SPC Benchmark 1™

Full Disclosure Report

Inspur Electronic Information Industry Co. Ltd.

Inspur HF18000G5-I

SPC-1™ v3.10.0

Submission Identifier: A32023

Submitted For Review: August 16, 2021
First Edition – August 2021

THE INFORMATION CONTAINED IN THIS DOCUMENT IS DISTRIBUTED ON AN AS IS BASIS WITHOUT ANY WARRANTY EITHER EXPRESS OR IMPLIED. The use of this information or the implementation of any of these techniques is the customer’s responsibility and depends on the customer’s ability to evaluate and integrate them into the customer’s operational environment. While each item has been reviewed by Inspur Electronic Information Industry Co. Ltd. for accuracy in a specific situation, there is no guarantee that the same or similar results will be obtained elsewhere. Customers attempting to adapt these techniques to their own environment do so at their own risk.

This publication was produced in the United States. Inspur Electronic Information Industry Co. Ltd. may not offer the products, services, or features discussed in this document in other countries, and the information is subject to change with notice. Consult your local Inspur Electronic Information Industry Co. Ltd. representative for information on products and services available in your area.

© Copyright Inspur Electronic Information Industry Co. Ltd. 2021. All rights reserved.

Permission is hereby granted to publicly disclose and reproduce this document, in whole or in part, provided the copyright notice as printed above is set forth in full text on the title page of each item reproduced.

Trademarks

SPC Benchmark 1, SPC-1, SPC-1 IOPS, SPC-1 LRT and SPC-1 Price-Performance are trademarks of the Storage Performance Council.

Inspur, the Inspur logo, and HF18000G5-I are trademarks or registered trademarks of Inspur Electronic Information Industry Co. Ltd. in the United States and other countries. All other brands, trademarks, and product names are the property of their respective owners.

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.
# Table of Contents

Audit Certification........................................................................................................... 4  
Letter of Good Faith........................................................................................................ 6  
Executive Summary ........................................................................................................ 7  
Pricing Details .................................................................................................................. 8  
  Differences Between Tested and Priced Storage Configurations ................................ 8  
Publication Details .......................................................................................................... 9  
  Contact Information ..................................................................................................... 9  
  Revision Information .................................................................................................... 9  
  Anomalies, Exceptions, Waivers .................................................................................. 9  
Configuration Information ............................................................................................... 10  
  Tested Storage Product Description ........................................................................... 10  
  Host System and Tested Storage Configuration Components .................................... 10  
  Configuration Diagrams .............................................................................................. 11  
  Benchmark Configuration Creation Process ............................................................... 12  
  Space Optimization Information ................................................................................ 13  
Benchmark Execution Results ......................................................................................... 14  
  Benchmark Execution Overview .................................................................................. 14  
  ASU Pre-Fill ................................................................................................................ 15  
  SUSTAIN Test Phase .................................................................................................... 16  
  RAMPD_100 Test Phase .............................................................................................. 19  
  Response Time Ramp Test ........................................................................................... 22  
  Repeatability Test ........................................................................................................ 24  
  Data Persistence Test ................................................................................................... 27  
Appendix A: Supporting Files .......................................................................................... 28  
Appendix B: Third Party Quotation ................................................................................ 29  
Appendix C: Tuning Parameters and Options ................................................................. 30  
Appendix D: Storage Configuration Creation ................................................................. 31  
Appendix E: Configuration Inventory .............................................................................. 32  
Appendix F: Workload Generator .................................................................................. 33
AUDIT CERTIFICATION

Xudong Wang
Inspur Electronic Information Industry Co. Ltd.
NO.1035, Inspur Road, Jinan
People’s Republic of China

August 16, 2021

I verified the SPC Benchmark 1™ (SPC-1™ v3.10.0) test execution and performance results of the following Tested Storage Product:

**Inspur HF18000G5-I**

The results were:

