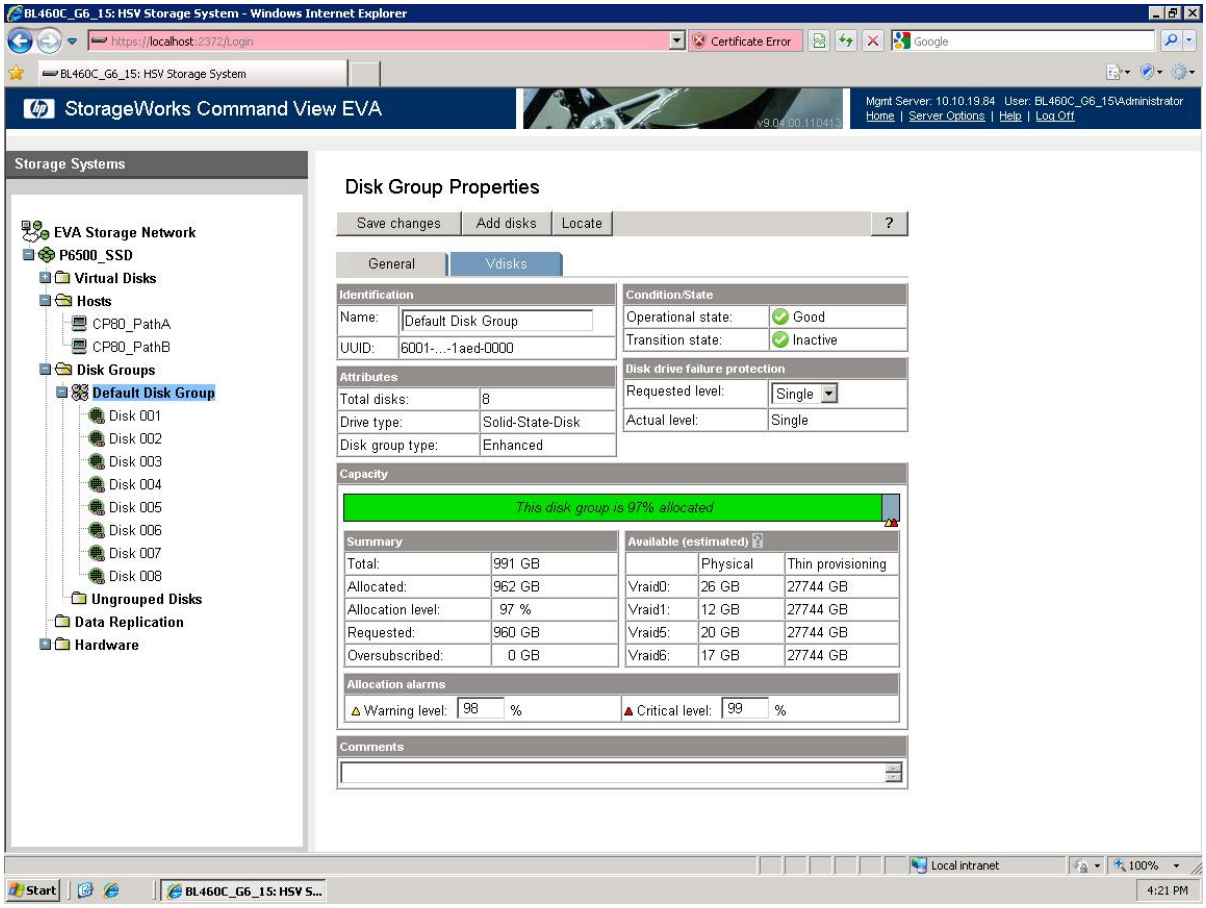


Define the Disk Group

Physical storage devices installed, which have not been assigned to a disk group, are placed in the default disk group. New disk groups can be created and populated as needed by a storage administrator.

The default disk group was used for the TSC and contained a total of 8 Solid State Devices (SSDs), as described above, providing 1,600.391 GB of Physical Storage Capacity.

The maximum amount of the Physical Storage Capacity available for application use was 991 GiB *(1,064.078 GB)* as illustrated below in the **Disk Group Properties** window. The remaining Physical Storage Capacity of 499.480 GiB *(536.313 GB)* was utilized for storage overhead.

