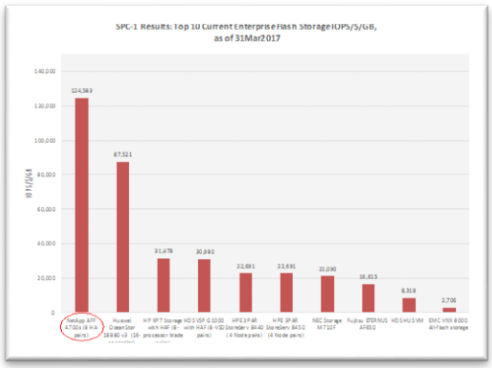
NetApp All-Flash FAS AFF A700s SAN Storage Performance Leadership

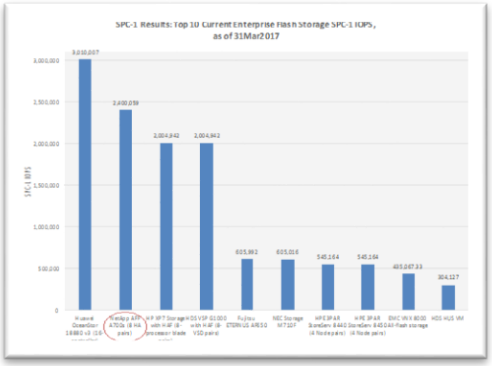
Silverton Consulting, Inc. StorInt™ Briefing

Executive Summary

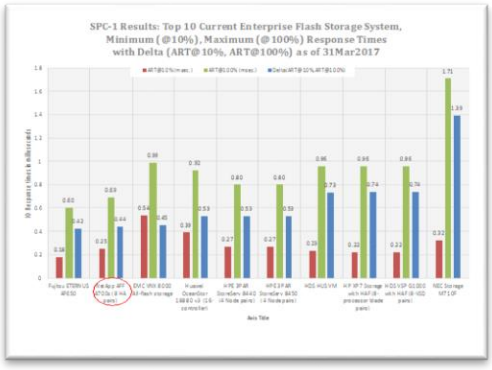
This report discusses NetApp's AFF and FAS product lines, ONTAP 9 advanced functionality, NetApp SAN history and NetApp AFF A700s SAN IO performance. Our performance review uses recent benchmark results, ranks the A700s against a list of enterprise flash storage systems and shows where the NetApp AFF A700s falls on Silverton Consulting's All-Flash Storage ChampionsChart™.



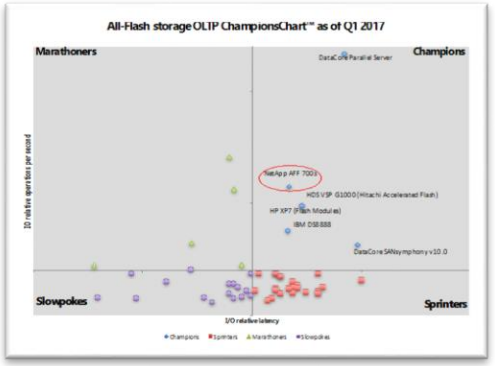
NetApp FAS and AFF product families offer a broad portfolio of storage that cover small, midrange and enterprise class systems. NetApp's ONTAP 9 software supplies some of the most advanced clustering, data reduction and other enterprise storage functionality available in the market today. Finally, NetApp has been shipping FC SAN storage on their ONTAP systems since 2001, over 16 years ago.



For our performance rankings, we use independently validated, published SAN storage benchmark results and report on select formal benchmark metrics as well as Silverton Consulting computed metrics. Silverton calculations used in this analysis are described in line and are based on data supplied in full benchmark reports. Our ChampionsChart data are derived from industry standard benchmarks and use an undisclosed, proprietary formula to rank systems.



Results of our examination show that NetApp AFF A700s places #1 in IO/second/$/GB, #2 in IO/second, and #2 in Performance Consistency. Also, the NetApp A700s ranks #2 in our All-Flash Storage ChampionsChart for Q1 2017.



In summary, the NetApp AFF A700s ranks among the highest, most economical and most consistent IO performing enterprise class AFA available in the industry today.

So, if your data center is looking for enterprise AFA SAN storage with verifiably great and consistent IO performance, at an affordable price, you can't go wrong with the NetApp A700s and be sure to check out the rest of NetApp's AFF product line.

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Introduction

The data storage industry has been undergoing a significant transition over the last decade. The rise of flash storage, solid-state drives (SSDs) and all-flash arrays (AFAs) has forever changed storage mostly due to flash's high IO performance, low response time and consistency of performance.

