SPC Benchmark 1™

Full Disclosure Report

China Electronics Cloud Technology Co., Ltd.

CeASTor 18116E

SPC-1™ v3.10.0

Submission Identifier: A32026

Submitted For Review: April 25, 2023
First Edition – April 2023

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 China Electronics Cloud Technology 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. China Electronics Cloud Technology 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 China Electronics Cloud Technology Co., Ltd. representative for information on products and services available in your area.

© Copyright China Electronics Cloud Technology Co., Ltd. 2023. 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.

CeaStor and the CECTC logo are trademarks or registered trademarks of China Electronics Cloud Technology Co., Ltd. in China 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
  Step 0: Edit configure file .................................................. 31
  Step 1: Create and format storage cluster: ................................ 31
  Step 2: Create logical volumes and map them as NVMe disks on host nodes .................................................................................................... 32
  Step 3: Change the Scheduler on each Host System ...................... 34
Appendix E: Configuration Inventory ........................................ 35
Appendix F: Workload Generator ............................................. 36
AUDIT CERTIFICATION

Yao Mi
N3013,3F,N R&D building, A.I. Technology Park,
Economic and Technological Development Zone,
Wuhan,Hubei,China

April 23, 2023

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

CeaStor 18116E

The results were:

<table>
<thead>
<tr>
<th>SPC-1 IOPS™</th>
<th>10,000,690</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC-1 Price-Performance</td>
<td>$165.82/SPC-1 KIOPS™</td>
</tr>
<tr>
<td>SPC-1 Total System Price</td>
<td>1,658,233.00</td>
</tr>
<tr>
<td>SPC-1 IOPS Response Time</td>
<td>0.548 ms</td>
</tr>
<tr>
<td>SPC-1 Overall Response Time</td>
<td>0.352 ms</td>
</tr>
<tr>
<td>SPC-1 ASU Capacity</td>
<td>127,131 GB</td>
</tr>
<tr>
<td>SPC-1 ASU Price</td>
<td>$13.05/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. 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 China Electronics Cloud Technology 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 China Electronics Cloud Technology Co., Ltd., and can be found at www.spcresults.org under the Submission Identifier A32026.

The independent audit process conducted by InfoSizing included the verifications of the following items:

- The physical capacity of the data repository (349,440 GB).
- The total capacity of the Application Storage Unit (127,131 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:

None.

Respectfully Yours,

Doug Johnson, Certified SPC Auditor
LETTER OF GOOD FAITH

April 22, 2023

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 CeaStor18116E

China Electronics Cloud Technology 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 result 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 result even if the items are not explicitly required
to be disclosed by the SPC-1 benchmark specification.

Sincerely,

Signed:

Yao Mi
Storage Product Department
China Electronics Cloud Technology Co., Ltd

Date:

2023-4-22

Full disclosure Report  CeaStor 18116E  SPC Benchmark 1™ v3.10.0 China Electronics Cloud Technology Co., Ltd.  Submission ID: A32026  Submitted: April 25, 2023
CeaStor 18116E

Executive Summary

SPC Benchmark 1™ Executive Summary

CeaStor 18116E

SPC-1 IOPS™: 10,000,690
SPC-1 IOPS Response Time: 0.548 ms

SPC-1 Price Performance: $165.82/SPC-1 KIOPS™

SPC-1 Total System Price: $1,658,233.00
SPC-1 Overall Discount: 61.52%

Currency / Target Country: USD / China
Availability Date: May 31, 2023

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: 349,440 GB
- SPC-1 ASU Capacity: 127,131 GB
- SPC-1 ASU Price: $13.05/GB

Priced Storage Configuration Summary

- 40 Mellanox MCX623106AN-CDAT
- 1 CeaStor 18116E
- 30 Storage Nodes
- 15,360 GB Total Cache
- 60 Total Front-End Ports
- 420 Total Storage Devices (240x 256 GB Optane, 180x 1.6 TB NVMe SSD)
- 4 100Gb Huawei CE8851-32CQ8DQ-P Switches
- 68 Total RUs

RAMPD Average Response Time (ms) vs. IOPS

SUSTAIN Response Time (ms)

RAMPD_100 Response Time (ms)

SPC Benchmark 1™ Specification Revision: v3.10.0
SPC Benchmark 1™ Workload Generator Revision: v3.0.2
Submitted for Review: April 25, 2023
Submission Details: www.storageperformance.org/r/A32026
**Discount Details:** The discounts shown are based on the storage capacity purchased and are generally available.