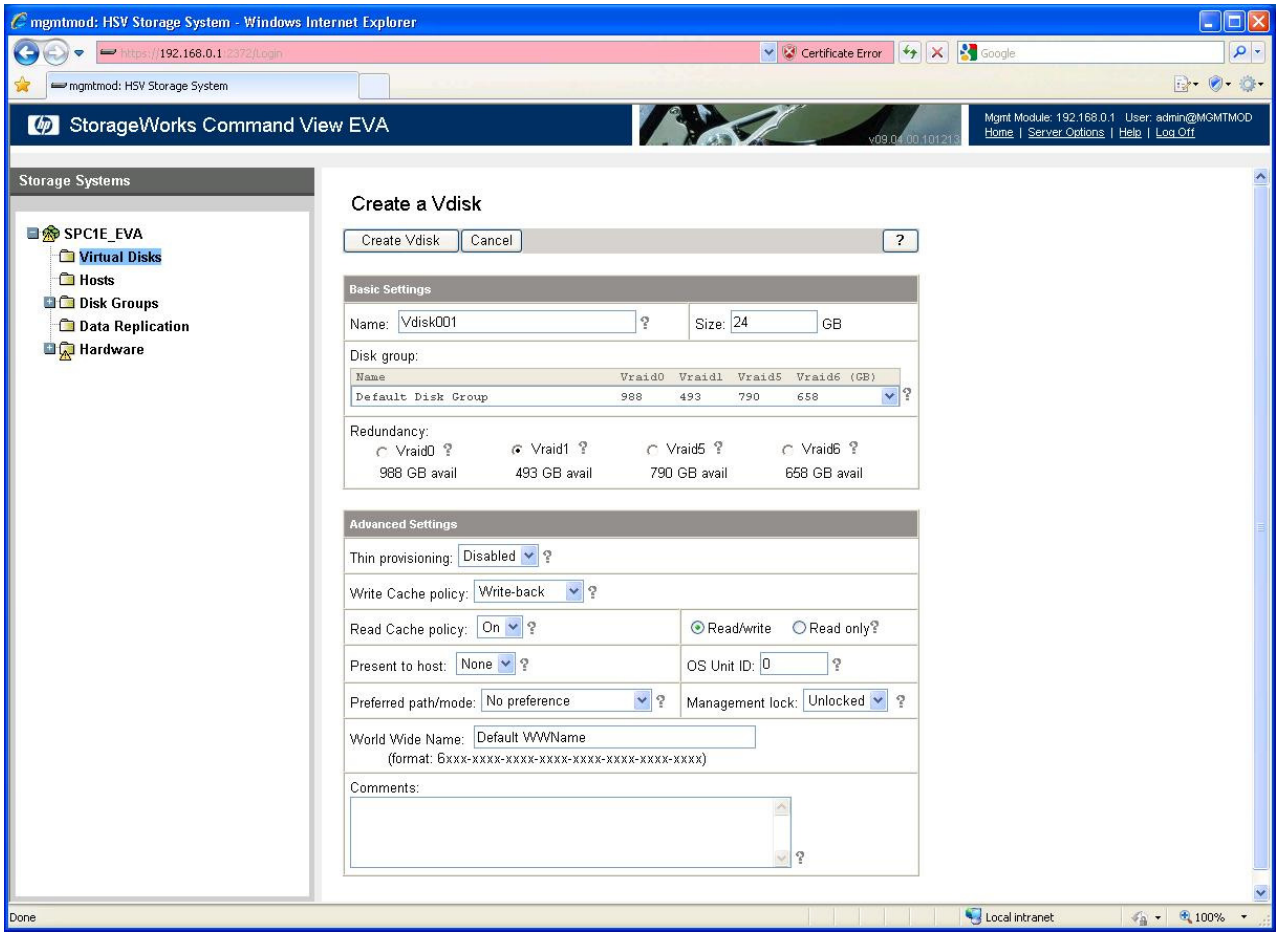


Create the Vdisks

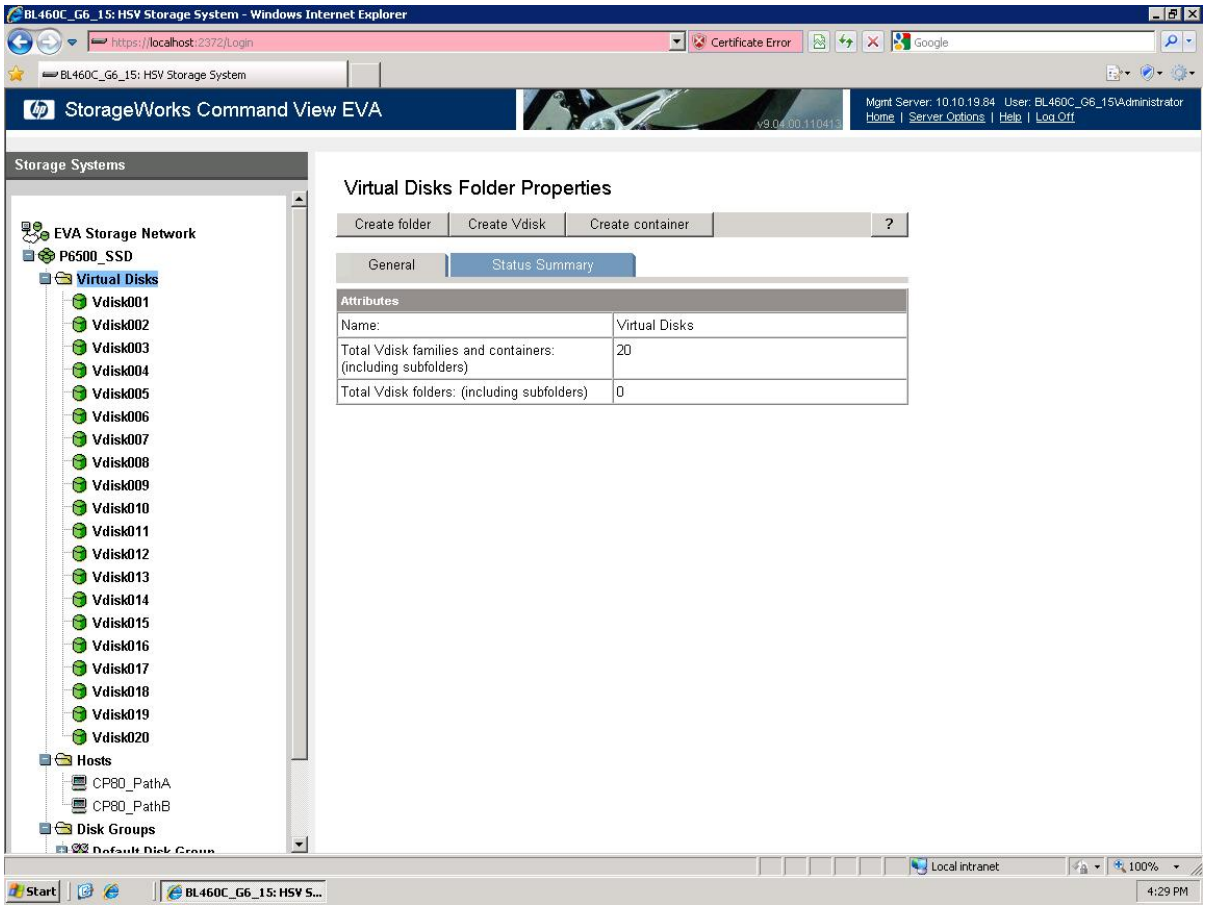
The **Create a Vdisk** window below illustrates the creation of first *(Vdisk001)* of 20 identical Vdisks for the TSC. The ***Virtual Disks*** node of the configuration tree on the left of the window is highlighted, which illustrates the configuration properties of Vdisk001.

The window displays the default disk group capacity available, when specifying an available level of data protection (***Redundancy***), for each Vdisk that will be created.

Vraid1 (RAID10) was selected for of the Vdisks. A capacity of 24 GiB (25.770 GB) was specified for each of the 20 Vdisks, which utilized all of the available disk group capacity.