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC-1 IOPS™</td>
<td>23,001,502</td>
</tr>
<tr>
<td>SPC-1 Price-Performance</td>
<td>$375.56/SPC-1 KIOPS™</td>
</tr>
<tr>
<td>SPC-1 Total System Price</td>
<td>8,638,347.84</td>
</tr>
<tr>
<td>SPC-1 IOPS Response Time</td>
<td>0.294 ms</td>
</tr>
<tr>
<td>SPC-1 Overall Response Time</td>
<td>0.246 ms</td>
</tr>
<tr>
<td>SPC-1 ASU Capacity</td>
<td>343,597 GB</td>
</tr>
<tr>
<td>SPC-1 ASU Price</td>
<td>$25.15/GB</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 Inspur Electronic Information Industry Co. Ltd., 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 Inspur Electronic Information Industry Co. Ltd., and can be found at [www.spcresults.org](http://www.spcresults.org) under the Submission Identifier A32023.
The independent audit process conducted by InfoSizing included the verifications of the following items:

- The physical capacity of the data repository (957,600 GB).
- The total capacity of the Application Storage Unit (343,597 GB).
- 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.
- 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:

The SPC-1 Specification requires PERSIST1 to be run with the following settings:

- 3-minute ramp up
- 10-minute measurement interval
- 1-minute ramp down
- 25% of the workload level of RAMPD_100

At sufficiently high IOPs levels and when run for the required times, the SPC-1 toolkit exhibits anomalous behavior which prevents the PERSIST1 test from completing properly.

The SPC Compliance Review Committee has reviewed this situation and granted permission for the test sponsor to run at reduced settings so that the PERSIST1 test can complete properly.

The following setting were used for this result.

- 3-minute ramp up
- 10-minute measurement interval
- 1-minute ramp down
- 8% of the workload level of RAMPD_100

Respectfully Yours,

[Signature]

Doug Johnson, Certified SPC Auditor

63 Lourdes Dr. | Leominster, MA 01453 | 978-343-6562 | www.sizing.com
LETTER OF GOOD FAITH

Aug 12, 2021

To: Doug Johnson, SPC Auditor
   PerfLabs, Inc. DBA InfoSizing
   63 Lourdes Drive
   Leominster, MA 01453-6709
   USA

Subject: SPC-1 Letter of Good Faith for the HF18000G5-I

Inspur Electronic Information Industry Co. Ltd is the SPC-1 test sponsor for the above listed product. To the best of our knowledge and belief, the required SPC-1 results and materials we have submitted for that product are complete, accurate, and in full compliance with version 3.10 of the SPC-1 benchmark specification.

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

Sincerely,

[Signature]

Lay Sun
PDTM of Storage Product Department
Inspur Electronic Information Industry Co. Ltd.

Date: Aug 12, 2021
Inspur HF18000G5-I

Executive Summary

Inspur HF18000G5

- SPC-1 IOPS™: 23,001,502
- SPC-1 Price Performance: $375.56/SPC-1 KIOPS™
- SPC-1 IOPS Response Time: 0.294 ms
- SPC-1 Total System Price: $8,638,347.84
- SPC-1 Overall Response Time: 0.246 ms
- SPC-1 Overall Discount: 74.95%

Currency / Target Country: USD / China
Availability Date: July 25, 2021

Extensions

- SPC-1 Data Reduction: NA
- SPC-1 Encryption: NA
- SPC-1 NDU: NA
- SPC-1 Synchronous Replication: NA
- SPC-1 Snapshot: NA

Storage Metrics

- SPC-1 Data Protection Level: Protected 2
- SPC-1 Physical Storage Capacity: 957,600 GB
- SPC-1 ASU Capacity: 343,597 GB
- SPC-1 ASU Price: $25.15/GB

Priced Storage Configuration Summary

- Emulex 31002 2-port 16 Gb FC HBAs: 122
- Inspur HF18000G5 Storage Nodes: 16
- Controllers (2 per node): 32
- GB Total Cache (1,536 per controller): 49,152
- Total Front-End Ports (320 used): 384
- 1.92 TB NVMe SSDs: 480
- 375 GB NVMe Optane SSDs: 96
- FS9620 32 Gb FC Switches: 2
- Total RUs: 144

RAMPD Average Response Time (ms) vs. IOPS

SUSTAIN Response Time (ms)

RAMPD_100 Response Time (ms)

Submitted for Review: August 16, 2021
Submission Details: www.storageperformance.org/r/A32023

SPC Benchmark 1™ Specification Revision: v3.10.0
SPC Benchmark 1™ Workload Generator Revision: v3.0.2-1-g823a

SPC-1, SPC-1 IOPS, SPC-1 KIOPS, SPC-1 Price Performance, SPC Benchmark 1, and the SPC Logo are trademarks of the Storage Performance Council.
**PRICING DETAILS**

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

**Warranty:** Provides 7x24x4H arrival service within designated city and distance. The service includes 7x24 contact to the Inspur call center with 4-hours on-site hardware replacement or troubleshooting, and online software support with access to all new software updates or troubleshooting.

