SPC Benchmark 1™

Full Disclosure Report

Lenovo
ThinkSystem DE6000H

SPC-1 V3.8

Submission Identifier: A32008

Submitted For Review: November 9, 2018
First Edition – November 2018

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Benchmark Specification and Glossary

The official SPC Benchmark 1™ (SPC-1™) specification is available on the website of the Storage Performance Council (SPC) at www.spcresults.org.

The SPC-1™ specification contains a glossary of the SPC-1™ terms used in this publication.
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AUDIT CERTIFICATION

Mr. Vincent Kao
Lenovo
7001 Development Drive
Morrisville, NC 27560

November 6, 2018

I verified the SPC Benchmark 1™ (SPC-1™ V3.8) test execution and performance results of the following Tested Storage Product:

**Lenovo ThinkSystem DE6000H**

The results were:

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC-1 IOPS™</td>
<td>460,011</td>
</tr>
<tr>
<td>SPC-1 Price-Performance™</td>
<td>$91.78/SPC-1 KIOPS™</td>
</tr>
<tr>
<td>SPC-1 IOPS™ Response Time</td>
<td>0.411 ms</td>
</tr>
<tr>
<td>SPC-1 Overall Response Time</td>
<td>0.252 ms</td>
</tr>
<tr>
<td>SPC-1 ASU Capacity</td>
<td>9.448 GB</td>
</tr>
<tr>
<td>SPC-1 Space Effectiveness Ratio</td>
<td>NA</td>
</tr>
<tr>
<td>SPC-1 ASU Price</td>
<td>$4.47/GB</td>
</tr>
<tr>
<td>SPC-1 Total System Price</td>
<td>$42,207.87</td>
</tr>
</tbody>
</table>

In my opinion, these performance results were produced in compliance with the SPC requirements for the benchmark.

The testing was executed using the SPC-1 Toolkit Version v3.0.2-1-g823a. The audit process was conducted in accordance with the SPC Policies and met the requirements for the benchmark.

A Letter of Good Faith was issued by the Test Sponsor, stating the accuracy and completeness of the documentation and testing data provided in support of the audit of this result.

A Full Disclosure Report for this result was prepared by InfoSizing, reviewed and approved by the Test Sponsor, and can be found at [www.spcresults.org](http://www.spcresults.org) under the Submission Identifier A32008.
The independent audit process conducted by Infosizing included the verifications of the following items:

- The physical capacity of the data repository;
- The total capacity of the Application Storage Unit (ASU);
- The accuracy of the Benchmark Configuration diagram;
- The tuning parameters used to configure the Benchmark Configuration;
- The Workload Generator commands used to execute the testing;
- The validity and integrity of the test result files;
- The compliance of the results from each performance test;
- The compliance of the results from each persistence test;
- The compliance of the submitted pricing model; and
- The differences between the tested and the priced configuration, if any.

The Full Disclosure Report for this result was prepared in accordance with the disclosure requirements set forth in the specification for the benchmark.

The following benchmark requirements, if any, were waived in accordance with the SPC Policies:

None.

Respectfully Yours,

[Signature]

Doug Johnson, Certified SPC Auditor
LETTER OF GOOD FAITH

Lenovo.com

8001 Development Drive
Morrisville, NC 27560

November 06, 2018

From: Kamran Amini
VP&GM, Data Center Infrastructure
Lenovo

Subject: SPC-1 Letter of Good Faith for Lenovo ThinkSystem DE6000H

Lenovo is the SPC-1 Test Sponsor for the above-listed product. To the best of our knowledge and belief, the required SPC-1 benchmark results and materials we have submitted for the product are complete, accurate, and in full compliance with version 3.6 of the SPC-1 benchmark specification.

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

Sincerely,

Kamran Amini
VP&GM, Data Center Infrastructure
Lenovo
Tel: 919-237-8593
Email: kammin2@lenovo.com

Date: 11/5/2018
SPC Benchmark 1™

EXECUTIVE SUMMARY

LENOVO
THINKSystem DE6000H

<table>
<thead>
<tr>
<th>SPC-1 IOPS™</th>
<th>460,011</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC-1 Price-Performance™</td>
<td>$91.76/SPC-1 KIOPS™</td>
</tr>
<tr>
<td>SPC-1 IOPS™ Response Time</td>
<td>0.411 ms</td>
</tr>
<tr>
<td>SPC-1 Overall Response Time</td>
<td>0.252 ms</td>
</tr>
<tr>
<td>SPC-1 ASU Capacity</td>
<td>9,448 GB</td>
</tr>
<tr>
<td>SPC-1 Space Effectiveness Ratio</td>
<td>NA</td>
</tr>
<tr>
<td>SPC-1 ASU Price</td>
<td>$4.47/GB</td>
</tr>
<tr>
<td>SPC-1 Total System Price</td>
<td>$42,207.87</td>
</tr>
<tr>
<td>Data Protection Level</td>
<td>Protected 1 (RAID-10)</td>
</tr>
<tr>
<td>Physical Storage Capacity</td>
<td>19,200 GB</td>
</tr>
<tr>
<td>Pricing Currency / Target Country</td>
<td>U.S. Dollars / USA</td>
</tr>
</tbody>
</table>

SPC-1 V3.8
SUBMISSION IDENTIFIER: A32008
SUBMITTED FOR REVIEW: NOVEMBER 9, 2018
Benchmark Configuration Diagram