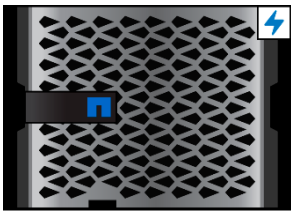
NetApp has been an innovator in incorporating flash technology into their storage systems and offers both AFA storage and traditional hybrid (flash disk) storage systems. From the start, NetApp has been the leader in network-attached storage (NAS), but for over a decade they have also provided block or storage area network (SAN) using fibre channel (FC), FC over Ethernet (FCoE) and iSCSI IP/SAN.

In this paper, we will introduce NetApp's enterprise SAN storage product line and its software functionality and then turn our focus to NetApp's AFA SAN IO performance.

NetApp enterprise SAN storage

NetApp has three main storage product families, but the ones based on ONTAP 9 software provide advanced functioning, general purpose storage, that range from entry-level to enterprise-class storage systems and include all-flash fabric-attached storage (AFF) and hybrid fabric-attached storage (FAS).

NetApp AFF storage includes the A700, A700s, A300 and A200. Selected hardware specifications, per high availability (HA) pair, for AFF storage include the following:



- **AFF A700** supports a maximum 7.3PB raw capacity, using a maximum of 480 SSDs with (front-end) host ports that include 32 32Gb, 64 16Gb (autoranging) and 64 8Gb/4Gb FC ports, along with 64 10GbE FCoE ports and up to 64 12Gb/6Gb SAS (backend) storage ports.

- **AFF A700s** supports a 3.3PB maximum raw capacity, with 24 internal SSD slots and using a maximum of 216 SSDs, with host ports that include 8 32Gb, 8 16Gb (autoranging) and 8 8Gb/4Gb FC ports and up to 8 12Gb/6Gb SAS storage ports.

- **AFF A300** supports a 5.9PB maximum raw capacity, using a maximum of 384 SSDs, with host ports that include 8 32Gb, 24 16Gb (autoranging), and 16 8Gb/4Gb FC ports, along with 24 10GbE FCoE ports and up to 24 12Gb/6Gb SAS storage ports.

- **AFF A200** supports a 2.2PB maximum raw capacity, with 24 internal SSD slots and using a maximum of 144 SSDs, with host ports that include 8 16Gb

(autoranging) and 8 8Gb/4Gb FC ports, 8 10GbE FCoE ports and up to 4 12Gb/6Gb SAS storage ports.

NetApp FAS storage includes the FAS9000, FAS8200, FAS2650 and FAS2620 systems. Selected hardware specifications for these systems, per HA pair, include the following:

- **FAS9000** supports a 14.4PB maximum capacity, using up to 1440 disk drives or 480 SSDs, with host ports that include 32 32Gb, 64 16Gb (autoranging) and 64 8Gb/4Gb FC ports, along with 64 10GbE FCoE ports and up to 64 12Gb/6Gb SAS storage ports.

- **FAS8200** supports a 4.8PB maximum capacity, using up to 480 disk drives or SSDs, with 8 32Gb, 24 16Gb (autoranging), and 16 8Gb/4Gb FC ports, with 24 10GbE FCoE ports, and up to 24 12Gb/6Gb SAS storage ports.

- **FAS2650** supports a 1.2PB maximum capacity, with 24 internal drive slots and using a maximum of 144 disk drives or SSDs, with 8 16Gb/8Gb (UTA2) FC or FCoE ports and up to 4 12Gb SAS ports.

- **FAS2620** supports a 1.4PB maximum capacity, with 12 internal drive slots and using a maximum of 144 disk drives or SSDs, with 8 16Gb/8Gb (UTA2) FC or FCoE ports and up to 4 12Gb SAS ports.

ONTAP 9 storage software capabilities

ONTAP 9 storage software has many advanced storage capabilities. For starters, ONTAP 9 offers both SAN and NAS storage clustering. That is, you can either cluster up to 6 HA pairs of AFF, FAS or any combination thereof to form a SAN storage cluster or cluster up to 12 HA pairs of AFF, FAS or any combination thereof to form a NAS cluster. As a SAN or NAS cluster, ONTAP 9 offers access to logical unit number (LUN) or file data that resides anywhere in the cluster to any attached host. Further, LUN or file data can be migrated from any node in the cluster to any other node without interrupting access to the storage or the data that's being migrated. Finally, you can configure a SAN-NAS cluster with ONTAP 9 that supports both file and block storage for a complete scale-out storage environment.

ONTAP 9 supports a maximum LUN size of 16TB and offers up to 8192 LUNs per HA pair or a maximum of 49K LUNs when operating as a SAN or SAN-NAS cluster.

