SPC BENCHMARK 2™

FULL DISCLOSURE REPORT

NETAPP, INC.

NETAPP EF600 ALL-FLASH ARRAY

SPC-2™ V1.7.0

SUBMITTED FOR REVIEW: JULY 24, 2020

SUBMISSION IDENTIFIER: B12006

First Edition – July 2020

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AUDIT CERTIFICATION

InfoSizing
The Right Metric For Sizing IT

Storage Performance Council
Certified Auditor

Mark Regester
NetApp, Inc.
3718 North Rock Road
Wichita, KS 67226

July 23, 2020

I verified the SPC Benchmark 2™ (SPC-2 ™ v1.7.0) test execution and performance results of the following Tested Storage Product:

NetApp EF600 All-Flash Array

The results were:

SPC-2 MBPS™	**31,070.79**
SPC-2 Price-Performance™	**$3.53/SPC-2 MBPS™**
Total ASU Capacity	25,737.793 GB
Data Protection Level	Protected 2 (*RAID-6*)
Total Price (including 3-year maintenance)	$109,710.97
Currency Used	USD
Target Country for Availability, Sales and Support	USA

In my opinion, these performance results were produced in compliance with the SPC requirements for the benchmark. In particular, the following requirements were reviewed and found compliant with v1.7.0 of the SPC Benchmark 2™ specification:

- A Letter of Good Faith, signed by a senior executive.
- The following Data Repository items were verified by information supplied by NetApp, Inc.:
  - Physical Storage Capacity and associated requirements
  - Configured Storage Capacity and associated requirement
  - Addressable Storage Capacity and associated requirements
  - Capacity of each Logical Volume and associated requirements
  - Capacity of the Application Storage Unit (ASU) and associated requirements
- The total Application Storage Unit (ASU) Capacity was filled with random data, using an auditor-approved tool, prior to execution of the SPC-2 Tests.
- The accuracy of the Benchmark Configuration diagram

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- The tuning parameters used to configure the Benchmark Configuration
- SPC-2 Workload Generator commands and parameters used for the audited SPC-2 Test Runs.
- The following Host System requirements were verified by information supplied by NetApp, Inc.:
  - The type of Host Systems, including the number of processors and the amount of main memory
  - The presence and version number of the SPC-2 Workload Generator on each Host System.
  - The TSC boundary within each Host System.
- The execution of the following Tests, including all Test Phases and Test Runs, was found compliant with all applicable requirements and constraints.
  - Large Database Query Test
  - Large File Processing Test
  - Video on Demand Delivery Test
  - Data Persistence Test
- The submitted pricing information met all applicable requirements and constraints.

The Full Disclosure Report for this result was prepared in accordance with the disclosure requirements set forth in the specification for the benchmark. The report, prepared by InfoSizing and reviewed by NetApp, Inc., can be found at www.storageperformance.org under the Submission Identifier B12006}.

Additional Audit Notes:

> Test Run 15 of the Large Database Query Test (LDQ-TR15) showed an anomalous change in the measured data rate. Consequently, the Measurement Interval of LQD-TR15 was not in Steady State. This change in data rate has no impact on any of the overall reported metrics. It is my opinion that this minor deviation does not compromise the integrity of this submission (B12006).

Respectfully Yours,

Doug Johnson, Certified SPC Auditor

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LETTER OF GOOD FAITH

NetApp

www.netapp.com 316 636 8000 Tel 3718 North Rock Road
Wichita, KS 67226

July 21, 2020

Mr. Doug Johnson, Certified SPC Auditor
InfoSizing, Inc.
63 Lourdes Drive
Leominster, MA 01453-6709

Subject: SPC-2 Letter of Good Faith for the NetApp EF600 Storage System w/11.60.2

Dear Mr. Johnson,

NetApp Inc. is the SPC-2 test sponsor for the above listed product. To the best of our knowledge and belief, the required SPC-2 benchmark results and materials we have submitted for that product are complete, accurate, and in full compliance with version 1.7 of the SPC-2 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-2 benchmark specification.

Sincerely,

Robin Huber
Vice President & GM, E-Series

Legal Reference

EXECUTIVE SUMMARY

Test Sponsor and Contact Information

Test Sponsor and Contact Information	
Test Sponsor **Primary Contact**	NetApp, Inc. – www.netapp.com Mark Regester – mark.regester@netapp.com
Auditor	InfoSizing – http://www.sizing.com/ Doug Johnson – doug@sizing.com

Revision Information and Key Dates

Revision Information and Key Dates	
SPC-2 Specification revision number	v1.7.0
SPC-2 Workload Generator revision number	v1.4.0
Date Results were first used publicly	July 23, 2020
Date FDR was submitted to the SPC	July 24, 2020
Date the TSC will be available for shipment to customers	July 1, 2020
Date the TSC completed audit certification	July 23, 2020

Tested Storage Product Description

The NetApp EF600 is a 5th generation all-flash end to end NVMe array designed specifically for performance - intensive workloads supporting artificial intelligence, big data analytics, research, and high-performance computing. With extremely high throughput, and low latencies, the EF600 is designed to increase application responsiveness and accelerate modern enterprise applications. The system supports 367TB of raw flash capacity in a modular 2U building block.

The EF600 supports multiple high-speed host interfaces including NVMe/IB, NVMe/RoCE, NVMe/FC, 32Gb FC, 100Gb IB, and 200Gb IB. SANtricity System Manager gives customers the flexibility to manage their NetApp EF600 systems wherever they are through an easy-to-use, on-box, web-based interface. SANtricity Cloud Connector enables NetApp Data Fabric, or Hybrid Cloud capabilities, by providing cost-effective backup and recovery to the cloud.

NetApp E-Series arrays have a rich, 20+ year legacy of providing industry leading price/performance, value, and reliability with over 1 million systems installed.

SPC-2 Reported Data

SPC-2 Reported Data consists of three groups of information:

- The following SPC-2 Primary Metrics, which characterize the overall benchmark result:
  - SPC-2 MBPS™
  - SPC-2 Price Performance™
  - Application Storage Unit (ASU) Capacity
- Supplemental data to the SPC-2 Primary Metrics.
  - Total Price
  - Data Protection Level
  - Currency Used
  - Target Country
- Reported Data for each SPC Test: Large File Processing (LFP), Large Database Query (LDQ), and Video on Demand Delivery (VOD) Test.

SPC-2 MBPS™ represents the aggregate data rate, in megabytes per second, of all three SPC-2 workloads: Large File Processing (LFP), Large Database Query (LDQ), and Video on Demand (VOD).

SPC-2 Price-Performance™ is the ratio of **Total Price** to **SPC-2 MBPS™**.

ASU *(Application Storage Unit)* **Capacity** represents the total storage capacity available to be read and written in the course of executing the SPC-2 benchmark.

Total Price includes the cost of the Priced Storage Configuration plus three years of hardware maintenance and software support.

Data Protection Level of **Protected 2** using ***RAID-6***, which provides double parity RAID protection against data loss.

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

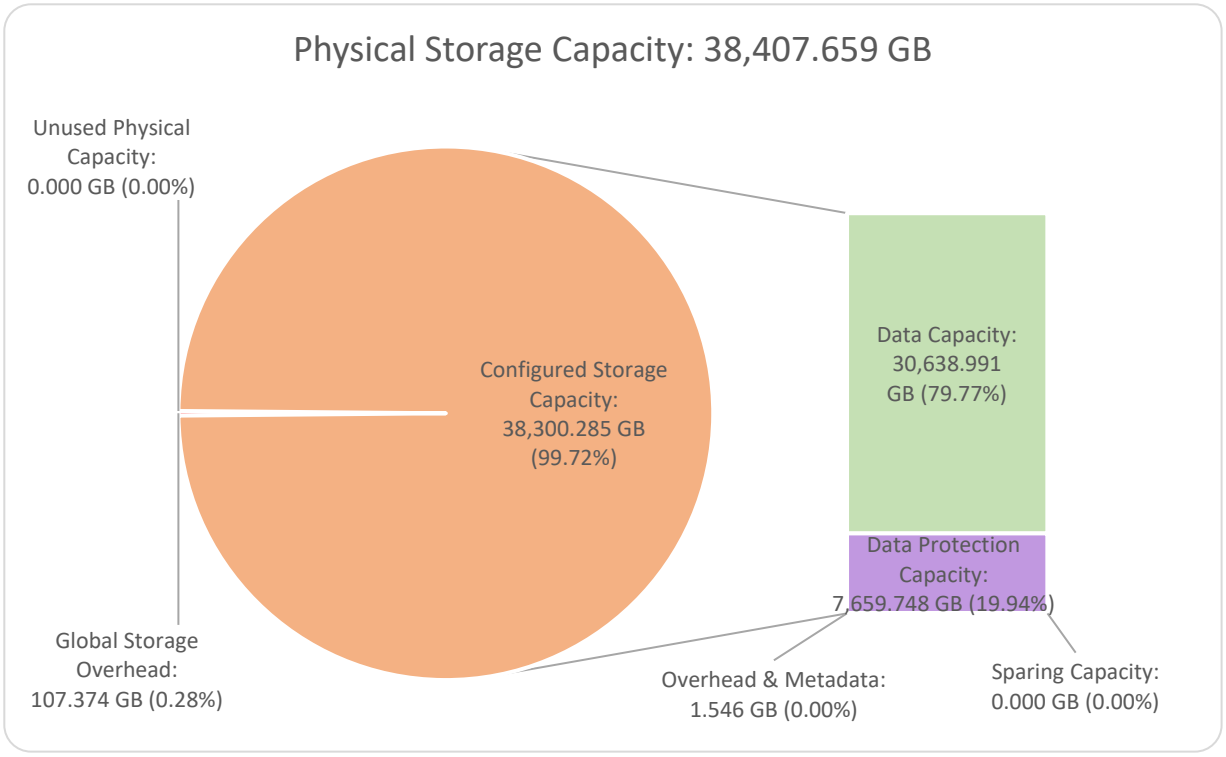
Currency Used is formal name for the currency used in calculating the **Total Price** and **SPC-2 Price-Performance™**. That currency may be the local currency of the **Target Country** or the currency of a difference country *(non-local currency)*.

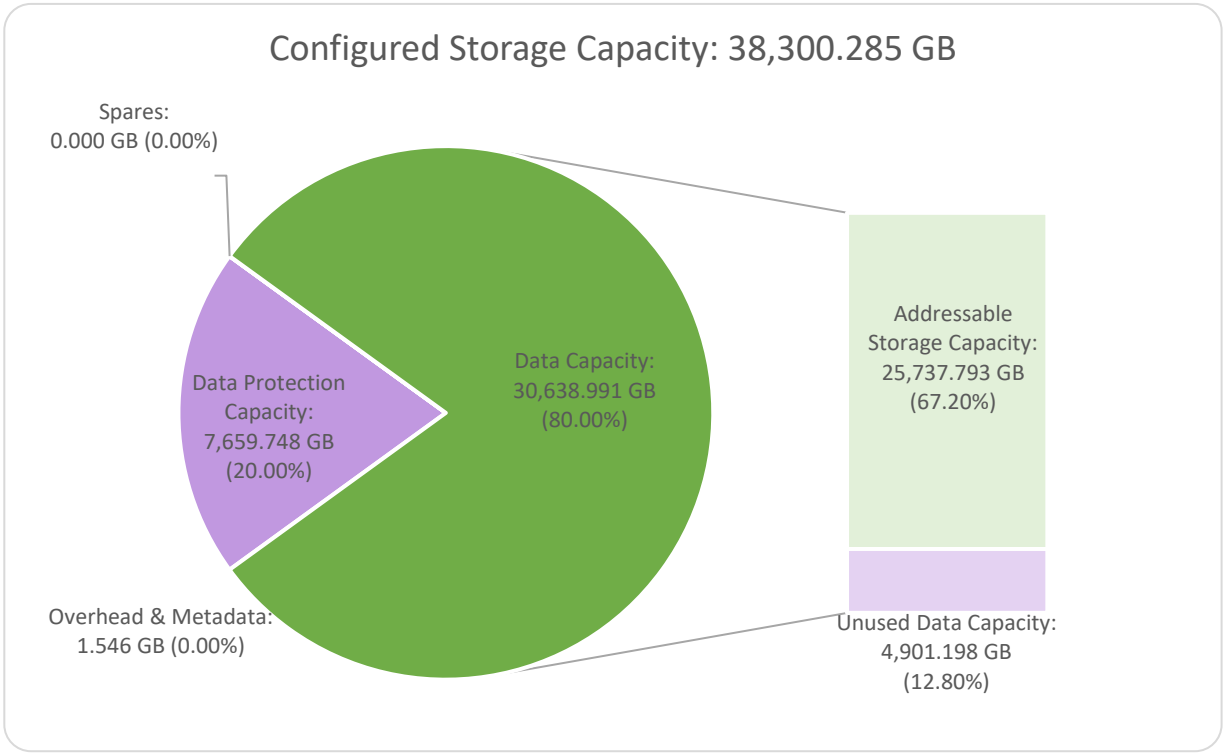
The **Target Country** is the country in which the Priced Storage Configuration is available for sale and in which the required hardware maintenance and software support is provided either directly from the Test Sponsor or indirectly via a third-party supplier.

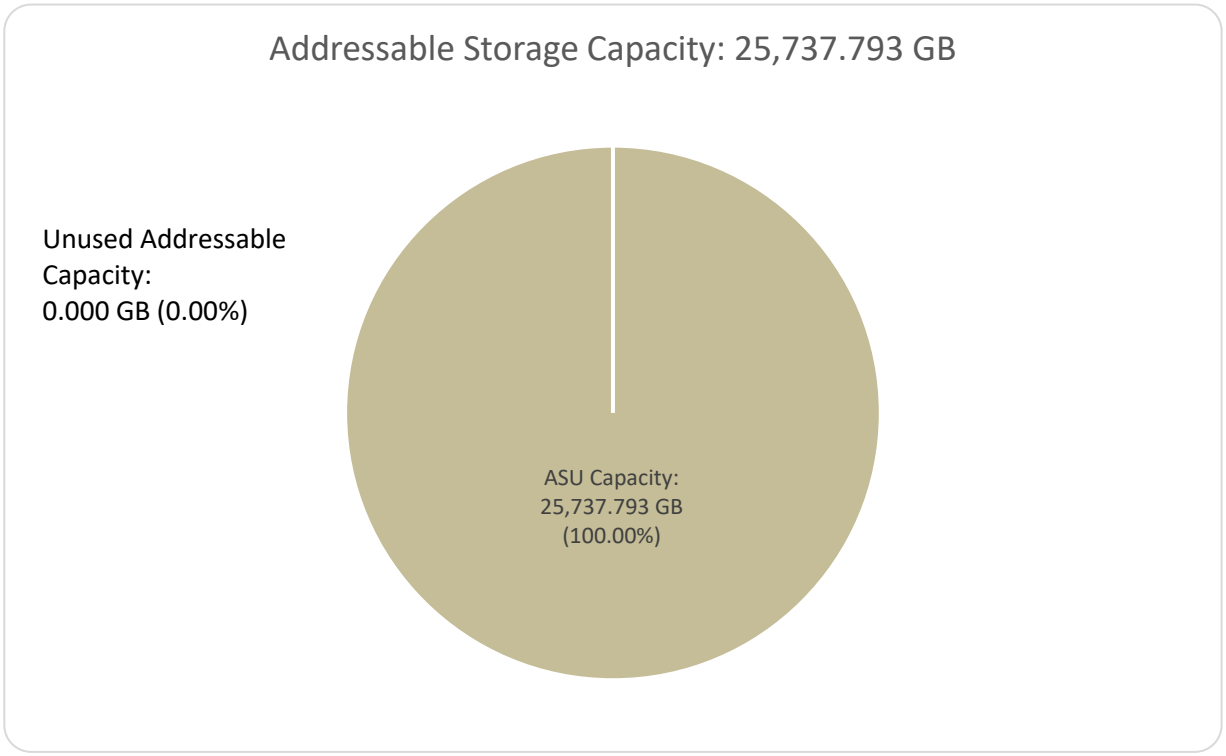
SPC-2 Reported Data				
NetApp EF600 All-Flash Array				
SPC-2 MBPS™	**SPC-2 Price-Performance**	**ASU Capacity (GB)**	**Total Price**	**Data Protection Level**
31,070.79	$3.53	25,737.793	$109,710.97	Protected 2 *(RAID-6)*
The above SPC-2 MBPS™ value represents the aggregate data rate of all three SPC-2 workloads: Large File Processing (LFP), Large Database Query (LDQ), and Video On Demand (VOD).				
Currency Used:		**"Target Country":**		
U.S. Dollars		USA		
SPC-2 Large File Processing (LFP) Reported Data				
	Data Rate (MB/second)	**Number of Streams**	**Data Rate per Stream**	**Price-Performance**
LFP Composite	23,277.19			$4.71
Write Only:				
1024 KiB Transfer	10,931.24	48	227.73	
256 KiB Transfer	10,862.34	48	226.30	
Read-Write:				
1024 KiB Transfer	18,942.97	48	394.65	
256 KiB Transfer	18,917.03	96	197.05	
Read Only:				
1024 KiB Transfer	40,184.85	96	418.59	
256 KiB Transfer	39,824.75	96	414.84	
The above SPC-2 Data Rate value for LFP Composite represents the aggregate performance of all three LFP Test Phases: (Write Only, Read-Write, and Read Only).				
SPC-2 Large Database Query (LDQ) Reported Data				
	Data Rate (MB/second)	**Number of Streams**	**Data Rate per Stream**	**Price-Performance**
LDQ Composite	39,264.31			$2.79
1024 KiB Transfer Size				
4 I/Os Outstanding	40,118.16	96	417.90	
1 I/O Outstanding	39,670.85	96	413.24	
64 KiB Transfer Size				
4 I/Os Outstanding	37,919.78	48	790.00	
1 I/O Outstanding	39,348.44	96	409.88	
The above SPC-2 Data Rate value for LDQ Composite represents the aggregate performance of the two LDQ Test Phases: (1024 KiB and 64 KiB Transfer Sizes).				
SPC-2 Video On Demand (VOD) Reported Data				
	Data Rate (MB/second)	**Number of Streams**	**Data Rate per Stream**	**Price-Performance**
	30,670.87	39,000	0.79	$3.58