Host Systems

2x Lenovo ThinkSystem SR630 (each with)
2x Intel Xeon Gold 6148 20-Core CPU 2.4 GHz
256 GB Memory

Lenovo ThinkSystem DE6000H

2x Controllers (each with):
16 GB
4x 12 Gb SAS Port (SFF-8644) (Front-end)
2x 12 Gb SAS Port (SFF-8644) (Back-end)
2x 10 Gb iSCSI or 8/16 FC Port
24x 800 GB SSD

Tested Storage Configuration (TSC)

2x Lenovo 430-8e 12Gb SAS External HBA (one per host)

4x 12Gb SAS Cables (2 per host)
Tested Storage Product Description

Lenovo ThinkSystem DE6000H is a scalable, hybrid mid-range storage system that is designed to provide high performance, simplicity, capacity, security, and high availability for medium to large businesses. The ThinkSystem DE6000H delivers enterprise-class storage management capabilities in a performance-optimized system with a wide choice of host connectivity options, flexible drive configurations, and enhanced data management features. The ThinkSystem DE6000H is a perfect fit for a wide range of enterprise workloads, including big data and analytics, video surveillance, technical computing, backup and recovery, and other storage I/O-intensive applications.

ThinkSystem DE6000H models are available in a 2U rack form-factor with 24 small form-factor (2.5-inch SFF) drives (2U24 SFF) or a 4U rack form-factor with 60 LFF drives (4U60 LFF) and include two controllers, each with 16 GB cache for a system total of 32 GB. Universal 10 Gb iSCSI or 8/16 Gb Fibre Channel (FC) ports provide base host connectivity, and the host interface cards provide additional 12 Gb SAS, 10/25 Gb iSCSI, or 8/16/32 Gb FC connections.

The ThinkSystem DE6000H Storage Array scales up to 240 drives with the attachment of Lenovo ThinkSystem DE240S 2U24 SFF and DE600S 4U60 LFF Expansion Enclosures. It also offers flexible drive configurations with the choice of 2.5-inch (SFF) and 3.5-inch (LFF) form factors, 10 K rpm SAS and 7.2 K rpm NL SAS hard disk drives (HDDs), and SAS solid-state drives (SSDs).

For more details, visit:

Priced Storage Configuration Components

<table>
<thead>
<tr>
<th>2 x ThinkSystem 430-8E SAS HBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 x ThinkSystem DE6000H, with:</td>
</tr>
<tr>
<td>2 x Storage Controllers, each with:</td>
</tr>
<tr>
<td>16 GB cache</td>
</tr>
<tr>
<td>2 x 12 Gb Front End Ports</td>
</tr>
<tr>
<td>2 x 12 Gb Back End Connections (not used in this test)</td>
</tr>
<tr>
<td>24 x 800 GB SAS SSD</td>
</tr>
</tbody>
</table>
## Storage Configuration Pricing

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Description</th>
<th>Source</th>
<th>Qty</th>
<th>Unit Price</th>
<th>Ext. Price</th>
<th>Disc.</th>
<th>Disc. Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>7Y78A000WW</td>
<td>Lenovo ThinkSystem DE6000H SAS Hybrid Flash Array SFF</td>
<td>1</td>
<td>1</td>
<td>24,999.00</td>
<td>24,999.00</td>
<td>47%</td>
<td>13,249.47</td>
</tr>
<tr>
<td>4XB7A14105</td>
<td>Lenovo ThinkSystem DE Series 800GB 3DWD 2.5&quot; SSD 2U24</td>
<td>1</td>
<td>24</td>
<td>2,499.00</td>
<td>59,976.00</td>
<td>55%</td>
<td>26,989.20</td>
</tr>
<tr>
<td>00YL847</td>
<td>0.5m External MiniSAS HD 8644/MiniSAS HD 8644 Cable</td>
<td>1</td>
<td>4</td>
<td>49.00</td>
<td>196.00</td>
<td>50%</td>
<td>98.00</td>
</tr>
<tr>
<td>7Y37A01090</td>
<td>ThinkSystem 430-8E SAS HBA</td>
<td>1</td>
<td>2</td>
<td>499.00</td>
<td>998.00</td>
<td>45%</td>
<td>548.90</td>
</tr>
<tr>
<td></td>
<td><strong>Hardware &amp; Software Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>40,885.57</strong></td>
</tr>
<tr>
<td>5PS7A21772</td>
<td>Essential Service - 3Yr 24x7 4Hr Response +YourDrive YourData</td>
<td>1</td>
<td>1</td>
<td>1,889.00</td>
<td>1,889.00</td>
<td>30%</td>
<td>1,322.30</td>
</tr>
<tr>
<td></td>
<td><strong>Support &amp; Maintenance Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>1,322.30</strong></td>
</tr>
<tr>
<td></td>
<td><strong>SPC-1 Total System Price</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>42,207.87</strong></td>
</tr>
<tr>
<td></td>
<td>SPC-1 IOPS™</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>460,011</td>
</tr>
<tr>
<td></td>
<td><strong>SPC-1 Price-Performance™ ($/SPC-1 KIOPS™)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>91.76</strong></td>
</tr>
<tr>
<td></td>
<td>SPC-1 ASU Capacity (GB)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9,448</td>
</tr>
<tr>
<td></td>
<td><strong>SPC-1 ASU Price ($/GB)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>4.47</strong></td>
</tr>
</tbody>
</table>

**Discount Details:** The discounts shown are based on the storage capacity purchased and are generally available.

**Availability Date:** November 9, 2018.
**Response Time and Throughput Graph**

![Graph showing response time and throughput](image)