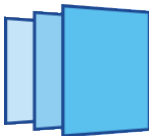
Moreover, ONTAP 9 offers extensive data storage (footprint) reduction capabilities, such as:

- **Data compression** – data is compressed within a block/file to reduce the physical storage space required on backend storage and uncompressed when requested by the host.

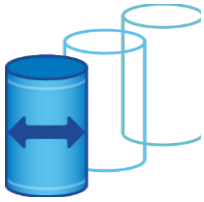
- **Data deduplication** – duplicate data is identified and its storage space is released using the original data as a stand-in whenever and wherever requested by the host.

- **Data compaction** – deduped and compressed data is compacted, inline into a single block of storage so that more data can be accessed within a single IO operation

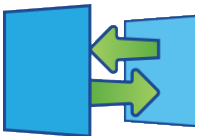
- **Thin provisioning** – free but unused (non-written) storage space is available for use by other LUNs or file systems within the storage system.



Although not specifically a data reduction capability, ONTAP 9 provides space-efficient, point-in-time copies called **Snapshots**, which can be used anytime read-only access to original data is needed. Snapshots are often used for backups or remote replication of data and are deleted or released when the backup or replication completes.



As an alternative to Snapshots, ONTAP 9 offers read-writeable, point-in-time **FlexClones**, which are updateable copies of LUN or file system data. FlexClones can be a complete, useable copy of active customer application data, making them ideal for use by development, test and quality assurance teams. FlexClones typically exist longer than snapshots and, as such, can often live through a complete development cycle before being released/refreshed prior to the next development cycle.



ONTAP 9 also offers **SnapMirror**, remote replication of data that can be used for disaster recovery and business continuance in the event of a data center outage. Many enterprises today have business-critical applications that need to continue to operate even when a primary site goes down. SnapMirror is designed to provide an up-to-date copy of business-critical data at a secondary site, enabling operations to recover application activities when necessary.

In addition, NetApp provides excellent storage support for VMware and Microsoft Windows Server/Hyper-V environments.

For **VMware**, NetApp offers a vCenter plugin used to configure, monitor and troubleshoot NetApp storage operations from a VMware console; supports VMware Virtual Volumes (VVols) to enable VMware admins to more easily configure, manage and back up VM data; supplies full support for VMware vRealize Automation using a Workflow Automation plugin; and provides VMware disaster recovery with vSphere

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Site Recovery Manager (SRM) to SnapMirror integration.

For **Microsoft Windows Server/Hyper-V**, NetApp supplies System Center Virtual Machine Manager (SCVMM) add-ins used to configure, monitor and troubleshoot NetApp storage operations from a Windows Server console. NetApp Workforce Automation offers PowerShell scripting for storage automation under Windows Server. ONTAP 9 also supports failover clustering or Microsoft Cluster Service with shared disks.

In addition to VMware and Windows Server environments, NetApp provides OpenStack SAN storage through its driver for OpenStack Block Storage (Cinder) and provides Docker Engine SAN storage through its NetApp Docker Volume Plugin (nDVP).

Standalone management for NetApp FAS and AFF storage is also available outside of VMware and Microsoft Server environments using the **OnCommand System Manager**, which provides a simple, browser-based GUI storage management console. Moreover, ONTAP 9 offers storage management facilities via a command line interface (CLI) or a RESTful (Representative State Transfer) API. Using ONTAP 9's CLI or RESTful API, any data center can automate/program NetApp storage configuration, monitoring and management activities.

NetApp FC SAN experience

NetApp first rolled out FC SAN storage support for its FAS systems more than 16 years ago and has been a leader in FC SAN storage functionality ever since. Further, NetApp was the first major vendor to offer FCoE for their FAS storage more than eight years ago and the first to support FCoE and file access (NAS) protocols over the same physical Ethernet link.

Recently, NetApp was the first major vendor in the industry to offer 32Gb FC storage links on their AFF and FAS systems to help SAN storage customers with high-bandwidth application requirements. High-speed 32Gb FC ports are offered in every current enterprise-class and midrange NetApp AFF and FAS storage offering.

NetApp is currently the fastest growing, top 5 SAN storage vendor, increasing revenue 3.6 times faster than the nearest SAN storage competitor over the past year.[1]

[1] Source IDC, WW Quarterly Enterprise Storage Systems Tracker – 2016Q4, March 2, 2107

SAN storage performance benchmarking

The Storage Performance Council (SPC) supports major industry-standard FC SAN and IP/SAN storage IO performance benchmarking. All SPC benchmarks are defined by a consortium of major and minor SAN storage vendors across the industry. Every official (published) SPC benchmark is formally and independently audited to ensure integrity and compliance with SPC benchmark rules and regulations. In this way, SPC warrants that official benchmark results are an accurate representation of a storage system's IO performance under the specified workloads.[2]

Over the years, the SPC-1 benchmark has been the most popular because its workload is more like a customer's use of SAN storage. SPC-1 simulates an online transaction processing (OLTP) workload, which is frequently one of the key reasons for deploying SAN storage in most data centers. Vendors often submit some of their highest IO-performing storage for SPC-1 benchmarks. Published SPC-1 benchmarks exist from just about every major FC SAN storage provider and most minor vendors.