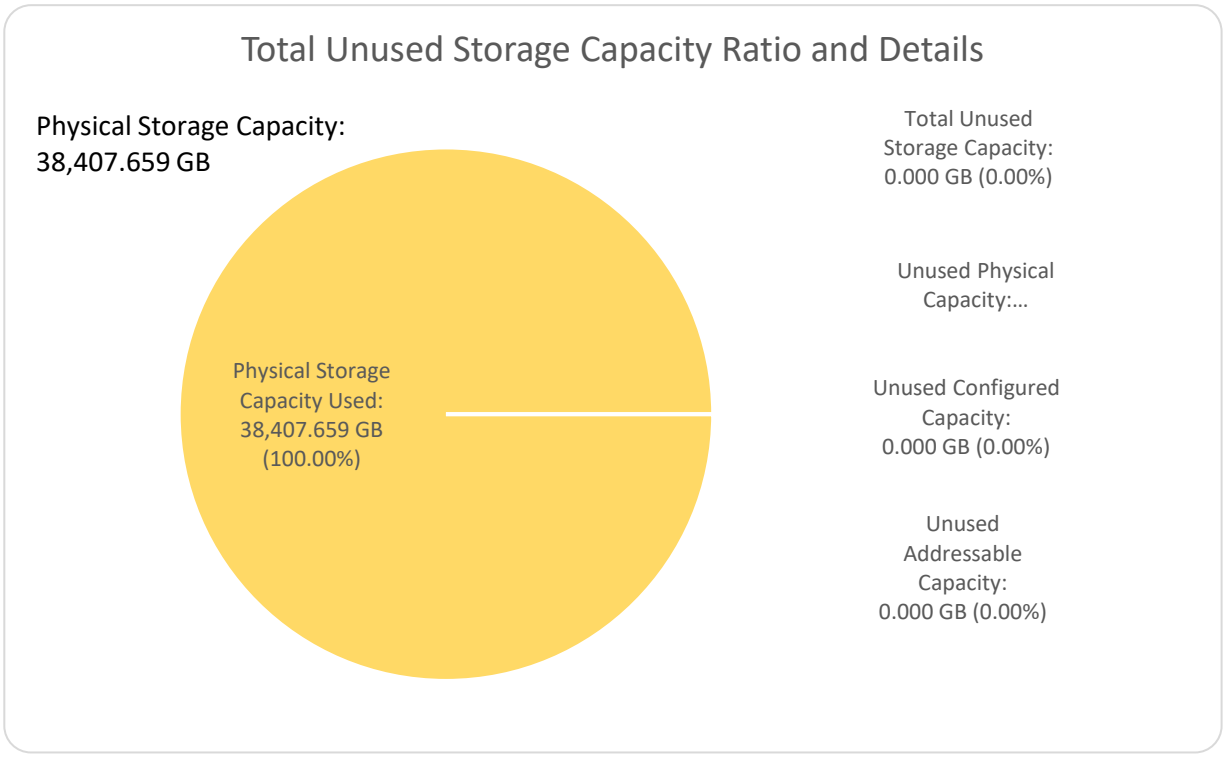
Storage Capacities, Relationships and Utilization

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






Addressable Storage Capacity: 25,737.793 GB
Unused Addressable Capacity:
0.000 GB (0.00%)
ASU Capacity:
25,737.793 GB
(100.00%)


Total Unused Storage Capacity Ratio and Details
Physical Storage Capacity:
38,407.659 GB
Physical Storage Capacity Used:
38,407.659 GB
(100.00%)
Total Unused Storage Capacity:
0.000 GB (0.00%)
Unused Physical Capacity:...
Unused Configured Capacity:
0.000 GB (0.00%)
Unused Addressable Capacity:
0.000 GB (0.00%)

SPC-2 Storage Capacity Utilization	
Application Utilization	67.01%
Protected Application Utilization	86.96%
Unused Storage Ratio	0.00%

Application Utilization: Total ASU Capacity *(25,737.793 GB)* divided by Physical Storage Capacity *(38,407.659 GB)*.

Protected Application Utilization: Total ASU Capacity *(25,737.793 GB)* plus total Data Protection Capacity *(7,659.748 GB)* minus unused Data Protection Capacity *(0.000 GB)* divided by Physical Storage Capacity *(38,407.659 GB)*.

Unused Storage Ratio: Total Unused Capacity *(0.000 GB)* divided by Physical Storage Capacity *(38,407.659 GB)* and may not exceed 45%.

Priced Storage Configuration Pricing

Part No.	Description	Source	Qty	Unit Price	Ext. Price	Disc.	Disc. Price
Hardware & Software							
E-X5725A-C	Enclosure,2U-24,NE224,Empty,-C, Rail Kit	1	1	2,400.00	2,400.00	55%	1,080.00
EF600A-32GB-C	EF600A, 32GB Ctlr,No HIC,-C	1	2	20,780.00	41,560.00	55%	18,702.00
X-56036-00-C	HIC, EF600, NVMe-FC,32Gb, 4-ports, -C	1	4	2,150.00	8,600.00	55%	3,870.00
X6603A-C	SFP+ Optical, 32Gb FC Shortwave, -C	1	16	1,250.00	20,000.00	55%	9,000.00
E-X4136B-C	SSD,1.9TB, NVMe, SED, NE224C,-C	1	20	3,690.00	73,800.00	55%	33,210.00
OS-SANTRICITY-NVME-01	OS Enable, Per-0.1TB, SANTRCTY, Low Latency, 01	1	380	99.00	37,620.00	55%	16,929.00
X-52197-00-0E-C	Power Cords, In-Cab, 2, C14-C13, E-Series,0E, -C	1	1	53.00	53.00	55%	23.85
X-50541-00-C	Blank, Drive Filler, NE224,-C	1	4	40.00	160.00	55%	72.00
DOC-NE224-SYS-C	Install Documents, System, NE224, -C	1	1	0.00	0.00	55%	0.00
AllHDD LPe32002	Broadcom/Emulex LPe32002 HBA, 32gb FC, 2-ports	2	8	1,740.00	13,920.00	0%	13,920.00
CDW PN 2445875	Tripp Lite, 2M, OM4, Fibre, Optical cable	3	16	26.80	428.80	0%	428.80
					Hardware & Software Subtotal		**97,235.65**
Support & Maintenance							
CS-BASE-SUPPORT	Base Software Support	1	1	5,643.05	5,643.05	55%	2,539.38
CS-02-NOINSTALL-4HR	SupportEdge Premium 4hr Onsite	1	1	22,079.86	22,079.86	55%	9,935.94
					Support & Maintenance Subtotal		**12,475.32**
					SPC-2 Total System Price		**109,710.97**

Prices used in SPC benchmarks reflect the actual prices a customer would pay for a one-time purchase of the stated components. Individually negotiated discounts are not permitted. Special prices based on assumptions about past or future purchases are not permitted. All discounts reflect standard pricing policies for the listed components. For complete details, see the pricing sections of the SPC benchmark specifications. If you find that the stated prices or maintenance levels are not available according to these terms, please inform the SPC at spcadmin@spcresults.org.

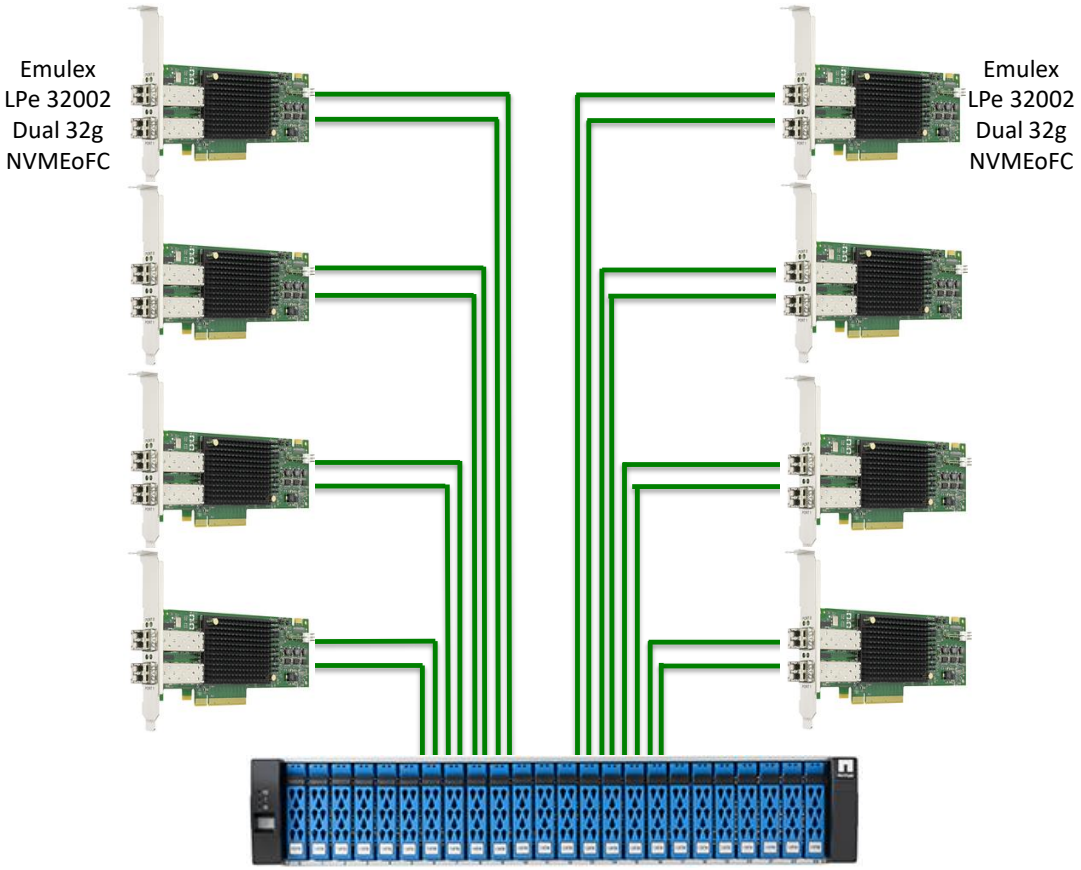
The above pricing includes the following:

- Acknowledgement of new and existing hardware and/or software problems within four hours.
- Onsite presence of a qualified maintenance engineer or provision of a customer replaceable part within four hours of the above acknowledgement for any hardware failure that results in an inoperative Priced Storage Configuration component.

Differences between Tested Storage Configuration 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
8x Emulex LPe32002 32Gb Dual Port FC HBAs
NetApp EF600 All-Flash Array 2x controllers, each with: 32 GB cache (64 GB total) 8x 32Gb FC connections (16 total) 20x 1.9 TB NVMe SSDs

CONFIGURATION INFORMATION

This portion of the Full Disclosure Report documents and illustrates the detailed information necessary to recreate the Benchmark Configuration (BC), including the Tested Storage Configuration (TSC), so that the SPC-2 benchmark result produced by the BC may be independently reproduced.

In each of the following sections of this document, the appropriate Full Disclosure Report requirement, from the SPC-2 benchmark specification, is stated in italics followed by the information to fulfill the stated requirement.

Benchmark Configuration/Tested Storage Configuration Diagram

Clause 10.6.6

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

Please see Benchmark Configuration / Tested Storage Configuration Diagram.

Storage Network Configuration

Clause 10.6.6.1

If a storage network was configured as a part of the Tested Storage Configuration and the Benchmark Configuration described in Clause 10.6.6 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 10.11.

The Tested Storage Configuration was configured with direct-attached storage.

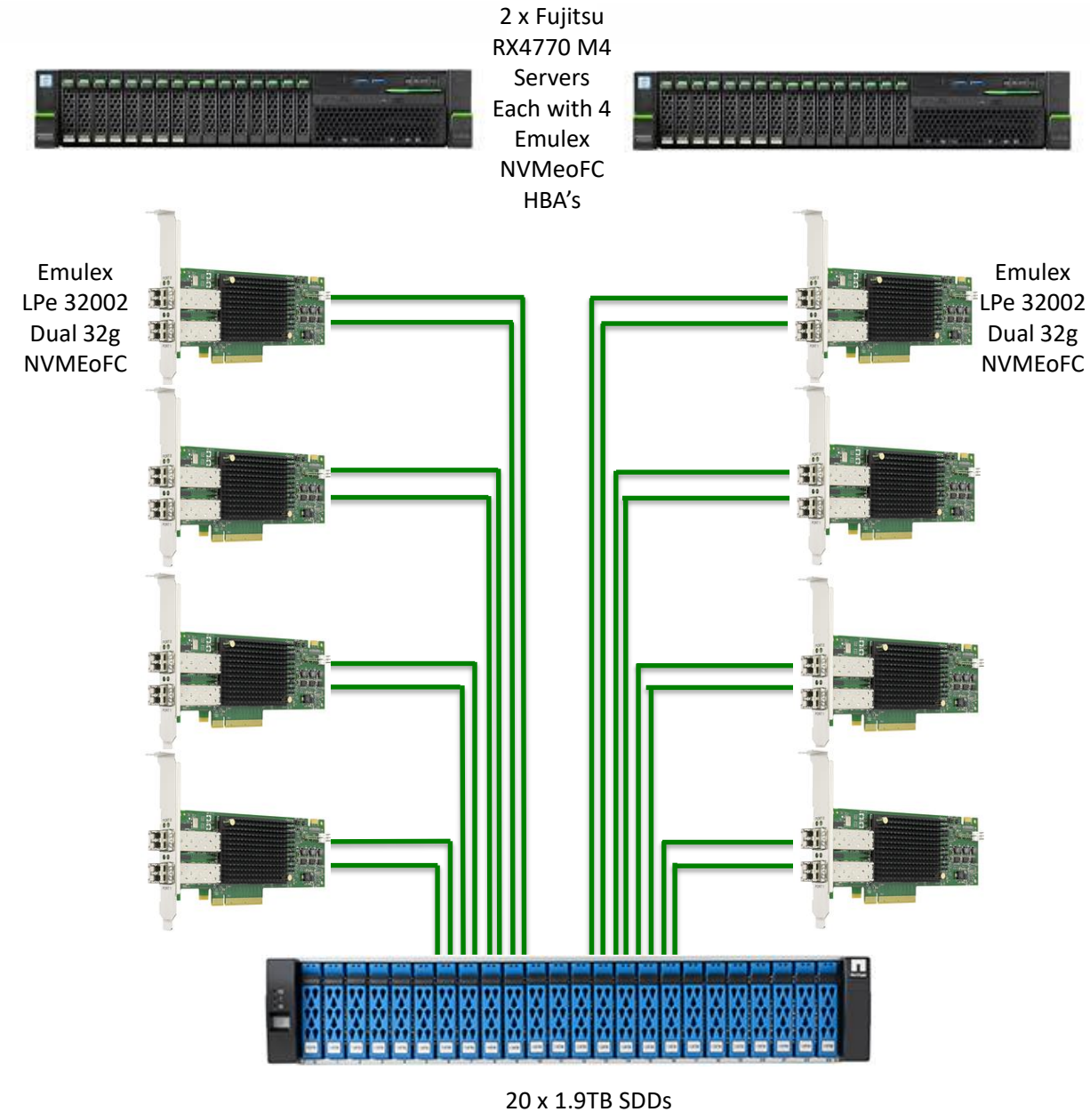
Host System and Tested Storage Configuration Table

Clause 10.6.6.2

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

Please see Host System and Tested Storage Configuration Components.

Benchmark Configuration/Tested Storage Configuration Diagram



Host System and Tested Storage Configuration Components

Host Systems
2x Fujitsu RX4770 M4, each with: 2x Intel® Xeon® Gold 6136 CPU (12-core, 24-thread, 3.0 GHz, 24.75 MB L3) 192 GB main memory SUSE Linux Enterprise Server 12 SP4
Tested Storage Configuration
8x Emulex LPe32002 32Gb Dual Port FC HBAs
NetApp EF600 All-Flash Array 2x controllers, each with: 32 GB cache (64 GB total) 8x 32Gb FC connections (16 total) 20x 1.9 TB NVMe SSDs

Customer Tunable Parameters and Options

Clause 10.6.7.1

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.

Please see Appendix B: Customer Tunable Parameters and Options.

Tested Storage Configuration Creation and Configuration

Clause 10.6.7.2

The Full Disclosure Report must include sufficient information to recreate the logical representation of the Tested Storage Configuration (TSC). In addition to customer tunable parameters and options (Clause10.6.6.1), that information must include, at a minimum:

- *A diagram and/or description of the following:*
  - *All physical components that comprise the TSC. Those components are also illustrated in the BC Configuration Diagram in Clause 10.6.5.7 and the Storage Network Configuration Diagram in Clause 10.6.5.8.*
  - *The logical representation of the TSC, configured from the above components that will be presented to the SPC-2 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.*

Please see Appendix C: Tested Storage Configuration Creation.

SPC-2 Workload Generator Storage Configuration

Clause 10.6.7.3

The Full Disclosure Report will include all SPC-2 Workload Generator storage configuration commands and parameters used in the SPC-2 benchmark measurement.

Please see Appendix D: SPC-2 Workload Generator Storage Commands and Parameter Files.

ASU Pre-Fill

Clause 6.3.3

The SPC-2 ASU is required to be completely filled with specified content prior to the execution of audited SPC-2 Tests. The content is required to consist of random data pattern such as that produced by an SPC recommended tool.

…

Clause 6.3.3.3

The required ASU pre-fill must be executed as the first step in the uninterrupted benchmark execution sequence described in Clause 6.4.2. That uninterrupted sequence will consist of: ASU Pre-Fill, Large File Processing, Large Database Query, Video on Demand Delivery and Persistence Test Run 1. The only exception to this requirement is described in Clause 6.3.3.4.

Clause 6.3.3.4

If approved by the Auditor, the Test Sponsor may complete the required ASU pre-fill prior to the execution of the audited SPC-2 Tests and not as part of the SPC-2 Test execution sequence.

The Auditor will verify the required random data pattern content in the ASU prior to the execution of the audited SPC-2 Tests. If that verification fails, the Test Sponsor is required to reload the specified content to the ASU.

Please see Appendix D: SPC-2 Workload Generator Storage Commands and Parameter Files.

SPC-2 DATA REPOSITORY

This portion of the Full Disclosure Report presents the detailed information that fully documents the various SPC-2 storage capacities and mappings used in the Tested Storage Configuration. SPC-2 Data Repository Definitions contains definitions of terms specific to the SPC-2 Data Repository.

In each of the following sections of this document, the appropriate Full Disclosure Report requirement, from the SPC-2 benchmark specification, is stated in italics followed by the information to fulfill the stated requirement.

Storage Capacities and Relationships

Clause 10.6.8.1

Two tables and four charts documenting the storage capacities and relationships of the SPC-2 Storage Hierarchy (Clause 2.1) shall be included in the FDR. … The capacity value in each chart may be listed as an integer value, for readability, rather than the decimal value listed in the table below.

Storage Capacities

The Physical Storage Capacity consisted of 38,407.659 GB distributed over 20 disk drives each with a formatted capacity of 1,920 GB. There was 0.000 GB (0.00%) of Unused Storage within the Physical Storage Capacity. Global Storage Overhead consisted of 107.374 GB (0.28%) of the Physical Storage Capacity. There was 0.000 GB (0.00%) 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 *(RAID-6)* capacity was 7,659.748 GB of which 7,659.748 GB was utilized. The total Unused Storage was 0.000 GB.