### Contact Information

**Test Sponsor Primary Contact**
- Lenovo – [www.lenovo.com](http://www.lenovo.com)
- Vincent Kao – vkao@lenovo.com

**SPC Auditor**
- InfoSizing – [www.sizing.com](http://www.sizing.com)
- Doug Johnson – doug@sizing.com

### Revision Information

<table>
<thead>
<tr>
<th>SPC Benchmark 1™ Revision</th>
<th>V3.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC-1 Workload Generator Revision</td>
<td>v3.0.2-1-g823a</td>
</tr>
<tr>
<td>Publication Revision History</td>
<td>Initial Publication</td>
</tr>
</tbody>
</table>
Benchmark Configuration and Tested Storage Configuration

The following diagram illustrates the Benchmark Configuration (BC), including the Tested Storage Configuration (TSC) and the Host System(s).

### Storage Network Configuration

The Benchmark Configuration utilized direct-attached storage.
Host System and Tested Storage Configuration Components

The following table lists the components of the Host System(s) and the TSC.

<table>
<thead>
<tr>
<th>Host Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 x ThinkSystem SR630, each with:</td>
</tr>
<tr>
<td>2 x Intel Xeon Gold 6148 (2.40 GHz, 20-Core, 27.5 MB L3)</td>
</tr>
<tr>
<td>256 GB Main Memory</td>
</tr>
<tr>
<td>Windows Server 2012 Datacenter Edition</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tested Storage Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 x ThinkSystem 430-8E SAS HBA</td>
</tr>
<tr>
<td>1 x ThinkSystem DE6000H, with:</td>
</tr>
<tr>
<td>2 x Storage Controllers, each with:</td>
</tr>
<tr>
<td>16 GB cache</td>
</tr>
<tr>
<td>2 x 12 Gb Front End Ports</td>
</tr>
<tr>
<td>2 x 12 Gb Back End Connections (not used in this test)</td>
</tr>
<tr>
<td>24 x 800 GB SAS SSD</td>
</tr>
</tbody>
</table>

Differences Between Tested and Priced Storage Configurations

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

Component Changes in Revised Full Disclosure Report

The following table outlines component changes that were made in revisions to this Full Disclosure Report.

<table>
<thead>
<tr>
<th>Original Component</th>
<th>Revised Component</th>
<th>Description of Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>n/a</td>
<td>n/a</td>
<td>Initial submission</td>
</tr>
</tbody>
</table>
Benchmark Configuration Creation Process

Customer Tuning Parameters and Options

All the customer tuning parameters and options that have been altered from their default values for this benchmark are included in Appendix C and in the Supporting Files (see Appendix A).

Tested Storage Configuration Creation

A detailed description of how the logical representation of the TSC was created is included in Appendix D and in the Supporting Files (see Appendix A).

Tested Storage Configuration Inventory

An inventory of the components in the TSC, as seen by the Benchmark Configuration, is included in Appendix E and in the Supporting Files (see Appendix A).

Workload Generator Storage Configuration

The SPC-1 Workload Generator storage configuration commands and parameters used to invoke the execution of the tests are included in Appendix F and in the Supporting Files (see Appendix A).

Logical Volume Capacity and Application Storage Unit Mapping

The following table details the capacity of the Application Storage Units (ASUs) and how they are mapped to logical volumes (LVs). All capacities are reported in GB.

<table>
<thead>
<tr>
<th>ASU</th>
<th>LV per ASU</th>
<th>LV Capacity</th>
<th>Used per LV</th>
<th>Total per ASU</th>
<th>% ASU Capacity</th>
<th>Optimized*</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASU-1</td>
<td>1</td>
<td>4,251.7</td>
<td>4,251.7</td>
<td>4,251.7</td>
<td>45.0%</td>
<td>No</td>
</tr>
<tr>
<td>ASU-2</td>
<td>1</td>
<td>4,251.7</td>
<td>4,251.7</td>
<td>4,251.7</td>
<td>45.0%</td>
<td>No</td>
</tr>
<tr>
<td>ASU-3</td>
<td>1</td>
<td>944.6</td>
<td>944.6</td>
<td>944.6</td>
<td>10.0%</td>
<td>No</td>
</tr>
</tbody>
</table>

*See Space Optimization Techniques

Physical Storage Capacity and Utilization

The following table details the Physical Capacity of the storage devices and the Physical Capacity Utilization (percentage of Total Physical Capacity used) in support of hosting the ASUs. All capacities are reported in GB.

<table>
<thead>
<tr>
<th>Devices</th>
<th>Count</th>
<th>Physical Capacity</th>
<th>Total Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAS SSD</td>
<td>24</td>
<td>800.0</td>
<td>19,200.0</td>
</tr>
<tr>
<td>Total Physical Capacity</td>
<td></td>
<td></td>
<td>19,200</td>
</tr>
<tr>
<td>Physical Capacity Utilization</td>
<td></td>
<td></td>
<td>49.21%</td>
</tr>
</tbody>
</table>

Data Protection

The data protection level used for all LVs was Protected 1 (RAID-10), which was accomplished by configuring 2 pools of 12 drives each into 6 RAID-10 arrays.
BENCHMARK EXECUTION RESULTS
This portion of the Full Disclosure Report documents the results of the various SPC-1 Tests, Test Phases, and Test Runs.

Benchmark Execution Overview

Workload Generator Input Parameters
The SPC-1 Workload Generator commands and input parameters for the Test Phases are presented in the Supporting Files (see Appendix A).