**Differences Between Tested and Priced Storage Configurations**

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

---

**Pricing Details**

<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>UHF180G5I000</td>
<td>Inspur HF18000G5 Storage System Base Unit (4U, Dual Controllers, BBU+Flash, 3Y 5x10xND Basic Svc&amp;Warranty)</td>
<td>1</td>
<td>16</td>
<td>409,856.74</td>
<td>6,557,707.84</td>
<td>75%</td>
<td>1,639,426.96</td>
</tr>
<tr>
<td>EGW-0230VL</td>
<td>Inspur 1.92TB NVMe SSD Enterprise Drive (2.5’), For HF18000G5 JBOD</td>
<td>1</td>
<td>480</td>
<td>12,965.62</td>
<td>6,223,497.60</td>
<td>75%</td>
<td>1,555,874.40</td>
</tr>
<tr>
<td>EGW-0230VS</td>
<td>Inspur 375GB NVMe Optane SSD Enterprise Drive (2.5’), For HF18000G5 JBOD</td>
<td>1</td>
<td>96</td>
<td>114,204.16</td>
<td>10,963,599.36</td>
<td>75%</td>
<td>2,740,899.84</td>
</tr>
<tr>
<td>UHFJ25NF1000</td>
<td>Inspur J025S GG5 JBOF (2U, 25*2.5” NVMe SSD)</td>
<td>1</td>
<td>32</td>
<td>9,899.72</td>
<td>316,791.04</td>
<td>75%</td>
<td>79,197.76</td>
</tr>
<tr>
<td>EGW-06901G</td>
<td>Inspur HF18000G5 4*16Gbps FC Ports +SFP</td>
<td>1</td>
<td>96</td>
<td>10,157.60</td>
<td>975,129.60</td>
<td>75%</td>
<td>243,782.40</td>
</tr>
<tr>
<td>EGW-08906G</td>
<td>Inspur HF18000G5 4*NVMe</td>
<td>1</td>
<td>64</td>
<td>1,117.48</td>
<td>71,518.72</td>
<td>75%</td>
<td>17,879.68</td>
</tr>
<tr>
<td>THSS50</td>
<td>Inspur HF18000G5 Basic Software (InThin, InSnapshot, InClone, InBackup, InVdisk, InMirr, InQos, InRAID, InPath)</td>
<td>1</td>
<td>16</td>
<td>3,979.66</td>
<td>63,674.56</td>
<td>75%</td>
<td>15,918.64</td>
</tr>
<tr>
<td>THS18000</td>
<td>HF18000 Series Rack</td>
<td>1</td>
<td>4</td>
<td>11,934.10</td>
<td>47,736.40</td>
<td>75%</td>
<td>11,934.10</td>
</tr>
<tr>
<td>NA</td>
<td>Inspur 3M LC-LC OM4 Fibre Channel Cable</td>
<td>1</td>
<td>320</td>
<td>42.98</td>
<td>13,753.60</td>
<td>75%</td>
<td>3,438.40</td>
</tr>
<tr>
<td>NA</td>
<td>Inspur 5M LC-LC OM4 Fibre Channel Cable</td>
<td>1</td>
<td>244</td>
<td>28.66</td>
<td>6,993.04</td>
<td>75%</td>
<td>1,748.26</td>
</tr>
<tr>
<td>TSI203</td>
<td>Inspur 2*Port 16Gbps Fibre Channel Adapter</td>
<td>1</td>
<td>122</td>
<td>5,114.62</td>
<td>623,983.64</td>
<td>75%</td>
<td>155,995.91</td>
</tr>
<tr>
<td>NA</td>
<td>Inspur FS9620 SAN switch director, Enable 16Gbps</td>
<td>1</td>
<td>2</td>
<td>681,696.28</td>
<td>1,363,392.56</td>
<td>75%</td>
<td>340,848.14</td>
</tr>
<tr>
<td>NA</td>
<td>Inspur FS9620 48 FC IO port board</td>
<td>1</td>
<td>14</td>
<td>516,260.75</td>
<td>7,227,650.50</td>
<td>75%</td>
<td>1,806,912.63</td>
</tr>
<tr>
<td>F2HII04</td>
<td>Installation Service - Engineering</td>
<td>1</td>
<td>16</td>
<td>1,027.94</td>
<td>16,447.04</td>
<td>0%</td>
<td>16,447.04</td>
</tr>
<tr>
<td>F2GD0030ASS5G25</td>
<td>Upgrade To Onsite Premier 24x7x4H Engineer Onsite Service - 36Month(s)</td>
<td>1</td>
<td>16</td>
<td>502.73</td>
<td>8,043.68</td>
<td>0%</td>
<td>8,043.68</td>
</tr>
</tbody>
</table>

