

Critical Capabilities for Primary Storage

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Primary storage arrays and software-defined storage products are crucial to mission-critical and hybrid cloud use cases. I&O leaders need to assess platform offerings, core technologies and vendor business model capabilities across the use cases herein, which are driving IT operating model outcomes.

Overview

Key Findings

- Infrastructure and operations leaders have increased their adoption and use of consumption-based, managed storage, as-a-service offerings, driven by modernization initiatives and cloud-like benefits.
- Vendor investment in artificial intelligent operations and software-defined infrastructure improves operational efficiencies, reduces complexity, and lowers administration and support costs.
- Advances in IT operating model, SLA-based outcomes have increased productivity, improved asset utilization and reduced the impact of cyberthreats to data.

Recommendations

I&O leaders who are modernizing their mission and business-critical application infrastructure and executing hybrid platform initiatives should:

- Ensure that vendors are aligned with mission-critical platform requirements across the spectrum of cloud-like modernization commitments by validating their capabilities and initiatives.
- Demonstrate that vendors can use their AIOps capabilities and software-defined storage functionality to improve efficiency, and are willing to commit to a reduction in operational costs.
- Require vendors to improve productivity and asset utilization, and mitigate cyber threats by providing tangible and measurable SLA guarantees.

Strategic Planning Assumptions

- By 2026, storage consumption-based platform service-level agreement (SLA) guarantees will replace more than 50% of traditional, on-premises IT capacity management, budgeting, assessment, sourcing and fulfillment activities, which represents a significant increase from less than 10% in 2023.
- By 2027, less than 30% of the IT storage infrastructure budget will be spent on hardware management and support IT skills, which is a major decrease from 85% in 2023.
- By 2028, more than 85% of primary storage will be solid-state arrays (SSAs), which is a significant increase from 63% in 2023, resulting in a favorable 40% offset to flash pricing today.

What You Need to Know

Infrastructure and operations (I&O) leaders should use this research to evaluate external-controller based (ECB) storage infrastructure vendor solutions and software-defined storage (SDS) products in support of primary storage use cases and workloads. This research assesses the specific critical capability attributes that are core to the IT platform initiatives that address SSAs, hybrid arrays and SDS solutions being deployed to support primary storage workloads. This research should be used by I&O leaders to determine the best fit for IT hybrid platform storage infrastructure and operational goals.

I&O leaders need to recognize the maturity of the primary storage market and that primary storage appliances generally meet and often exceed the requirements for all use cases. The primary differentiators in appliance and SDS scoring align with the critical capabilities from the analysis.

The SSA, hybrid array and SDS solutions assessed in this research are diverse in design — e.g., scale-up and scale-out — offering varying software licensing options to affect desired management and service outcomes. Vendors' capabilities vary across use cases that focus on performance, asset management, the use of public cloud infrastructure as part of a hybrid cloud operating model platform and security. I&O leaders are encouraged to understand application requirements, then map to one or more use cases in which the vendors' products have been assessed.

Vendor SDS solutions are composite and composable elements of existing storage appliance OSs (storage OS) that are likely to trade on-premises appliance features and capabilities for more-flexible options for use in a hybrid platform environment. Some SDS architectures are relatively new and are designed with cloud-like, scale-out as-a-service attributes in support of infrastructure consumption services (ICS) and storage as a service (STaaS) initiatives. Centralized control planes integrate with advanced artificial intelligent for IT operations (AIOps) features to provide highly flexible orchestration and life-cycle-managed solutions that underpin platform SLA guarantees.

Advances in cloud-native technologies; managed consumption-based STaaS offerings; advanced AIOps features; SLA-metric-driven sourcing; and vendor-based asset financing and management programs set the stage for the next phase of the enterprise storage industry.

Vendor-based ICS — sometimes referred to as hybrid multicloud or private cloud — is rapidly emerging as a preferred primary storage approach to centralize enterprise IT operations and data center modernization, with cloud operating model capabilities and benefits. (See [Leverage Storage as a Service Platform SLAs and Capabilities to Transform IT Outcomes.](#))

Advanced AIOps capabilities can favorably augment IT administrative activities, as well as support, and substantially reduce, hardware administration and support costs. Investments in AIOps platforms will become the central command and control point for hybrid platform ITOps as a service. Furthermore, vendor asset financing and asset management capabilities in support of a consumption-based, as-a-service sourcing model provide favorable return on asset (ROA) rates, beyond what is possible in current IT financing and budgeting initiatives.

Finally, cyberstorage security threats dominate IT concerns in 2023, and have grown in frequency and in impact on business operations. The effect of ransomware is destructive, affecting such areas as loss of business, insurance costs and overall business recovery costs. Vendors are making progress in adapting their storage systems to include elements of data resiliency and reduction in cyberthreat exposure.

