SPC Benchmark 1™

Full Disclosure Report

Fujitsu Limited
ETERNUS AF650 S3

SPC-1 V3.8.0

Submission Identifier: A32010

Submitted For Review: November 5, 2019
First Edition – November 2019

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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](http://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. Kun Katsumata
Fujitsu Limited
1250 East Arques Ave.
PO box 3470
Sunnyvale, CA 94088-3470

October 28, 2019

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

ETERNUS AF650 S3

The results were:

<table>
<thead>
<tr>
<th>SPC-1 IOPS™</th>
<th>800,140</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC-1 Price-Performance™</td>
<td>$255.09/SPC-1 KIOPS™</td>
</tr>
<tr>
<td>SPC-1 IOPS™ Response Time</td>
<td>0.308 ms</td>
</tr>
<tr>
<td>SPC-1 Overall Response Time</td>
<td>0.203 ms</td>
</tr>
<tr>
<td>SPC-1 ASU Capacity</td>
<td>33,137 GB</td>
</tr>
<tr>
<td>SPC-1 ASU Price</td>
<td>$6.16/GB</td>
</tr>
<tr>
<td>SPC-1 Total System Price</td>
<td>$204,090.88</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-g923a. 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 under the Submission Identifier A32010.
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,

Doug Johnson, Certified SPC Auditor
LETTER OF GOOD FAITH

Kanagawa-ken, Kawasaki-shi, Nakahara-ku, Kamiokanaka, 4-1-1, JAPAN 211-8588
Phone: 044-754-3423

October 23, 2019
From: Koji Uchida, Fujitsu Limited

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

Contact Information: Kun Katsumata
Fujitsu America, Inc.
1250 East Arques Ave. PO Box 3470
Sunnyvale, CA 94088, U.S.A.

Subject: SPC-1 Letter of Good Faith for the FUJITSU Storage ETERNUS AF650 S3

Fujitsu Limited 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 that product are complete, accurate, and in full compliance with V3.8 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.

Signed:                      Date:

Koji Uchida
Vice President, Storage System Business Div.

Oct 23, 2019
# SPC BENCHMARK 1™

## EXECUTIVE SUMMARY

**FUJITSU LIMITED**

**ETERNUS AF650 S3**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC-1 IOPS™</td>
<td>800,140</td>
</tr>
<tr>
<td>SPC-1 Price-Performance™</td>
<td>$255.09/SPC-1 KIOPS™</td>
</tr>
<tr>
<td>SPC-1 IOPS™ Response Time</td>
<td>0.308 ms</td>
</tr>
<tr>
<td>SPC-1 Overall Response Time</td>
<td>0.203 ms</td>
</tr>
<tr>
<td>SPC-1 ASU Capacity</td>
<td>33,137 GB</td>
</tr>
<tr>
<td>SPC-1 Space Effectiveness Ratio</td>
<td>NA</td>
</tr>
<tr>
<td>SPC-1 ASU Price</td>
<td>$6.16/GB</td>
</tr>
<tr>
<td>SPC-1 Total System Price</td>
<td>$204,099.88</td>
</tr>
<tr>
<td>Data Protection Level</td>
<td>Protected 2 (RAID1)</td>
</tr>
<tr>
<td>Physical Storage Capacity</td>
<td>92,160 GB</td>
</tr>
<tr>
<td>Pricing Currency / Target Country</td>
<td>U.S. Dollars / USA</td>
</tr>
</tbody>
</table>

**SPC-1 V3.8.0**

**SUBMISSION IDENTIFIER: A32010**

**SUBMITTED FOR REVIEW: NOVEMBER 5, 2019**
Benchmark Configuration Diagram

ETERNUS AF650 S3
1x ETERNUS AF650 S3
2x Host interface for AF650 (16Gbit/s, FC, 8port)
2x AC Power Cords (125V - IEC320-C14, 0.5m)

3x Drive enclosure for AF650
96x Value SSD (2.5inch) 960GB for AF650
8x LC-LC 10 GIGABIT MULTIMODE OM3 LASER OPTIMIZED DUPLEX 50/125 FIBER PATCH CABLE RISER RATED AQUA - 5M

8x FC16Gbps connection

PRIMERGY Server
4x PRIMERGY RX2540 M4, each with:
- 2x Intel(R) Xeon(R) Platinum 8168 CPU, 24 cores, 33MB Cache, 2.7GHz
- 384GB Main Memory
- 2x PFC EP LPe3200 2x 32Gb Broadcom
- Red Hat Enterprise Linux Server 6.9