The SPC-1 workload simulates database updates for OLTP activities using multiple IO streams across three different storage groups called application storage units (ASUs) for database, user and log storage.

Two concerns with SPC-1 and other storage benchmarks are that (1) they regularly intermix enterprise-class, midrange and SMB-class storage systems representing hybrid, all-flash and direct access storage, and (2) they sometimes include older but active storage system results along with more current generation results.

Because of these concerns, our analysis includes (1) only SPC-1 results that represent enterprise-class flash storage systems and (2) only SPC-1 benchmark submissions from the last two years. Our current enterprise flash storage SPC-1 benchmark rankings include the following storage systems:

- EMC VNX8000 flash storage
- Fujitsu ETERNUS AF650
- Hitachi Data Systems (HDS) VSP G1000 with Hitachi Accelerated Flash modules
- Hitachi Unified Storage (HUS) VM
- HPE 3PAR StoreServ 8440
- HPE 3PAR StoreServ 8450
- HPE XP7 with flash modules
- Huawei OceanStor™ 18800
- NEC M710F

[2] For more information, please see http://www.storageperformance.org/home as of 29 March 2017.

- NetApp AFF A700s.[3]

Although some of these systems may not all be named AFA, they were all configured with the majority of their raw storage capacity in flash, and most non-AFA systems in the list above had all their storage capacity in flash.

Finally, all the SPC-1 metrics that follow come from active SPC-1 Version 1 and Version 2 benchmark results. SPC-1 Version 2 is a newer version of the original benchmark, but SPC reports SPC-1 results for both Versions 1 and 2 together, on the same page of their website. Our analysis follows a similar approach.

A full description of the SPC-1 benchmark is available online.[4] SPC documents SPC-1 benchmark results in a full disclosure report (FDR) and executive summary report, which are also available online.[5]

Current enterprise flash storage SPC-1 IO performance results

Figure 1 ranks systems by economical IO performance. The Silverton Consulting, Inc. (SCI) **IOPS/$/GB** metric is derived from standard SPC-1 reported metrics. Essentially, the IOPS/$/GB metric is SPC-1 IOPS™ (maximum IO/second) divided by (total system price divided by total ASU capacity).

[3] Please see the Appendix for a listing of the specific URLs for the full disclosure reports for these enterprise flash storage systems used in the SPC-1 analysis.
[4] See http://www.storageperformance.org/specs/#spc1 as of 29 March 2017.
[5] See http://www.storageperformance.org/results/benchmark_results_spc1_active as of 29 March 2017.