Primary Metrics Test Phases
The benchmark execution consists of the Primary Metrics Test Phases, including the Test Phases SUSTAIN, RAMPD_100 to RAMPD_10, RAMPU_50 to RAMPU_100, RAMP_0, REPEAT_1 and REPEAT_2.

Each Test Phase starts with a transition period followed by a Measurement Interval (MI).

Measurement Intervals by Test Phase Graph
The following graph presents the average IOPS and the average Response Times measured over the MI of each Test Phase.

Exception and Waiver
None.
SUSTAIN Test Phase

SUSTAIN – Results File

The results file generated during the execution of the SUSTAIN Test Phase is included in the Supporting Files (see Appendix A) as follows:

- SPC1_METRICS_0_Raw_Results.xlsx

SUSTAIN – Execution Times

<table>
<thead>
<tr>
<th>Interval</th>
<th>Start Date &amp; Time</th>
<th>End Date &amp; Time</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement Interval</td>
<td>25-Oct-18 05:01:37</td>
<td>25-Oct-18 13:01:38</td>
<td>8:00:01</td>
</tr>
</tbody>
</table>

SUSTAIN – Throughput Graph

Throughput Graph (SUSTAIN @ 460,000 IOPS)
**SUSTAIN – Response Time Graph**

![Response Time Graph](image)

**SUSTAIN – Data Rate Graph**

![Data Rate Graph](image)
SUSTAIN – Response Time Frequency Graph

The following table lists the targeted intensity multiplier (Defined), the measured intensity multiplier (Measured) for each I/O stream, its coefficient of variation (Variation), and the percentage of difference (Difference) between Defined and Measured.

<table>
<thead>
<tr>
<th></th>
<th>ASU1-1</th>
<th>ASU1-2</th>
<th>ASU1-3</th>
<th>ASU1-4</th>
<th>ASU2-1</th>
<th>ASU2-2</th>
<th>ASU2-3</th>
<th>ASU3-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defined</td>
<td>0.0350</td>
<td>0.2810</td>
<td>0.0700</td>
<td>0.2100</td>
<td>0.0180</td>
<td>0.0700</td>
<td>0.0350</td>
<td>0.2810</td>
</tr>
<tr>
<td>Measured</td>
<td>0.0350</td>
<td>0.2810</td>
<td>0.0700</td>
<td>0.2100</td>
<td>0.0180</td>
<td>0.0700</td>
<td>0.0350</td>
<td>0.2810</td>
</tr>
<tr>
<td>Variation</td>
<td>0.0010</td>
<td>0.0003</td>
<td>0.0007</td>
<td>0.0004</td>
<td>0.0014</td>
<td>0.0007</td>
<td>0.0010</td>
<td>0.0003</td>
</tr>
<tr>
<td>Difference</td>
<td>0.006%</td>
<td>0.000%</td>
<td>0.003%</td>
<td>0.002%</td>
<td>0.001%</td>
<td>0.005%</td>
<td>0.000%</td>
<td>0.004%</td>
</tr>
</tbody>
</table>
RAMPD_100 Test Phase

RAMPD_100 – Results File

The results file generated during the execution of the RAMPD_100 Test Phase is included in the Supporting Files (see Appendix A) as follows:

- SPC1_METRICS_0_Raw_Results.xlsx

RAMPD_100 – Execution Times

<table>
<thead>
<tr>
<th>Interval</th>
<th>Start Date &amp; Time</th>
<th>End Date &amp; Time</th>
<th>Duration</th>
</tr>
</thead>
</table>

RAMPD_100 – Throughput Graph
RAMPD_100 – Response Time Graph

![Response Time Graph (RampD_100 @ 460,000 IOPS)]

RAMPD_100 – Data Rate Graph

![Data Rate Graph (RampD_100 @ 460,000 IOPS)]
RAMPD_100 – Response Time Frequency Graph

Response Time Frequency Graph
(RampD_100 @ 460,000 IOPS)

RAMPD_100 – Intensity Multiplier

The following table lists the targeted intensity multiplier (Defined), the measured intensity multiplier (Measured) for each I/O stream, its coefficient of variation (Variation), and the percentage of difference (Difference) between Defined and Measured.

<table>
<thead>
<tr>
<th>ASU</th>
<th>Defined</th>
<th>Measured</th>
<th>Variation</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0350</td>
<td>0.0350</td>
<td>0.0010</td>
<td>0.012%</td>
</tr>
<tr>
<td>2</td>
<td>0.2810</td>
<td>0.2810</td>
<td>0.0002</td>
<td>0.007%</td>
</tr>
<tr>
<td>3</td>
<td>0.0700</td>
<td>0.0700</td>
<td>0.0007</td>
<td>0.017%</td>
</tr>
<tr>
<td>4</td>
<td>0.2100</td>
<td>0.2100</td>
<td>0.0004</td>
<td>0.012%</td>
</tr>
<tr>
<td>1</td>
<td>0.0180</td>
<td>0.0180</td>
<td>0.0012</td>
<td>0.055%</td>
</tr>
<tr>
<td>2</td>
<td>0.0700</td>
<td>0.0700</td>
<td>0.0008</td>
<td>0.020%</td>
</tr>
<tr>
<td>3</td>
<td>0.0180</td>
<td>0.0180</td>
<td>0.0010</td>
<td>0.028%</td>
</tr>
<tr>
<td>3</td>
<td>0.0350</td>
<td>0.0350</td>
<td>0.0002</td>
<td>0.017%</td>
</tr>
<tr>
<td>1</td>
<td>0.2810</td>
<td>0.2810</td>
<td>0.0002</td>
<td>0.017%</td>
</tr>
</tbody>
</table>