1x PRIMECENTER M1 RACK 6425 (42U, 1050x600mm) with Front & Rear Doors, side panels
1x Power Distribution Unit for DX (AC240V, 6 enclosures, 2RU)
8x LC-LC 10 GIGABIT MULTIMODE OM3 LASER OPTIMIZED DUPLEX 50/125 FIBER PATCH CABLE RISER RATED AQUA - 5M
96x Value SSD (2.5inch) 960GB for AF650
8x LC-LC 10 GIGABIT MULTIMODE OM3 LASER OPTIMIZED DUPLEX 50/125 FIBER PATCH CABLE RISER RATED AQUA - 5M
Tested Storage Product Description

The Fujitsu Storage ETERNUS AF650 S3 delivers leading storage performance and automated quality of service management, enabling a maximum of system utilization and contributing to a fast ROI. It is the perfect solution when consolidating data of large-scale databases, business-critical applications and business analytics/big data—all into one all-flash system. Extensive high-availability and disaster recovery capabilities make ETERNUS AF650 an ideal storage system for any business data.

For additional details, please visit:

Priced Storage Configuration Components

<table>
<thead>
<tr>
<th>8x Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1x ETERNUS AF650 S3 with:</td>
</tr>
<tr>
<td>1x Controller Enclosure Module with:</td>
</tr>
<tr>
<td>2x Control Module, each with:</td>
</tr>
<tr>
<td>384 GB cache</td>
</tr>
<tr>
<td>1x Channel Adapter with:</td>
</tr>
<tr>
<td>4x 16 Gbps Fibre Channel Host Ports</td>
</tr>
<tr>
<td>96x 960 GB SSD Storage Devices (without Hot Spare)</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>ET653SAU</td>
<td>ETERNUS AF650 S3</td>
<td>1</td>
<td>1</td>
<td>49,030.00</td>
<td>49,030.00</td>
<td>53%</td>
<td>23,044.10</td>
</tr>
<tr>
<td>ETREADAU</td>
<td>Drive enclosure for AF650 S3(2.5inch)</td>
<td>1</td>
<td>3</td>
<td>4,700.00</td>
<td>14,100.00</td>
<td>53%</td>
<td>6,627.00</td>
</tr>
<tr>
<td>ETRHBA</td>
<td>Host interface for AF650 S3(16Gbit/s, P, 8port)</td>
<td>1</td>
<td>1</td>
<td>8,310.00</td>
<td>8,310.00</td>
<td>53%</td>
<td>3,905.70</td>
</tr>
<tr>
<td>ETRSA02</td>
<td>Value SSD(2.5inch)960GB x12 for AF650 S3</td>
<td>1</td>
<td>8</td>
<td>10,400.00</td>
<td>83,200.00</td>
<td>53%</td>
<td>45,680.00</td>
</tr>
<tr>
<td>S26361-F4994-L502</td>
<td>PFC EP LPe32002 2x32Gb Broadcom</td>
<td>1</td>
<td>8</td>
<td>1,368.00</td>
<td>10,944.00</td>
<td>53%</td>
<td>5,143.68</td>
</tr>
<tr>
<td>ETRKC15U</td>
<td>AC100/200V Power Cord for AF650 S3, DX500/DX600/DX900 S5(BC60320 C14, 1.5m)</td>
<td>1</td>
<td>4</td>
<td>342.00</td>
<td>1,368.00</td>
<td>53%</td>
<td>628.32</td>
</tr>
<tr>
<td>ET4BU</td>
<td>Power distribution unit for AF650 S3, DX500/DX600/DX900 S5(EC22A/200-240V, 2U, 16Outlets)</td>
<td>1</td>
<td>1</td>
<td>1,870.00</td>
<td>1,870.00</td>
<td>53%</td>
<td>878.90</td>
</tr>
<tr>
<td>ETRASU</td>
<td>19-inch rack (Standard door, 2000mm, Base rack with stabilizers)</td>
<td>1</td>
<td>1</td>
<td>4,070.00</td>
<td>4,070.00</td>
<td>53%</td>
<td>1,912.90</td>
</tr>
<tr>
<td>13-61-343827-003</td>
<td>Custom Fibre Host interface cable 3m LC-LC Crossed Polarity Duplex MM-50/125um; 3.0mm; Riser rated; OM3; Aqua Jacket</td>
<td>1</td>
<td>8</td>
<td>80.00</td>
<td>640.00</td>
<td>53%</td>
<td>300.80</td>
</tr>
</tbody>
</table>

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

**Warranty:** The 3-year maintenance and support included in the above pricing meets or exceeds a 24x7 coverage with a 4-hour response time.