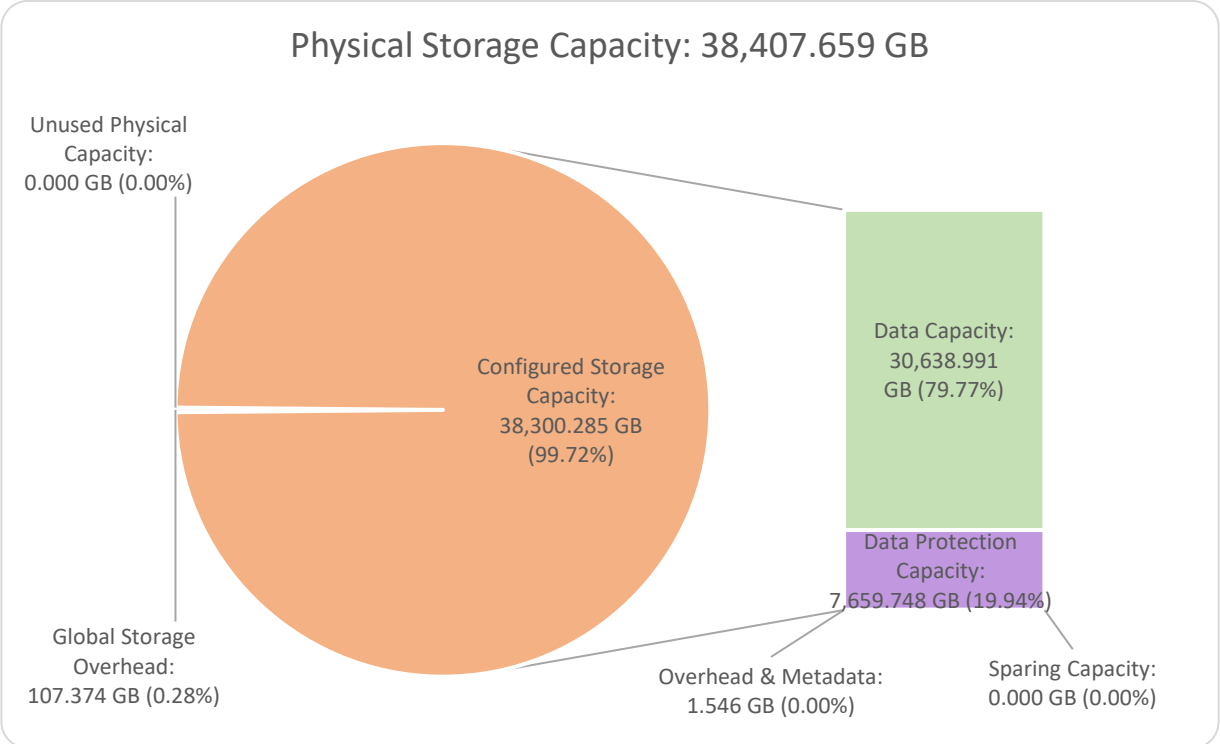
Note: The configured Storage Devices may include additional storage capacity reserved for system overhead, which is not accessible for application use. That storage capacity may not be included in the value presented for Physical Storage Capacity.

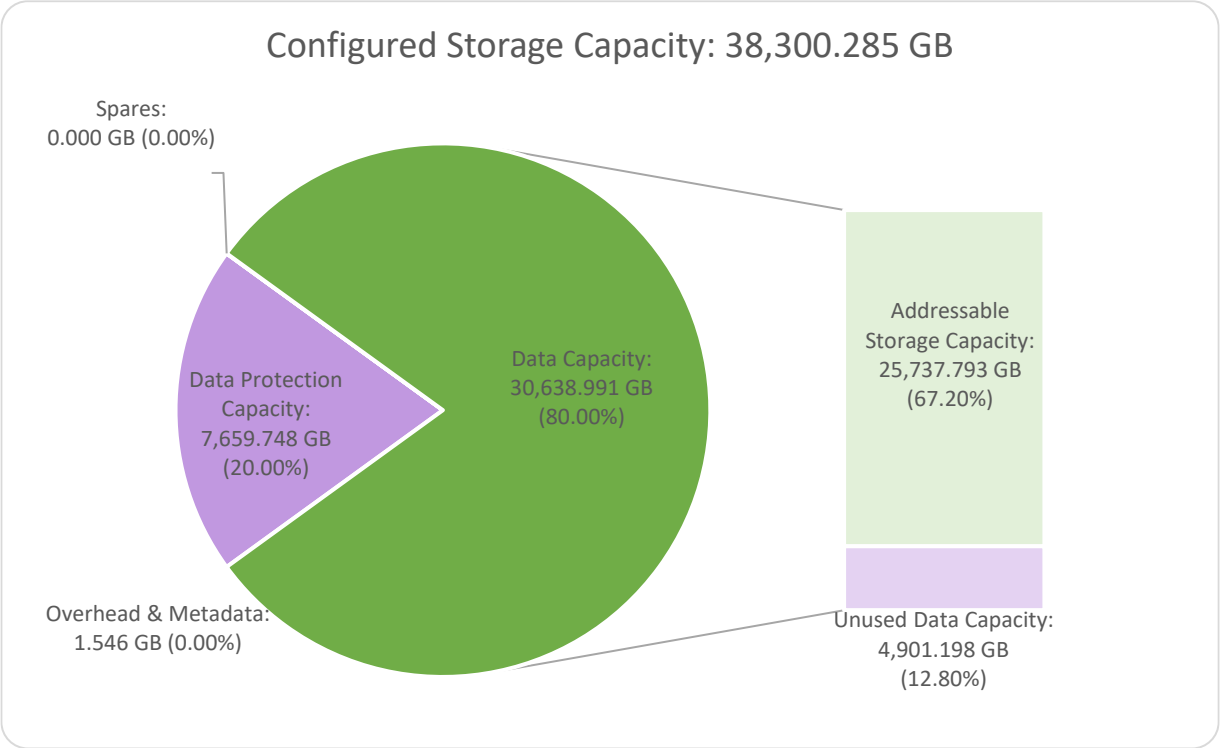
SPC-2 Storage Capacities		
Storage Hierarchy Component	**Units**	**Capacity**
Total ASU Capacity	Gigabytes (GB)	25,737.793
Addressable Storage Capacity	Gigabytes (GB)	25,737.793
Configured Storage Capacity	Gigabytes (GB)	38,300.285
Physical Storage Capacity	Gigabytes (GB)	38,407.659
Data Protection *(RAID-6)*	Gigabytes (GB)	7,659.748
Required Storage *(overhead/sparing)*	Gigabytes (GB)	1.546
Global Storage Overhead	Gigabytes (GB)	107.374
Total Unused Storage	Gigabytes (GB)	0.000

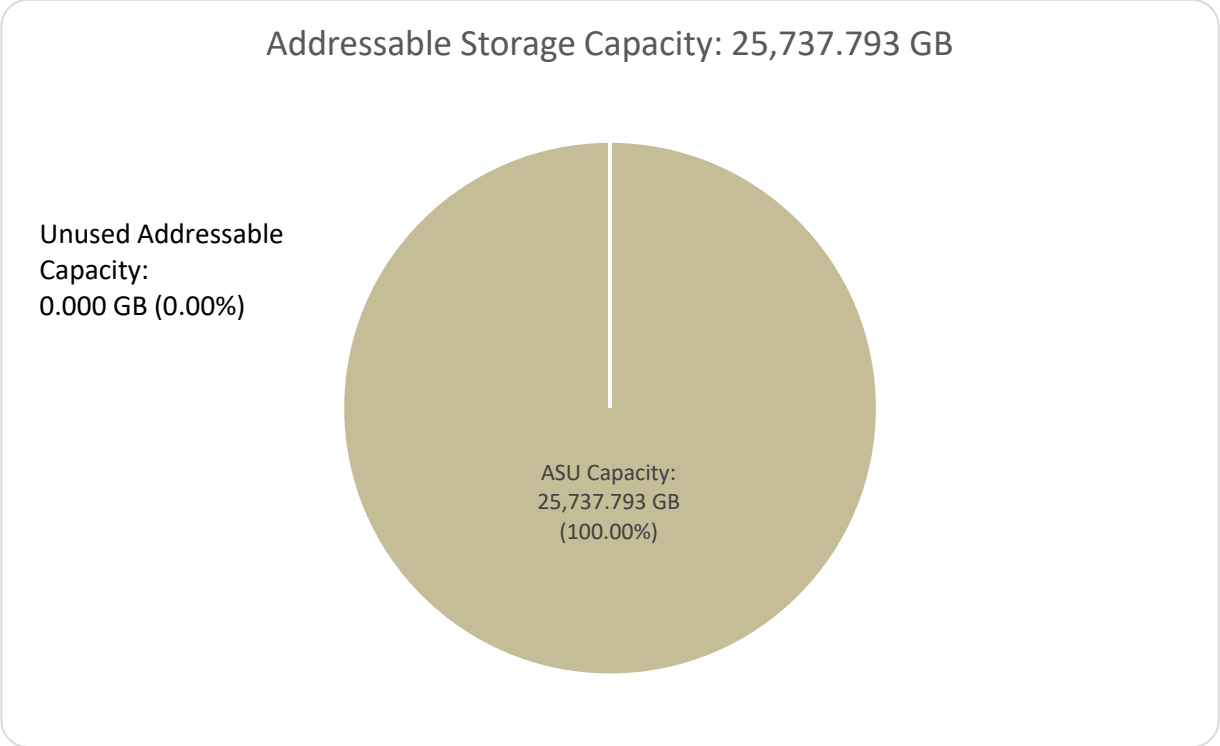
Storage Hierarchy Ratios

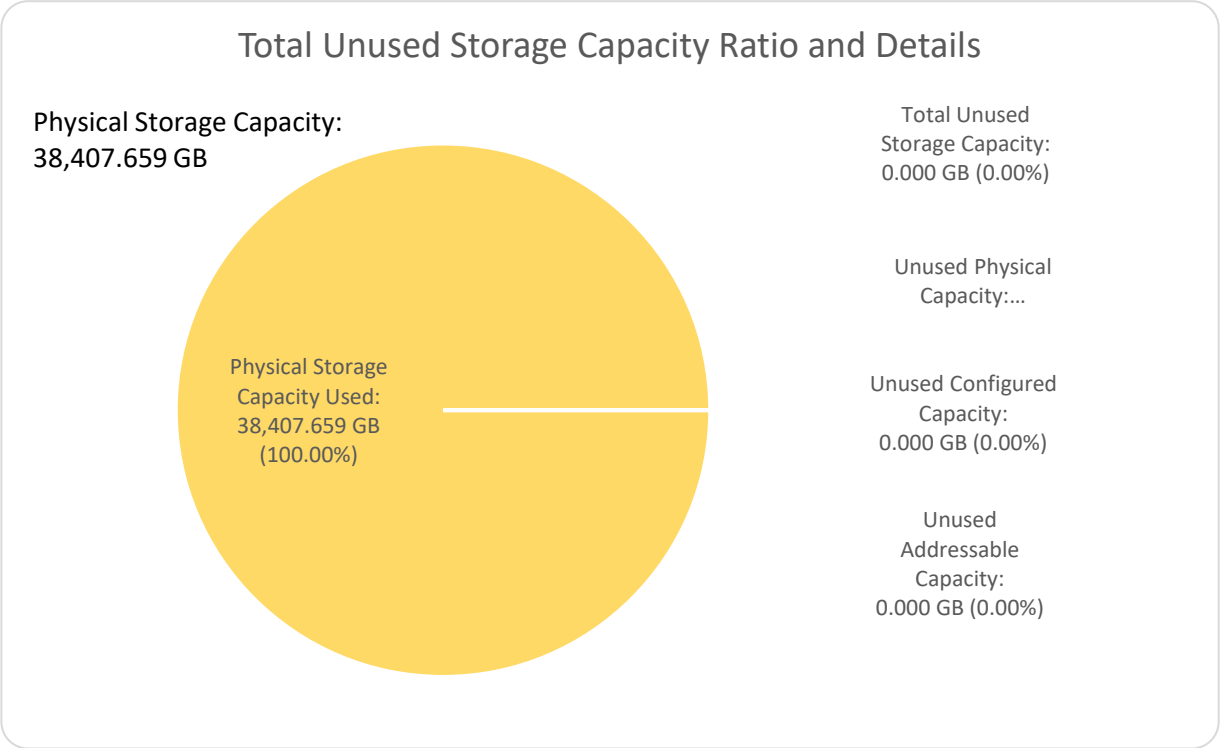
	Addressable Storage Capacity	Configured Storage Capacity	Physical Storage Capacity
Total ASU Capacity	100.00%	67.20%	67.01%
Data Protection *(RAID-6)*		20.00%	19.94%
Addressable Storage Capacity		67.20%	67.01%
Required Storage		0.00%	0.00%
Configured Storage Capacity			99.72%
Global Storage Overhead			0.28%
Unused Storage:			
Addressable	0.00%		
Configured		0.00%	
Physical			0.00%

Storage Capacity Charts




Configured Storage Capacity: 38,300.285 GB
Spares:
0.000 GB (0.00%)
Data Protection Capacity:
7,659.748 GB
(20.00%)
Data Capacity:
30,638.991 GB
(80.00%)
Overhead & Metadata:
1.546 GB (0.00%)
Addressable Storage Capacity:
25,737.793 GB
(67.20%)
Unused Data Capacity:
4,901.198 GB
(12.80%)


Addressable Storage Capacity: 25,737.793 GB
Unused Addressable Capacity:
0.000 GB (0.00%)
ASU Capacity:
25,737.793 GB
(100.00%)



Storage Capacity Utilization

Clause 10.6.8.2

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-2 Storage Capacity Utilization	
Application Utilization	67.01%
Protected Application Utilization	86.96%
Unused Storage Ratio	0.00%

Logical Volume Capacity and ASU Mapping

Clause 10.6.8.3

A table illustrating the capacity of the Application Storage Unit (ASU) and the mapping of Logical Volumes to ASU will be provided in the FDR. Capacity must be stated in gigabytes (GB) as a value with a minimum of two digits to the right of the decimal point. Each Logical Volume will be sequenced in the table from top to bottom per its position in the contiguous address space of the ASU. Each Logical Volume entry will list its total capacity, the portion of that capacity used for the ASU, and any unused capacity.

Logical Volume (LV) Capacity and Mapping			
ASU (25,737.793 GB)			
	Total Capacity *(GB)*	Capacity Used *(GB)*	Capacity Unused *(GB)*
4 Logical Volumes	6,434.448 per LV	6,434.448 per LV	0.000 per LV

Please see the Storage Definition (sd) entries in Appendix D: SPC-2 Workload Generator Storage Commands and Parameter Files for more detailed configuration information.

SPC-2 BENCHMARK EXECUTION RESULTS

This portion of the Full Disclosure Report documents the results of the various SPC-2 Tests, Test Phases, Test Run Sequences, and Test Runs. An SPC-2 glossary contains definitions of terms specific to the SPC-2 Data Repository.

In each of the following sections of this document, the appropriate Full Disclosure Report requirement, from the SPC-2 benchmark specification, is stated in italics followed by the information to fulfill the stated requirement.

SPC-2 Tests, Test Phases, Test Run Sequences, and Test Runs

The SPC-2 benchmark consists of the following Tests, Test Phases, Test Run Sequences, and Test Runs:

- Large File Processing Test
  - WRITE ONLY Test Phase
    - Test Run Sequence 1
      - Test Run 1 – 1024 KiB Transfer – maximum number of Streams
      - Test Run 2 – 1024 KiB Transfer – 50% of Test Run 1's Streams value
      - Test Run 3 – 1024 KiB Transfer – 25% of Test Run 1's Streams value
      - Test Run 4 – 1024 KiB Transfer – 12.5% of Test Run 1's Streams value
      - Test Run 5 – 1024 KiB Transfer – single (1) Stream
    - Test Run Sequence 2
      - Test Run 6 – 256 KiB Transfer – maximum number of Streams
      - Test Run 7 – 256 KiB Transfer – 50% of Test Run 6's Streams value
      - Test Run 8 – 256 KiB Transfer – 25% of Test Run 6's Streams value
      - Test Run 9 – 256 KiB Transfer – 12.5% of Test Run 6's Streams value
      - Test Run 10 – 256 KiB Transfer – single (1) Stream
  - READ-WRITE Test Phase
    - Test Run Sequence 3
      - Test Run 11 – 1024 KiB Transfer – maximum number of Streams
      - Test Run 12 – 1024 KiB Transfer – 50% of Test Run 11's Streams value
      - Test Run 13 – 1024 KiB Transfer – 25% of Test Run 11's Streams value
      - Test Run 14 – 1024 KiB Transfer – 12.5% of Test Run 11's Streams value
      - Test Run 15 – 1024 KiB Transfer – single (1) Stream
    - Test Run Sequence 4
      - Test Run 16 – 256 KiB Transfer – maximum number of Streams
      - Test Run 17 – 256 KiB Transfer – 50% of Test Run 16's Streams value
      - Test Run 18 – 256 KiB Transfer – 25% of Test Run 16's Streams value
      - Test Run 19 – 256 KiB Transfer – 12.5% of Test Run 16's Streams value
      - Test Run 20 – 256 KiB Transfer – single (1) Stream
  - READ ONLY Test Phase
    - Test Run Sequence 5
      - Test Run 21 – 1024 KiB Transfer – maximum number of Streams
      - Test Run 22 – 1024 KiB Transfer – 50% of Test Run 21's Streams value
      - Test Run 23 – 1024 KiB Transfer – 25% of Test Run 21's Streams value
      - Test Run 24 – 1024 KiB Transfer – 12.5% of Test Run 21's Streams value
      - Test Run 25 – 1024 KiB Transfer – single (1) Stream
    - Test Run Sequence 6
      - Test Run 26 – 256 KiB Transfer – maximum number of Streams
      - Test Run 27 – 256 KiB Transfer – 50% of Test Run 26's Streams value
      - Test Run 28 – 256 KiB Transfer – 25% of Test Run 26's Streams value
      - Test Run 29 – 256 KiB Transfer – 12.5% of Test Run 26's Streams value
      - Test Run 30 – 256 KiB Transfer – single (1) Stream
- Large Database Query Test
  - 1024 KIB TRANSFER SIZE Test Phase
    - Test Run Sequence 1
      - Test Run 1 – 4 I/O Requests Outstanding – maximum number of Streams
      - Test Run 2 – 4 I/O Requests Outstanding – 50% of Test Run 1's Streams value
      - Test Run 3 – 4 I/O Requests Outstanding – 25% of Test Run 1's Streams value

- Test Run 4 – 4 I/O Requests Outstanding – 12.5% of Test Run 1's Streams value
- Test Run 5 – 4 I/O Requests Outstanding – single (1) Stream

▪ Test Run Sequence 2

- Test Run 6 – 1 I/O Request Outstanding – maximum number of Streams
- Test Run 7 – 1 I/O Request Outstanding – 50% of Test Run 6's Streams value
- Test Run 8 – 1 I/O Request Outstanding – 25% of Test Run 6's Streams value
- Test Run 9 – 1 I/O Request Outstanding – 12.5% of Test Run 6's Streams value
- Test Run 10 – 1 I/O Request Outstanding – single (1) Stream

o 64 KIB TRANSFER SIZE Test Phase

▪ Test Run Sequence 3

- Test Run 11 – 4 I/O Requests Outstanding – maximum number of Streams
- Test Run 12 – 4 I/O Requests Outstanding – 50% of Test Run 11's Streams value
- Test Run 13 – 4 I/O Requests Outstanding – 25% of Test Run 11's Streams value
- Test Run 14 – 4 I/O Requests Outstanding – 12.5% of Test Run 11's Streams value
- Test Run 15 – 4 I/O Requests Outstanding – single (1) Stream

▪ Test Run Sequence 4

- Test Run 16 – 1 I/O Request Outstanding – maximum number of Streams
- Test Run 17 – 1 I/O Request Outstanding – 50% of Test Run 16's Streams value
- Test Run 18 – 1 I/O Request Outstanding – 25% of Test Run 16's Streams value
- Test Run 19 – 1 I/O Request Outstanding – 12.5% of Test Run 16's Streams value
- Test Run 20 – 1 I/O Request Outstanding – single (1) Stream

- Video on Demand Delivery Test
  - Video on Demand Delivery 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 Large File Processing, Large Database Query, and Video On Demand Delivery Tests may be executed in any sequence. The Data Persistence Test must follow the last Test Run of the selected sequence.