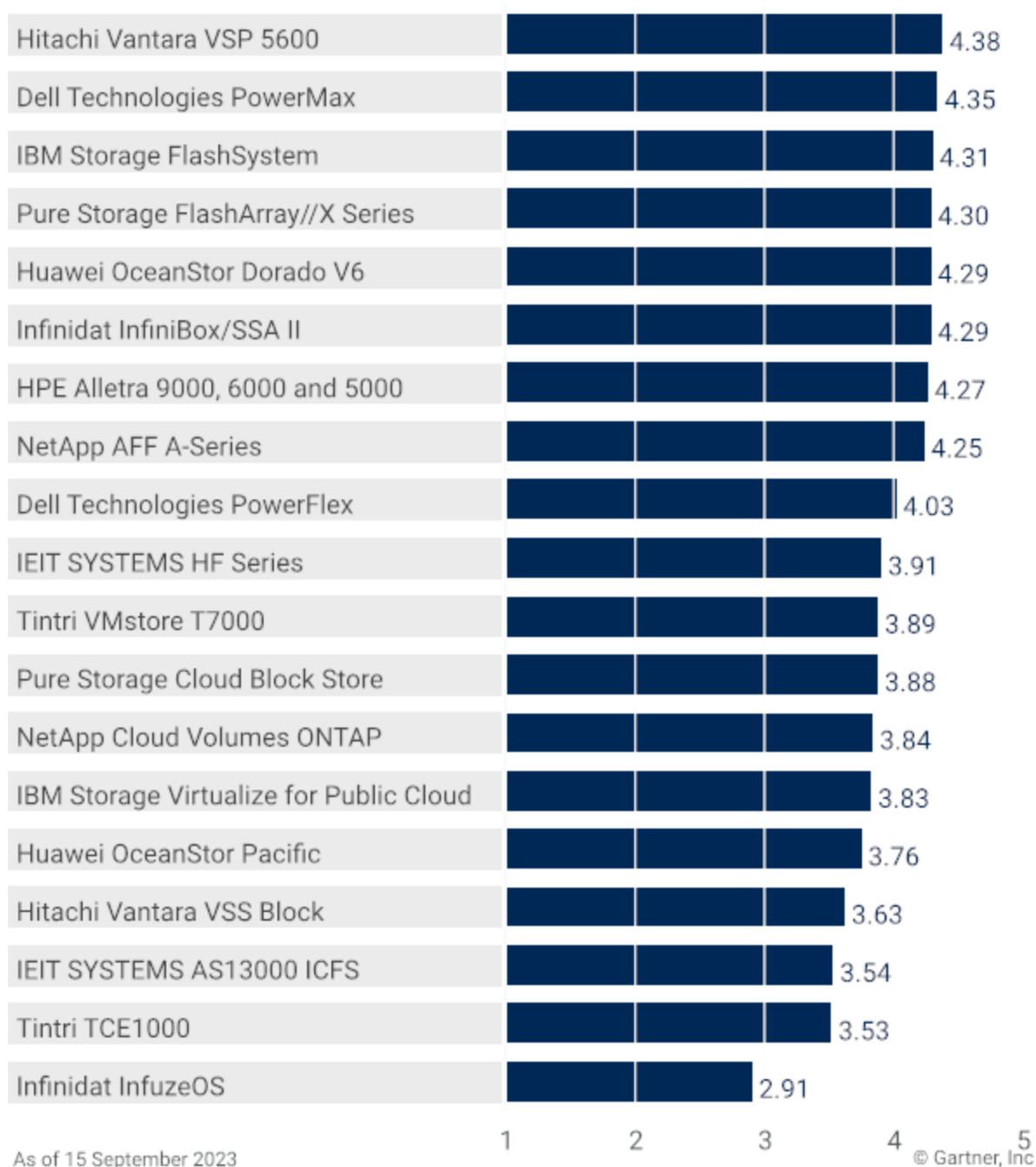
Analysis

Critical Capabilities Use-Case Graphics

Vendors' Product Scores for the Online Transaction Processing Use Case



Product or Service Scores for Online Transaction Processing



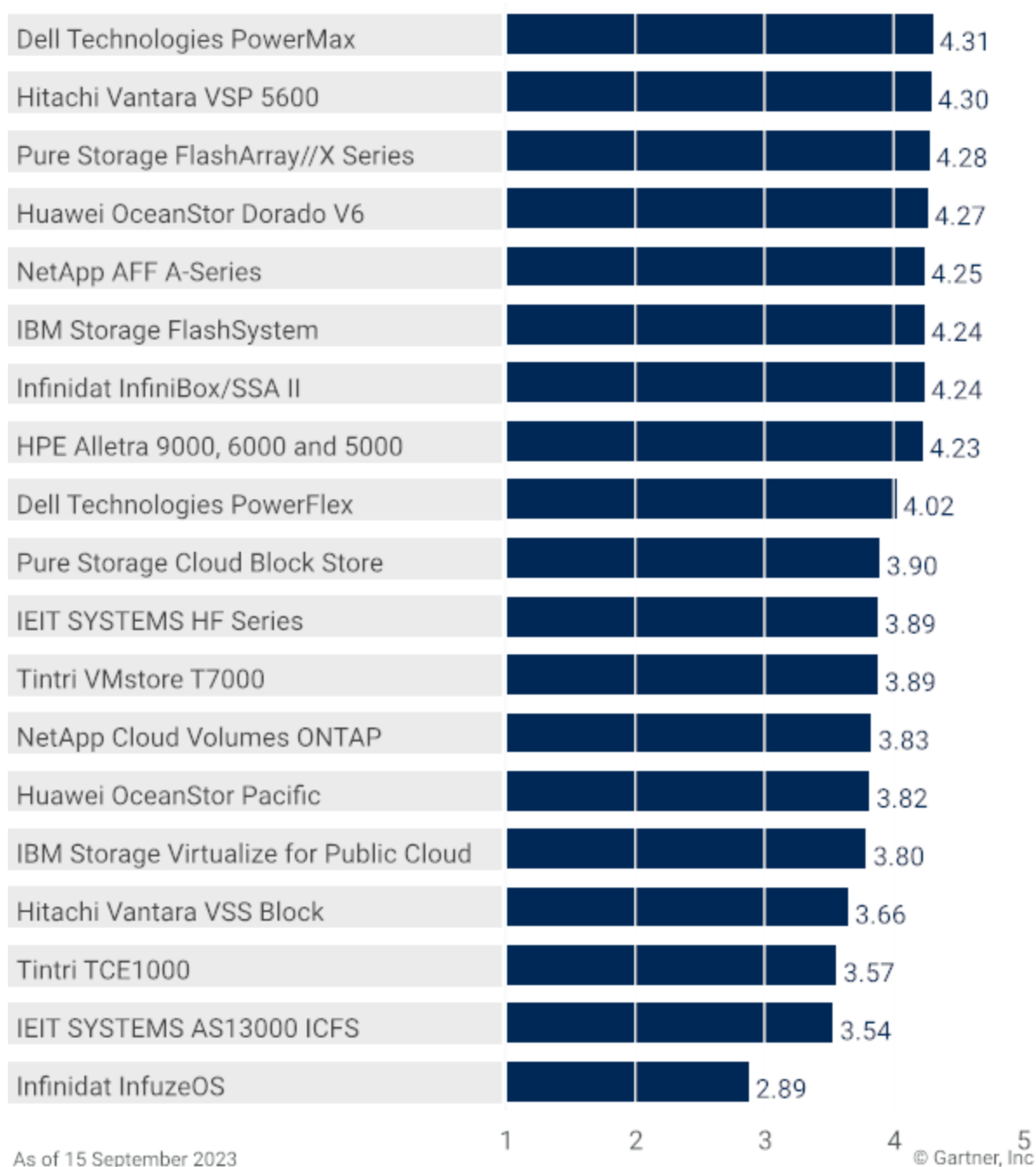
Gartner

Source: Gartner (September 2023)