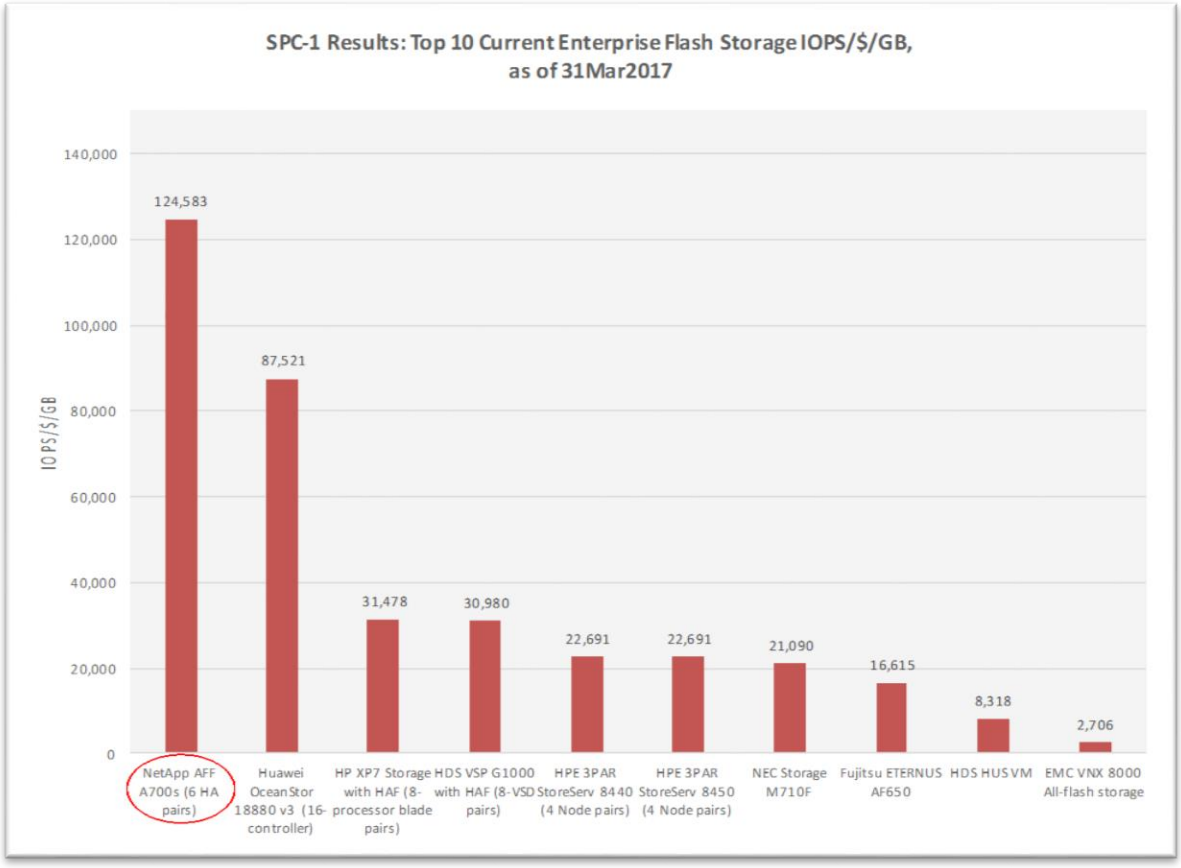

Figure 1 SPC-1 Results for Current Enterprise Flash Storage – Top 10 IOPS/$/GB

In Figure 1, NetApp AFF A700s came in first place with 124,583 IOPS/$/GB, which speaks well to the overall economical IO performance available from NetApp AFF A700s.

There are other ways to report on economical IO performance. SPC-1 uses a $/IOPS (SPC-1 Price-Performance™) metric, which can be skewed with smaller storage configurations. However, if we had reported SPC-1 Price-Performance for this group of systems, the NetApp AFF A700s would have ranked fifth because all the higher ranked systems had less than 7TB of Total ASU capacity while NetApp's A700s used over 77TB.

In other words, the A700s is closer in capacity to what enterprise customers would purchase in AFA systems, but with SPC-1's Price-Performance metric higher capacity systems will always place worse than smaller capacity systems with similar performance. Therefore, the SCI IOPS/$/GB metric in Figure 1 includes storage system capacity.

Next, Figure 2 shows the current enterprise flash storage **SPC-1 IOPS™** (IO/second)

results. This metric is the system's maximum IO/sec for the SPC-1 workload.