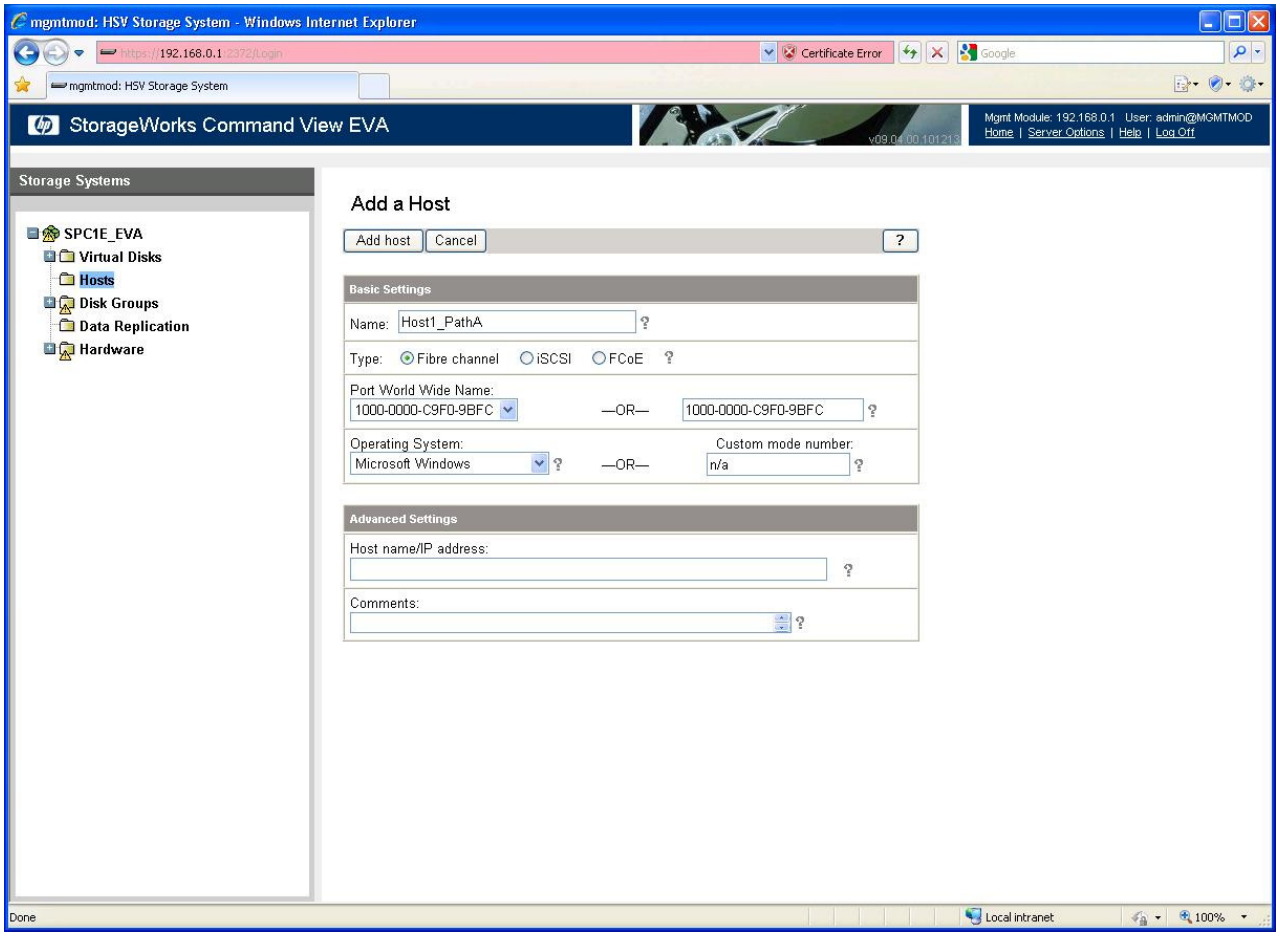


The **Virtual Disks Folder Properties** window displays all 20 Vdisks.