Vendors' Product Scores for the Virtualization Use Case



Product or Service Scores for Virtualization



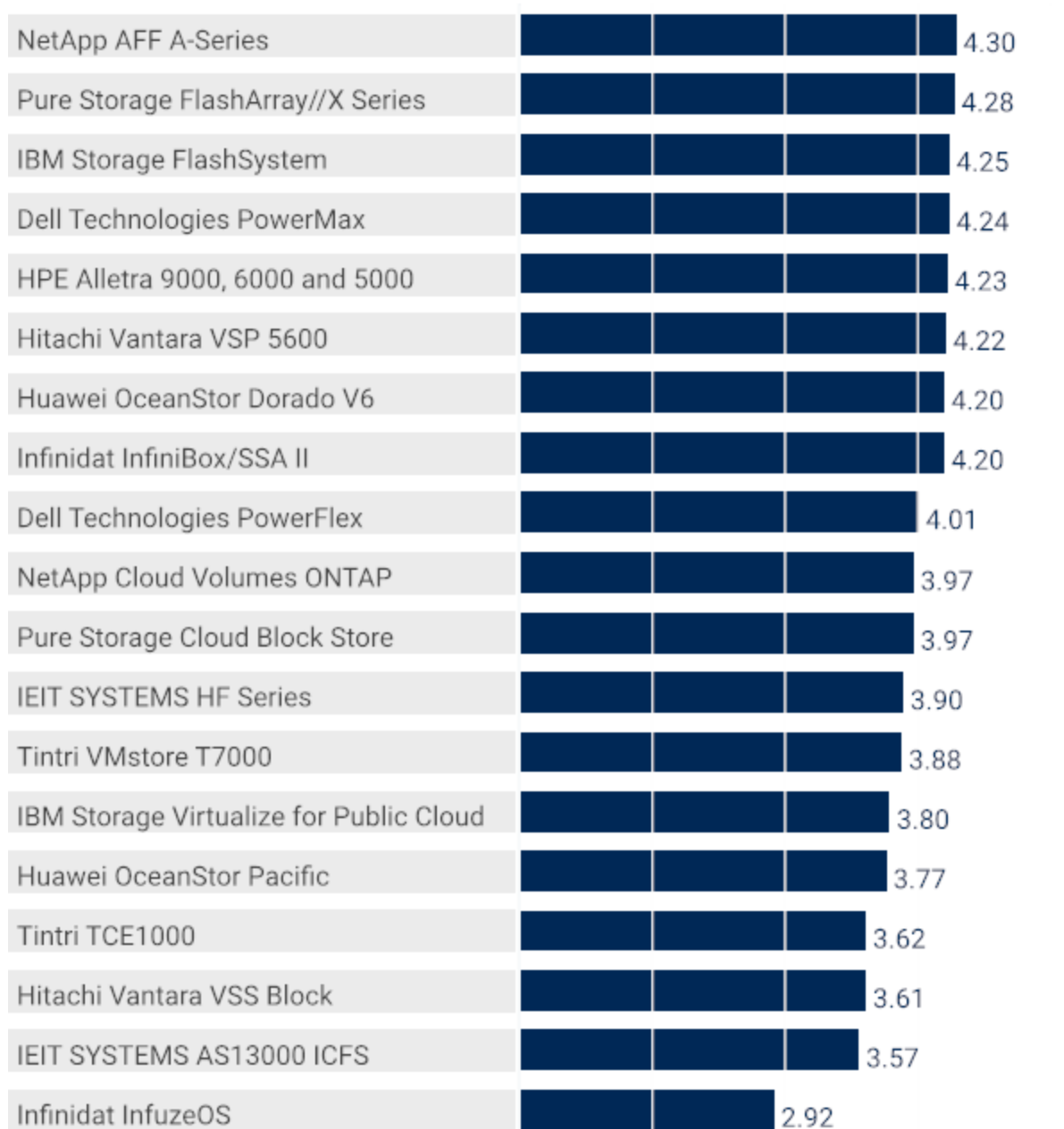
Gartner

Source: Gartner (September 2023)

Vendors' Product Scores for the Containers Use Case



Product or Service Scores for Containers



As of 15 September 2023

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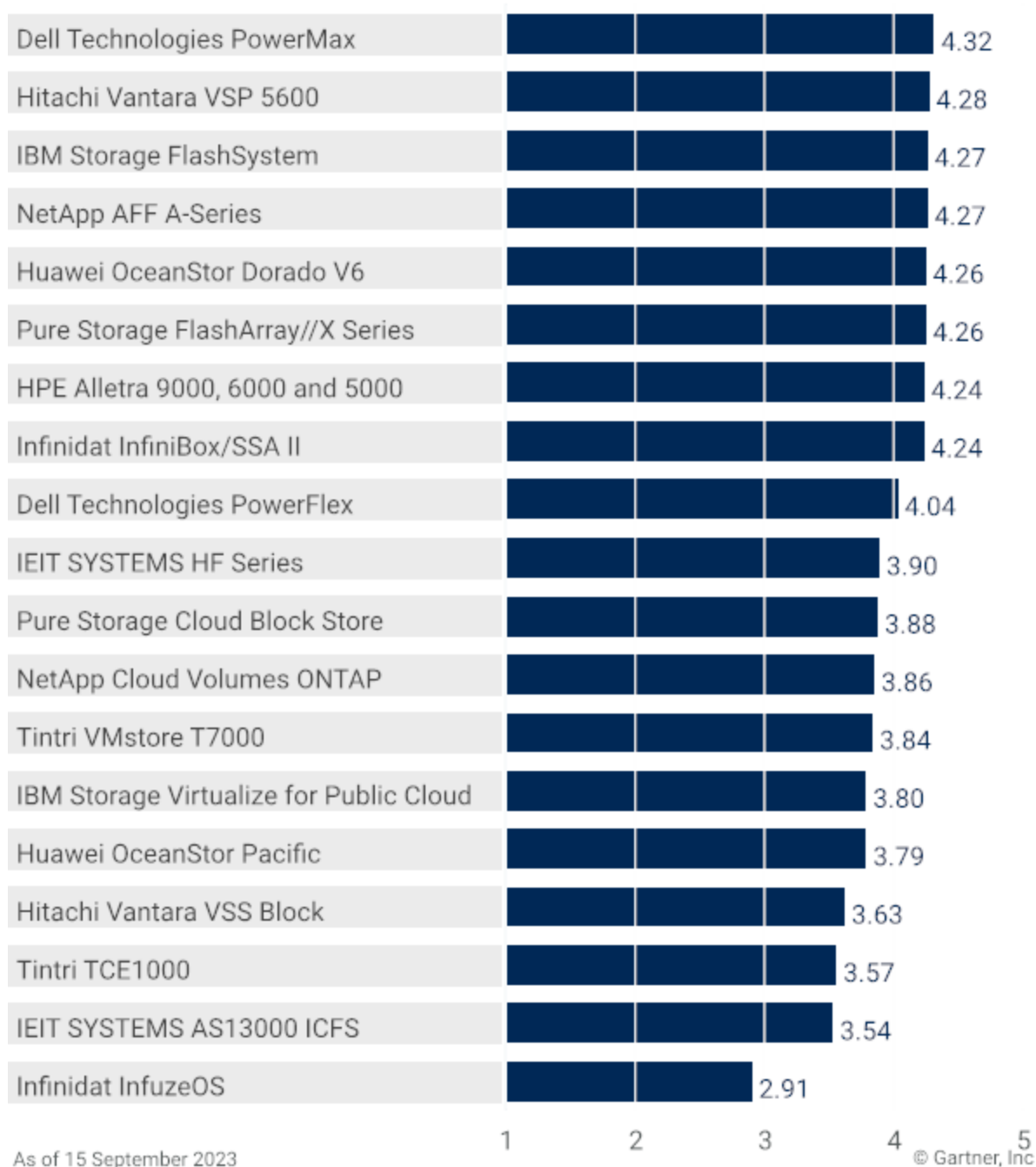
Gartner

Source: Gartner (September 2023)