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

Large File Processing Test - Overview

Clause 6.4.3.1

The Large File Processing Test consists of the I/O operations associated with the type of applications, in a wide range of fields, which require simple sequential processing of one or more large files. Specific examples of those types of applications include scientific computing and large-scale financial processing

Clause 6.4.3.2

The Large File Processing Test has three Test Phases, which shall be executed in the following uninterrupted sequence:

1. *WRITE ONLY*
2. *READ-WRITE*
3. *READ ONLY*

The BC shall not be restarted or manually disturbed, altered, or adjusted during the execution of the Large File Processing Test. If power is lost to the BC during this Test all results shall be rendered invalid and the Test re-run in its entirety.

Clause 10.6.9.1

The Full Disclosure Report will contain the following content for the Large File Processing Test:

1. *A listing of the SPC-2 Workload Generator commands and parameters used to execute each of the Test Runs in the Large File Processing Test.*
2. *The human readable SPC-2 Test Results File for each of the Test Runs in the Large File Processing Test.*
3. *The following three tables:*
   - *Average Data Rate: The average Data Rate, in MB per second for the Measurement Interval of each Test Run in the Large File Processing Test.*
   - *Average Data Rate per Stream: The average Data Rate per Stream, in MB per second, for the Measurement Interval of each Test Run in the Large File Processing Test.*
   - *Average Response Time: The average response time, in milliseconds (ms), for the Measurement Interval of each Test Run in the Large File Processing Test.*
4. *Average Data Rate, Average Data Rate per Stream and Average Response Time graphs as defined in Clauses 10.1.1, 10.1.2 and 10.1.3.*

Workload Generator Commands and Parameters

The SPC-2 Workload Generator commands and parameters for the Large File Processing Test Runs are documented in Appendix E: SPC-2 Workload Generator Execution Commands and Parameters.

Test Results File

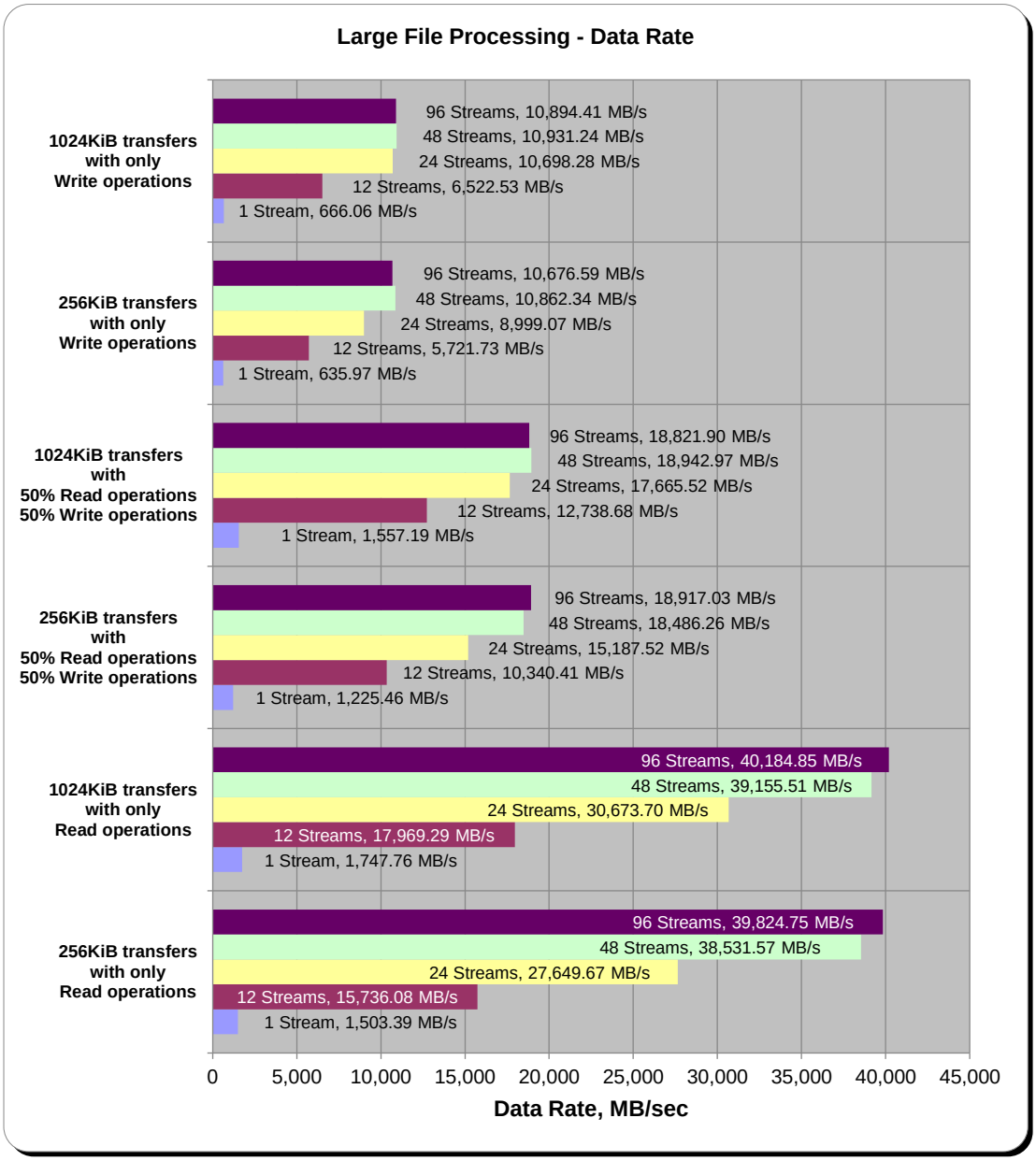
A link to the SPC-2 Test Results file generated from the Large File Processing Test Runs is listed below.

SPC-2 Large File Processing Test Results File

Average Data Rates (MB/s)

The average Data Rate (MB/s) for each Test Run in the three Test Phases of the SPC-2 Large File Processing Test is listed in the table below as well as illustrated in the following graph.

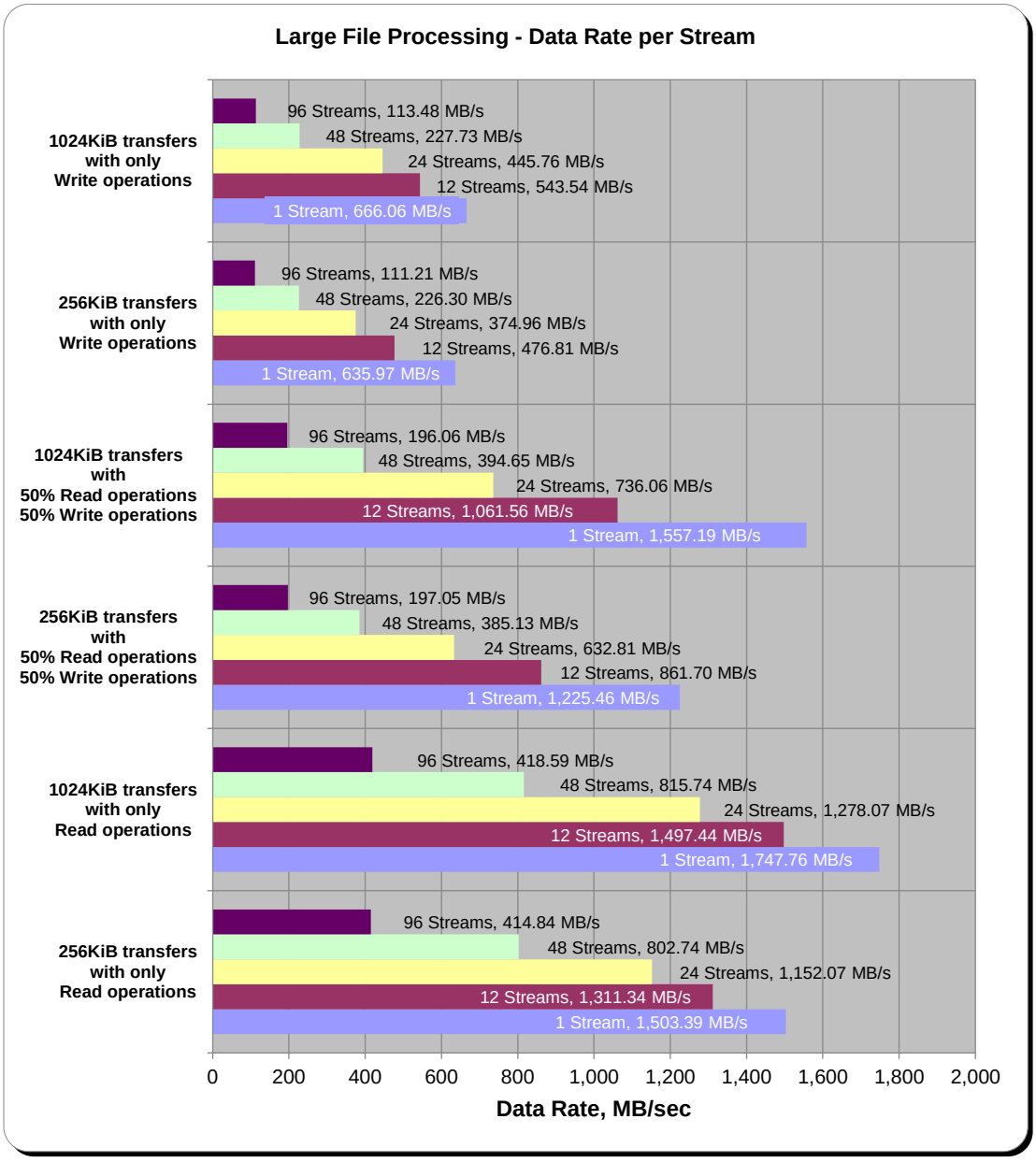
Test Run Sequence	1 Stream	12 Streams	24 Streams	48 Streams	96 Streams
Write 1024KiB	666.06	6,522.53	10,698.28	10,931.24	10,894.41
Write 256KiB	635.97	5,721.73	8,999.07	10,862.34	10,676.59
Read/Write 1024KiB	1,557.19	12,738.68	17,665.52	18,942.97	18,821.90
Read/Write 256KiB	1,225.46	10,340.41	15,187.52	18,486.26	18,917.03
Read 1024KiB	1,747.76	17,969.29	30,673.70	39,155.51	40,184.85
Read 256KiB	1,503.39	15,736.08	27,649.67	38,531.57	39,824.75



Average Data Rate per Stream

The average Data Rate per Stream for each Test Run in the three Test Phases of the SPC-2 Large File Processing Test is listed in the table below as well as illustrated in the following graph.

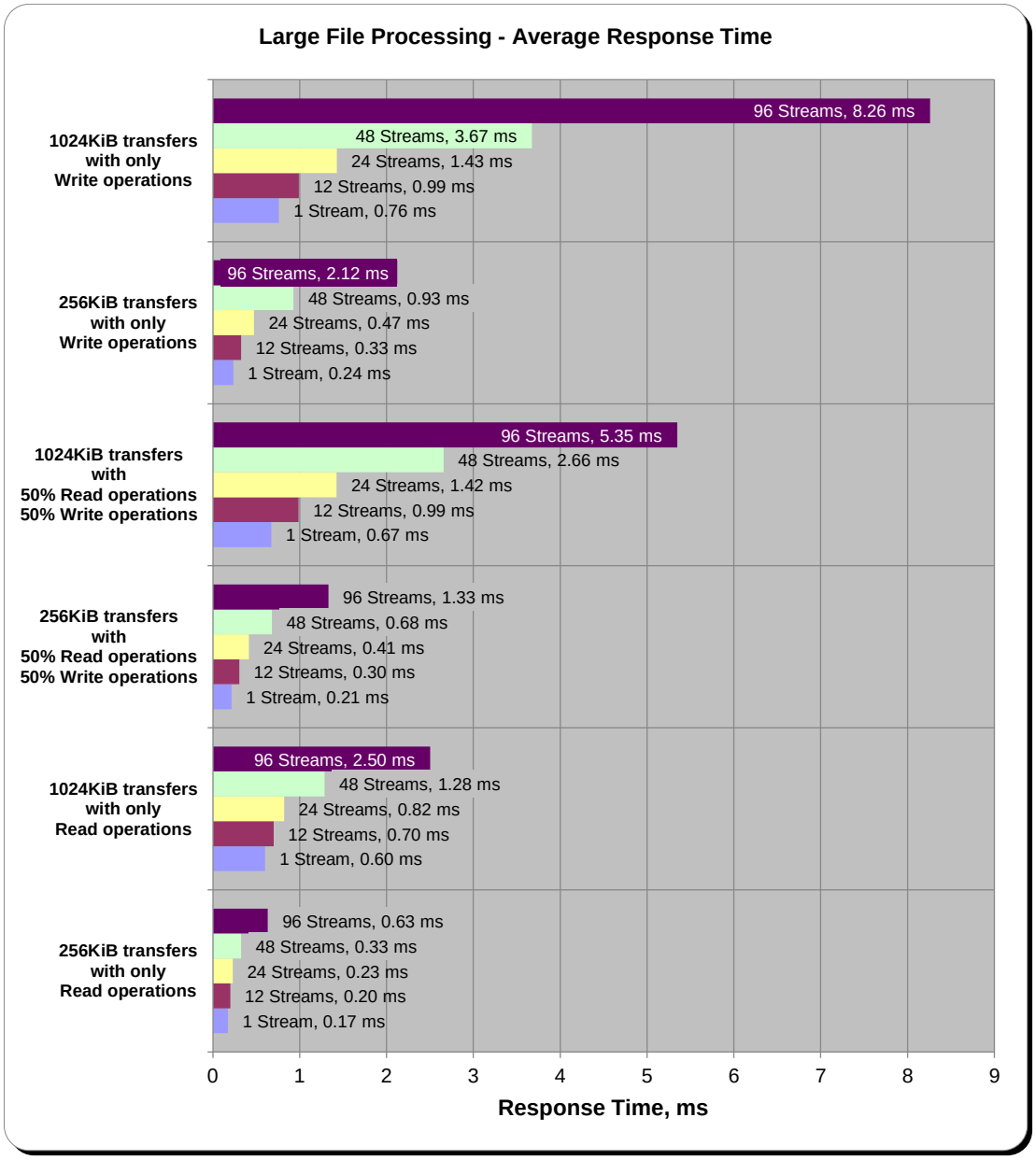
Test Run Sequence	1 Stream	12 Streams	24 Streams	48 Streams	96 Streams
Write 1024KiB	666.06	543.54	445.76	227.73	113.48
Write 256KiB	635.97	476.81	374.96	226.30	111.21
Read/Write 1024KiB	1,557.19	1,061.56	736.06	394.65	196.06
Read/Write 256KiB	1,225.46	861.70	632.81	385.13	197.05
Read 1024KiB	1,747.76	1,497.44	1,278.07	815.74	418.59
Read 256KiB	1,503.39	1,311.34	1,152.07	802.74	414.84



Average Response Time

The average Response Time, milliseconds (ms), for each Test Run in the three Test Phases of the SPC-2 Large File Processing Test is listed in the table below as well as illustrated in the following graph.

Test Run Sequence	1 Stream	12 Streams	24 Streams	48 Streams	96 Streams
Write 1024KiB	0.76	0.99	1.43	3.67	8.26
Write 256KiB	0.24	0.33	0.47	0.93	2.12
Read/Write 1024KiB	0.67	0.99	1.42	2.66	5.35
Read/Write 256KiB	0.21	0.30	0.41	0.68	1.33
Read 1024KiB	0.60	0.70	0.82	1.28	2.50
Read 256KiB	0.17	0.20	0.23	0.33	0.63



Large File Processing Test – WRITE ONLY Test Phase

Clause 10.6.9.1.1

1. *A table that will contain the following information for each "WRITE ONLY, 1024 KiB Transfer Size" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
2. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "WRITE ONLY, 1024 KiB Transfer Size" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*
3. *A table that will contain the following information for each "WRITE ONLY, 256 KiB Transfer Size" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
4. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "WRITE ONLY, 256 KiB Transfer Size" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*

A hyperlink for each of the above tables and graphs may appear in the FDR to provide access to the table or graph.

A hyperlink to a table with the SPC-2 "Large File Processing/WRITE ONLY/1024 KiB Transfer Size" Test Run data appears on the next page. That entry is followed by hyperlinks to graphs illustrating the average Data Rate, average Data Rate per Stream, and average Response Time produced by the same Test Runs. The table and graphs present the data at five-second intervals.

Immediately following the above SPC-2 "Large File Processing/WRITE ONLY/1024 KiB Transfer Size" entries will be hyperlinks for SPC-2 "Large File Processing/WRITE ONLY/256 KiB Transfer Size" table and graphs. The table contains the Test Run data and the graphs illustrate the average Data Rate, average Data Rate per Stream, and average Response Time produced by the Test Runs.

1,024 KiB Transfer Size Test Run

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval
- Run Out / Ramp-Down

1,024 KiB Transfer Size Test Run Data

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

1,024 KiB Transfer Size Test Run Graphs

256 KiB Transfer Size Test Run

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval

- Run Out / Ramp-Down

256 KiB Transfer Size Test Run Data

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

256 KiB Transfer Size Test Run Graphs

Large File Processing Test – READ-WRITE Test Phase

Clause 10.6.9.1.2

1. *A table that will contain the following information for each "READ-WRITE, 1024 KiB Transfer Size" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
2. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "READ-WRITE, 1024 KiB Transfer Size" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*
3. *A table that will contain the following information for each " READ-WRITE, 256 KiB Transfer Size" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
4. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "READ-WRITE, 256 KiB Transfer Size" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*

A hyperlink for each of the above tables and graphs may appear in the FDR to provide access to the table or graph.