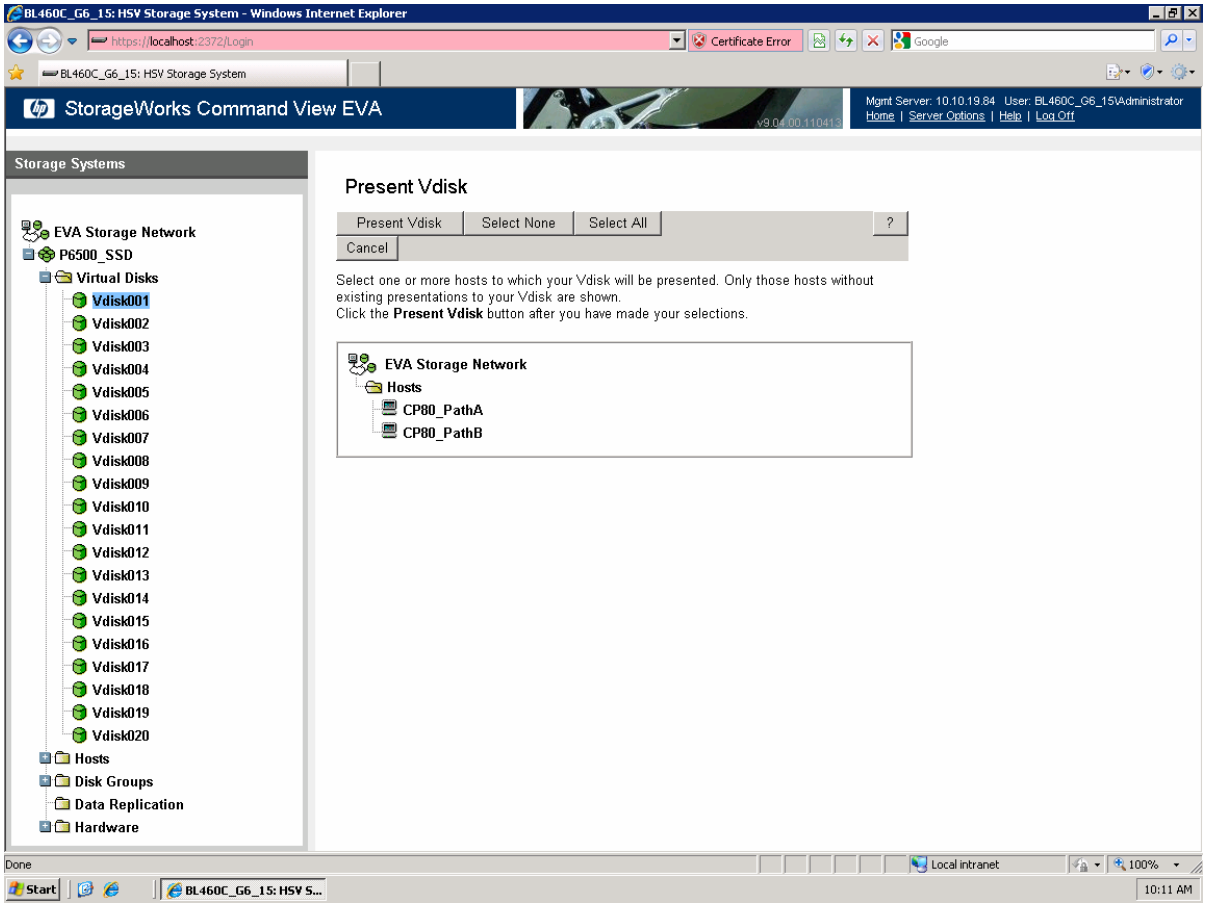
Define the Host System Paths

The **Add a Host** window is used to define the host port path names on the Host System that will be used to present the Vdisks to the Host System. The path names chosen for the TSC were ***CP80_PathA*** and ***CP80_PathB***.