**Hardware & Software Subtotal**: 8,613,857.12

**Support & Maintenance**

<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>
</table>

**Support & Maintenance Subtotal**: 24,490.72

**SPC-1 Total System Price**: 8,638,347.84

**SPC-1 IOPS™**: 23,001,502

**SPC-1 Price-Performance™ ($/SPC-1 KIOPS™)**: 375.56

**SPC-1 ASU Capacity (GB)**: 343,597

**SPC-1 ASU Price ($/GB)**: 25.15
### Publication Details

This section provides contact information for the test sponsor and auditor, a revision history of this document, and a description of any exceptions or waivers associated with this publication.

#### Contact Information

<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Sponsor Primary Contact</td>
<td>Inspur Electronic Information Industry Co. Ltd. Xudong Wang</td>
<td><a href="http://en.inspur.com/">http://en.inspur.com/</a> <a href="mailto:wangxudong02@inspur.com">wangxudong02@inspur.com</a></td>
</tr>
<tr>
<td>SPC Auditor</td>
<td>InfoSizing Doug Johnson</td>
<td><a href="http://www.sizing.com">www.sizing.com</a> <a href="mailto:doug@sizing.com">doug@sizing.com</a></td>
</tr>
</tbody>
</table>

#### Revision Information

<table>
<thead>
<tr>
<th>Date</th>
<th>FDR Revision</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>August 16, 2021</td>
<td>First Edition</td>
<td>Initial Publication</td>
</tr>
</tbody>
</table>

#### Anomalies, Exceptions, Waivers

The SPC-1 Specification requires PERSIST1 to be run with the following settings:

- 3-minute ramp up
- 10-minute measurement interval
- 1-minute ramp down
- 25% of the workload level of RAMPD_100

At sufficiently high IOPs levels and when run for the required times, the SPC-1 toolkit exhibits anomalous behavior which prevents the PERSIST1 test from completing properly.

The SPC Compliance Review Committee has reviewed this situation and granted permission for the test sponsor to run at reduced settings so that the PERSIST1 test can complete properly.

The following setting were used for this result.

- 3-minute ramp up
- 10-minute measurement interval
- 1-minute ramp down
- 8% of the workload level of RAMPD_100
**Configuration Information**

**Tested Storage Product Description**

HF18000G5-I is an enterprise-level high-end all-flash storage system for enterprise core applications and provides both SAN and NAS. It adopts a new NVMe architecture, all-flash optimization algorithm and intelligent InView management platform, bringing lower latency, higher performance, and greater flexibility. Expand capacity and simplify management. HF18000G5-I is optimized in terms of performance, function, reliability, and ease of use, which satisfies data storage, disaster recovery, and active-active under various applications such as OLTP/OLAP, virtualization, and file sharing for large and medium-sized databases, backup and other needs, and are widely used in finance, communications, energy, media, medical, education, SMB and other industries.