RAMPD_100 – I/O Request Summary

| I/O Requests Completed in the Measurement Interval | 276,004,938 |
| I/O Requests Completed with Response Time <= 30 ms | 276,004,937 |
| I/O Requests Completed with Response Time > 30 ms | 1 |
Response Time Ramp Test

Response Time Ramp Test – Results File

The results file generated during the execution of the Response Time Ramp Test is included in the Supporting Files (see Appendix A) as follows:

- SPC1_METRICS_0_Raw_Results.xlsx

Response Time Ramp Test – Phases

The Response Time Ramp Test is comprised of 11 Test Phases, including six Ramp-Down Phases (executed at 100%, 95%, 90%, 80%, 50%, and 10% of the Business Scaling Unit) and five Ramp-Up Phases (executed at 50%, 80%, 90%, 95%, and 100% of the Business Scaling Unit).

Response Time Ramp Test – Average Throughput Graph

![Average Throughput Graph (Response Time Ramp Test)]
Response Time Ramp Test – Average Response Time Graph

Response Time Ramp Test – RAMPD_10 Response Time Graph
Repeatability Test

Repeatability Test Results File

The results file generated during the execution of the Repeatability Test is included in the Supporting Files (see Appendix A) as follows:

- SPC1_METRICS_0_Raw_Results.xlsx

Repeatability Test Results

The throughput measurements for the Response Time Ramp Test (RAMPD) and the Repeatability Test Phases (REPEAT_1 and REPEAT_2) are listed in the table below.

<table>
<thead>
<tr>
<th>Test Phase</th>
<th>100% IOPS</th>
<th>10% IOPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAMPD</td>
<td>460,012.0</td>
<td>46,016.2</td>
</tr>
<tr>
<td>REPEAT_1</td>
<td>460,056.1</td>
<td>46,013.1</td>
</tr>
<tr>
<td>REPEAT_2</td>
<td>460,076.1</td>
<td>45,999.9</td>
</tr>
</tbody>
</table>

REPEAT_1_100 – Throughput Graph
**BENCHMARK EXECUTION RESULTS**

Repeatability Tests

---

**REPEAT_1_100 – Response Time Graph**

![Response Time Graph (Repeat_1_100 @ 460,000 IOPS)](image)

**REPEAT_2_100 – Throughput Graph**

![Throughput Graph (Repeat_2_100 @ 460,000 IOPS)](image)
Repeatability Test – Intensity Multiplier

The following tables list the targeted intensity multiplier (Defined), the measured intensity multiplier (Measured) for each I/O stream, its coefficient of variation (Variation), and the percent of difference (Difference) between Defined and Measured.

**REPEAT_1_100 Test Phase**

<table>
<thead>
<tr>
<th></th>
<th>ASU1-1</th>
<th>ASU1-2</th>
<th>ASU1-3</th>
<th>ASU1-4</th>
<th>ASU2-1</th>
<th>ASU2-2</th>
<th>ASU2-3</th>
<th>ASU3-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defined</td>
<td>0.0350</td>
<td>0.2810</td>
<td>0.0700</td>
<td>0.2100</td>
<td>0.0180</td>
<td>0.0700</td>
<td>0.0350</td>
<td>0.2810</td>
</tr>
<tr>
<td>Measured</td>
<td>0.0350</td>
<td>0.2810</td>
<td>0.0700</td>
<td>0.2100</td>
<td>0.0180</td>
<td>0.0700</td>
<td>0.0350</td>
<td>0.2810</td>
</tr>
<tr>
<td>Variation</td>
<td>0.0010</td>
<td>0.0003</td>
<td>0.0004</td>
<td>0.0003</td>
<td>0.0011</td>
<td>0.0004</td>
<td>0.0009</td>
<td>0.0004</td>
</tr>
<tr>
<td>Difference</td>
<td>0.010%</td>
<td>0.013%</td>
<td>0.005%</td>
<td>0.009%</td>
<td>0.017%</td>
<td>0.015%</td>
<td>0.030%</td>
<td>0.005%</td>
</tr>
</tbody>
</table>

**REPEAT_2_100 Test Phase**

<table>
<thead>
<tr>
<th></th>
<th>ASU1-1</th>
<th>ASU1-2</th>
<th>ASU1-3</th>
<th>ASU1-4</th>
<th>ASU2-1</th>
<th>ASU2-2</th>
<th>ASU2-3</th>
<th>ASU3-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defined</td>
<td>0.0350</td>
<td>0.2810</td>
<td>0.0700</td>
<td>0.2100</td>
<td>0.0180</td>
<td>0.0700</td>
<td>0.0350</td>
<td>0.2810</td>
</tr>
<tr>
<td>Measured</td>
<td>0.0350</td>
<td>0.2810</td>
<td>0.0700</td>
<td>0.2100</td>
<td>0.0180</td>
<td>0.0700</td>
<td>0.0350</td>
<td>0.2810</td>
</tr>
<tr>
<td>Variation</td>
<td>0.0011</td>
<td>0.0004</td>
<td>0.0007</td>
<td>0.0002</td>
<td>0.0013</td>
<td>0.0006</td>
<td>0.0012</td>
<td>0.0003</td>
</tr>
<tr>
<td>Difference</td>
<td>0.075%</td>
<td>0.003%</td>
<td>0.047%</td>
<td>0.001%</td>
<td>0.022%</td>
<td>0.031%</td>
<td>0.017%</td>
<td>0.009%</td>
</tr>
</tbody>
</table>
Space Optimization Techniques

**Description of Utilized Techniques**

The TSC did not use any space optimization techniques.