**Warranty:** The warranty provides 24x7x4H arrival of service within designated city and distance. The service includes 24x7 contact to the CeaStor call center with 4-hour 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.
**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>China Electronics Cloud Technology Co., Ltd. Yao Mi</td>
<td><a href="https://www.cecloud.com/">https://www.cecloud.com/</a> <a href="mailto:miyao@cestc.cn">miyao@cestc.cn</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>April 25, 2023</td>
<td>First Edition</td>
<td>Initial Publication</td>
</tr>
</tbody>
</table>

**Anomalies, Exceptions, Waivers**

There were no anomalies, exceptions or waivers associated with the audit of the CeaStor 18116E.
CONFIGURATION INFORMATION

Tested Storage Product Description

CeaStor 18116E is a next-generation storage product designed and developed by China Electronic Cloud for future storage architecture. It fully adopts a whole range of new storage hardware and new technologies, delivering industry-leading ultimate data access performance. This product features hyperscale, high availability, high reliability, elasticity, intelligence, simplicity, and efficiency. It can be widely used in cloud computing and cloud native environments to support key business applications and satisfy the strict requirements for data scale and access performance in emerging technologies and applications such as online transaction, supercomputing, AI, and autonomous driving.

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>10x Huawei 2288H V6</td>
</tr>
<tr>
<td>2x Intel® Xeon® Platinum 8358P CPU @ 2.60 GHz</td>
</tr>
<tr>
<td>512 GB Main Memory</td>
</tr>
<tr>
<td>CentOS Linus Release 8.4</td>
</tr>
<tr>
<td>10x Inspur NF5280M6</td>
</tr>
<tr>
<td>2x Intel® Xeon® Platinum 8358P CPU @ 2.60 GHz</td>
</tr>
<tr>
<td>512 GB Main Memory</td>
</tr>
<tr>
<td>CentOS Linus Release 8.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tested Storage Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>40x Mellanox MCX623106AN-CDAT 100 Gb 2-port</td>
</tr>
<tr>
<td>30x CeaStor18116E storage nodes, each with:</td>
</tr>
<tr>
<td>2x Intel® Xeon® Platinum 8358P CPU @ 2.60 GHz</td>
</tr>
<tr>
<td>512 GB cache (15,360 GB total)</td>
</tr>
<tr>
<td>2x 100 Gbps Front End Ports</td>
</tr>
<tr>
<td>240x Optane 256 GB, 180x NVMe SSD Storage Devices</td>
</tr>
<tr>
<td>4x 100Gb Huawei CE8851-32CQ8DQ-P Switches</td>
</tr>
</tbody>
</table>

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>
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).

![BC/TSC Configuration Diagram](image-url)
**Storage Network Configuration**

The Tested Storage Configuration (TSC) involved 30 CeaStor18116E Storage Nodes and 4 100Gb Huawei CE8851-32CQ8DQ-P switches, driven by 20 host systems.

Each host system had 2 Mellanox MCX623106AN-CDAT HBAs. Each HBA was connected to one of two switches. This is a total of 40x 100 Gb connections between the hosts and two of the switches.

Each CeaStor18116E storage node had 2 Mellanox MCX623106AN-CDAT HBAs. Each HBA was connected to one of the other two switches. This is a total of 60x 100 Gb connections between the storage nodes and the other two switches.

The 4 switches were interconnected with 400GE ports.

**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>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>9</td>
<td>6,356.5</td>
<td>6,356.5</td>
<td>57,208.9</td>
<td>45.0%</td>
</tr>
<tr>
<td>ASU-2</td>
<td>9</td>
<td>6,356.5</td>
<td>6,356.5</td>
<td>57,208.9</td>
<td>45.0%</td>
</tr>
<tr>
<td>ASU-3</td>
<td>2</td>
<td>6,356.5</td>
<td>6,356.5</td>
<td>12,713.1</td>
<td>10.0%</td>
</tr>
</tbody>
</table>

**SPC-1 ASU Capacity** 127,131

*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>Optane</td>
<td>240</td>
<td>256.0</td>
<td>61,440.0</td>
</tr>
<tr>
<td>NVMe SSD</td>
<td>180</td>
<td>1,600.0</td>
<td>288,000.0</td>
</tr>
<tr>
<td><strong>Total Physical Capacity</strong></td>
<td></td>
<td></td>
<td>349,440</td>
</tr>
<tr>
<td><strong>Physical Capacity Utilization</strong></td>
<td></td>
<td></td>
<td>36.38%</td>
</tr>
</tbody>
</table>

**Data Protection**

The data protection level used for all LVs was **Protected 2 (Replication)**, which was accomplished by providing fully redundant pathways from each host to the storage cluster where all data was replicated and distributed on two separate storage nodes.