**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>62 x Inspur NF5280M5 Servers (1 Admin ; 61 Load Driving), each with: 2 x Intel® Xeon® Gold 6230 CPU (2.1 GHz, 26-Core, 36 MB L3) 128 GB Main Memory CentOS Linux Release 7.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tested Storage Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>122 x Emulex 31002 2-port 16 Gb FC HBAs</td>
</tr>
</tbody>
</table>

| 16 x HF18000G5-I, each with: 2 x Controllers, each with: 1,536 GB cache (49,152 GB total) 3 x 4-port 16 Gbps FC Front End Ports |
| 32 x Disk Enclosures, each with: 15 x 1.92 TB NVMe SSD 3 x 375 GB NVMe Optane SSD |
| 576 x NVMe Storage Devices Total |

| 2 x FS9620 32Gb Switches          |

**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>

Full Disclosure Report  Inspur HF18000G5-I  SPC Benchmark 1<sup>st</sup> v3.10.0 Inspur Electronic Information Industry Co. Ltd.  Submission ID: A32023  Submitted: August 16, 2021
Configuration Diagrams

**BC/TSC Configuration Diagram**

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

---

**Host Systems**

- **62 x Servers**
  - 1 administrator/61 load-driving

**Inspur NF5280M5**
- 2 x Emulex 2-port FC HBAs

**Inspur NF5280M5**
- 2 x Emulex 2-port FC HBAs

**244 x 16Gb FC connections**
- (4 connections per server)
- (administrator host is not connected)

**Inspur FS9620 Switch**

**Inspur FS9620 Switch**

**Tested Storage Configuration (TSC)**

- **Controller-1**
- **Controller-2**

- **HF18000G5-I**
  - 32 Controllers

- **2 x 2U SSD Disk Enclosures**
- **15 x 1.92TB NVMe SSD**
- **3 x 375GB NVMe Optane SSD**

---

**Benchmark Configuration (BC)**
Storage Network Configuration

The Tested Storage Configuration (TSC) comprised 16 HF18000G5-I storage nodes driven by one administrative server and 61 load-driving host systems (Inspur NF5280M5). Each load-driving host was connected to each FS9620 switch using the four ports of the two Emulex 31002s. This was a total of 244 16Gb connections between the hosts and the switches. Each HF18000G5-I storage node had 10 connections (5 per controller) to each FS9620 switch. This was a total of 320 16 Gb connections between the storage nodes and the switches.

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>18</td>
<td>8,589.9</td>
<td>8,589.9</td>
<td>154,618.8</td>
<td>45.0%</td>
<td>No</td>
</tr>
<tr>
<td>ASU-2</td>
<td>18</td>
<td>8,589.9</td>
<td>8,589.9</td>
<td>154,618.8</td>
<td>45.0%</td>
<td>No</td>
</tr>
<tr>
<td>ASU-3</td>
<td>4</td>
<td>8,589.9</td>
<td>8,589.9</td>
<td>34,359.7</td>
<td>10.0%</td>
<td>No</td>
</tr>
<tr>
<td>SPC-1 ASU Capacity</td>
<td>343,597</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></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.
### Devices Count Physical Capacity Total Capacity

<table>
<thead>
<tr>
<th>Devices</th>
<th>Count</th>
<th>Physical Capacity</th>
<th>Total Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>NVMe SSD</td>
<td>480</td>
<td>1,920.0</td>
<td>921,600.0</td>
</tr>
<tr>
<td>NVMe Optane SSD</td>
<td>96</td>
<td>375</td>
<td>36,000.0</td>
</tr>
<tr>
<td><strong>Total Physical Capacity</strong></td>
<td></td>
<td></td>
<td><strong>957,600</strong></td>
</tr>
<tr>
<td><strong>Physical Capacity Utilization</strong></td>
<td></td>
<td></td>
<td><strong>35.88%</strong></td>
</tr>
</tbody>
</table>

### Data Protection

The data protection level used for all LVs was Protected 2 (RAID10), which was accomplished by providing fully redundant pathways from each host to the storage cluster where all drives were protected via RAID10.

### Space Optimization Information

#### 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>
**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).

**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.
Response Time vs. Throughput Graph

The following graph presents the average Response Times versus the average IOPS for RAMPD_100 to RAMPD_10.