**Physical Free Space Metrics**

The following table lists the Physical Free Space as measured at each of the required points during test execution. If space optimization techniques were not used, “NA” is reported.

<table>
<thead>
<tr>
<th>Physical Free Space Measurement</th>
<th>Free Space (GB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>After Logical Volume Creation</td>
<td>NA</td>
</tr>
<tr>
<td>After ASU Pre-Fill</td>
<td>NA</td>
</tr>
<tr>
<td>After Repeatability Test Phase</td>
<td>NA</td>
</tr>
</tbody>
</table>

**Space Optimization Metrics**

The following table lists the required space optimization metrics. If space optimization techniques were not used, “NA” is reported.

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC-1 Space Optimization Ratio</td>
<td>NA</td>
</tr>
<tr>
<td>SPC-1 Space Effectiveness Ratio</td>
<td>NA</td>
</tr>
</tbody>
</table>
Data Persistence Test

Data Persistence Test Results File

The results files generated during the execution of the Data Persistence Test is included in the Supporting Files (see Appendix A) as follows:

- SPC1_PERSIST_1_0_Raw_Results.xlsx
- SPC1_PERSIST_2_0_Raw_Results.xlsx

Data Persistence Test Execution

The Data Persistence Test was executed using the following sequence of steps:

- The PERSIST_1_0 Test Phase was executed to completion.
- The Benchmark Configuration was taken through an orderly shutdown process and powered off.
- The Benchmark Configuration was powered on and taken through an orderly startup process.
- The PERSIST_2_0 Test Phase was executed to completion.

Data Persistence Test Results

<table>
<thead>
<tr>
<th>Data Persistence Test Phase: Persist1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Number of Logical Blocks Written</td>
<td>94,501,580</td>
</tr>
<tr>
<td>Total Number of Logical Blocks Verified</td>
<td>90,748,315</td>
</tr>
<tr>
<td>Total Number of Logical Blocks Overwritten</td>
<td>3,753,265</td>
</tr>
<tr>
<td>Total Number of Logical Blocks that Failed Verification</td>
<td>0</td>
</tr>
<tr>
<td>Time Duration for Writing Test Logical Blocks (sec.)</td>
<td>601</td>
</tr>
<tr>
<td>Size in bytes of each Logical Block</td>
<td>8,192</td>
</tr>
<tr>
<td>Number of Failed I/O Requests in the process of the Test</td>
<td>0</td>
</tr>
</tbody>
</table>

Committed Data Persistence Implementation

Each controller mirrors the cache to the other controller. In the case that one controller fails, the other controller can take over ownership of the failed controller's volumes and cached data. The controller has the persistent cache backup flash in which cache contents can be stored for an indefinite period of time. The controller also has a battery with enough capacity to let it write the full contents of the cache memory to the persistent cache backup flash in the event of a power failure.
## APPENDIX A: SUPPORTING FILES

The following table details the content of the Supporting Files provided as part of this Full Disclosure Report.

<table>
<thead>
<tr>
<th>File Name</th>
<th>Description</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>/SPC1_RESULTS</td>
<td>Data reduction worksheets</td>
<td>root</td>
</tr>
<tr>
<td>SPC1_INIT_0_Raw_Results.xlsx</td>
<td>Raw results for INIT Test Phase</td>
<td>/SPC1_RESULTS</td>
</tr>
<tr>
<td>SPC1_METRICS_0_Quick_Look.xlsx</td>
<td>Quick Look Test Run Overview</td>
<td>/SPC1_RESULTS</td>
</tr>
<tr>
<td>SPC1_METRICS_0_Raw_Results.xlsx</td>
<td>Raw results for Primary Metrics Test</td>
<td>/SPC1_RESULTS</td>
</tr>
<tr>
<td>SPC1_METRICS_0_Summary_Results.xlsx</td>
<td>Primary Metrics Summary</td>
<td>/SPC1_RESULTS</td>
</tr>
<tr>
<td>SPC1_PERSIST_1_0_Raw_Results.xlsx</td>
<td>Raw results for PERSIST1 Test Phase</td>
<td>/SPC1_RESULTS</td>
</tr>
<tr>
<td>SPC1_PERSIST_2_0_Raw_Results.xlsx</td>
<td>Raw results for PERSIST2 Test Phase</td>
<td>/SPC1_RESULTS</td>
</tr>
<tr>
<td>SPC1_Run_Set_Overview.xlsx</td>
<td>Run Set Overview Worksheet</td>
<td>/SPC1_RESULTS</td>
</tr>
<tr>
<td>SPC1_VERIFY_0_Raw_Results.xlsx</td>
<td>Raw results for first VERIFY Test Phase</td>
<td>/SPC1_RESULTS</td>
</tr>
<tr>
<td>SPC1_VERIFY_1_Raw_Results.xlsx</td>
<td>Raw results for second VERIFY Test Phase</td>
<td>/SPC1_RESULTS</td>
</tr>
<tr>
<td>/C_Tuning</td>
<td>Tuning parameters and options</td>
<td>root</td>
</tr>
<tr>
<td>storage-array-configuration_1024.cfg</td>
<td>Change array default settings</td>
<td>/C_Tuning</td>
</tr>
<tr>
<td>/D_Creation</td>
<td>Storage configuration creation</td>
<td>root</td>
</tr>
<tr>
<td>storage-array-configuration_1024.cfg</td>
<td>Create Volume Groups, Volumes and Mapping</td>
<td>/D_Creation</td>
</tr>
<tr>
<td>/E_Inventory</td>
<td>Configuration inventory</td>
<td>root</td>
</tr>
<tr>
<td>/DE6000H_BEFORE_Run</td>
<td>Configuration before the run</td>
<td>/E_Inventory</td>
</tr>
<tr>
<td>/DE6000H_AFTER_Run</td>
<td>Configuration after the run</td>
<td>/E_Inventory</td>
</tr>
<tr>
<td>/F_Generator</td>
<td>Workload generator</td>
<td>Root</td>
</tr>
<tr>
<td>SPC1.asu</td>
<td>ASU configuration file</td>
<td>/F_generator</td>
</tr>
<tr>
<td>DE6000_full_run.bat</td>
<td>Execute all test phases exclude PERSIST_2</td>
<td>/F_generator</td>
</tr>
<tr>
<td>SPC1_METRICS</td>
<td>12-hour RAMP for SUSTAIN</td>
<td>/F_generator</td>
</tr>
<tr>
<td>slave.HST</td>
<td>Dual hosts</td>
<td>/F_generator</td>
</tr>
</tbody>
</table>
APPENDIX B: THIRD PARTY QUOTATION