**Availability Date:** November 5, 2019.
Response Time and Throughput Graph

Contact Information

Test Sponsor Primary Contact
Fujitsu Limited – http://www.fujitsu.com/services/computing/storage/
Kun Katsumata – kkatsumata@us.fujitsu.com

SPC Auditor
InfoSizing – www.sizing.com
Doug Johnson – doug@sizing.com

Revision Information

SPC Benchmark 1™ Revision
V3.8.0

SPC-1 Workload Generator Revision
v3.0.2-1-g823a

Publication Revision History
Initial Publication
**CONFIGURATION INFORMATION**

**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).

![Configuration Diagram]

**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>4x Fujitsu PRIMERGY RX2540 M4 Servers, each with:</td>
</tr>
<tr>
<td>2x Intel® Xeon® Platinum 8168 (2.7 GHz, 24-Core, 33 MB L3)</td>
</tr>
<tr>
<td>384 GB Main Memory</td>
</tr>
<tr>
<td>Red Hat Enterprise Linux Server 6.9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tested Storage Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>8x Emulex LightPulse LPe32002-M2 2-Port 32Gb Fibre Channel Adapter</td>
</tr>
<tr>
<td>1x ETERNUS AF650 S3 with:</td>
</tr>
<tr>
<td>1x Controller Enclosure Module with:</td>
</tr>
<tr>
<td>2x Control Module, each with:</td>
</tr>
<tr>
<td>384 GB cache</td>
</tr>
<tr>
<td>1x Channel Adapter with:</td>
</tr>
<tr>
<td>4x 16 Gbps Fibre Channel Host Ports</td>
</tr>
<tr>
<td>96x 960 GB SSD Storage Devices (without Hot Spare)</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>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>1,656.8</td>
<td>1,656.8</td>
<td>14,911.6</td>
<td>45.0%</td>
</tr>
<tr>
<td>ASU-2</td>
<td>9</td>
<td>1,656.8</td>
<td>1,656.8</td>
<td>14,911.6</td>
<td>45.0%</td>
</tr>
<tr>
<td>ASU-3</td>
<td>2</td>
<td>1,656.8</td>
<td>1,656.8</td>
<td>3,313.7</td>
<td>10.0%</td>
</tr>
<tr>
<td>SPC-1 ASU Capacity</td>
<td>33,137</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.

<table>
<thead>
<tr>
<th>Devices</th>
<th>Count</th>
<th>Physical Capacity</th>
<th>Total Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSD</td>
<td>96</td>
<td>960.0</td>
<td>92,160.0</td>
</tr>
<tr>
<td><strong>Total Physical Capacity</strong></td>
<td></td>
<td></td>
<td>92,160</td>
</tr>
<tr>
<td><strong>Physical Capacity Utilization</strong></td>
<td></td>
<td></td>
<td>35.96%</td>
</tr>
</tbody>
</table>

Data Protection

The data protection level used for all LVs was Protected 2 (RAID1), which was accomplished by configuring dual controllers, dual power, dual fans, and RAID1 device protection.
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.

![Measurement Intervals by Test Phase Graph](image)

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>Transition Period</td>
<td>09-Oct-19 19:00:16</td>
<td>09-Oct-19 21:00:16</td>
<td>2:00:00</td>
</tr>
<tr>
<td>Measurement Interval</td>
<td>09-Oct-19 21:00:16</td>
<td>10-Oct-19 05:00:17</td>
<td>8:00:01</td>
</tr>
</tbody>
</table>

SUSTAIN – Throughput Graph
**SUSTAIN – Response Time Graph**

Response Time Graph (SUSTAIN @ 800,100 IOPS)

- ASU1
- ASU2
- ASU3
- All ASUs

**SUSTAIN – Data Rate Graph**

Data Rate Graph (SUSTAIN @ 800,100 IOPS)

- ASU1
- ASU2
- ASU3
- All ASUs

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SPC Benchmark ™ V3.8.0
Fujitsu Limited
ETERNUS AF650 S3