Vendors' Product Scores for the Application Consolidation Use Case



Product or Service Scores for Application Consolidation



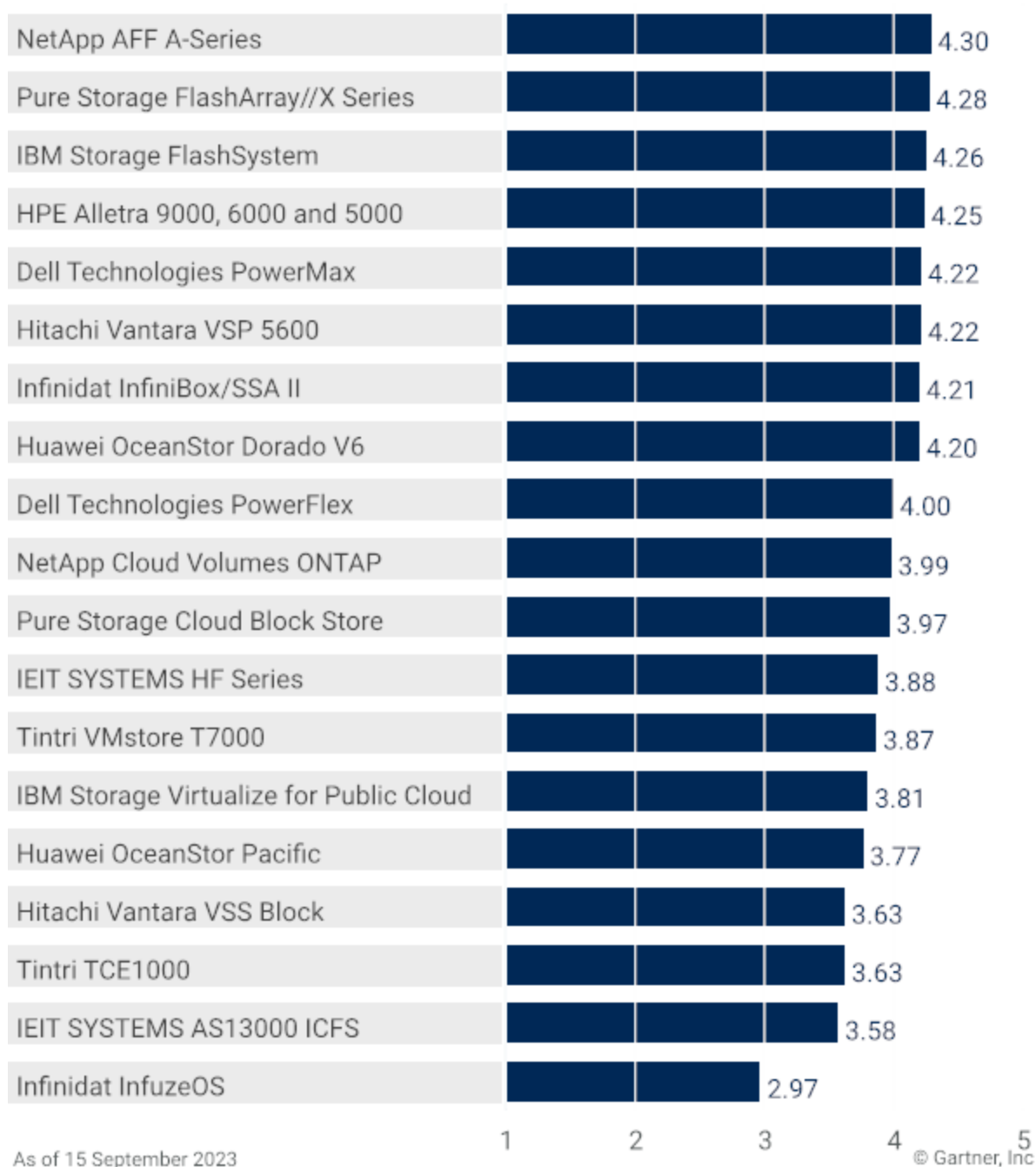
Gartner

Source: Gartner (September 2023)