A hyperlink to a table with the SPC-2 "Large File Processing/READ-WRITE/1024 KiB Transfer Size" Test Run data appears on the next page. That entry is followed by hyperlinks to graphs illustrating the average Data Rate, average Data Rate per Stream, and average Response Time produced by the same Test Runs. The table and graphs present the data at five-second intervals.

Immediately following the above SPC-2 "Large File Processing/READ-WRITE/1024 KiB Transfer Size" entries will be hyperlinks for SPC-2 "Large File Processing/READ-WRITE/256 KiB Transfer Size" table and graphs. The table contains the Test Run data and the graphs illustrate the average Data Rate, average Data Rate per Stream, and average Response Time produced by the Test Runs.

1,024 KiB Transfer Size Test Run

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval
- Run Out / Ramp-Down

1,024 KiB Transfer Size Test Run Data

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only

- Average Data Rate per Stream
- Average Response Time

1,024 KiB Transfer Size Test Run Graphs

256 KiB Transfer Size Test Run

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval
- Run Out / Ramp-Down

256 KiB Transfer Size Test Run Data

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

256 KiB Transfer Size Test Run Graphs

Large File Processing Test – READ ONLY Test Phase

Clause 10.6.9.1.3

1. *A table that will contain the following information for each "READ ONLY, 1024 KiB Transfer Size" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
2. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "READ ONLY, 1024 KiB Transfer Size" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*
3. *A table that will contain the following information for each "READ ONLY, 256 KiB Transfer Size" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
4. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "READ ONLY, 256 KiB Transfer Size" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*

A hyperlink for each of the above tables and graphs may appear in the FDR to provide access to the table or graph.

A hyperlink to a table with the SPC-2 "Large File Processing/READ ONLY/1024 KiB Transfer Size" Test Run data appears on the next page. That entry is followed by hyperlinks to graphs illustrating the average Data Rate, average Data Rate per Stream, and average Response Time produced by the same Test Runs. The table and graphs present the data at five-second intervals.

Immediately following the above SPC-2 "Large File Processing/READ ONLY/1024 KiB Transfer Size" entries will be hyperlinks for SPC-2 "Large File Processing/READ ONLY/256 KiB Transfer Size" table and graphs. The table contains the Test Run data and the graphs illustrate the average Data Rate, average Data Rate per Stream, and average Response Time produced by the Test Runs.

1,024 KiB Transfer Size Test Run

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval
- Run Out / Ramp-Down

1,024 KiB Transfer Size Test Run Data

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

1,024 KiB Transfer Size Test Run Graphs

256 KiB Transfer Size Test Run

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval
- Run Out / Ramp-Down

256 KiB Transfer Size Test Run Data

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

256 KiB Transfer Size Test Run Graphs

Large Database Query Test - Overview

Clause 6.4.4.1

The Large Database Query Test is comprised of a set of I/O operations representative of scans or joins of large relational tables such as those performed for data mining or business intelligence.

Clause 6.4.4.2

The Large Database Query Test has two Test Phases, which shall be executed in the following uninterrupted sequence:

1. *1024 KiB Transfer Size*

2. *64 KiB Transfer Size*

The BC shall not be restarted or manually disturbed, altered, or adjusted during the execution of the Large File Processing Test. If power is lost to the BC during this Test all results shall be rendered invalid and the Test re-run in its entirety.

Clause 10.6.9.2

The Full Disclosure Report will contain the following content for the Large Database Query Test:

1. *A listing of the SPC-2 Workload Generator commands and parameters used to execute each of the Test Runs in the Large Database Query Test.*

2. *The human readable SPC-2 Test Results File for each of the Test Runs in the Large Database Query Test.*

3. *A table that contains the following information for each Test Run in the two Test Phases of the Large Database Query Test:*

    - *Average Data Rate: The average Data Rate, in MB per second for the Measurement Interval of each Test Run in the Large Database Query Test.*

    - *Average Data Rate per Stream: The average Data Rate per Stream, in MB per second, for the Measurement Interval of each Test Run in the Large Database Query Test.*

    - *Average Response Time: The average response time, in milliseconds (ms), for the Measurement Interval of each Test Run in the Large Database Query Test.*

4. *Average Data Rate, Average Data Rate per Stream and Average Response time graphs as defined in Clauses 10.1.1, 10.1.2 and 10.1.3.*

Workload Generator Commands and Parameters

The SPC-2 Workload Generator commands and parameters for the Large Database Query Test Runs are documented in Appendix E: SPC-2 Workload Generator Execution Commands and Parameters.

Test Results File

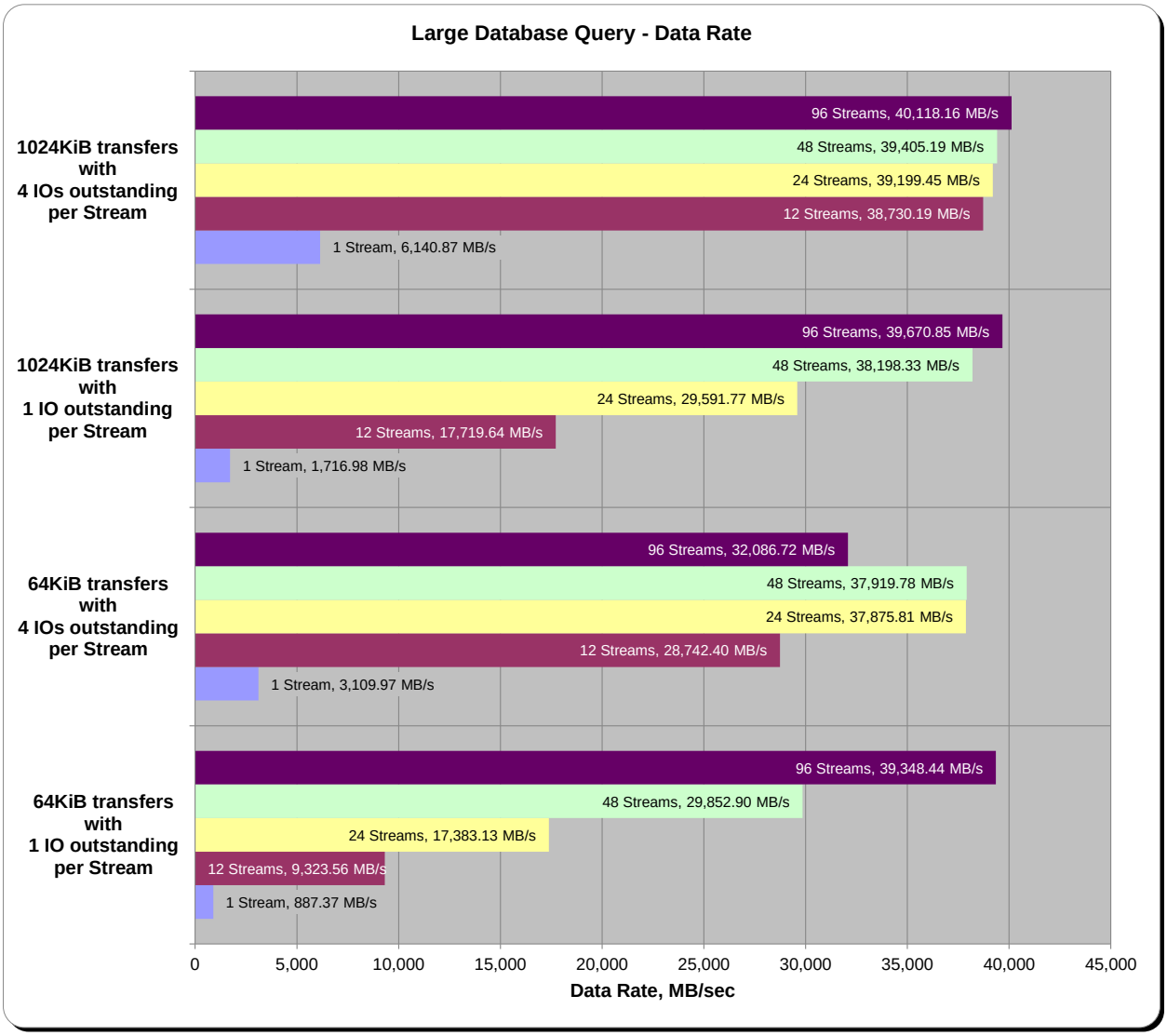
A link to the SPC-2 Test Results file generated from the Large Database Query Test Runs is listed below.

SPC-2 Large Database Query Test Results File

Average Data Rates (MB/s)

The average Data Rate (MB/s) for each Test Run in the two Test Phases of the SPC-2 Large Database Query Test is listed in the table below as well as illustrated in the following graph.

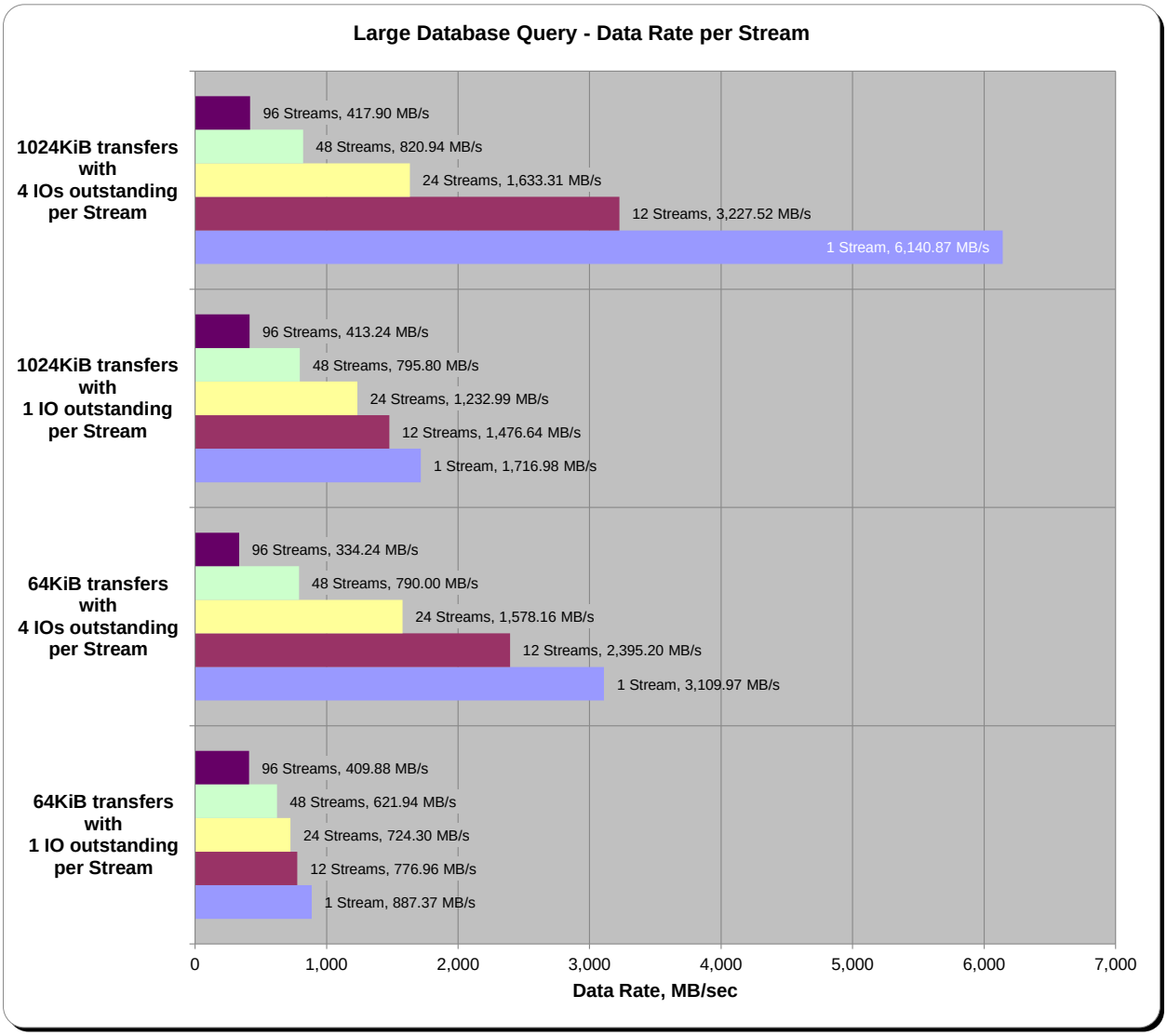
Test Run Sequence	1 Stream	12 Streams	24 Streams	48 Streams	96 Streams
1024KiB w/ 4 IOs/Stream	6,140.87	38,730.19	39,199.45	39,405.19	40,118.16
1024KiB w/ 1 IO/Stream	1,716.98	17,719.64	29,591.77	38,198.33	39,670.85
64KiB w/ 4 IOs/Stream	3,109.97	28,742.40	37,875.81	37,919.78	32,086.72
64KiB w/ 1 IO/Stream	887.37	9,323.56	17,383.13	29,852.90	39,348.44



Average Data Rate per Stream

The average Data Rate per Stream for each Test Run in the two Test Phases of the SPC-2 Large Database Query Test is listed in the table below as well as illustrated in the following graph.

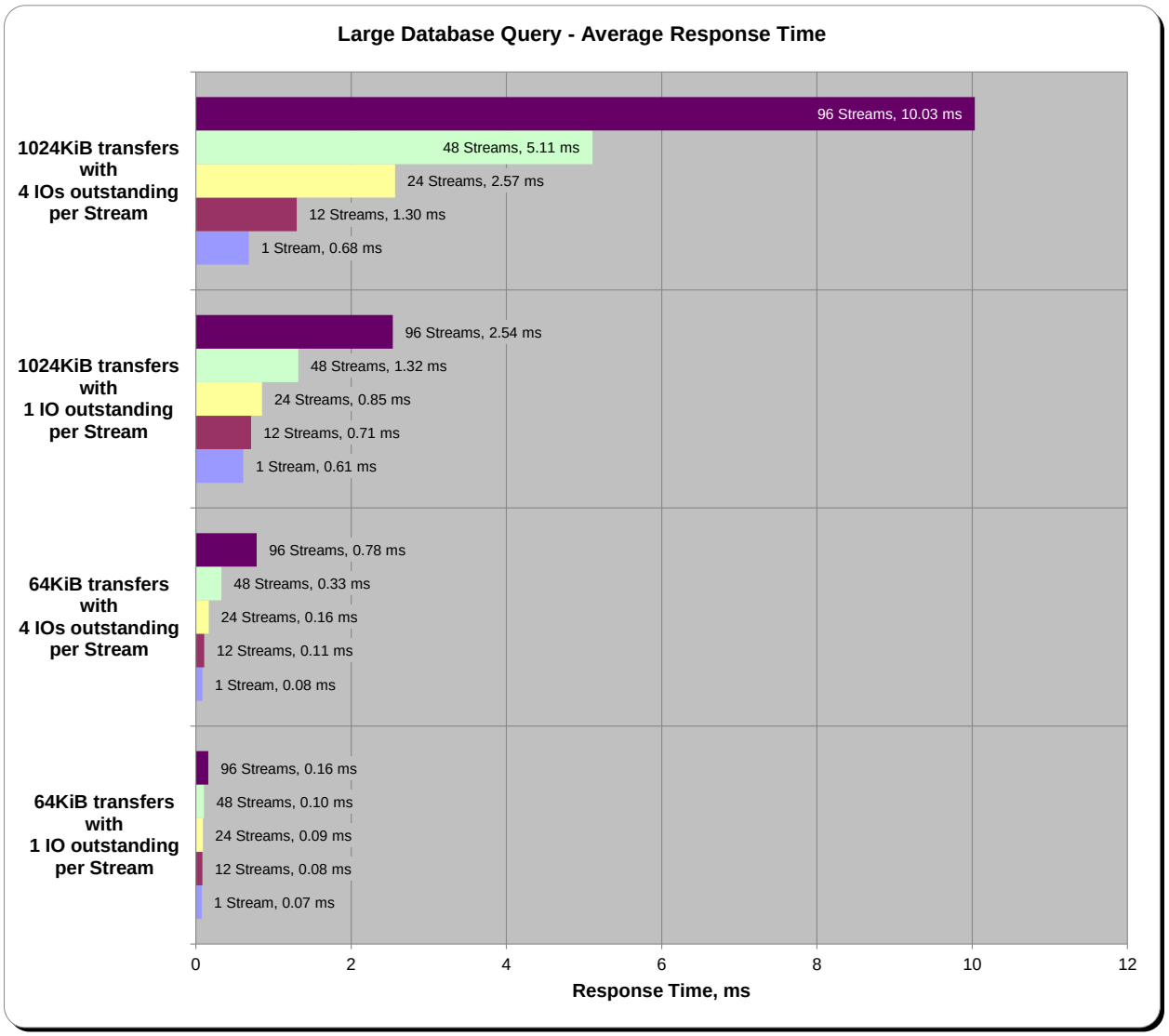
Test Run Sequence	1 Stream	12 Streams	24 Streams	48 Streams	96 Streams
1024KiB w/ 4 IOs/Stream	6,140.87	3,227.52	1,633.31	820.94	417.90
1024KiB w/ 1 IO/Stream	1,716.98	1,476.64	1,232.99	795.80	413.24
64KiB w/ 4 IOs/Stream	3,109.97	2,395.20	1,578.16	790.00	334.24
64KiB w/ 1 IO/Stream	887.37	776.96	724.30	621.94	409.88



Average Response Time

The average Response Time, in milliseconds, for each Test Run in the two Test Phases of the SPC-2 Large Database Query Test is listed in the table below as well as illustrated in the following graph.

Test Run Sequence	1 Stream	12 Streams	24 Streams	48 Streams	96 Streams
1024KiB w/ 4 IOs/Stream	0.68	1.30	2.57	5.11	10.03
1024KiB w/ 1 IO/Stream	0.61	0.71	0.85	1.32	2.54
64KiB w/ 4 IOs/Stream	0.08	0.11	0.16	0.33	0.78
64KiB w/ 1 IO/Stream	0.07	0.08	0.09	0.10	0.16



Large Database Query Test – 1,024 KiB Transfer Size Test Phase

Clause 10.6.9.2.1

1. *A table that will contain the following information for each "1024 KiB Transfer Size, 4 Outstanding I/Os" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
2. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "1024 KiB Transfer Size, 4 Outstanding I/Os" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*
3. *A table that will contain the following information for each "1024 KiB Transfer Size, 1 Outstanding I/O" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
4. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "1024 KiB Transfer Size, 1 Outstanding I/O" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*

A hyperlink for each of the above tables and graphs may appear in the FDR to provide access to the table or graph.