Full Disclosure Report
Submission Identifier: A32010
Submitted for Review: November 5, 2019
SUSTAIN – Response Time Frequency Graph

![Response Time Frequency Graph](image)

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>0.0008</td>
<td>0.0002</td>
<td>0.0005</td>
<td>0.0003</td>
<td>0.0010</td>
<td>0.0005</td>
<td>0.0007</td>
<td>0.0002</td>
</tr>
<tr>
<td>Difference</td>
<td>0.002%</td>
<td>0.001%</td>
<td>0.001%</td>
<td>0.000%</td>
<td>0.011%</td>
<td>0.005%</td>
<td>0.008%</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>10-Oct-19 05:01:16</td>
<td>10-Oct-19 05:04:16</td>
<td>0:03:00</td>
</tr>
</tbody>
</table>

RAMPD_100 – Throughput Graph
**RAMPD_100 – Response Time Graph**

![Response Time Graph (RampD_100 @ 800,100 IOPS)](image)

**RAMPD_100 – Data Rate Graph**

![Data Rate Graph (RampD_100 @ 800,100 IOPS)](image)
**RAMPD_100 – 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>0.0009</td>
<td>0.0002</td>
<td>0.0005</td>
<td>0.0003</td>
<td>0.0014</td>
<td>0.0004</td>
<td>0.0008</td>
<td>0.0002</td>
</tr>
<tr>
<td>Difference</td>
<td>0.011%</td>
<td>0.006%</td>
<td>0.036%</td>
<td>0.006%</td>
<td>0.022%</td>
<td>0.016%</td>
<td>0.024%</td>
<td>0.006%</td>
</tr>
</tbody>
</table>

**RAMPD_100 – I/O Request Summary**

<table>
<thead>
<tr>
<th>I/O Requests Completed in the Measurement Interval</th>
<th>480,086,178</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/O Requests Completed with Response Time &lt;= 30 ms</td>
<td>480,086,178</td>
</tr>
<tr>
<td>I/O Requests Completed with Response Time &gt; 30 ms</td>
<td>0</td>
</tr>
</tbody>
</table>
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)
Response Time Ramp Test – Average Response Time Graph

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

Response Time Ramp Test – RAMPD_10 Response Time Graph

![Response Time Graph (RampD_10 @ 80,010 IOPS)]
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>800,140.9</td>
<td>80,002.5</td>
</tr>
<tr>
<td>REPEAT_1</td>
<td>800,208.7</td>
<td>80,007.3</td>
</tr>
<tr>
<td>REPEAT_2</td>
<td>800,152.8</td>
<td>80,023.2</td>
</tr>
</tbody>
</table>

REPEAT_1_100 – Throughput Graph

Throughput Graph (Repeat_1_100 @ 800,100 IOPS)
**REPEAT_1_100 – Response Time Graph**

![Response Time Graph](image)

**REPEAT_2_100 – Throughput Graph**

![Throughput Graph](image)
**REPEAT_2_100 – Response Time Graph**

![Response Time Graph (Repeat_2_100 @ 800,100 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>Test Phase</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>0.0007</td>
<td>0.0002</td>
<td>0.0005</td>
<td>0.0003</td>
<td>0.0011</td>
<td>0.0005</td>
<td>0.0006</td>
<td>0.0001</td>
</tr>
<tr>
<td>Difference</td>
<td>0.005%</td>
<td>0.004%</td>
<td>0.010%</td>
<td>0.007%</td>
<td>0.011%</td>
<td>0.002%</td>
<td>0.014%</td>
<td>0.003%</td>
</tr>
</tbody>
</table>

### REPEAT_2_100 Test Phase

<table>
<thead>
<tr>
<th>Test Phase</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>0.0009</td>
<td>0.0003</td>
<td>0.0007</td>
<td>0.0003</td>
<td>0.0011</td>
<td>0.0004</td>
<td>0.0006</td>
<td>0.0003</td>
</tr>
<tr>
<td>Difference</td>
<td>0.017%</td>
<td>0.007%</td>
<td>0.029%</td>
<td>0.006%</td>
<td>0.016%</td>
<td>0.020%</td>
<td>0.006%</td>
<td>0.003%</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>164,388,396</td>
</tr>
<tr>
<td>Total Number of Logical Blocks Verified</td>
<td>84,500,163</td>
</tr>
<tr>
<td>Total Number of Logical Blocks Overwritten</td>
<td>79,888,233</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