Vendors' Product Scores for the Hybrid Cloud IT Operations Use Case



Product or Service Scores for Hybrid Cloud IT Operations



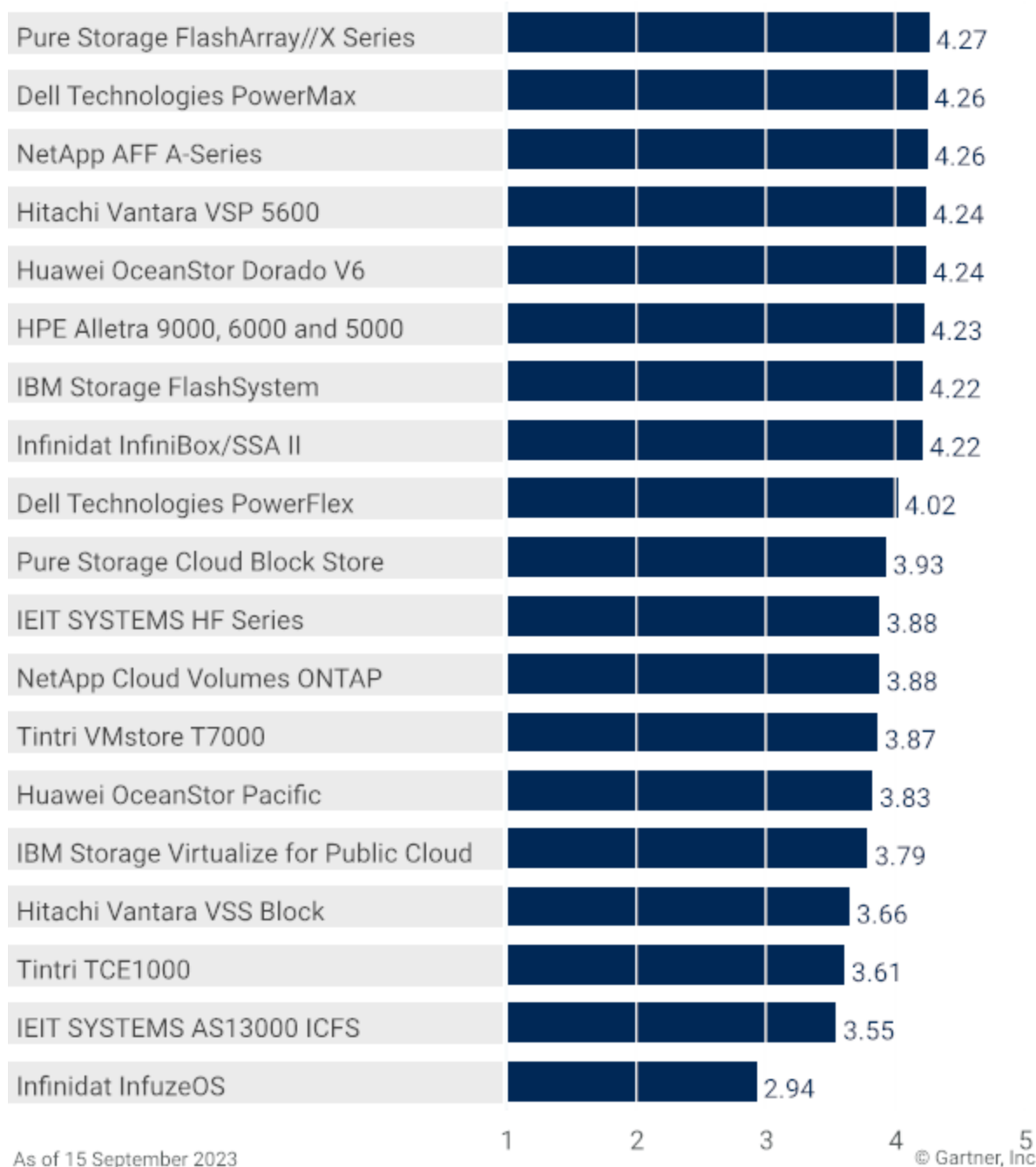
Gartner

Source: Gartner (September 2023)

Vendors' Product Scores for the Virtual Desktop Infrastructure Use Case



Product or Service Scores for Virtual Desktop Infrastructure



Gartner

Source: Gartner (September 2023)

Vendors

Dell Technologies PowerFlex

Dell Technologies' PowerFlex is an SDS offering that can run on Dell x86 servers and is compatible with multiple OSs and hypervisors. PowerFlex can scale both capacity and input/output per second (IOPS) in a linear performant manner, while sustaining a latency of less than a millisecond, operating in a single cloud environment that spans availability zones (AZs). It is available only in the Amazon Web Services (AWS) marketplace, as APEX Block Storage, and life-cycled by PowerFlex Manager. It

can use nonvolatile memory express (NVMe) media in each instance or aggregated shared storage, providing independent scaling of compute and capacity. PowerFlex can also be deployed in a hyperconverged mode and scale up to 512 storage nodes, supporting as many as 2,048 connected hosts.

PowerFlex delivers full-stack Federal Information Processing Standards (FIPS) support, immutable secure snapshots, and a site recovery adapter for VMware Site Recovery Manager (SRM) that enables disaster recovery (DR) management within vSphere. PowerFlex supports validated, or certified designs for multiple, mission-critical applications based on all popular databases, including Apache Cassandra, SAP/HANA, MongoDB and Elastic. It supports asynchronous replication with 15-second recovery point objectives (RPOs), 2:1 guaranteed compression, snapshots and thick/thin provisioning. PowerFlex has broad Kubernetes platform support and extends CSI support with specialized Dell Container Storage Modules (CSMs) and native capabilities for observability, authorization and resiliency.

Dell Technologies includes CloudIQ with PowerFlex, as a separate SaaS solution to other products, leveraging AIOps for proactive troubleshooting, performance and capacity tracking. During the past year, PowerFlex has added support for file services. These include network file system (NFS) and SMB; NVMe over TCP front end; new replication topologies; FIPS 140-2 certification and support; replication via container storage modules; and new AMD-based PowerFlex compute nodes. Dell APEX Block Storage is not yet supported in Azure or GCP. PowerFlex running on-premises in a hybrid platform in support of STaaS cannot be managed from the Dell APEX Console.

PowerFlex met or exceeded the requirements for all use cases evaluated in this research, and did particularly well for the application consolidation and online transaction processing (OLTP) use cases.

Dell Technologies PowerMax

Dell Technologies' PowerMax storage array family consists of two NVMe models, 2500 and 8500, based on PowerMaxOS. PowerMax is positioned for workloads demanding high resiliency, security and performance. PowerMax can scale-out up to 16 nodes in a "shared everything" deployment model and supports nondisruptive scaling. PowerMax guarantees a 4:1 data reduction ratio for reducible data and supports encryption through self-encrypting drives. PowerMax ensures high availability (HA) by providing no single point of hardware failure and proven synchronous, asynchronous and active-active remote replication techniques; however, it lacks a formal, written HA guarantee.

Dell Technologies offers a separate product, CloudIQ, to provide AIOps capabilities primarily focused on troubleshooting product issues, such as performance degradation or prediction of optics failures and capacity trend prediction. CloudIQ can also detect possible ransomware activity through real-time monitoring of critical configuration settings and identifying growth of nonreducible data outside the normal range of activity. During the past 12 months, PowerMax updated the hardware, doubling

the performance, and increased capacity sevenfold in half the footprint of the previous 2000 model. Enhancements include support for zHyperLink for ultrafast reads for mainframe, 32Gb FICON connectivity, Flexible RAID with single drive upgrades, anytime upgrades, NVMe over TCP, native multifactor authentication (MFA), and cyber-vault and recovery solution with Hardware Root of Trust designed for zero-trust adoption. PowerMax does not offer PCIe Gen 4 support, or any performance or availability guarantees at this time. Although PowerMax manages many things natively through Unisphere, its CloudIQ and AIOps capabilities are limited, compared with other leading offerings.

PowerMax meets and exceeds requirements for all five use cases in this research and does particularly well in the OLTP and application consolidation use cases in which reliability, availability and serviceability (RAS) and performance are concerned.

Hitachi Vantara VSP 5600

The Hitachi Virtual Storage Platform (VSP) storage array supports both scale-up and scale-out in performance and capacity for a broad range of mixed open-system and IBM mainframe applications. The 5000 series starts with VSP 5200 – a two-node, two-controller system – and the 5600, with two nodes and four controllers. The 5600 scales out to four- and six-node pair configurations, and each node pair can support as many as 768 drives and scale-out to 2,304 drives.

The 5600 uses an application-specific integrated circuits (ASIC)-based hardware compression offload to complement its media options. All Hitachi Vantara VSP models feature a common OS – Storage Virtualization Operating System RF (SVOS RF). The VSP models use DRAM for Cache and Storage Class Memory (SCM) as a media tier, and can deliver very high IOPS performance, with latency below 50 microseconds for the VSP 5600. Hitachi Vantara Storage as a Service can be run on-site, at Equinix, in conjunction with the Cloud Connect offering, and seamlessly burst to the public cloud. Hitachi provides a data reduction ratio guarantee of 7:1 and a 100% data availability guarantee. The AI-powered Hitachi Ops Center is used as the centralized control plane for the management and scaling of a federated VSP cluster.

The Ops Center automates application-specific setup and orchestrates SLA-specific provisioning of storage volumes, data protection and quality of service (QoS) policies. Hitachi offers a managed STaaS as part of its EverFlex XaaS for on-premises, but does not offer a managed. cloud-native VSS Block STaaS service. Dynamic Tiering provides user-designed profiles, policies and thresholds that can be assigned and customized. During the past 12 months, Hitachi added the Thin Image Advanced snapshot engine to the VSP series, which provides higher performance when snapshot enabled, reduces storage consumption through data reduction of snap data and improves restore time. Other updates include Mainframe Cyber Resiliency – an automated air gap solution for mainframes.