A hyperlink to a table with the SPC-2 "Large Database Query/1024 KIB TRANSFER SIZE/4 Outstanding I/Os" Test Run data appears on the next page. That entry is followed by hyperlinks to graphs illustrating the average Data Rate, average Data Rate per Stream, and average Response Time produced by the same Test Runs. The table and graphs present the data at five-second intervals.

Immediately following the above SPC-2 "Large Database Query/1024 KIB TRANSFER SIZE/4 Outstanding I/Os" entries will be hyperlinks for SPC-2 "Large Database Query/1024 KIB TRANSFER SIZE/1 Outstanding I/O" table and graphs. The table contains the Test Run data and the graphs illustrate the average Data Rate, average Data Rate per Stream, and average Response Time produced by the Test Runs.

4 Outstanding I/Os Test Run

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval
- Run Out / Ramp-Down

4 Outstanding I/Os Test Run Data

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

4 Outstanding I/Os Test Run Graphs

1 Outstanding I/O Test Run

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval

- Run Out / Ramp-Down

1 Outstanding I/O Test Run Data

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

1 Outstanding I/O Test Run Graphs

Large Database Query Test – 64 KiB Transfer Size Test Phase

Clause 10.6.9.2.2

1. *A table that will contain the following information for each "64 KiB Transfer Size, 4 Outstanding I/Os" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
2. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "64 KiB Transfer Size, 4 Outstanding I/Os" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*
3. *A table that will contain the following information for each "64 KiB Transfer Size, 1 Outstanding I/O" Test Run:*
   - *The number of Streams specified.*
   - *The Average Data Rate, Average Data Rate per Stream, and Average Response Time reported at five second intervals.*
4. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the "64 KiB Transfer Size, 1 Outstanding I/O" Test Runs as specified in Clauses 10.1.4 – 10.1.6.*

A hyperlink for each of the above tables and graphs may appear in the FDR to provide access to the table or graph.

A hyperlink to a table with the SPC-2 "Large Database Query/64 KIB TRANSFER SIZE/4 Outstanding I/Os" Test Run data appears on the next page. That entry is followed by hyperlinks to graphs illustrating the average Data Rate, average Data Rate per Stream, and average Response Time produced by the same Test Runs. The table and graphs present the data at five-second intervals.

Immediately following the above SPC-2 "Large Database Query/64 KIB TRANSFER SIZE/4 Outstanding I/Os" entries will be hyperlinks for SPC-2 "Large Database Query/64 KIB TRANSFER SIZE/1 Outstanding I/O" table and graphs. The table contains the Test Run data and the graphs illustrate the average Data Rate, average Data Rate per Stream, and average Response Time produced by the Test Runs.

4 Outstanding I/Os Test Run

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval
- Run Out / Ramp-Down

4 Outstanding I/Os Test Run Data

The link below provides the following graphs.

- Average Data Rate – Complete Test Run

- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

4 Outstanding I/Os Test Run Graphs

1 Outstanding I/O Test Run

The link below provides data for the following test run periods.

- Ramp-Up
- Measurement Interval
- Run Out / Ramp-Down

1 Outstanding I/O Test Run Data

The link below provides the following graphs.

- Average Data Rate – Complete Test Run
- Average Data Rate – Measurement Interval (MI) Only
- Average Data Rate per Stream
- Average Response Time

1 Outstanding I/O Test Run Graphs

Video on Demand Delivery Test

Clause 6.4.5.1

The Video on Demand Delivery Test represents the I/O operations required to enable individualized video entertainment for a community of subscribers, which draw from a digital film library.

Clause 6.4.5.2

The Video on Demand Delivery Test consists of one (1) Test Run.

The BC shall not be restarted or manually disturbed, altered, or adjusted during the execution of the Video on Demand Delivery Test. If power is lost to the BC during this Test all results shall be rendered invalid and the Test re-run in its entirety.

Clause 10.6.9.3

The Full Disclosure Report will contain the following content for the Video on Demand Delivery Test:

1. *A listing of the SPC-2 Workload Generator commands and parameters used to execute the Test Run in the Video on Demand Delivery Test.*
2. *The human readable SPC-2 Test Results File for the Test Run in the Video on Demand Delivery Test.*
3. *A table that contains the following information for the Test Run in the Video on Demand Delivery Test:*
    a. *The number Streams specified.*
    b. *The Ramp-Up duration in seconds.*
    c. *The Measurement Interval duration in seconds.*
    d. *The average data rate, in MB per second, for the Measurement Interval.*
    e. *The average data rate, in MB per second, per Stream for the Measurement Interval.*
4. *A table that contains the following information for the single Video on Demand Delivery Test Run:*
    a. *The number Streams specified.*
    b. *The average data rate, average data rate per stream, average Response Time, and Maximum Response Time reported at 60 second intervals.*
5. *Average Data Rate by Intervals, Average Data Rate per Stream by Intervals, and Average Response Time by Intervals graphs for the single Video on Demand Delivery Test Run as specified in Clause 10.1.8.*
6. *A Maximum Response Time (intervals) graph as specified in Clause 10.1.8.*

Workload Generator Commands and Parameters

The SPC-2 Workload Generator commands and parameters for the Video on Demand Delivery Test Run are documented in Appendix E: SPC-2 Workload Generator Execution Commands and Parameters.

Test Results File

A link to the SPC-2 Test Results file generated from the Video on Demand Delivery Test Run is listed below.

SPC-2 Video on Demand Delivery Test Results File

Test Run Data

The number of Streams specified, Ramp-Up duration in seconds, Measurement Interval duration in seconds, average Data Rate for the Measurement Interval, and average Data Rate per Stream for the Measurement Interval are listed in the following table.

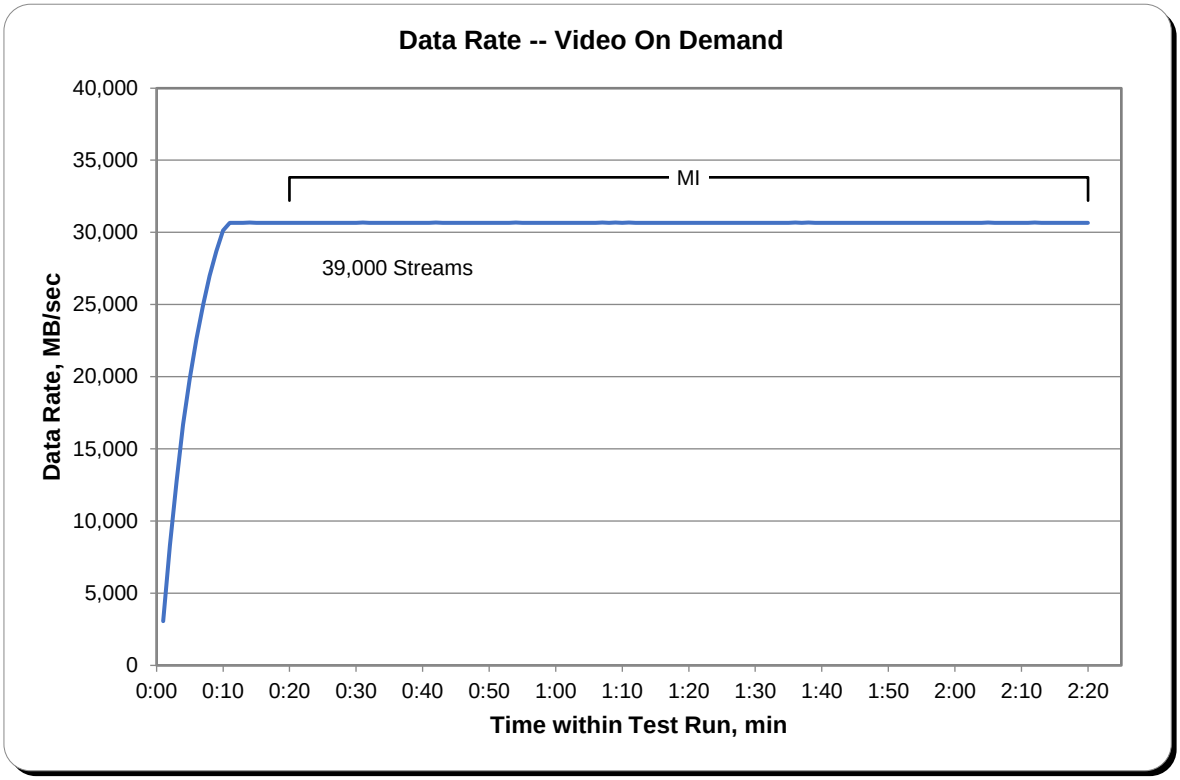
SPC-2 VOD	TR1
Number of Streams	39,000
Ramp-up Time, sec	1,200
Measurement Interval, sec	7,200
Average Data Rate, MB/sec	30,670.87
Per Stream Data Rate, MB/sec	0.79
Average Response Time, ms	0.64
Average Max Response Time, ms	5.10

Test Run Data By Interval

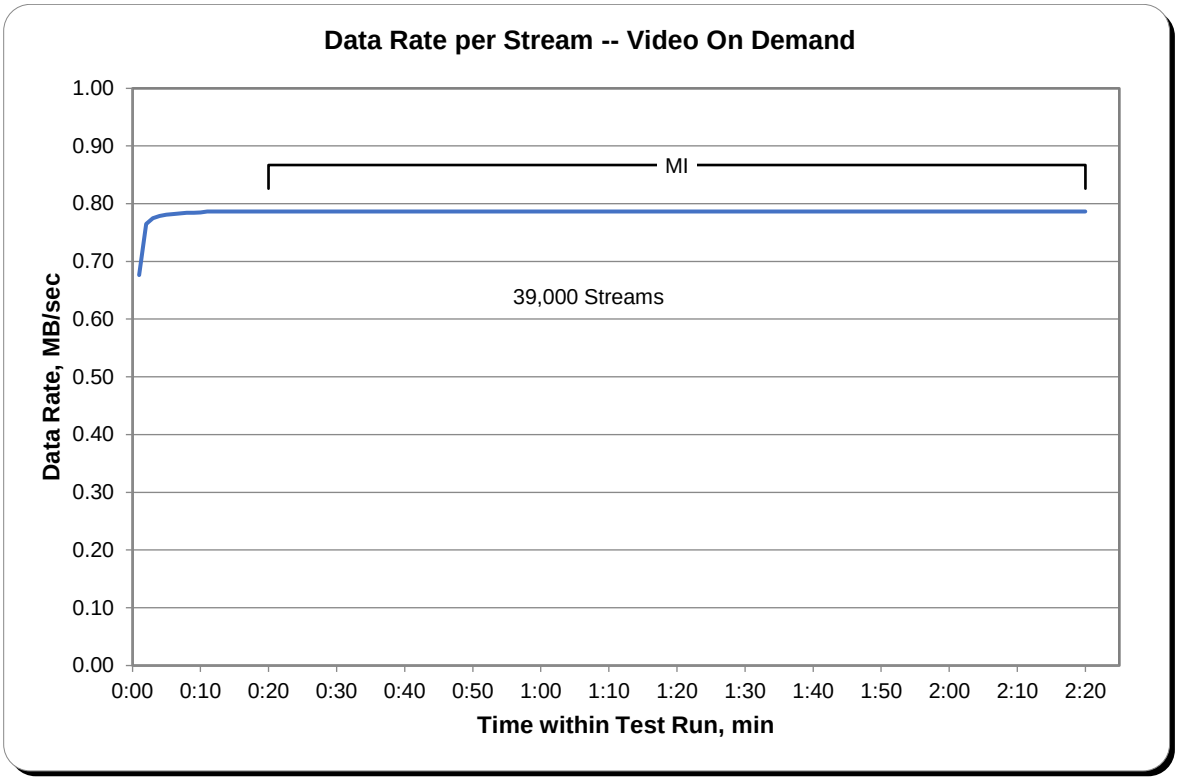
The SPC-2 Video on Demand Delivery Test Run data is contained in the table that appears below. That table is followed by graphs illustrating the average Data Rate and average Data Rate per Stream produced by the same Test Runs. The table and graphs present the data at sixty second intervals.

TR1	39,000 Streams				TR1	39,000 Streams				TR1	39,000 Streams			
Test Run Sequence Time	Data Rate, MB/sec	Data Rate / Stream, MB/sec	Response Time, ms	Maximum Response Time, ms	Test Run Sequence Time	Data Rate, MB/sec	Data Rate / Stream, MB/sec	Response Time, ms	Maximum Response Time, ms	Test Run Sequence Time	Data Rate, MB/sec	Data Rate / Stream, MB/sec	Response Time, ms	Maximum Response Time, ms
0:01:00	3,054.55	0.68	1.21	330.03	0:48:00	30,671.27	0.79	0.64	3.98	1:35:00	30,670.15	0.79	0.76	196.82
0:02:00	8,313.16	0.76	0.92	437.64	0:49:00	30,671.30	0.79	0.65	4.78	1:36:00	30,671.21	0.79	0.64	7.99
0:03:00	12,785.96	0.77	0.76	181.39	0:50:00	30,670.19	0.79	0.64	4.37	1:37:00	30,670.46	0.79	0.64	4.26
0:04:00	16,669.32	0.78	0.64	76.12	0:51:00	30,671.82	0.79	0.74	387.46	1:38:00	30,671.05	0.79	0.65	118.34
0:05:00	19,852.16	0.78	0.62	138.20	0:52:00	30,669.68	0.79	0.64	3.99	1:39:00	30,669.97	0.79	0.64	4.64
0:06:00	22,622.15	0.78	0.62	94.11	0:53:00	30,671.41	0.79	0.64	4.90	1:40:00	30,671.52	0.79	0.64	4.61
0:07:00	25,004.14	0.78	0.63	62.36	0:54:00	30,670.57	0.79	0.64	4.59	1:41:00	30,670.37	0.79	0.64	18.28
0:08:00	26,992.90	0.78	0.63	44.51	0:55:00	30,672.42	0.79	0.64	5.09	1:42:00	30,672.30	0.79	0.64	4.47
0:09:00	28,693.52	0.78	0.67	80.21	0:56:00	30,670.54	0.79	0.64	4.76	1:43:00	30,669.45	0.79	0.64	13.59
0:10:00	30,131.48	0.78	0.67	62.42	0:57:00	30,670.42	0.79	0.64	5.03	1:44:00	30,672.00	0.79	0.64	4.56
0:11:00	30,671.05	0.79	0.64	19.46	0:58:00	30,671.23	0.79	0.64	4.31	1:45:00	30,669.66	0.79	0.64	4.54
0:12:00	30,670.74	0.79	0.64	5.41	0:59:00	30,670.56	0.79	0.64	4.15	1:46:00	30,672.27	0.79	0.64	3.78
0:13:00	30,670.65	0.79	0.64	4.97	1:00:00	30,670.83	0.79	0.64	7.28	1:47:00	30,669.64	0.79	0.64	4.13
0:14:00	30,672.26	0.79	0.64	22.17	1:01:00	30,670.50	0.79	0.65	37.93	1:48:00	30,670.80	0.79	0.64	4.49
0:15:00	30,669.53	0.79	0.64	22.01	1:02:00	30,670.26	0.79	0.64	5.46	1:49:00	30,670.57	0.79	0.64	5.05
0:16:00	30,671.77	0.79	0.64	6.11	1:03:00	30,670.97	0.79	0.64	4.52	1:50:00	30,671.17	0.79	0.64	4.55
0:17:00	30,670.29	0.79	0.64	40.28	1:04:00	30,671.34	0.79	0.64	10.04	1:51:00	30,670.88	0.79	0.64	4.46
0:18:00	30,671.80	0.79	0.64	38.62	1:05:00	30,671.92	0.79	0.64	4.58	1:52:00	30,670.84	0.79	0.64	16.28
0:19:00	30,670.74	0.79	0.76	203.75	1:06:00	30,669.40	0.79	0.64	4.68	1:53:00	30,671.32	0.79	0.64	5.10
0:20:00	30,670.66	0.79	0.64	48.27	1:07:00	30,671.54	0.79	0.64	5.15	1:54:00	30,671.08	0.79	0.64	14.64
0:21:00	30,671.27	0.79	0.65	20.99	1:08:00	30,670.78	0.79	0.64	4.34	1:55:00	30,670.53	0.79	0.64	4.23
0:22:00	30,669.61	0.79	0.64	22.35	1:09:00	30,670.33	0.79	0.64	19.24	1:56:00	30,670.76	0.79	0.64	26.08
0:23:00	30,671.03	0.79	0.64	19.73	1:10:00	30,670.88	0.79	0.64	4.09	1:57:00	30,671.74	0.79	0.64	3.98
0:24:00	30,671.13	0.79	0.64	9.75	1:11:00	30,671.18	0.79	0.64	4.57	1:58:00	30,670.17	0.79	0.65	41.45
0:25:00	30,670.20	0.79	0.64	26.16	1:12:00	30,670.76	0.79	0.64	4.71	1:59:00	30,671.07	0.79	0.64	4.16
0:26:00	30,671.17	0.79	0.64	6.28	1:13:00	30,671.19	0.79	0.64	14.29	2:00:00	30,670.43	0.79	0.64	4.83
0:27:00	30,670.74	0.79	0.64	4.34	1:14:00	30,670.40	0.79	0.64	14.78	2:01:00	30,671.12	0.79	0.64	4.30
0:28:00	30,671.06	0.79	0.64	4.46	1:15:00	30,670.93	0.79	0.64	20.14	2:02:00	30,671.02	0.79	0.64	4.05
0:29:00	30,671.03	0.79	0.64	4.59	1:16:00	30,671.28	0.79	0.64	13.34	2:03:00	30,671.42	0.79	0.64	3.93
0:30:00	30,670.55	0.79	0.64	3.93	1:17:00	30,671.09	0.79	0.64	17.37	2:04:00	30,669.92	0.79	0.64	3.95
0:31:00	30,671.98	0.79	0.64	15.83	1:18:00	30,670.49	0.79	0.64	4.43	2:05:00	30,670.94	0.79	0.64	11.49
0:32:00	30,670.95	0.79	0.64	15.79	1:19:00	30,670.81	0.79	0.64	20.26	2:06:00	30,671.22	0.79	0.64	4.07
0:33:00	30,670.68	0.79	0.64	5.34	1:20:00	30,670.90	0.79	0.64	6.35	2:07:00	30,670.51	0.79	0.66	38.22
0:34:00	30,670.00	0.79	0.64	6.48	1:21:00	30,671.95	0.79	0.64	21.78	2:08:00	30,672.41	0.79	0.64	4.49
0:35:00	30,671.06	0.79	0.64	14.37	1:22:00	30,671.29	0.79	0.64	19.43	2:09:00	30,669.59	0.79	0.64	4.80
0:36:00	30,670.90	0.79	0.64	14.05	1:23:00	30,669.94	0.79	0.64	4.06	2:10:00	30,671.66	0.79	0.64	4.17
0:37:00	30,671.61	0.79	0.64	13.82	1:24:00	30,670.10	0.79	0.64	4.40	2:11:00	30,669.79	0.79	0.64	4.64
0:38:00	30,670.37	0.79	0.64	4.30	1:25:00	30,671.15	0.79	0.64	4.48	2:12:00	30,672.15	0.79	0.64	4.46
0:39:00	30,670.59	0.79	0.64	13.78	1:26:00	30,670.59	0.79	0.64	18.71	2:13:00	30,669.88	0.79	0.64	5.28
0:40:00	30,671.26	0.79	0.64	28.81	1:27:00	30,670.96	0.79	0.64	12.95	2:14:00	30,671.40	0.79	0.64	14.26
0:41:00	30,670.36	0.79	0.64	15.32	1:28:00	30,670.84	0.79	0.64	4.27	2:15:00	30,670.22	0.79	0.64	4.17
0:42:00	30,672.30	0.79	0.64	16.04	1:29:00	30,672.44	0.79	0.64	16.64	2:16:00	30,671.11	0.79	0.64	5.66
0:43:00	30,670.63	0.79	0.64	18.21	1:30:00	30,669.44	0.79	0.64	3.98	2:17:00	30,670.65	0.79	0.64	4.21
0:44:00	30,669.66	0.79	0.64	3.97	1:31:00	30,671.94	0.79	0.64	13.52	2:18:00	30,671.16	0.79	0.64	4.32
0:45:00	30,671.75	0.79	0.64	20.56	1:32:00	30,669.98	0.79	0.64	4.28	2:19:00	30,671.47	0.79	0.64	4.60
0:46:00	30,670.90	0.79	0.65	16.40	1:33:00	30,671.05	0.79	0.64	4.67	2:20:00	30,671.06	0.79	0.64	4.59
0:47:00	30,670.08	0.79	0.67	4.70	1:34:00	30,671.93	0.79	0.64	4.98	0:00:00	0.00	0.00	0.00	0.00