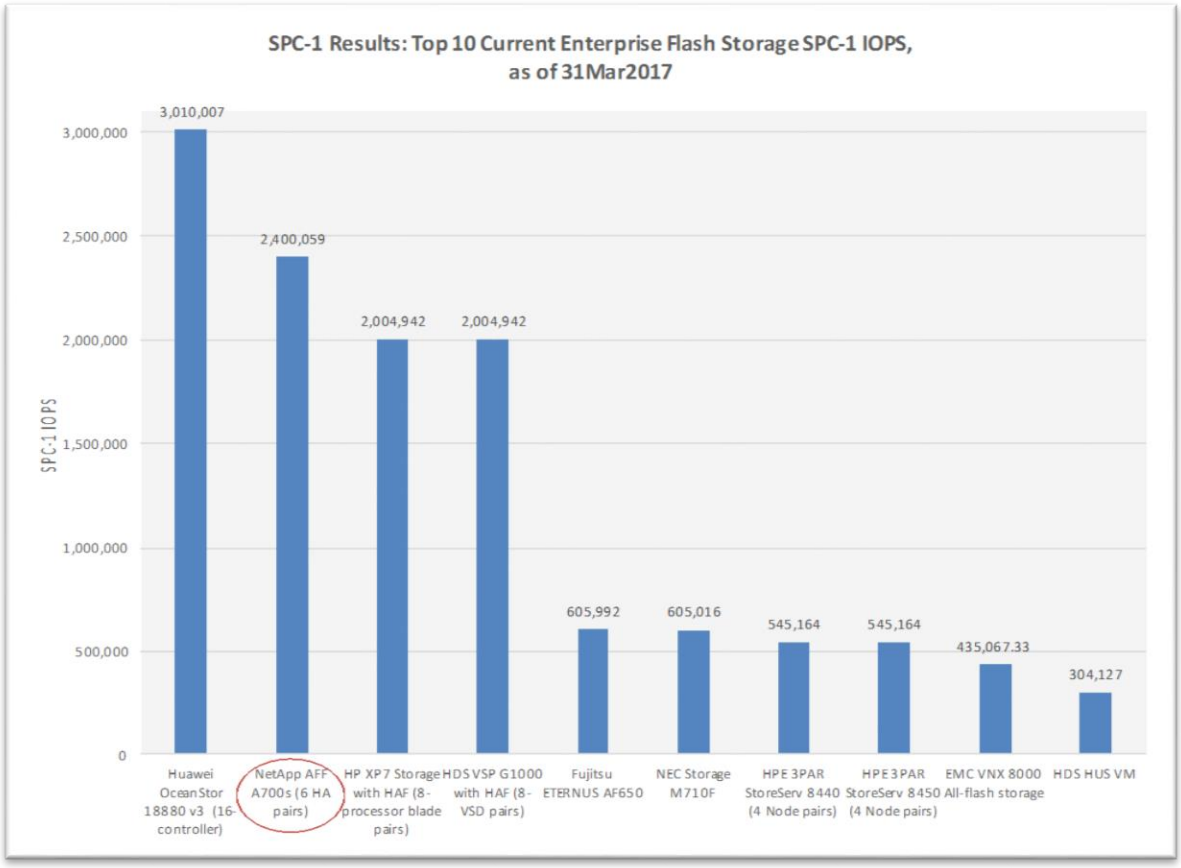

Figure 2 SPC-1 Results for Current Enterprise Flash Storage – Top 10 IOPS

As shown in Figure 2, the NetApp AFF A700s achieved a #2 ranking with 2,400,059 SPC-1 IOPS. The chart includes the controller, blade pair, VSD pair, Node pair or HA pair configuration for the enterprise flash storage systems that used more than one.

The NetApp AFF A700s submission was configured in an ONTAP 9 SAN storage cluster with 6 AFF A700s HA pairs with 24 960GB SSDs each across the cluster, for a total of 144 SSDs. In contrast, the #1 system, a 16-controller SAN storage cluster, used 32 400GB SSDs each, or a combined total of 512 SSDs to achieve its IOPS rate.

Finally, one key reason to buy an AFA over hybrid storage is due to its more consistent IO performance. SPC-1 doesn't report any metric that shows performance consistency or its opposite, variability, so we derived our own metric to rank relative AFA suitability for enterprise data centers.

For our last SPC-1 reported metric we dig deeper into the SPC-1 FDRs to extract minimum and maximum IO response time information available in the report. SPC-1 benchmarks start out with a light workload (@10% of maximum IOPS) and then increase activity until reaching the maximum attainable IOPS (@100%).

We use detailed SPC-1 FDR data at these two extreme levels of performance to rank current enterprise flash storage systems by their performance consistency. A system's IO **performance consistency** is the difference between a system's SPC-1 reported minimum (@10% load) and maximum (@100% load) workload IO average response time (ART) or **Delta (ART@10%, ART@100%)**

In Figure 3, current SPC-1 enterprise flash storage systems are ranked by this difference and show their minimum and maximum IO response times.