Presentation of the Vdisk to the Host System

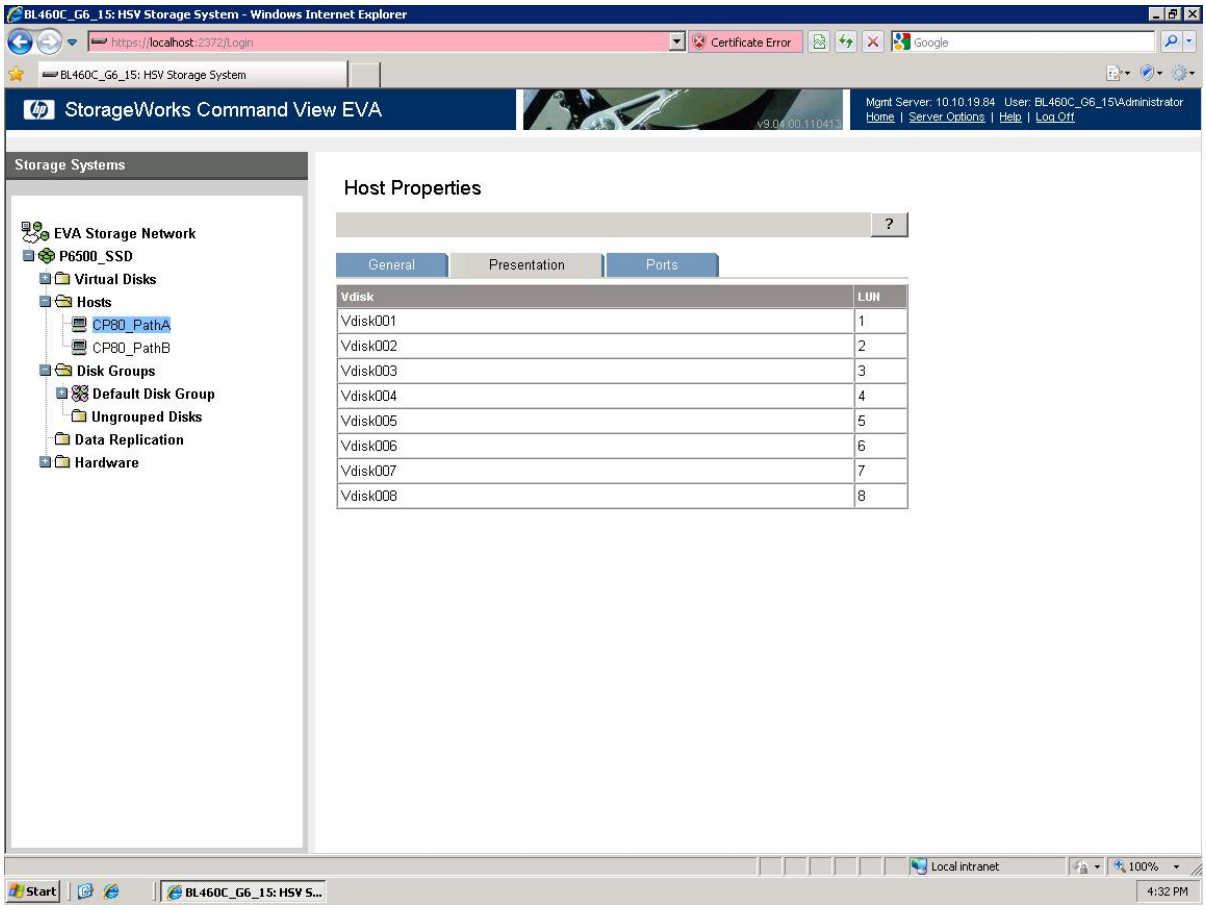
The **Present Vdisk** window below specifies the presentation of a Vdisk to a specific Host System path, as defined above. Each Vdisk is selected from the tree on the left of the window, the appropriate path is selected from the pane on the right and the ***Present Vdisk*** button on the upper left of the right pane is toggled.