Hitachi Vantara lacks support for PCIe Gen4 SSD, quad-level cell (QLC) flash media and NVMe/TCP.

Hitachi meets and exceeds some requirements for all use cases and is best for OLTP, virtualization and application consolidation, due to its strength in performance and resilience.

Hitachi Vantara VSS Block

Hitachi's Virtual Storage Software (VSS) block SDS is a software-only version of the Storage Virtualization Operating System (SVOS). Hitachi's VSS block was designed to run on commodity servers and public cloud infrastructure. The VSS block is a scale-out, disaggregated, software-defined, shared storage architecture that can store as much as 4.9 petabytes per system. VSS block has been qualified to scale from three nodes to 32 storage nodes, enabling customers to grow in terms of capacity and performance, as more servers are added to the cluster.

Hitachi VSS uses a patented polyphase erasure coding (HPEC) method for VSS systems with narrow internode network bandwidth for high-capacity efficiency and resilience. Nodes are connected via 10 or 25 Gb internode network connections. The VSS block and HA servers are covered by the global Hitachi Remote Ops monitoring system. VSS block supports workloads running on most of the major OSs, including ESXi 7.0u1,2,3, RHEL 8.x, SUSE 15 SP1 and Windows Server 2016/2019/2022. Hitachi Ops Center Automator enables storage infrastructure workflow orchestration and self-service. Mirroring for data protection was added to provide increased performance, compared with erasure coding. VSS Block was integrated into Hitachi Ops Center for monitoring, analytics and anomaly detection.

During the past 12 months, Hitachi added bare-metal support, the ability to use a spare node when automatic recovery is not possible, multitenancy and QoS. In addition, internal improvements to Hitachi Polyphase Erasure coding to provide more user capacity, support for any SSD in the HA810/HA820 server architecture, and support of deployments in AWS Japan. Hitachi VSS lacks enterprise storage features, including compression, deduplication or encryption. VSS is not currently supported in the public cloud in North America or Europe.

Hitachi VSS meets the requirements in most use cases. VSS is best used for hybrid cloud IT operations, in conjunction with Hitachi's VSP models for flexible scale-out applications.

HPE Alletra 9000, 6000 and 5000

The HPE Alletra 9000 storage array is based on the HPE Primera OS. HPE positions the all-active, multinode, scale-up/scale-out HPE Alletra 9000 and HPE Primera products for mission-critical applications, with a 100% data availability guarantee. HPE positions the HPE Alletra 6000 and HPE Alletra 5000 as a replacement for HPE Nimble Storage all-flash and hybrid flash products for business-critical and general-purpose applications that require 99.9999% data availability. HPE Alletra 9000 offers two all-flash storage models, the 9060 and the 9080, with a common storage OS.

The HPE Alletra 6000 is based on the HPE Nimble Storage OS, and includes the HPE Alletra 6010, 6030, 6050, 6070, 6090. The Alletra 6000 is built on a scale-up and scale-out, active-standby architecture. The HPE Alletra 9000, 6000 and 5000 products can be used in conjunction with the HPE

GreenLake Data Services Cloud Console (DSCC) for cloud-based data management and as a service offerings. The HPE Alletra 5000 is a new entrant positioned for transitioning all HPE Nimble storage hybrid offerings to a new cloud-native platform that is integrated with the HPE DSCC. The HPE Alletra 5000 provides improved performance to the previous comparable HPE Nimble Storage Adaptive Flash Arrays. HPE InfoSight is included with the products. It's an AIOps-powered platform, provides cross-stack analytics, support case automation and a predictive recommendation engine. HPE InfoSight's machine learning (ML) techniques use the telemetry data collected from HPE's fleet of installed systems to provide predictive capabilities that prevent a large percentage of storage and application issues.

HPE's Timeless Storage program offers customers a subscription to the HPE Technology Refresh Service to nondisruptive refresh technology every three years at no additional cost. It is renewable and designed to maintain HPE storage technology current through periodic technology updates, along with a more predictable cost structure by incorporating costs associated with future technology updates into a renewable subscription.

During the past 12 months, HPE expanded HPE GreenLake for Block Storage with the launch of its first disaggregated, software-defined, scale-out block storage service with a 100% data availability guarantee. HPE also introduced additional improvements in active/active paths support for Fibre Channel (FC) connectivity on HPE Alletra 6000 and HPE Alletra 5000. HPE also delivered support for expansion shelves on HPE Alletra 6000 and HPE Alletra 5000. Expansion of ecosystem support for all storage offerings, including vSphere8, VMware Cloud Foundation and several new HPE GreenLake cloud data services for backup and recovery, disaster recovery (DR), file storage, dHCI and storage fabric management. HPE Alletra 6000 and HPE 9000 have limited functional assist offload capabilities for increased storage efficiency, performance and data security. HPE arrays also lack support for QLC solid-state drives (SSDs).

Overall, HPE Alletra 5000, 6000 and 9000 products generally exceed all categories' requirements, with their best score in OLTP and hybrid cloud IT operations management use cases, due to having scored well in performance and operations management.

Huawei OceanStor Dorado V6

The OceanStor Dorado V6 series products include all-flash arrays and hybrid-flash arrays for enterprise mission-critical storage infrastructure. The OceanStor Dorado 2000 was added to the series as a lower-cost, entry-level product. The V6 array is an end-to-end NVMe dual or quad controller that leverages Huawei's SmartMatrix scale-up and scale-out architecture to support as many as 32 controllers. Using 30.7TB drives, the system will support a maximum capacity of 295PBs. However, Huawei does not offer QLC flash media for high-density capacity systems for major workloads with primary storage arrays.

The OceanStor Dorado V6 uses Huawei-developed dual-port PCIe Gen 3.0 NVMe SSDs and FlashLink technology to improve efficiency, reliability, performance and flash endurance. The Huawei designed

SSDs offload the flash translation layer (FTL) and NAND processing to provide 40-microsecond latency. Additional features include automated security patch upgrades, real-time performance anomaly detection, policy-based tiering and data migration to the cloud. Huawei's centralized, single-pane-of-glass management suite is based on a three-layer, AI-powered architecture that provides the management for storage arrays. It provides control for all system resources, data services and QoS parameters, along with analytics for predictive SLA capabilities and support activities. Huawei SmartQoS uses AI algorithms to predict workload changes and automatically adjust the data migration frequency. Huawei ElasEver STaaS offering is customized to meet specific customer requirements, and is available through select MSP partners.

During the past 12 months, Huawei has added many enhancements to the Dorado V6 series. These include NVMe over RDMA; active-active with asynchronous replication, plus active-active to support up to four data centers; application-level snapshot, clone, and backup for K8S; support for VMware SRM asynchronous replication; ransomware protection; and AIOps features, such as real-time performance anomaly detection. However, Huawei does not offer an NVMe-TCP product at this time.