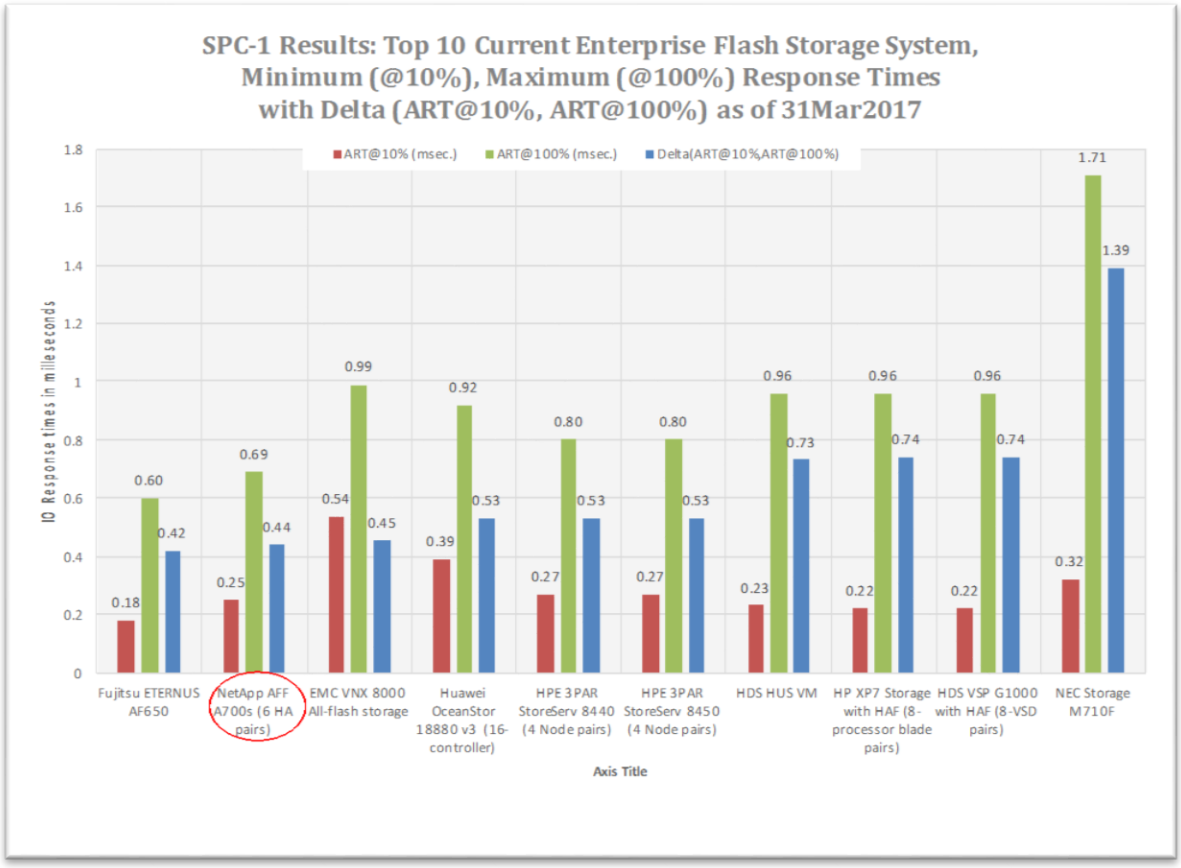

Figure 3 Top 10 Enterprise Flash Storage Systems – Performance Consistency

In Figure 3, lower is better and the NetApp AFF A700s achieved a #2 ranking in performance consistency, with a Delta (ART@10%, ART@100%) of 440µsec, just 20µsec behind the leader.

SCI Flash Storage OLTP ChampionsChart™

Silverton Consulting publishes a quarterly SAN Storage Buying Guide[6] that charts many storage system performance metrics and summarizes them in a set of SCIs ChampionsCharts. SCI ChampionsCharts derive results from various performance benchmarks used across the storage industry and divide storage systems into one of four quadrants:

- **Champions quadrant** – these systems have achieved both **superior** relative IOPS performance and **superior** relative IO response time and are the overall best performers.
- **Marathoners quadrant** – these systems have achieved **superior** relative IOPS performance but didn't do as well in relative IO responsiveness.
- **Sprinters quadrant** – these systems have achieved **superior** relative IO response time performance but didn't do as well in relative IOPS performance.
- **Slowpokes quadrant** – these systems have done poorly in both relative IOPS performance and IO response times.

SCI ChampionsCharts only identify storage systems in the Champions quadrant. Figure 4 shows our All-Flash Storage OLTP ChampionsChart™ for Q1 2017, which includes our analysis of the IO performance of more than 50 flash storage systems.

[6] The report is available for sale on our website. Please see: http://silvertonconsulting.com/cms1/product/san-storage-buying-guide/.