![Graph showing response time versus throughput]

ASU Pre-Fill

The following table provides a summary of the Pre-Fill performed on the ASU prior to testing.

<table>
<thead>
<tr>
<th>ASU Pre-Fill Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Start Time</strong></td>
</tr>
<tr>
<td><strong>End Time</strong></td>
</tr>
<tr>
<td><strong>Duration</strong></td>
</tr>
</tbody>
</table>

For additional details see the Supporting Files.
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>Transition Period</td>
<td>23-Jul-21 01:47:28</td>
<td>23-Jul-21 01:50:28</td>
<td>0:03:00</td>
</tr>
<tr>
<td>Measurement Interval</td>
<td>23-Jul-21 01:50:28</td>
<td>23-Jul-21 09:50:29</td>
<td>8:00:01</td>
</tr>
</tbody>
</table>

SUSTAIN – Throughput Graph

Throughput Graph (SUSTAIN @ 23,000,000 IOPS)
SUSTAIN – Response Time Graph

Response Time Graph (SUSTAIN @ 23,000,000 IOPS)

SUSTAIN – Data Rate Graph

Data Rate Graph (SUSTAIN @ 23,000,000 IOPS)
SUSTAIN – Response Time Frequency Graph

Response Time Frequency Graph
(SUSTAIN @ 23,000,000 IOPS)

SUSTAIN – 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></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>0.0001</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0002</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0000</td>
</tr>
<tr>
<td>Difference</td>
<td>0.004%</td>
<td>0.002%</td>
<td>0.004%</td>
<td>0.000%</td>
<td>0.006%</td>
<td>0.003%</td>
<td>0.005%</td>
<td>0.002%</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>
<tbody>
<tr>
<td>Transition Period</td>
<td>23-Jul-21 09:51:28</td>
<td>23-Jul-21 09:54:29</td>
<td>0:03:01</td>
</tr>
<tr>
<td>Measurement Interval</td>
<td>23-Jul-21 09:54:29</td>
<td>23-Jul-21 10:04:29</td>
<td>0:10:00</td>
</tr>
</tbody>
</table>

RAMPD_100 – Throughput Graph

![Throughput Graph (RampD_100 @ 23,000,000 IOPS)](image)
RAMPD_100 – Response Time Graph

![Response Time Graph (RampD_100 @ 23,000,000 IOPS)](image)

RAMPD_100 – Data Rate Graph

![Data Rate Graph (RampD_100 @ 23,000,000 IOPS)](image)
RAMPD_100 – 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>0.0002</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0000</td>
<td>0.0002</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0000</td>
</tr>
<tr>
<td>Difference</td>
<td>0.004%</td>
<td>0.001%</td>
<td>0.004%</td>
<td>0.004%</td>
<td>0.008%</td>
<td>0.004%</td>
<td>0.003%</td>
<td>0.004%</td>
</tr>
</tbody>
</table>

RAMPD_100 – I/O Request Summary

| I/O Requests Completed in the Measurement Interval | 13,801,001,141 |
| I/O Requests Completed with Response Time <= 30 ms | 13,800,924,494 |
| I/O Requests Completed with Response Time > 30 ms | 76,647 |
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
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>23,001,502.1</td>
<td>2,300,192.5</td>
</tr>
<tr>
<td>REPEAT_1</td>
<td>23,001,363.3</td>
<td>2,300,346.3</td>
</tr>
<tr>
<td>REPEAT_2</td>
<td>23,001,339.6</td>
<td>2,300,024.1</td>
</tr>
</tbody>
</table>

**REPEAT_1_100 – Throughput Graph**

![Throughput Graph (Repeat_1_100 @ 23,000,000 IOPS)](image-url)
**REPEAT_1_100 – Response Time Graph**

Response Time Graph (Repeat_1_100 @ 23,000,000 IOPS)

**REPEAT_2_100 – Throughput Graph**

Throughput Graph (Repeat_2_100 @ 23,000,000 IOPS)
REPEAT_2_100 – Response Time Graph