**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

Overview

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.

![Measurement Intervals by Test Phase Graph](image-url)
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 vs. 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>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Start Time</strong></td>
<td>14-Apr-23 15:33:37</td>
</tr>
<tr>
<td><strong>Requested IOP Level</strong></td>
<td>50,000 MB/sec</td>
</tr>
<tr>
<td><strong>End Time</strong></td>
<td>14-Apr-23 16:17:22</td>
</tr>
<tr>
<td><strong>Observed IOP Level</strong></td>
<td>48,449 MB/sec</td>
</tr>
<tr>
<td><strong>Duration</strong></td>
<td>0:43:44</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>Measurement Interval</td>
<td>14-Apr-23 21:02:06</td>
<td>15-Apr-23 05:02:07</td>
<td>8:00:01</td>
</tr>
</tbody>
</table>

SUSTAIN – Throughput Graph

![Throughput Graph (SUSTAIN @ 10,000,000 IOPS)](image-url)
SUSTAIN – Response Time Graph

SUSTAIN – Data Rate Graph
SUSTAIN – Response Time Frequency Graph

Response Time Frequency Graph
(SUSTAIN @ 10,000,000 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>0.0002</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0003</td>
<td>0.0001</td>
<td>0.0002</td>
<td>0.0001</td>
</tr>
<tr>
<td>Difference</td>
<td>0.004%</td>
<td>0.002%</td>
<td>0.003%</td>
<td>0.001%</td>
<td>0.006%</td>
<td>0.005%</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>15-Apr-23 05:03:06</td>
<td>15-Apr-23 05:06:07</td>
<td>0:03:01</td>
</tr>
<tr>
<td>Measurement Interval</td>
<td>15-Apr-23 05:06:07</td>
<td>15-Apr-23 05:16:07</td>
<td>0:10:00</td>
</tr>
</tbody>
</table>

**RAMPD_100 – Throughput Graph**

![Throughput Graph (RampD_100 @ 10,000,000 IOPS)](image-url)
**RAMPD_100 – Response Time Graph**

*Response Time Graph (RampD_100 @ 10,000,000 IOPS)*

**RAMPD_100 – Data Rate Graph**

*Data Rate Graph (RampD_100 @ 10,000,000 IOPS)*
**RAMPD_100 – Response Time Frequency Graph**

![Response Time Frequency Graph](image)

**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></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>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0003</td>
<td>0.0002</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>Difference</td>
<td>0.011%</td>
<td>0.000%</td>
<td>0.012%</td>
<td>0.002%</td>
<td>0.005%</td>
<td>0.003%</td>
<td>0.000%</td>
<td>0.002%</td>
</tr>
</tbody>
</table>

**RAMPD_100 – I/O Request Summary**

| I/O Requests Completed in the Measurement Interval | 6,000,432,362 |
| I/O Requests Completed with Response Time <= 30 ms | 6,000,427,609 |
| I/O Requests Completed with Response Time > 30 ms | 4,753 |
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)](image-url)
Response Time Ramp Test – Average Response Time Graph

Average Response Time Graph (Response Time Ramp Test)

Response Time Graph – RAMPD_10 Response Time Graph

Response Time Graph (RampD_10 @ 1,000,000 IOPS)

MI

0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.00
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Relative Run Time (minutes)

Response Time (ms)

Average Measured Response Time (ms)

Average Response Time Graph (Response Time Ramp Test)
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>10,000,690.3</td>
<td>1,000,048.2</td>
</tr>
<tr>
<td>REPEAT_1</td>
<td>10,000,517.8</td>
<td>1,000,011.9</td>
</tr>
<tr>
<td>REPEAT_2</td>
<td>10,000,422.1</td>
<td>1,000,154.2</td>
</tr>
</tbody>
</table>

REPEAT_1_100 – Throughput Graph
REPEAT_1_100 – Response Time Graph

Response Time Graph (Repeat_1_100 @ 10,000,000 IOPS)

- ASU1
- ASU2
- ASU3
- All ASUs

REPEAT_2_100 – Throughput Graph

Throughput Graph (Repeat_2_100 @ 10,000,000 IOPS)