All components are directly available through the Test Sponsor.
APPENDIX C: TUNING PARAMETERS AND OPTIONS

Array tuning options could be set by script (storage-array-configuration_1024.cfg) or ThinkSystem System Manager GUI (shown here).

1. **Change Cache Settings**

   Settings > System > Additional Settings > Change Cache Settings

   ![Change Cache Settings](image)

   - Start demand cache flushing
   - Cache block size

2. **Disable Auto Load Balancing**

   Settings > System > Additional Settings > Enable/Disable Automatic Load Balancing

   Click Yes to confirm disabling

3. **Disable Host Connectivity Report**

   Settings > System > Additional Settings > Enable/Disable Host Connectivity Reporting

   Click Yes to confirm disabling

4. **Disable AutoSupport**

   Support > Support Center > AutoSupport > Enable/Disable AutoSupport Features
APPENDIX D: STORAGE CONFIGURATION CREATION

Storage Array Configuration could be set by script (storage-array-configuration_1024.cfg) or ThinkSystem System Manager GUI (shown here).

1. Create Two RAID 1 Volume Groups (VG0 and VG1)

   Storage > Pools & Volume Groups > Create > Volume group

   - Create Two RAID 1 Volume Groups (VG0 and VG1)

2. Create Volumes

   Storage > Volumes > Create > Volume
3. Set Volume Ownership

Storage > Volumes > More > Change ownership

Change Volume Ownership

Changing a volume’s preferred controller while an application is using it will cause I/O errors UNLESS:
- The volumes are not in use, or
- There is a multi-path driver installed on all hosts using these volumes.

Filter

Volume Ownership

<table>
<thead>
<tr>
<th>Volume</th>
<th>Preferred Owner</th>
<th>Current Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>LUN0</td>
<td>Controller B</td>
<td>Controller B</td>
</tr>
<tr>
<td>LUN1</td>
<td>Controller B</td>
<td>Controller B</td>
</tr>
<tr>
<td>LUN2</td>
<td>Controller B</td>
<td>Controller B</td>
</tr>
<tr>
<td>LUN3</td>
<td>Controller A</td>
<td>Controller A</td>
</tr>
</tbody>
</table>

Type CHANGE OWNERSHIP to confirm that you want to perform this operation.

Change ownership

Change Ownership  Cancel
4. Set Volume cache settings

Storage > Volumes > More > Change cache settings

![Change Cache Settings Diagram]
5. Change Media Scan settings

Storage > Volumes > More > Change media scan settings

Note: Drive Media Scan is an important background maintenance task. Typical best-practice in production environments is to schedule it for regular intervals during non-peak hours. Drive Media Scan was changed to a long interval during this test as an “ease of benchmarking” practice to avoid scheduling issues.
6. Create Host

**Storage > Hosts > Create > Host**

![Create Host Form](image)

7. Map six volumes to Host

**Storage > Hosts > Assign Volumes**

![Assign Volumes Form](image)
8. Create Windows Striped Volumes
   a. On one of the hosts: make volumes Online -> Initialize Disk -> convert to Dynamic Disk
b. New Windows Striped Volumes

Use Windows Disk Management to create the striped ASU volumes

<table>
<thead>
<tr>
<th>&quot;Physical Disk&quot;</th>
<th>LUN #</th>
<th>ASU</th>
<th>Drive Letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 and 4</td>
<td>0 and 3</td>
<td>ASU-1</td>
<td>I:</td>
</tr>
<tr>
<td>2 and 5</td>
<td>1 and 4</td>
<td>ASU-2</td>
<td>J:</td>
</tr>
<tr>
<td>3 and 6</td>
<td>2 and 5</td>
<td>ASU-3</td>
<td>K:</td>
</tr>
</tbody>
</table>
APPENDIX D
Storage Configuration Creation

New Striped Volume

Select Disks
You can select the disks and set the disk size for this volume.