The Huawei OceanStor Dorado V6 is primarily best-suited to high-performance database workloads and application consolidation use cases. Overall, the OceanStor Dorado V6 exceeded requirements across all use cases.

Huawei OceanStor Pacific

Huawei OceanStor Pacific is a software-defined, shared-nothing storage architecture. The solution can be deployed as software-only for select customers, not broadly deployed, or on a Huawei appliance for general use. The SDS product is based on an asymmetrical design that allows for scaling compute and storage nodes independently to optimize compute and capacity efficiencies. It supports as many as 4,096 storage nodes, with a theoretical maximum of 3.2EB; however, the maximum node specification supported in production remains unproven. Each node connects to hosts by the iSCSI protocol. It automatically balances the distributed computing nodes (DCN), based on an AI algorithm to achieve zero packet loss and nearly 100% network utilization. Huawei OceanStor Pacific is not the same architecture as its OceanStor Dorado array product.

Hosts are allowed to connect to any storage nodes of the system via the Huawei virtual block service (VBS) controller, which provides distributed cluster resource operations. The VBS provides path failover software to maintain data accessibility in the presence of a failure. Each storage node has a single controller, with a minimum of three nodes to start. Storage capacity can be nondisruptively added or removed from logical unit numbers (LUNs) or pools. OceanStor Pacific SmartTier enables the system to divide different types of physical nodes in the same storage pool into different disk pools. In conjunction with dynamic storage tiering (DST), it allows users to define and place data within the pools, based on high and low data-value policies, optimizing against high availability and performance needs. OceanStor Pacific supports deduplication and compression, but lacks an efficiency guarantee. OceanStor Pacific product shares the same Dorado V6 management and AIOps capabilities for simplifying operations and improving system performance. It provides a range of data

management functions, including MultiPool for up to 128 storage pools. HyperSnap and HyperReplication provide synchronous and asynchronous remote replication. In addition, Huawei has added SmartQoS for SLA management, HyperMetro for active-active storage and EncryptDisk for security.

During the past 12 months, Huawei OceanStor Pacific has added NVMe support, backup to AWS and recovery from AWS to on-premises. OceanStor Pacific doesn't support dual-controller nodes or self-contained snapshots to restore onto another SDS instance. The SDS product is not available outside the Huawei cloud.

Huawei OceanStor Pacific generally meets requirements for all use cases, but scored well in operations management, due to its AIOps and management capabilities. It is best used for select hybrid cloud IT operations, where flexibility across hybrid infrastructure is needed.

IBM Storage FlashSystem

The IBM Storage FlashSystem family offers both all-NVMe configurations and hybrid appliances, based on IBM Storage Virtualize, its common storage OS. The appliance models offer a range of capacity points and consistent enterprise data services to meet the needs of entry-level to large-scale deployments. The FlashSystem family can scale up and scale out, as well as support external virtualization of heterogeneous storage systems from all major vendors under a single management pane of glass. IBM FlashSystem is also the underlying core storage for IBM STaaS that is delivered with Equinix cloud-adjacent data centers.

The high-performance FlashSystem models directly integrate with IBM FlashCore Modules to provide extremely low latency and intelligence-based drive assist functionality. These captive SSDs not only support computational storage for functions such as in-line hardware compression, but also enable QLC flash technology, without compromising on performance and reliability. The higher-capacity 38.4TB SSDs based on IBM FlashCore technology underpin leading performance per rack unit, attractive for power and space considerations. Other models also support NVMe SSDs, NVMe SCM drives, 7.2k NL-SAS, 10k rpm SAS HDDs and SAS SSDs. FlashSystem offers a 3:1 data reduction guarantee (up to 5:1 with workload profiling) and 99.9999% availability, with an optional 100% guarantee when using IBM HyperSwap.

For AIOps, IBM Storage Insights monitors the capacity, performance and health of the storage infrastructure, including VMware host and virtual machine (VM) monitoring, that now extends to STaaS usage. It provides predictive support and recommendations for corrective actions and spotting anomalies based on a feedback loop that involves the triage of anomalies by subject matter experts. During the past 12 months, IBM made improvements to data protection for better snapshot management and scheduler for snapshots and safeguarded copy, as well as new asynchronous replication with higher performance. In data security, IBM enhanced its Storage Sentinel ransomware protection/recovery solution for scanning, automation and orchestration for select database workloads.

IBM now offers NVMe-over TCP for high-performance workloads, although it does not have 64Gb FC support. IBM Storage Insights is lagging in fleet management capabilities, compared with the leaders in the market. It does not offer a single console that has integrated ordering, billing, monitoring and renewal capabilities.

IBM Storage FlashSystem meets and exceeds some of the requirements across all five use cases in this research, and does particularly well in the OLTP and application consolidation use cases.

IBM Storage Virtualize for Public Cloud

IBM Storage Virtualize for Public Cloud (SV4PC) is the SDS counterpart of IBM Storage Virtualize, used in FlashSystem arrays. It is designed to be used in IBM Cloud, AWS and Microsoft Azure. It can also be used in conjunction with Equinix platform-based colocation facilities to deploy Hybrid Cloud solutions. Storage Virtualize data management extends to all major vendors through on-premises external virtualization, connecting IBM and non-IBM storage to SV4PC. For scalability, Microsoft Azure supports only two performance nodes running SV4PC. AWS EC2 supports two or four nodes, while the IBM Cloud supports two, four or eight nodes.

Capacity scalability, which can be modified independently of performance nodes, depends on volume capacity and the number of volumes the public cloud integration as a service (IaaS) platform supports. Key features of IBM SV4PC include thin provisioning, synchronous and asynchronous replication, data reduction with compression and deduplication, IBM Easy Tier, and IBM FlashCopy. Additional features include clustering for capacity and performance scale, snapshots of volumes, for backup, business continuity and application test, and Cyber Resiliency and Cyber Vault solutions based on Safeguarded Copy for Hybrid Cloud. SV4PC integrates with IBM Storage Insights for cloud-based monitoring and to provide all the AIOps features available with Storage Virtualize running FlashSystem.

During the past 12 months, SV4PC improved its scalability by increasing its volumes and snapshots, while improving volume mobility beyond a single cluster. IBM Block Storage as a Service was introduced and featured Storage Insights improvements focused on capacity optimization and policy-based management for data protection. Lastly, SV4PC integrated the Sentinel ransomware scanning solutions for select databases.

IBM SV4PC does not support Metro/HA capability, present in the FlashSystem appliances, due to round-trip latency requirements. IBM SV4PC scalability is limited to only two nodes in Microsoft Azure, and is not available on Google Cloud Platform.

IBM Storage Virtualize meets the requirements and is ranked in the top two for all use cases among the SDS offerings evaluated in this research.