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>0.0002</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0000</td>
</tr>
<tr>
<td>Difference</td>
<td>0.009%</td>
<td>0.003%</td>
<td>0.005%</td>
<td>0.000%</td>
<td>0.009%</td>
<td>0.009%</td>
<td>0.002%</td>
<td>0.002%</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>0.0001</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0002</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0000</td>
</tr>
<tr>
<td>Difference</td>
<td>0.002%</td>
<td>0.003%</td>
<td>0.001%</td>
<td>0.001%</td>
<td>0.004%</td>
<td>0.001%</td>
<td>0.004%</td>
<td>0.002%</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>
</tr>
</thead>
<tbody>
<tr>
<td>Total Number of Logical Blocks Written</td>
</tr>
<tr>
<td>Total Number of Logical Blocks Verified</td>
</tr>
<tr>
<td>Total Number of Logical Blocks Overwritten</td>
</tr>
<tr>
<td>Total Number of Logical Blocks that Failed Verification</td>
</tr>
<tr>
<td>Time Duration for Writing Test Logical Blocks (sec.)</td>
</tr>
<tr>
<td>Size in bytes of each Logical Block</td>
</tr>
<tr>
<td>Number of Failed I/O Requests in the process of the Test</td>
</tr>
</tbody>
</table>

Committed Data Persistence Implementation

TSC uses the BBU power-down protection mechanism, each controller has two batteries and SSD as the system disk. When an unexpected power-down occurs, the controller continues to be powered by the battery and refreshes the cache data to SSD for permanent storage. When the power supply is restored, the data in the system disk SSD is automatically restored.
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/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/set_nr_requests.sh</td>
<td>Set queue depth, max AIO and scheduler</td>
<td>/C_Tuning</td>
</tr>
<tr>
<td>/D_Creation/initial_HF18000G5-I.sh</td>
<td>Create the storage environment</td>
<td>/D_Creation</td>
</tr>
<tr>
<td>/D_Creation/lv_scan.sh</td>
<td>Scan and activate logical volumes</td>
<td>/D_Creation</td>
</tr>
<tr>
<td>/D_Creation/lvm.sh</td>
<td>Create logical volumes</td>
<td>/D_Creation</td>
</tr>
<tr>
<td>/D_Creation/vg.sh</td>
<td>Create volume groups</td>
<td>/D_Creation</td>
</tr>
<tr>
<td>/E_Inventory/profile.sh</td>
<td>Captures profile of storage environment</td>
<td>/E_Inventory</td>
</tr>
<tr>
<td>/E_Inventory/profile_end_HF18000G5-I.txt</td>
<td>Storage configuration before INIT</td>
<td>/E_Inventory</td>
</tr>
<tr>
<td>/E_Inventory/profile_start_HF18000G5-I.txt</td>
<td>Storage configuration after restart</td>
<td>/E_Inventory</td>
</tr>
<tr>
<td>/E_Inventory/volume_list.sh</td>
<td>Captures list of logical volumes</td>
<td>/E_Inventory</td>
</tr>
<tr>
<td>/E_Inventory/volume_listing_end.txt</td>
<td>List of logical volumes before INIT</td>
<td>/E_Inventory</td>
</tr>
<tr>
<td>/E_Inventory/volume_listing_start.txt</td>
<td>List of logical volumes after restart</td>
<td>/E_Inventory</td>
</tr>
<tr>
<td>/F_Generator/HOST1.HST</td>
<td>Host configuration file (for VERIFY)</td>
<td>/F_generator</td>
</tr>
<tr>
<td>/F_Generator/HOST61.HST</td>
<td>Host configuration file (all except VERIFY)</td>
<td>/F_generator</td>
</tr>
<tr>
<td>/F_Generator/SPC1_40.asu</td>
<td>Define LUNs hosting the ASUs</td>
<td>/F_generator</td>
</tr>
<tr>
<td>/F_Generator/test_init.sh</td>
<td>Execute INIT</td>
<td>/F_generator</td>
</tr>
<tr>
<td>/F_Generator/test_metrics.sh</td>
<td>Execute METRICS</td>
<td>/F_generator</td>
</tr>
<tr>
<td>/F_Generator/testPersist1.sh</td>
<td>Execute PERSIST1</td>
<td>/F_generator</td>
</tr>
<tr>
<td>/F_Generator/testPersist2.sh</td>
<td>Execute PERSIST2</td>
<td>/F_generator</td>
</tr>
<tr>
<td>/F_Generator/test_verify_0.sh</td>
<td>Execute VERIFY0</td>
<td>/F_generator</td>
</tr>
<tr>
<td>/F_Generator/test_verify_1.sh</td>
<td>Execute VERIFY1</td>
<td>/F_generator</td>
</tr>
</tbody>
</table>
APPENDIX B: THIRD PARTY QUOTATION