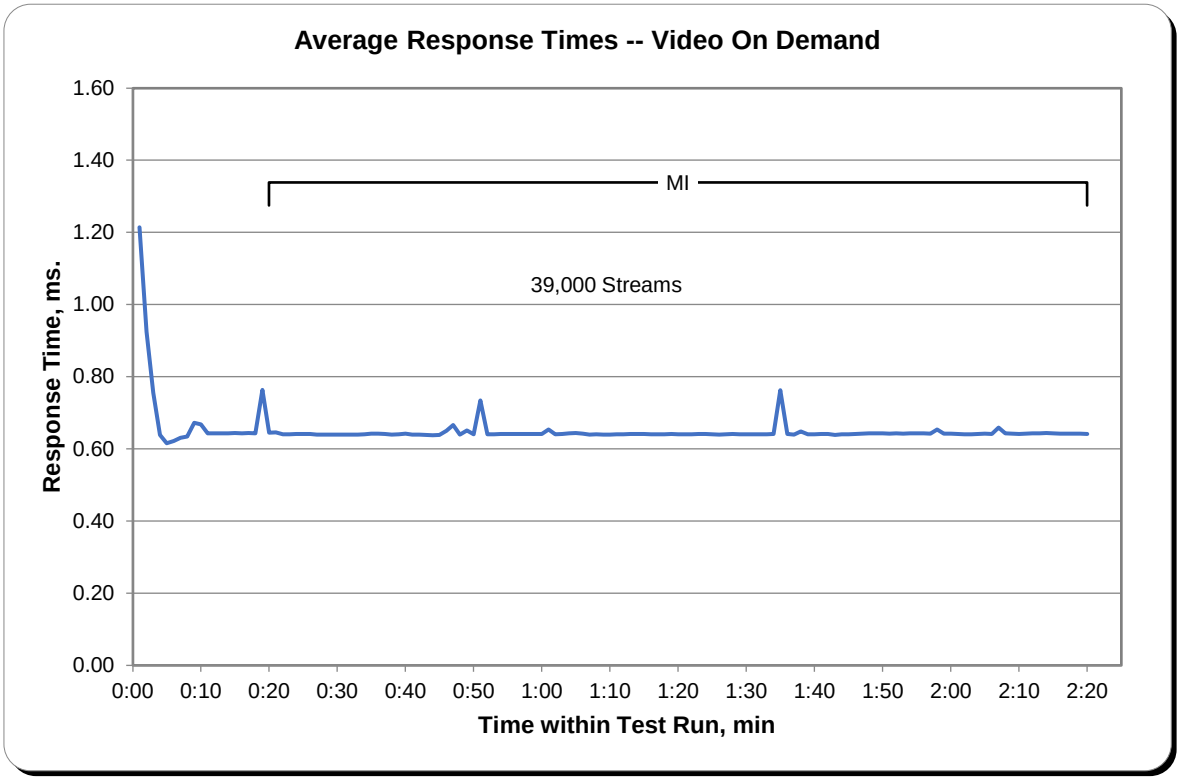
Average Data Rate Graph



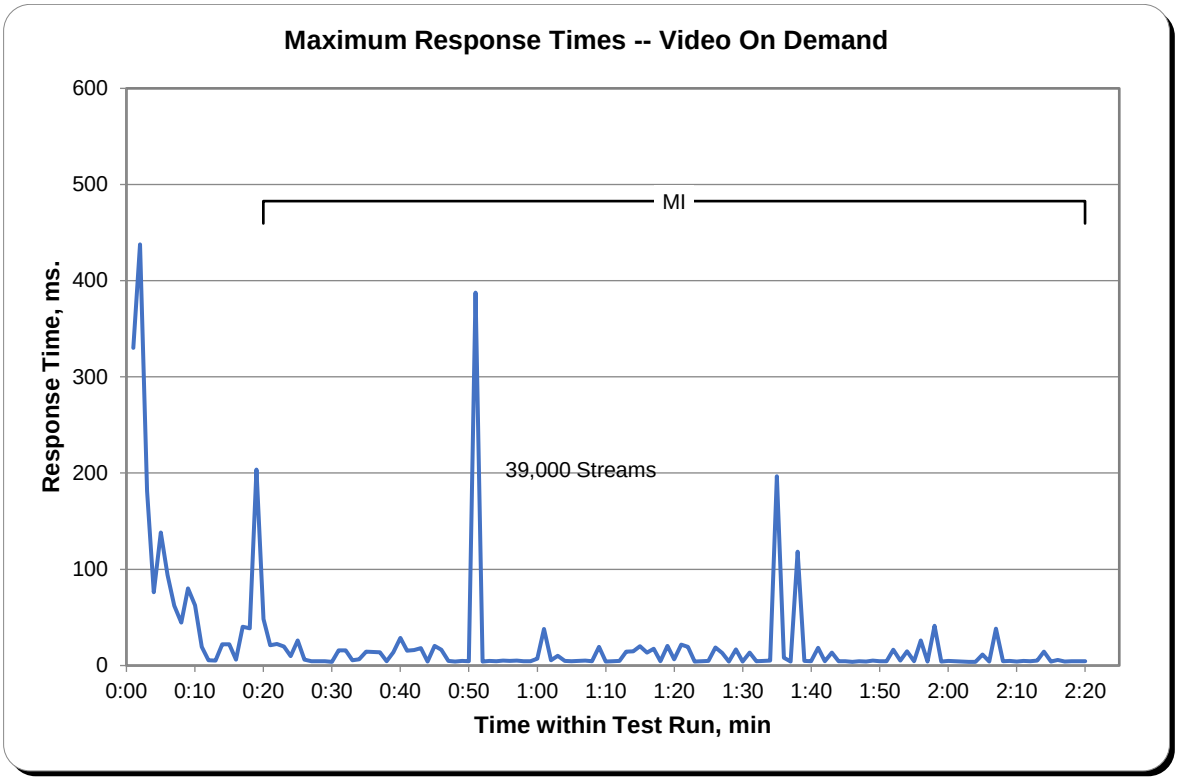
Average Data Rate per Stream Graph



Average Response Time Graph



Maximum Response Time Graph



Data Persistence Test

Clause 7

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

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

The SPC-2 Workload Generator will write a specific pattern at randomly selected locations throughout the Total ASU Capacity (Persistence Test Run 1). The SPC-2 Workload Generator will retain the information necessary to later validate the pattern written at each location.

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

Restart the TSC, and if the Host System(s) were shutdown and powered off, restart the Host System(s).

The SPC-2 Workload Generator will utilize the retained data from Persistence Test Run 1 to verify (Persistence Run 2) the bit patterns written in Persistence Test Run 1 and their corresponding location.

Clause 10.6.9.4

The Full Disclosure Report will contain the following content for the Data Persistence Test:

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

Workload Generator Commands and Parameters

The SPC-2 Workload Generator commands and parameters for the Persistence Test Runs are documented in Appendix E: SPC-2 Workload Generator Execution Commands and Parameters.

Test Results File

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

Persistence 1 Test Run (write phase) Results File

Persistence 2 Test Run (read phase) Results File

Test Results

Data Persistence Test Results	
Data Persistence Test Number: 1	
Total Number of Logical Blocks Written	3,307,198
Total Number of Logical Blocks Re-referenced	214,834
Total Number of Logical Blocks Verified	3,092,364
Total Number of Logical Blocks that Failed Verification	0
Number of Failed I/O Requests in the process of the Test	0

PRICED STORAGE CONFIGURATION AVAILABILITY DATE

Clause 10.6.9

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

The Availability Data shall be stated in either a combination of specific alphanumeric month, numeric day and numeric year or as "Currently Available".

The NetApp EF600 All-Flash Array, as documented in this SPC-2 Full Disclosure Report, will be available for customer purchase and shipment on 7/1/2020.

ANOMALIES OR IRREGULARITIES

Clause 10.6.12

The FDR shall include a clear and complete description of any anomalies or irregularities encountered in the course of executing the SPC-2 benchmark that may in any way call into question the accuracy, verifiability, or authenticity of information published in this FDR.

Test Run 15 of the Large Database Query Test (LDQ-TR15) showed an anomalous change in the measured data rate. Consequently, the Measurement Interval of LQD-TR15 was not in Steady State. This change in data rate has no impact on any of the overall reported metrics. It is the Auditor's opinion that this minor deviation does not compromise the integrity of this submission.

APPENDIX A: SPC-2 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-2 Data Repository Definitions

Total ASU Capacity: The total storage capacity read and written in the course of executing the SPC-2 benchmark.

Application Storage Unit (ASU): The logical interface between the storage and SPC-2 Workload Generator. The ASU is 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-2 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-2 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 ASU.

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 sum of unused storage capacity within the Physical Storage Capacity, Configured Storage Capacity, and Addressable Storage Capacity.

SPC-2 Data Protection Levels

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

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

SPC-2 Test Execution Definitions

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

Completion Time: The time recorded by the Workload Generator when an I/O Request is completed by the Tested Storage Configuration (TSC) as signaled by System Software.

Data Rate: The data volume, in MB, transferred by all Measured I/O Requests in an SPC2 Test Run divided by the length of the Test Run in seconds.

Failed I/O Request: Any I/O Request issued by the SPC-2 Workload Generator that meets one of the following conditions *(see "I/O Completion Types" illustrated below)*:

- The I/O Request was signaled as failed by System Software.
- The I/O Request started within the Measurement Interval, but did not complete prior to the end of the appropriate Run-Out period.
- The I/O Request started within the Run-Out period, but did not complete prior to the end of the appropriate Ramp-Down period.

I/O Request Throughput: The total number of Measured I/O Requests in an SPC-2 Test Run divided by the duration of the Measurement Interval in seconds.

Measured I/O Request: A Completed I/O Request that begins (Start Time) within a Measurement Interval and completes (Completion Time) prior to the end of the appropriate Ramp Down *(see "I/O Completion Types" illustrated below).*

Measurement Interval: A specified, contiguous period of time, after the TSC has reached Steady State, when data is collected by the Workload Generator to produce the test results for a SPC-2 Test Run *(see "SPC-2 Test Run Components" illustrated below, Test Run 1: T_2-T_3 and Test Run 2: T_7-T_8).*

Outstanding I/O Requests: The Outstanding I/O Requests parameter specifies the maximum number of concurrent I/O Requests, associated with a give Stream, which have been issued but not yet completed. *(Clause 3.4.4 of the SPC-2 Benchmark Specification).*

Ramp-Down: A specified, contiguous period of time in which the TSC is required to complete I/O Requests started but not completed during the preceding Run-Out period. Ramp-Down begins at the end of the preceding Run-Out period *(see "SPC-2 Test Run Components" illustrated below, Test Run 1: T_4-T_5 and Test Run 2: T_9-T_{10}).* The Workload Generator will not submit any I/O Requests during the Ramp-Down.

Ramp-Up: A specified, contiguous period of 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. The Ramp-Up period ends at the beginning of the Measurement Interval *(see "SPC-2 Test Run Components" illustrated below, Test Run 1: T_0-T_2 and Test Run 2: T_5-T_7).*

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

Run-Out: A specified, contiguous period of time in which the TSC is required to complete I/O Requests started but not completed during the preceding Measurement Interval. The Run-Out period begins at the end of the preceding Measurement Interval and is a component of the Steady State period *(see "SPC-2 Test Run Components" illustrated below, Test Run 1: T_3-T_4 and Test Run 2: T_9-T_{10}).* The Workload Generator will continue to submit I/O Requests at the Test Run's specified rate during the Run-Out period.

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 TSC.

Steady State: The period during which the workload presented to the TSC by the SPC-2 Workload Generator is constant and the resulting TSC I/O Request Throughput is both consistent and sustainable. The Steady State period includes both the Measurement Interval and Run-Out periods *(see "SPC-2 Test Run Components" illustrated below, Test Run 1: T_1-T_4 and Test Run 2: T_6-T_9).*

Steady State is achieved only after caches in the TSC have filled and as a result the I/O Request Throughput of the TSC has stabilized.

Stream: A collection of Stream Segments that started within a Test Run.

Stream Segment: A sequentially organized pattern of I/O requests, which transfers a contiguous range of data.

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

Test Phase: A collection of one or more SPC-2 Test Runs sharing a common objective and intended to be run in a specific sequence.

Test Run: The execution of SPC-2 that produces specific SPC-2 test results. SPC-2 Test

Runs have specified, measured Ramp-Up, Measurement Interval, Run-Out and RampDown periods. "SPC-2 Test Run Components" *(see below)* illustrates the Ramp-Up, Steady State, Measurement Interval, Run-Out, and Ramp-Down components contained in two uninterrupted SPC-2 Test Runs *(Test Run 1: T_0-T_5 and Test Run 2: T_5-T_{10}).*

Test Run Sequence: A related sequence of Large File Processing (LFP) or Large Database Query (LDQ) Test Runs. Each Test Run Sequence will consist of five Test Runs, which vary the number of Streams as follows:

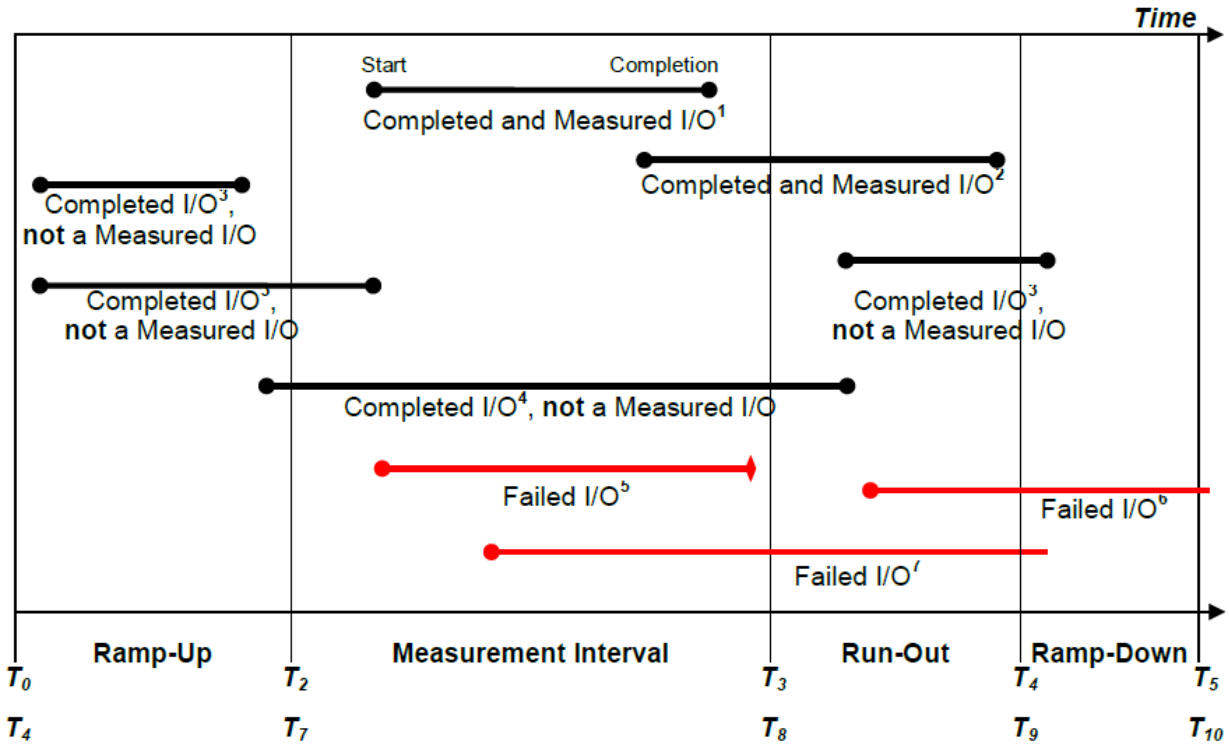
- Test Run 1: Maximum number of Streams, which is selected by the Test Sponsor
- Test Run 2: 50% of the maximum number of Streams used in Test Run 1.
- Test Run 3: 25% of the maximum number of Streams used in Test Run 1.
- Test Run 4: 12.5% of the maximum number of Streams used in Test Run 1.
- Test Run 5: 1 Stream.

Each of the five Test Runs in a Test Run Sequence will share the same attributes with the exception of the number of Streams. For example:

- Large File Processing, Read, 1024 KiB Transfer Size: Maximum Streams
- Large File Processing, Read, 1024 KiB Transfer Size: 50% of Maximum Streams
- Large File Processing, Read, 1024 KiB Transfer Size: 25% of Maximum Streams
- Large File Processing, Read, 1024 KiB Transfer Size: 12.5% of Maximum Streams
- Large File Processing, Read, 1024 KiB Transfer Size: 1 Stream

Transfer Size: The Transfer Size parameter specifies the number of bytes in KiB to transfer. *(Clause 3.4.7 of the SPC-2 Benchmark Specification)*

I/O Completion Types



Completed and Measured I/O[1]: I/O started and completed within the Measurement Interval.

Completed and Measured I/O[2]: I/O started within the Measurement Interval and completed within Ramp Down.

Completed I/O[3]: I/O started before or after the Measurement Interval – not measured.