- ASU1
- ASU2
- ASU3
- All ASUs
**REPEAT_2_100 – Response Time Graph**

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>0.0002</td>
<td>0.0001</td>
<td>0.0002</td>
<td>0.0001</td>
<td>0.0003</td>
<td>0.0000</td>
</tr>
<tr>
<td>Difference</td>
<td>0.007%</td>
<td>0.001%</td>
<td>0.005%</td>
<td>0.003%</td>
<td>0.006%</td>
<td>0.005%</td>
<td>0.004%</td>
<td>0.001%</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>0.0003</td>
<td>0.0000</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0002</td>
<td>0.0001</td>
<td>0.0002</td>
<td>0.0001</td>
</tr>
<tr>
<td>Difference</td>
<td>0.011%</td>
<td>0.002%</td>
<td>0.005%</td>
<td>0.000%</td>
<td>0.010%</td>
<td>0.002%</td>
<td>0.004%</td>
<td>0.000%</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>1,397,397,014</td>
</tr>
<tr>
<td>Total Number of Logical Blocks Verified</td>
<td>681,305,418</td>
</tr>
<tr>
<td>Total Number of Logical Blocks Overwritten</td>
<td>716,091,596</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

The Ceastor18116E adopts PMem which is a non-volatile memory to store meta data. When data is being written to the storage cluster, the I/O will not return success until all data (including replicated data and meta data) has been written into the PMem and NVME disks.
## 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>See Appendix D Step 3</td>
<td>Adjust aio-max-nr</td>
<td>N/A</td>
</tr>
<tr>
<td>/D_Creation</td>
<td>Storage configuration creation</td>
<td>root</td>
</tr>
<tr>
<td>hosts.sh</td>
<td>Define environment</td>
<td>/D_Creation</td>
</tr>
<tr>
<td>cluster-deploy.sh</td>
<td>Create/format storage cluster</td>
<td></td>
</tr>
<tr>
<td>client_deploy.sh</td>
<td>Create logical volumes</td>
<td></td>
</tr>
<tr>
<td>lun_map.sh</td>
<td>Map volumes on host as NVMe disks</td>
<td></td>
</tr>
<tr>
<td>pool_create.yaml</td>
<td>Define NVMe disk pool</td>
<td></td>
</tr>
<tr>
<td>/E_Inventory</td>
<td>Configuration inventory</td>
<td>root</td>
</tr>
<tr>
<td>collect_after_restart.sh</td>
<td>Collect reboot logs after restart</td>
<td>/E_Inventory</td>
</tr>
<tr>
<td>collect_before_restart.sh</td>
<td>Collect reboot logs before restart</td>
<td></td>
</tr>
<tr>
<td>collect_ceastor_info.sh</td>
<td>Collect CeaStor profile</td>
<td></td>
</tr>
<tr>
<td>collect_dmidecode.sh</td>
<td>Collect node system info</td>
<td></td>
</tr>
<tr>
<td>collect_lsblik.sh</td>
<td>Collect node disk info</td>
<td></td>
</tr>
<tr>
<td>collect_network_card.sh</td>
<td>Collect node network info</td>
<td></td>
</tr>
<tr>
<td>/F_Generator</td>
<td>Workload generator</td>
<td>root</td>
</tr>
<tr>
<td>cestc.HST</td>
<td>Host definition file</td>
<td>/F_generator</td>
</tr>
<tr>
<td>multi_lun.asu</td>
<td>ASU definition file</td>
<td></td>
</tr>
<tr>
<td>persist_test_2.sh</td>
<td>Run Persist2 test</td>
<td></td>
</tr>
<tr>
<td>spc_run.sh</td>
<td>Run Init – Persist1</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX B: THIRD PARTY QUOTATION

All components are available directly through the Test Sponsor (China Electronics Cloud Technology Co., Ltd.).
APPENDIX C: TUNING PARAMETERS AND OPTIONS

See Appendix D Step 3.
APPENDIX D: STORAGE CONFIGURATION CREATION

Step 0: Edit configure file

Edit host.h for identify the IP address of all storage node and host node, as well as the size and number of logical volume.

Step 1: Create and format storage cluster:

Running cluster-deploy.sh:

```
[root@node55 script]# ./cluster-deploy.sh
start ceastor
format
Format Summary:                                    SCM Devices Disk Devices
                                              Hosts                      10,255.153.[2-17,19-26,28-33] 2 6
create pool
Pool created with 5.66%,94.34% storage tier ratio

-------------------
  UUID            : 98a2a8ff-c983-475d-9812-2d14abfe9d98
  Service Ranks  : [0,10,20]
  Storage Ranks  : [0-59]
  Total Size     : 305 TB
  Storage tier 0 (Meta-Space) : 17 TB (288 GB / rank)
  Storage tier 1 (Data-Space) : 288 TB (4.8 TB / rank)

deploy finished
```
Step 2: Create logical volumes and map them as NVMe disks on host nodes

2.1 Running client-deploy.sh

Creating 1 container for creation logical volumes.