All components are available directly through the Test Sponsor (Inspur Electronic Information Industry Co. Ltd.).
APPENDIX C: TUNING PARAMETERS AND OPTIONS

Change the Scheduler on each Host System. Execute the set_nr_requests.sh script on each Host System to complete the following settings:

- Change the maximum number of AIO operations to 1048576.
- Change the queue depth from 128 to 1024 on each Host System for each device.
- Change the I/O scheduler from cfq to noop on each Host System.
APPENDIX D: STORAGE CONFIGURATION CREATION

Step 1: Create Storage Pools, RAIDs, LUNs, Hosts, Mapping and deploy LUNs.

Execute the init_HF18000G5-I.sh script on a remote server which can login on HF18000G5-I storage system to complete the following:

1. Create 16 storage pools: Pool0, Pool1, Pool2, Pool3, Pool4, Pool5, Pool6, Pool7, Pool8, Pool9, Pool10, Pool11, Pool12, Pool13, Pool14, Pool15
2. Create 64 RAID10
3. Create 256 LUNs (16 LUN per Pool, 1300 GB per LUN)
4. Create 61 Hosts in storage cluster
5. Add the FC port’s WWPN to the 61 hosts (4 WWPNs per Host)
6. Map LUNs to the 61 Hosts

Step 2: Create Volumes on the Master Host System

Execute the vg.sh script on the Master Host System to create 2 VGs, and then execute the lvm.sh script to create 40 logical volumes as follows. In addition, the script will make each logical volume available (activate).

1. Create Physical Volumes.
   Create 256 physical volumes using the pvcreate command.
2. Create Volumes Groups
   Create 2 volume groups (spc1vg1 spc1vg2) using the vgcreate command as follows:
   Create spc1vg1 using 128 of 256 physical volumes, and create spc1vg2 using another 128 of 256 physical volumes

3. Create Logical Volumes
   • Create 9 logical volumes, every volume capacity is 8000 GB, on spc1vg1 for ASU-1.
   • Create 9 logical volumes, every volume capacity is 8000 GB, on spc1vg2 for ASU-1.
   • Create 9 logical volumes, every volume capacity is 8000 GB, on spc1vg1 for ASU-2.
   • Create 9 logical volumes, every volume capacity is 8000 GB, on spc1vg2 for ASU-2.
   • Create 2 logical volumes, every volume capacity is 8000 GB, on spc1vg1 for ASU-3.
   • Create 2 logical volumes, every volume capacity is 8000 GB, on spc1vg2 for ASU-3.

Step 3: Change the Scheduler on each Host System.

1. Execute the set_nr_requests.sh script on each Host System to complete the following settings:
   • Change the maximum number of AIO operations to 1048576.
   • Change the queue depth from 128 to 1024 on each Host System for each device.
   • Change the I/O scheduler from cfq to noop on each Host System.
**APPENDIX E: CONFIGURATION INVENTORY**

An inventory of the configuration was collected by running the following scripts.

- profile.sh
- volume_list.sh

The following log files were generated by running the above scripts.

- profile_start_HF18000G5-I.txt
- profile_end_HF18000G5-I.txt
- volume_listing_start.txt
- volume_listing_end.txt

These files are all available in the Supporting Files (see Appendix A).
APPENDIX F: WORKLOAD GENERATOR

The ASUs accessed by the SPC-1 workload generator were defined using the script SPC1_40.asu.

The hosts used to drive the SPC-1 workload were defined using the script HOST61.HST (HOST1.HST was used for VERIFY). The scripts used to execute the benchmark sequence were:

- test_init.sh
- test_metrics.sh
- testPersist1.sh
- testPersist2.sh
- test_verify_0.sh
- test_verify_1.sh

These files are all available in the Supporting Files (see Appendix A).