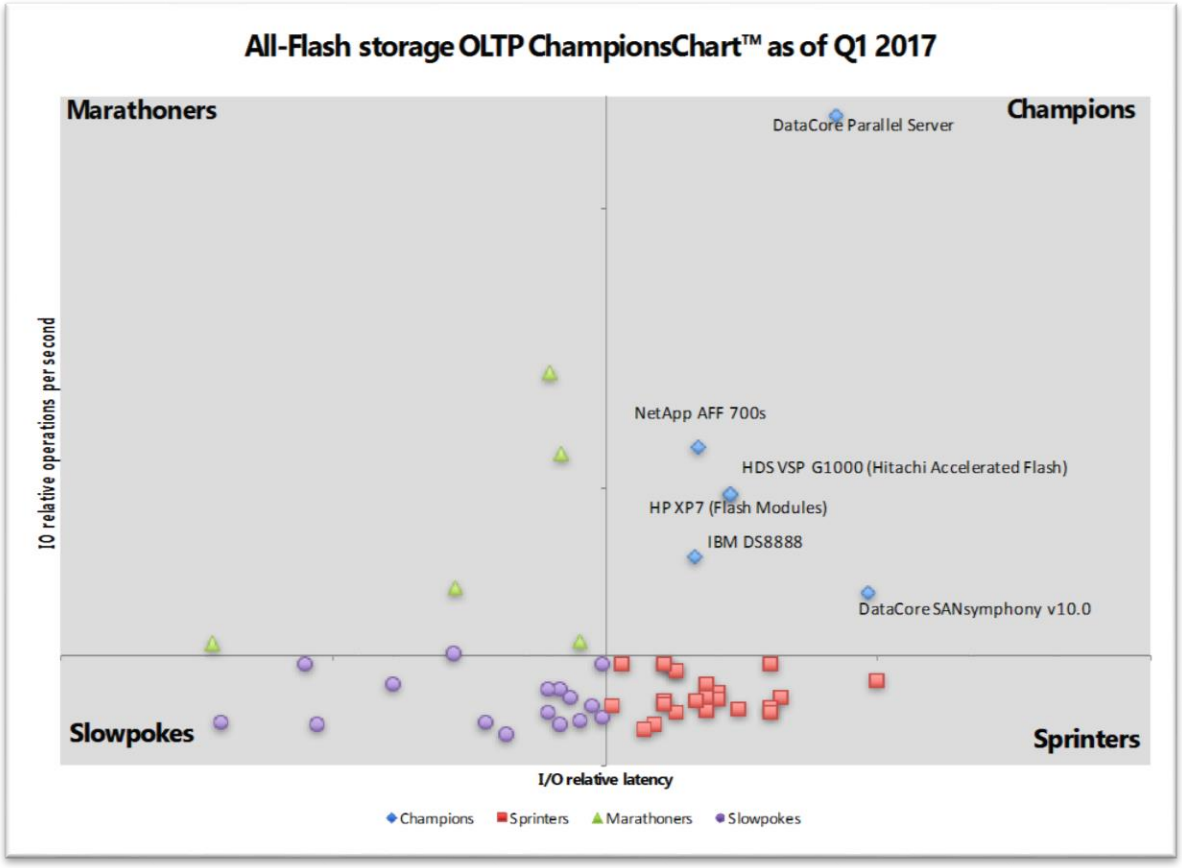

Figure 4 SCI All-Flash Storage OLTP ChampionsChart for Q1 2017

In Figure 4, the horizontal axis depicts relative IO response time or latency achieved by a flash storage system (systems to the right have better latency). The vertical axis shows the relative IOPS achieved by a flash storage system (systems higher on the chart achieved better IOPS). For 1Q 2017, the NetApp AFF A700s achieved a second-place ranking behind a non-enterprise flash storage system.

Summary

For current enterprise flash storage systems, the NetApp AFF A700s AFA achieved #1 performance in SCI's IOPS/$/GB, #2 performance in SPC-1 IOPS and a #2 ranking in performance consistency. In SCI's ChampionsChart summary of all-flash storage OLTP performance, the A700s also achieved a #2 ranking. As this data shows, the NetApp AFF A700s provides superior storage IO performance at an economical price for enterprise-class SAN storage systems.

Moreover, with ONTAP 9, the NetApp AFF A700s provides scale-out storage capabilities with the advanced SAN storage functionality needed by today's enterprise data centers.

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If your enterprise data center needs AFA SAN storage that provides very high IOPS with consistent performance at a great price, you can't go wrong with the NetApp AFF A700s storage system.

Silverton Consulting, Inc., is a U.S.-based Storage, Strategy & Systems consulting firm offering products and services to the data storage community.

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Appendix SPC-1 results – official URLs

- For EMC VNX8000, please see http://www.storageperformance.org/results/benchmark_results_spc1_active#a00159
- For Fujitsu ETERNUS AF650, please see http://www.storageperformance.org/results/benchmark_results_spc1_active#a02001
- For Hitachi Data Systems (HDS) VSP G1000 with Hitachi Accelerated Flash (HAF) modules, please see http://www.storageperformance.org/results/benchmark_results_spc1_active - a00153
- For Hitachi Unified Storage (HUS) VM, please see http://www.storageperformance.org/results/benchmark_results_spc1_active - a00145
- For HPE 3PAR StoreServ 8440, please see http://www.storageperformance.org/results/benchmark_results_spc1_active#a02001
- For HPE 3PAR StoreServ 8450, please see http://www.storageperformance.org/results/benchmark_results_spc1_active - a00168
- For HPE XP7 with flash modules, please see http://www.storageperformance.org/results/benchmark_results_spc1_active - a00162
- For Huawei OceanStor 18800, please see http://www.storageperformance.org/results/benchmark_results_spc1_active#a02001
- For NEC M710F, please see http://www.storageperformance.org/results/benchmark_results_spc1_active - a00170
- For NetApp AFF A700s, please see http://www.storageperformance.org/results/benchmark_results_spc1_active - a02002