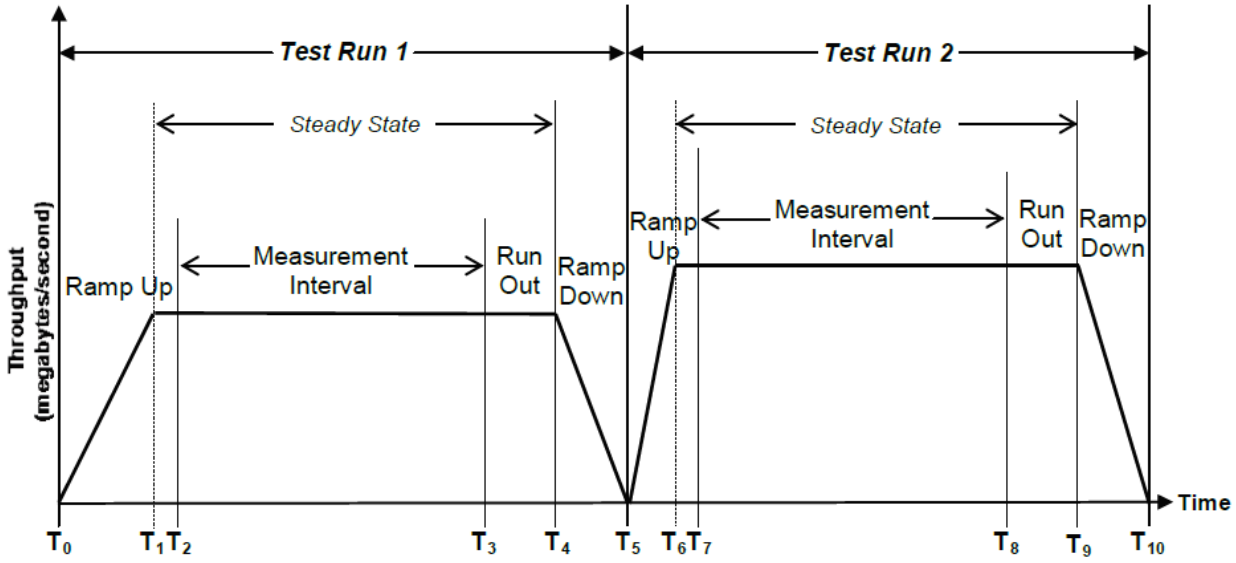
Completed I/O[4]: I/O started before and completed after the Measurement Interval – not measured.

Failed I/O[5]: Signaled as failed by System Software.

Failed I/O[6]: I/O did not complete prior to the end of Ramp-Down.

Failed I/O[7]: I/O did not complete prior to the end of Run-Out.

SPC-2 Test Run Components



APPENDIX B: CUSTOMER TUNABLE PARAMETERS AND OPTIONS

Storage Array Parameters

The following storage array parameters were changed from their default values by the TSC creation/configuration script documented in *"Error! Reference source not found."*.

	Default Value	New Value
cacheBlockSize	***8***	***32***

CacheBlockSize – disk array controller cache allocation unit size in KiB (1024).

	Default Value	New Value
AutoLoadBalance	***on***	***off***

AutoLoadBalance – monitor IO load across volumes and migrate volumes across controllers if imbalance occurs.

HBA Parameters

The following Emulex HBA parameters were changed from their default values in /etc/modprobe.d/lpfc.conf.

Parameter	Default Value	New Value
options lpfc lpfc_enable_fc4_type		
Enable FC and NVMe support	1	3

Operating System Settings

Enable SCSI and DM device multi-queue scheduling

(1) Add "scsi_mod.use_blk_mq=y dm_mod.use_blk_mq=y dm_mod.dm_mq_nr_hw_queues=4" to GRUB_CMDLINE_LINUX_DEFAULT in /etc/default/grub
(2) Rebuild grub with "grub2-mkconfig -o /boot/grub2/grub.cfg"
(3) sync;reboot

Disable processor C-States

(1) Add "processor.max_cstate=1 intel_idle.max_cstate=0" to GRUB_CMDLINE_LINUX_DEFAULT in /etc/default/grub
(2) Rebuild grub with "grub2-mkconfig -o /boot/grub2/grub.cfg"
(3) sync; reboot

Set Block device parameters

```
Change queue/rotational from 1 to 0
Change queue/scheduler from none to none
Change queue/nr_requests from 2048 to 1024
Change queue/nomerges from 0 to 2
Change queue/read_ahead_kb from 512 to 0
Change queue/rq_affinity from 1 to 2

  SUBSYSTEM!="block", GOTO="end_rule"
  ATTRS{model}=="SAM*", GOTO="end_rule"
  ENV{DEVTYPE}=="partition", GOTO="end_rule"
  ACTION!="add|change", GOTO="end_rule"
ACTION=="add|change", KERNEL=="nvme*", ATTR{queue/rotational}=="0",
ATTR{queue/scheduler}="none", ATTR{queue/nr_requests}="1024",
ATTR{queue/nomerges}="2", ATTR{queue/read_ahead_kb}="0",
ATTR{queue/rq_affinity}="2"
ACTION=="add|change", KERNEL=="dm*", ATTR{queue/rotational}=="0",
ATTR{queue/scheduler}="none", ATTR{queue/nr_requests}="1024",
ATTR{queue/nomerges}="2", ATTR{queue/read_ahead_kb}="0",
ATTR{queue/rq_affinity}="2"
  LABEL="end_rule"
```

Maximum system processes

```
Increase kernel.pid_max from 98304 to 262144 in /etc/sysctl.conf
```

Maximum asynchronous IO requests

```
Increase fs.aio-max-nr from 65536 to 1048576 in /etc/sysctl.conf
```

Multipath Configuration

```
Add the following to /etc/multipath.conf for NetApp NVMe device support
devices {
                    device {
                    vendor "NVME"
                    product "NetApp E-Series*"
                    path_grouping_policy group_by_prio
                    prio netappnvme
                    failback immediate
                    no_path_retry 30
                    }
      }
```

NVMe Configuration

```
Install nvme-cli package
       zypper install nvme-cli

Enable and start the NVMe boot services
       service enable nvmefc-boot-connections.service
       service start nvmefc-boot-connections.service
```

APPENDIX C: TESTED STORAGE CONFIGURATION CREATION

Before creating volumes on the storage array, please refer to Appendix B for a listing of the required HBA settings.

Storage Array Volume Creation

The storage management utility software, **SANtricity System Manager**, is a browser based application that runs on the array. The SANtricity Storage Manager command line utility (CLI) is used to configure the array and is downloaded from the array by navigating to Home→Settings→System→Add-ons→Command Line Interface. The ZIP package downloads to the browser. Save the ZIP file to the management system where it will be used to run CLI commands for the storage array, and then extract the files. The CLI command to create the RAID configuration is run with the following command:

```
smcli/SMcli-01.20.00.9001/bin/SMcli      10.113.120.248      10.113.120.249      -f
SPC2_RAID_Config.script -k -u admin -p admin
```

After successful CLI execution, there will be 2 volume groups on the storage subsystem. Each volume group contains two RAID 6 volumes. All 4 RAID 6 volumes are visible by each Host System.

SPC-2 Logical Volume Creation

The steps that follow are executed on each Host System to discover array volumes.

- Reboot each Host System.
- Execute "multipath -ll" to display the 4 RAID volumes.

SPC2_RAID_Config.script

```
/* SPC-2 RAID Configuration Script */

set storageArray mediaScanRate=30;

create volume drives[ 0,0  0,1  0,2  0,3  0,4  0,5  0,6  0,7  0,8  0,9 ]
RAIDLevel=6
segmentSize=256
userLabel="LUN_1"
volumeGroupUserLabel="VG_1"
capacity=6434448211968
owner = A;

create volume volumeGroup["VG_1"]  RAIDLevel=6  segmentSize=256  userLabel="LUN_2"
capacity=6434448211968  owner = b;

create volume drives[ 0,12  0,13  0,14  0,15  0,16  0,17  0,18  0,19  0,20  0,21 ]
RAIDLevel=6
segmentSize=256
userLabel="LUN_3"
volumeGroupUserLabel="VG_2"
capacity=6434448211968
owner = b;

create volume volumeGroup["VG_2"]  RAIDLevel=6  segmentSize=256  userLabel="LUN_4"
capacity=6434448211968  owner = A;

/* define host mappings */
set volume["LUN_1"] logicalUnitNumber=1 hostGroup="Host_Cluster";
set volume["LUN_2"] logicalUnitNumber=2 hostGroup="Host_Cluster";
```

```
set volume["LUN_3"] logicalUnitNumber=3 hostGroup="Host_Cluster";
set volume["LUN_4"] logicalUnitNumber=4 hostGroup="Host_Cluster";

set allVolumes  mirrorEnabled = True writeCacheEnabled = True
cacheWithoutBatteryEnabled = False cacheReadPrefetch = True;

set storageArray cacheBlockSize  = 32;
set storageArray cacheFlushStart = 80;
set storageArray autoLoadBalancingEnable = false;
```

APPENDIX D: SPC-2 WORKLOAD GENERATOR STORAGE COMMANDS AND PARAMETER FILES

ASU Pre-Fill

Please see Pre-Fill Params File

Large Database Query Test

Please see LDQ Params File

Large File Processing Test

Please see LFP Params File

Video on Demand Delivery Test

Please see VOD Params File

Persistence Test Run 1 (write phase)

Please see Persist1 Params File

SPC-2 Persistence Test Run 2 (read phase)

Please see Persist2 Params File

APPENDIX E: SPC-2 WORKLOAD GENERATOR EXECUTION COMMANDS AND PARAMETERS

ASU Pre-Fill, Large Database Query Test, Large File Processing Test, Video on Demand Delivery Test, and Persistence Test Run 1 (write phase)

The script phase1.spc2.sh executes the following:

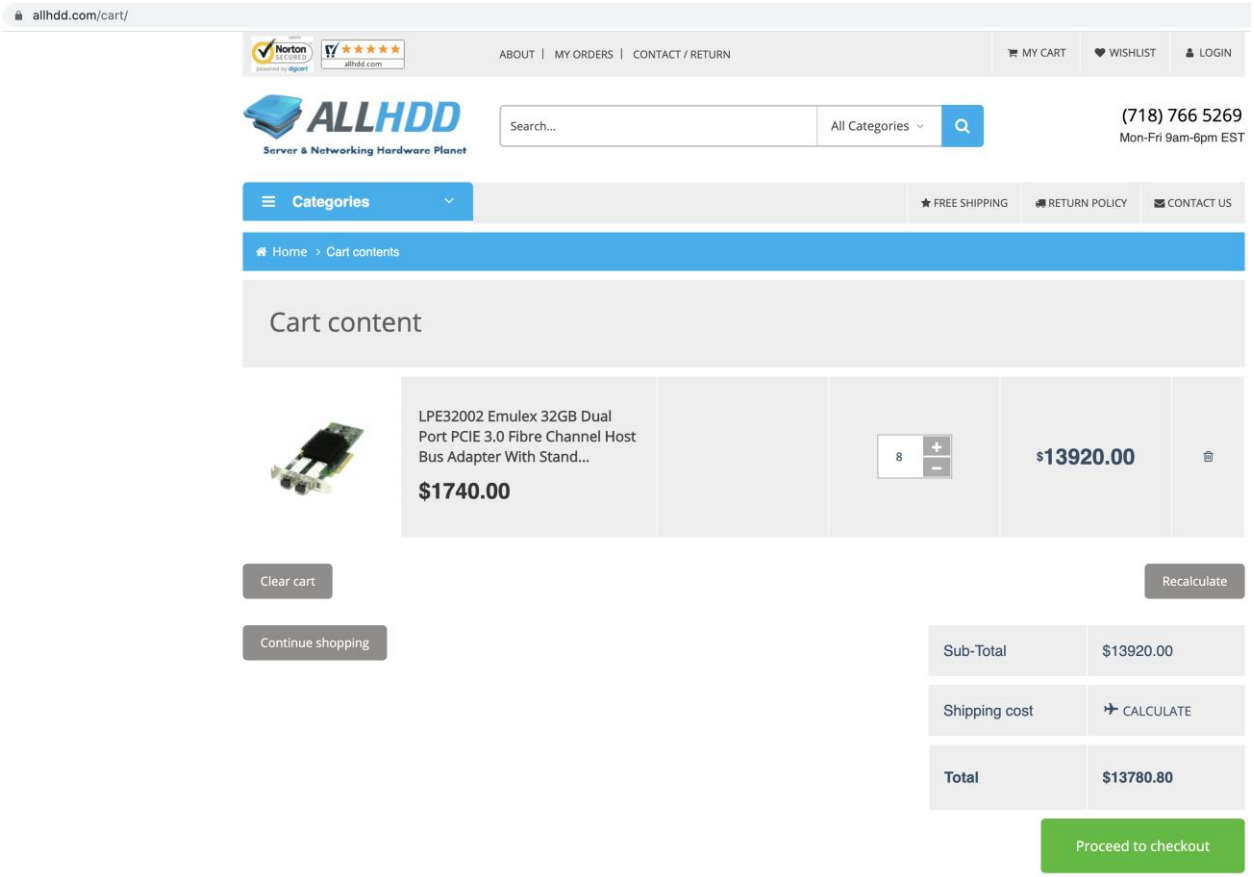
- Collects various configuration information required for the audit
- The required ASU pre-fill
- The SPC-2 Tests:
- Large File Processing (LFP)
- Large Database Query (LDQ)
- Video on Demand (VOD)
- SPC-2 Persistence – Test Run 1 (write phase)
- Various housekeeping in support of the test execution

Persistence Test Run 2 (read phase)

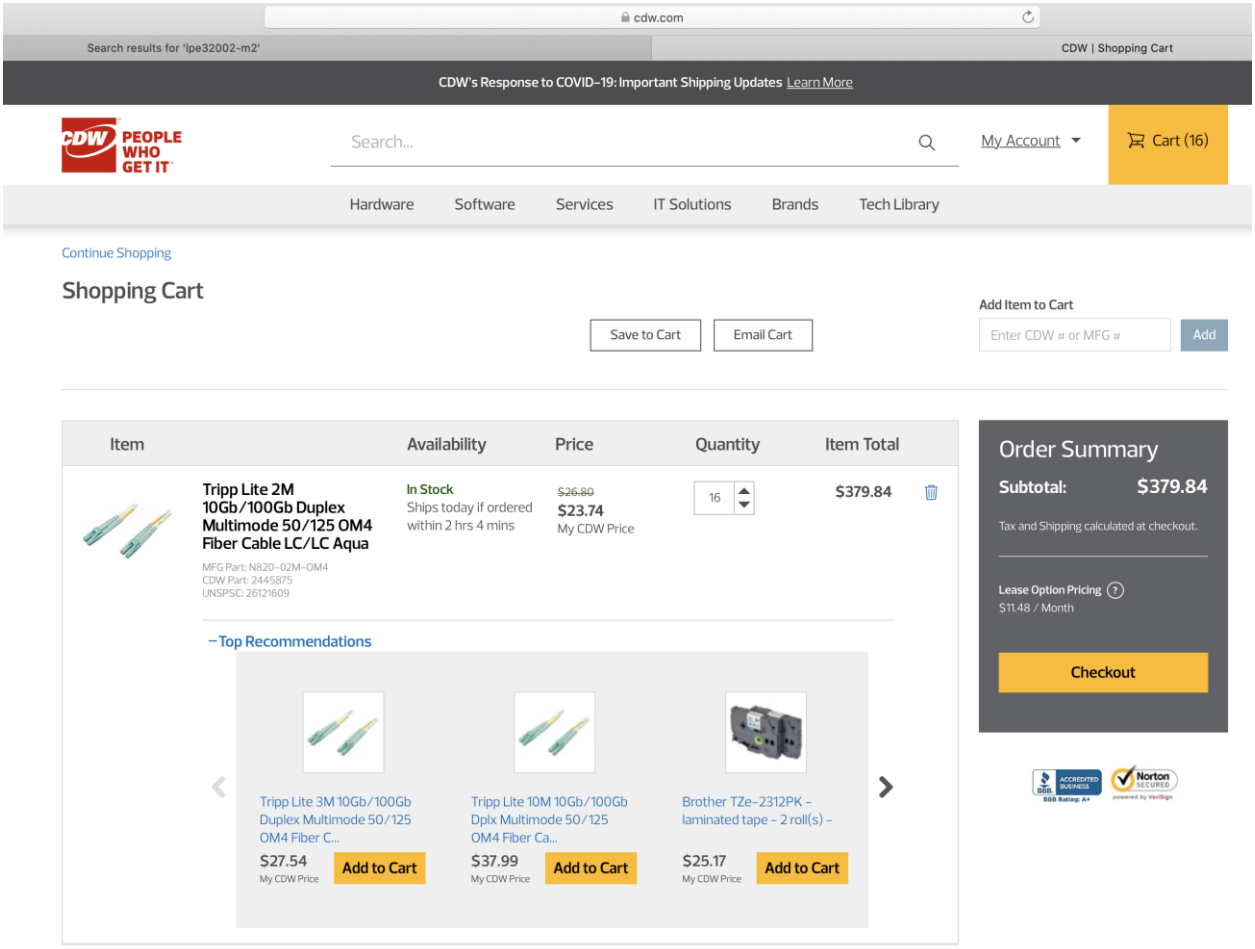
The script phase2.spc2.sh, was invoked to execute SPC-2 Persistence Test Run 2 (read phase) after the required TSC power off/power on cycle.

APPENDIX F: THIRD PARY QUOTATION

All HDD



CDW


cdw.com
Search results for 'lpe32002-m2'
CDW | Shopping Cart
CDW's Response to COVID-19: Important Shipping Updates Learn More
PEOPLE WHO GET IT
Search...
My Account
Cart (16)
Hardware
Software
Services
IT Solutions
Brands
Tech Library
Continue Shopping
Shopping Cart
Save to Cart
Email Cart
Add Item to Cart
Enter CDW # or MFG #
Add
Item
Availability
Price
Quantity
Item Total
Tripp Lite 2M 10Gb/100Gb Duplex Multimode 50/125 OM4 Fiber Cable LC/LC Aqua
MFG Part: N820-02M-OM4
CDW Part: 2445875
UNSPSC: 26121609
In Stock
Ships today if ordered within 2 hrs 4 mins
$26.80
$23.74
My CDW Price
16
$379.84
Order Summary
Subtotal:
$379.84
Tax and Shipping calculated at checkout.
Lease Option Pricing
$11.48 / Month
Checkout
Top Recommendations
Tripp Lite 3M 10Gb/100Gb Duplex Multimode 50/125 OM4 Fiber C...
$27.54
My CDW Price
Add to Cart
Tripp Lite 10M 10Gb/100Gb Dplx Multimode 50/125 OM4 Fiber Ca...
$37.99
My CDW Price
Add to Cart
Brother TZe-2312PK - laminated tape - 2 roll(s) -
$25.17
My CDW Price
Add to Cart