Redundantly configured batteries inside the ETERNUS AF650 S3 storage system allow data in cache memory to be moved to non-volatile memory or to physical disk drives in the event of a power outage. This secured data can then be maintained in that state indefinitely until the power is 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</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>
</tbody>
</table>

All tuning done via GUI (see Appendix C)

<table>
<thead>
<tr>
<th>/D_Creation</th>
<th>Storage configuration creation</th>
<th>root</th>
</tr>
</thead>
<tbody>
<tr>
<td>AF650S3_20190911.exp</td>
<td>Configure CLI expect script</td>
<td>/D_Creation</td>
</tr>
<tr>
<td>AF650S3_20190911makeLV.sh</td>
<td>Linux LVM configuration script</td>
<td>/D_Creation</td>
</tr>
<tr>
<td>definitions.exp</td>
<td>Procedure definitions</td>
<td>/D_Creation</td>
</tr>
<tr>
<td>doFDRCfg.sh</td>
<td>Shell script to configure the array</td>
<td>/D_Creation</td>
</tr>
<tr>
<td>showFormatStatus.exp</td>
<td>Check for physical format progress</td>
<td>/D_Creation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>/E_Inventory</th>
<th>Configuration inventory</th>
<th>root</th>
</tr>
</thead>
<tbody>
<tr>
<td>log_BeforeF_AM191009170554.zlg_001.txt</td>
<td>Configuration details before the run</td>
<td>/E_Inventory</td>
</tr>
<tr>
<td>log_AfterJ_AM191009170554.zlg_001.txt</td>
<td>Configuration details after the run</td>
<td>/E_Inventory</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>/F_Generator</th>
<th>Workload generator</th>
<th>root</th>
</tr>
</thead>
<tbody>
<tr>
<td>doFDRall_01.sh</td>
<td>Master run file 1</td>
<td>/F_generator</td>
</tr>
<tr>
<td>doFDRall_02.sh</td>
<td>Master run file 2</td>
<td>/F_generator</td>
</tr>
<tr>
<td>exportLog.exp</td>
<td>Storage array log export</td>
<td>/F_generator</td>
</tr>
<tr>
<td>SPC1_AF650S3_20190911.asu</td>
<td>ASU configuration file</td>
<td>/F_generator</td>
</tr>
<tr>
<td>SPC1_AF650S3_20190911.hst</td>
<td>Host configuration file</td>
<td>/F_generator</td>
</tr>
</tbody>
</table>
APPENDIX B: THIRD PARTY QUOTATION

All components are available directly through the Test Sponsor (Fujitsu Limited).
APPENDIX C: TUNING PARAMETERS AND OPTIONS
The standard Fujitsu GUI was used to apply the Tuning options for this test.

1. In order to execute some of the commands listed below it is necessary to create an user account with maintainer role. Please create such user account and login with the new account.

2. Change DCMF (Disk Command Multiplication Factor) value from the default (1) to (10) for all RAID Groups.
The following GUI screen (RAID Group -> Tuning -> Modify RAID Group Parameter is used for each RAID Group and the DCMF parameter is changed to 10 as highlighted in red frame below:

![Modify RAID Group Parameters GUI Screenshot]

3. Disable Debug Trace
   The following GUI setting was applied:
   System-> System Settings -> Setup Debug Mode: The Master Trace Level was set to Off (Default: Standard)
4. **Disable Read Sequential/Write Sequential**

   The following GUI setting was applied.
   **System-> System Settings -> Setup Subsystem Parameters:**
   Flexible Write Through was set to Disable (Default: Enable)
   Read Sequential/Write Sequential was set to Disable (Default: Enable)
APPENDIX D: STORAGE CONFIGURATION CREATION

The standard Fujitsu Command Line tool (CLI) was used to create the ETERNUS AF650 S3 SPC-1 configuration.

The ‘master’ script, doFDRcfg.sh, was executed, which in turn, invoked the script, AF650S3_20190911.exp. The ‘master’ script included shell commands to monitor the progress as the physical formatting proceeded, which used the expect script showFormatStatus.exp to pick up the status information from the array.

The AF650S3_20190911.exp script completed steps 1-4, described below for the 8-host port configuration.

Each expect script included the docli procedure, which was used to issue the CLI commands to the array. That procedure used ssh for communication with the array. A second procedure in the script, doexit, was used to conclude the execution sequence at the end of the script.