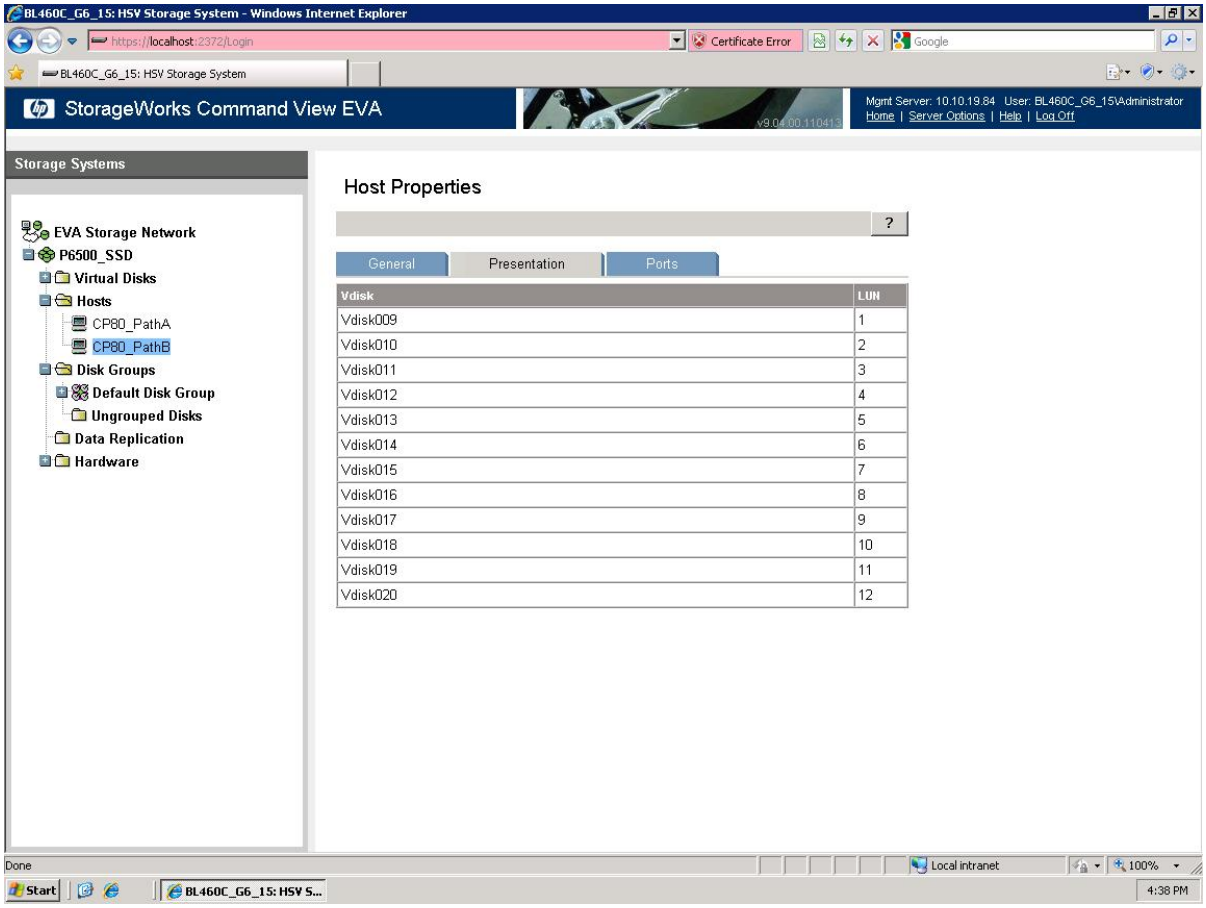
Each of the 20 Vdisks are presented to either **CP80_PathA** or **CP80_PathB**. The 20 Vdisks, as presented to the Host System, define the SPC-1/E Logical Volumes, which comprise the required SPC-1/E ASUs.

The Vdisks on **CP80_PathA** and **CP80_PathB** are illustrated below.

CP80_PathA Vdisks



CP80_PathB Vdisks



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

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

```
sd=asu1_1,lun=\\.\PhysicalDrive0
sd=asu1_2,lun=\\.\PhysicalDrive10
sd=asu1_3,lun=\\.\PhysicalDrive1
sd=asu1_4,lun=\\.\PhysicalDrive11
sd=asu1_5,lun=\\.\PhysicalDrive2
sd=asu1_6,lun=\\.\PhysicalDrive12
sd=asu1_7,lun=\\.\PhysicalDrive3
sd=asu1_8,lun=\\.\PhysicalDrive13
sd=asu1_9,lun=\\.\PhysicalDrive4
sd=asu2_1,lun=\\.\PhysicalDrive14
sd=asu2_2,lun=\\.\PhysicalDrive5
sd=asu2_3,lun=\\.\PhysicalDrive15
sd=asu2_4,lun=\\.\PhysicalDrive6
sd=asu2_5,lun=\\.\PhysicalDrive16
sd=asu2_6,lun=\\.\PhysicalDrive7
sd=asu2_7,lun=\\.\PhysicalDrive17
sd=asu2_8,lun=\\.\PhysicalDrive8
sd=asu2_9,lun=\\.\PhysicalDrive18
sd=asu3_1,lun=\\.\PhysicalDrive9
sd=asu3_2,lun=\\.\PhysicalDrive19
```

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 Idle Test *(Conditioning Phase, Application Idle Phase, and Recovery Phase)* 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.

```
call vdbench.bat -f prefill.txt -o prefill.out
java range -b 400
rename rangetest conditioning
choice /T 2100 /D Y
java range -b 40
rename rangetest recovery
java metrics -b 400 -t 28800
java repeat1 -b 400
java repeat2 -b 400
java persist1 -b 400
```

Persistence Test Run 2

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

```
rem java persist1
java persist2
```