Select the disks you want to use, and then click Add.

Available:
Disk 2 2027390 MB
Disk 3 450430 MB
Disk 4 2027390 MB
Disk 6 450430 MB

Selected:
Disk 1 2027390 MB
Disk 4 2027390 MB

Total volume size in megabytes (MB):
4054780

Maximum available space in MB:
2027390

Select the amount of space in MB:
2027390

New Striped Volume

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

- Assign the following drive letter:

- Mount in the following empty NTFS folder:

- Do not assign a drive letter or drive path

< Back Next > Cancel
c. Repeat steps a. and b. for drives J; and K;
d. One the second host, Rescan Disks in Disk Management
e. Make volumes online and import foreign disks
APPENDIX E: CONFIGURATION INVENTORY

The Test Storage Configuration was collected before and after the test phases. Use ThinkSystem System Manager GUI.

Collect DE6000H info:

Support > Support Center > Support Resources > Launch detailed storage array information > Storage Array Profile

The outputs of the commands were in the log files (see Appendix A):

/DE6000H_BEFORE_Run
/DE6000H_AFTER_Run
APPENDIX F: WORKLOAD GENERATOR

The ASU Definition file and host parameter file are included in the Supporting Files.

**SPC1.asu**
OFFSET=0
SIZE=0
ASU=1
DEVICE=\\.\i:
ASU=2
DEVICE=\\.\j:
ASU=3
DEVICE=\\.\k:

**slave.HST**
PORT=1001
WEIGHT=1
STORAGE=SPC1.asu
HOST=localhost

PORT=1002
WEIGHT=1
STORAGE=SPC1.asu
HOST=localhost

PORT=1003
WEIGHT=1
STORAGE=SPC1.asu
HOST=localhost

PORT=1004
WEIGHT=1
STORAGE=SPC1.asu
HOST=localhost

PORT=1005
WEIGHT=1
STORAGE=SPC1.asu
HOST=localhost

PORT=1006
WEIGHT=1
STORAGE=SPC1.asu
HOST=localhost

LOGIN=Administrator
PASSWORD=Teamw0rk
EXEC=spc1_v3.0.2.exe
CONFIG=C:\SPC\v302
OUTPUT=C:\SPC\v302
WINDOWS=Y
PORT=2001
WEIGHT=1
STORAGE=SPC1.asu
HOST=10.241.68.190

LOGIN=Administrator
PASSWORD=Teamwork
EXEC=spc1_v3.0.2.exe
CONFIG=C:\SPC\v302
OUTPUT=C:\SPC\v302
WINDOWS=Y
PORT=2002
WEIGHT=1
STORAGE=SPC1.asu
HOST=10.241.68.190

LOGIN=Administrator
PASSWORD=Teamwork
EXEC=spc1_v3.0.2.exe
CONFIG=C:\SPC\v302
OUTPUT=C:\SPC\v302
WINDOWS=Y
PORT=2003
WEIGHT=1
STORAGE=SPC1.asu
HOST=10.241.68.190

LOGIN=Administrator
PASSWORD=Teamwork
EXEC=spc1_v3.0.2.exe
CONFIG=C:\SPC\v302
OUTPUT=C:\SPC\v302
WINDOWS=Y
PORT=2004
WEIGHT=1
STORAGE=SPC1.asu
HOST=10.241.68.190

LOGIN=Administrator
PASSWORD=Teamwork
EXEC=spc1_v3.0.2.exe
CONFIG=C:\SPC\v302
OUTPUT=C:\SPC\v302
WINDOWS=Y
PORT=2005
WEIGHT=1
STORAGE=SPC1.asu
HOST=10.241.68.190

LOGIN=Administrator
PASSWORD=Teamwork
EXEC=spc1_v3.0.2.exe
CONFIG=C:\SPC\v302
OUTPUT=C:\SPC\v302
WINDOWS=Y
PORT=2006
WEIGHT=1
STORAGE=SPC1.asu
HOST=10.241.68.190

SPC Benchmark 1™ V3.8
Lenovo
ThinkSystem DE6000H
The full-run of the test used the script `DE6000_full_run.bat` and manually invoke the PERSIST_2 after the TSC was restarted.

**DE6000_full_run.bat**

```batch
set IOPS=460000
set INIT_IOPS=1200
set PERSIST_IOPS=115000
set OUTPUT=DE6000H_1024
set STORAGE=SPC1.asu
set SPC1=spc1_v3.0.2

%SPC1% -run SPC1_INIT -output %OUTPUT% -iops %INIT_IOPS% -storage %STORAGE%
%SPC1% -run SPC1_VERIFY -output %OUTPUT% -iops 100 -storage %STORAGE%
%SPC1% -run SPC1_METRICS -output %OUTPUT% -iops %IOPS% -storage %STORAGE% -master slave.HST
%SPC1% -run SPC1_VERIFY -output %OUTPUT% -iops 100 -storage %STORAGE%
%SPC1% -run SPC1_PERSIST_1 -output %OUTPUT% -iops %PERSIST_IOPS% -storage %STORAGE%

echo "Now Restart the TSC and run:"
echo "DE6000run > .\SPC1_v3.0.2 -run SPC1_PERSIST_2 -output DE6000H_1024 -iops 115000 -storage SPC1.asu"
```

Manually invoke PERSIST_2:

```bash
.\SPC1_v3.0.2 -run SPC1_PERSIST_2 -output DE6000H_1024 -iops 115000 -storage SPC1.asu
```