Step 1 – Creation of RAID Groups
A total of 48 RAID Groups were created, according to the configuration plan, ConfigurationDesign_AF650S3_20190911.xlsx, which is typically prepared in concert with a Fujitsu SE. Each RAID Group was made up of 2 disk drives in a RAID1(1+1) configuration and assigned to a specific CM for operational control. The RAID Groups were named RG#0-00 through RG#1-23.

Step 2 – Creation of the Logical Volumes
4 wide striped logical volumes were created across 24 RAID Groups assigned to the same CM. Total of 8 wide striped logical volumes were created.

Step 3 – Creation of the Global Hot Spares
No drives were designated as the Global Hot Spare.

Step 4 – Assignment of LUN Mapping to the Linux Host Systems
The AF650S3_20190911.exp script provided mapping to 8 host ports.

The port LUN mapping was assigned for each of the Logical Volumes using 4 ports on Channel Adapters (CA) in each of the 2 Controller Modules (CM). Each of the volumes, which were defined on RAID Groups owned by a CM, were assigned LUN numbers on the active ports on the CAs installed on same CM.

Step 5 – Creation of striped logical volumes.
Built in logical volume manager in Linux is used to stripe each LUN presented by ETERNUS AF650 S3 array.

This is done in 3 steps included in the AF650S3_20190911makeLV.sh script.
1. Create Physical Volumes (PV) for each LUN presented from AF650 S3.

   pvcreate /dev/disk/by-id/scsi-36000000e00d30000000300000000000000000
   pvcreate /dev/disk/by-id/scsi-36000000e00d3000000030000000000010000
   pvcreate /dev/disk/by-id/scsi-36000000e00d300000003000000000020000
   pvcreate /dev/disk/by-id/scsi-36000000e00d300000003000000000030000
   pvcreate /dev/disk/by-id/scsi-36000000e00d300000003000000000040000
   pvcreate /dev/disk/by-id/scsi-36000000e00d300000003000000000050000
   pvcreate /dev/disk/by-id/scsi-36000000e00d300000003000000000060000
   pvcreate /dev/disk/by-id/scsi-36000000e00d300000003000000000070000

2. Create one Volume Group with physical extent size of 512KiB

   vgcreate asu_vg1 /dev/sda
   vgextend asu_vg1 /dev/sdf
   vgextend asu_vg1 /dev/sdb
   vgextend asu_vg1 /dev/sdg
   vgextend asu_vg1 /dev/sdc
   vgextend asu_vg1 /dev/sdh
   vgextend asu_vg1 /dev/sdd
   vgextend asu_vg1 /dev/sdi

3. Create 20 Logical Volumes for each ASU with 512KiB Stripe size

   lvcreate -n asu101 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu102 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu103 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu104 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu105 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu106 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu107 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu108 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu109 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu201 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu202 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu203 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu204 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu205 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu206 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu207 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu208 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu209 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu301 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
   lvcreate -n asu302 -i 8 -I 512 -C y -L 1580096MiB asu_vg1
Referenced Scripts

- doFDRcfg.sh
- AF650S3_20190911.exp
- showFormatStatus.exp
- AF650S3_20190911makeLV.sh
APPENDIX E: CONFIGURATION INVENTORY

The following files (included in the Supporting Files) capture the configuration before and after the test run.

- log_BeforeF_AM191009170554.zlg_001.txt
- log_AfterJ_AM191009170554.zlg_001.txt
APPENDIX F: WORKLOAD GENERATOR

The ASU configuration file can be found in the Supporting Files.

- SPC1_AF650S3_20190911.asu

The host configuration file can be found in the Supporting Files.

- SPC1_AF650S3_20190911.hst

The following ‘master’ script was used to execute the required ASU pre-fill, Primary Metrics Test (Sustainability Test Phase, IOPS Test Phase, and Response Time Ramp Test Phase), Repeatability Test (Repeatability Test Phase 1 and Repeatability Test Phase 2), the SPC-1 Persistence Test Run 1 and the SPC-2 Persistence Test in an uninterrupted sequence with doFDRall_01.sh and doFDRall_02.sh.

The ‘master’ script invokes various other scripts which appear below in the Referenced Scripts section with a brief description of each referenced script.

- doFDRall_01.sh
- doFDRall_02.sh

Referenced Scripts

The ‘master’ script invokes the following script in order to export the log file from the storage array.

- exportLog.exp