Creating 20 logical volumes each with 5920GiB (6207.5GB) and start agent on all host node.

```
start agent
create container BLK001
########################start init global########################
worker 116 ThreadPool worker start
worker 116 ThreadPool worker start
worker 116 ThreadPool worker start
start 65: contextcnt 4, threadcnt2
worker 116 ThreadPool worker start
start 78: ioctx#0 thread0
start 78: ioctx#0 thread1
start 78: ioctx#1 thread0
start 78: ioctx#1 thread1
start 78: ioctx#2 thread0
start 78: ioctx#2 thread1
start 78: ioctx#3 thread0
start 78: ioctx#3 thread1
start 78: ioctx#4 thread0
start 78: ioctx#4 thread1
start watcher_tick
cbd_init 782 memory_list aio_comp size 0
cbd_init 783 memory_list aio_comp retry count 0
###########################container create test START###########################
Pool uuid: 9ba2a0ff-c9c3-475d-9d12-2d14abfe9d90
container uuid: eb6789f6-cc95-5ebd-bee4-03209f87fee9
container logic id: BLK001
##############################start query cont
#####end query cont, start get prop entry
#####end get entry
#####start get entry roots
#####verify BDM
#####End verify BDM!
###############################container create test END##############################
stop 193 ThreadPool stop
worker 130 ThreadPool worker finish
worker 130 ThreadPool worker finish
worker 130 ThreadPool worker finish
worker 130 ThreadPool worker finish
stop 208 ThreadPool stopped
stop 98: stop ioctx0
stop 98: stop ioctx1
stop 98: stop ioctx2
stop 98: stop ioctx3
stop 98: stop ioctx4
create image BLK001-00000001, size=59206
```
2.2 Connect Logical Volume to Host:

Run Lun_map.sh script to map all logical volume on host as NVMe disk.

- Map logical volume BLK001-00000001 to BLK001-00000009 for ASU-1
- Map logical volume BLK001-00000010 to BLK001-00000018 for ASU-2
- Map logical volume BLK001-00000019 to BLK001-00000020 for ASU-3
After finished Mapping:

```
[root@node34 script]# lskblk
NAME     MAJ:MIN  RM  SIZE   RO  TYPE  MOUNTPOINT
sda       8:0     0  446.1G  0  disk
    sda1    8:1     0  600M   0  part  /boot/efi
    sda2    8:2     0   1G   0  part  /boot
    sda3    8:3     0  444.5G  0  part
        └─cl-root 253:0  0  70G   0  lvm  /
        └─cl-swap 253:1  0   4G  0  lvm  [SWAP]
        └─cl-home 253:2 0  816.6G 0  lvm  /home
sdb       8:16    0  446.1G  0  disk
    sdb1    8:17    0  446.1G  0  part
        └─cl-home 253:2 0  816.6G 0  lvm  /home
nvme0n1   259:3    0  5.8T   0  disk
nvme1n1   259:7    0  5.8T   0  disk
nvme2n1   259:11   0  5.8T   0  disk
nvme3n1   259:15   0  5.8T   0  disk
nvme4n1   259:19   0  5.8T   0  disk
nvme5n1   259:23   0  5.8T   0  disk
nvme6n1   259:27   0  5.8T   0  disk
nvme7n1   259:31   0  5.8T   0  disk
nvme8n1   259:35   0  5.8T   0  disk
nvme9n1   259:39   0  5.8T   0  disk
nvme10n1  259:41   0  5.8T   0  disk
nvme11n1  259:43   0  5.8T   0  disk
nvme12n1  259:45   0  5.8T   0  disk
nvme13n1  259:47   0  5.8T   0  disk
nvme14n1  259:49   0  5.8T   0  disk
nvme15n1  259:51   0  5.8T   0  disk
nvme16n1  259:53   0  5.8T   0  disk
nvme17n1  259:55   0  5.8T   0  disk
nvme18n1  259:57   0  5.8T   0  disk
nvme19n1  259:59   0  5.8T   0  disk
```

**Step 3: Change the Scheduler on each Host System**

Run command: `echo 1048576 > /proc/sys/fs/aio-max-nr` on all host nodes
APPENDIX E: CONFIGURATION INVENTORY

The scripts used to collect the configuration inventory and the log files that were generated are available in the Supporting Files (see Appendix A)
APPENDIX F: WORKLOAD GENERATOR

The ASUs accessed by the SPC-1 workload generator are defined in multi_lun.asu. The test phases up through PERSIST1 are executed by spc_run.sh. PERSIST2 is executed by persist_test_2.sh.

The files are included in the Supporting Files (see Appendix_A).