IEIT SYSTEMS AS13000 ICFS

The IEIT SYSTEMS AS13000 ICFS SDS product is a new entrant with a shared-nothing architecture. The solution can be deployed as software-only for select customers or on an IEIT SYSTEMS hardware appliance for general use. The SDS product is based on a mesh-like network architecture with each compute-storage node scaling to 10,240 nodes and a maximum raw storage cluster capacity of 47.2PB. However the upper node specification is unproven in production. The AS13000 ICFS SDS product does not scale asymmetrically, and each node contains both computing and storage resources. It supports NVMe SSD drives with a maximum raw storage capacity per system node of 184.32TB. An AS13000 ICFS cluster supports splitting node groups based on different fault domains. Customers can create storage pools based on different node groups for isolation from domain failures. IEIT SYSTEMS recommends a maximum storage pool of 40 nodes to maintain linear performance.

Other AS13000 ICFS features include synchronous and asynchronous replication, volume-level encryption, deduplication, and support for mixed in-line and post-process deduplication. Other features include online and nondisruptive upgrades, append write support for sequential data drop to improve write performance, and storage pool compression. Supported clouds include Tianyi Cloud and Alibaba Cloud. AS13000 ICFS is managed by the IEIT SYSTEMS InServices and InView SaaS management software that is deployed remotely and operated on the Tencent cloud. On the back end, ML algorithms are used to train AI Ops data to provide proactive analysis and support. IEIT Systems does not provide an auto-tiering capability for its SDS product.

IEIT SYSTEMS AS13000 ICFA generally meets requirements of all the use cases. Use case options should be limited to hybrid cloud IT operations in IEIT SYSTEMS accounts, with access to the major Chinese clouds for the near term.

IEIT SYSTEMS HF Series

The IEIT SYSTEMS HF Series storage array is based on a redundant, active-active, dual-controller, all-flash NVMe architecture that can scale up to 48 controller nodes. The HF Series is positioned for mission-critical applications with seven nines of availability. The HF Series scales to a maximum capacity of 32PB and leverages an optimization algorithm that performs data compression and stripe aggregation operations to extend SSD reliability. Each controller is equipped with two data reduction chips. The no single point of failure, and fully redundant architecture allows for nondisruptive upgrades to next-generation controllers.

Both arrays support SAS and NVMe SSDs, as well as use SCM for caching operations. The NVMe expansion enclosure supports PCIe Gen4.0 protocol. The platform offers a broad range of host interconnect options, including NVMe-oF, FC (64 Gbit/s), iSCSI (100GbE), NFS v4 and SMB 3.0. HF18000 offers a built-in cloud tiering. The use of an IEIT SYSTEMS proprietary data reduction chip improves deduplication and compression performance, without burdening CPU resources. Array-level deduplication was expanded to the cluster level, allowing for higher levels of efficiency. IEIT SYSTEMS does not support NVMe-TCP or a flexible STaaS licensing option that can operate anywhere in the hybrid cloud, including public cloud.

Integrated with the HF Series is the combination of InStorageManager, InService and InView provide a range of management and servicing capabilities from device-level monitoring to provisioning to AIOps for IT administration support. InStorageManager is the management console that supports storage provisioning, monitoring and management. During the past 12 months, IEIT SYSTEMS announced support for RoCE and intra-and-inter increase in single-port bandwidth to 100Gb/s with support of as much as 1,000 NVMe SSD drives per dual controller. In addition, it provides cross-chassis multicontrol cache mirroring to support up to four controllers; and expanded fault tolerance capability by allowing the back-end hard drive to be accessed by four controllers, instead of two. The AIOps fault prediction algorithm has also been upgraded, with a fault prediction rate of up to 95% and an added end-to-end topology. Support for anti-ransomware detection and the launch of recovery solutions has been introduced, but it does not offer a guarantee.

IEIT SYSTEMS HF Series generally exceeded requirements of all the use cases, with an emphasis on scalability and storage efficiency. IEIT SYSTEMS performs well in the OLTP and virtualization use cases.

Infinidat InfiniBox/SSA II

The Infinidat InfiniBox consists of its hybrid storage system available in three different models: F2300, F4300 and F6300, supporting a minimum 360TB in the F2300 and as much as 9.4PB in the F6300. The SSA II consists of the F4304T and F4308T, reaching up to 1.8PB capacity. Both configurations leverage the same InfuzeOS and architecture; however, the media technology is based on SAS for hard-disk drive (HDD) and SSD technologies.

InfiniBox differentiates itself based on its performance, ease of use and availability. Local InfiniOps capabilities include data placement. This is monitored and optimized using its Neural Cache architecture, a proprietary implementation that continuously maximizes cache hit ratios, prefetch effectiveness, and the process of destaging data held in DRAM, flash (SSA), and HDDs (hybrid). In concert with Neural Cache, which is part of InfiniOps, it also includes InfiniVerse, a cloud-based AIOps platform that provides predictive capacity and performance monitoring and management capabilities that automate and simplify the user experience.

The InfiniBox offers integration with popular container platforms and backup platforms. The Infinidat products boast three active-active-active controller architecture and triple redundancy across key components, supported by a 100% availability guarantee. Its declustered, dual-parity redundant array of independent disks (RAID) technology, InfiniRAID, offers one of the lowest rebuild times and extensive replication capabilities. The InfiniBox is also the foundation for its InfiniGuard backup appliance. During the past 12 months, the company released its SDS offering, InfuzeOS, as well as InfuzeOS Cloud Edition, which will be covered subsequently. Enhancements were made to InfiniSafe, which is a cyber resiliency framework that offers immutable snapshots, air-gapping, isolation and fast restore, which now has a data-scanning option. InfiniSafe enables fast recovery and is supported by a recovery time guarantee of less than 1.0 minute on InfiniBox.

Although InfiniBox supports NVM-oF TCP, it does not use internal NVMe PCIe SSD technology. It lacks in-line deduplication attractive for select workloads. Its Server Message Block (SMB) protocol support was upgraded to include 3.1 file support, but is not well-suited for some file workloads.

Infinidat InfuzeOS

The newly introduced Infinidat InfuzeOS is the common SDS OS across the InfiniBox, InfiniBox SSA II and InfiniGuard on-premises solutions for block-and-file protocols. The InfuzeOS offers the same enterprise data services available in the InfiniBox. These include InfiniRAID for data integrity, InfiniSafe for data protection and cyber resiliency, and InfiniOps, which includes InfiniVerse for resident and cloud-based AIOps. InfiniVerse, the cloud-based AIOps platform, provides predictive capacity and performance monitoring and management capabilities that automate and simplify the user experience. InfiniOps encompasses autonomous operations, AIOps and DevOps and is AI-powered for advanced, prescriptive analytics. The nucleus of the Infinidat InfuzeOS is its Neural Cache approach, a unique implementation for data placement optimization that maximizes input/output (I/O) efficiency and performance by destaging data held across DRAM, flash (SSA), and HDDs (hybrid).

InfuzeOS Cloud Edition is a single-node implementation for AWS that offers the same enterprise data services as on-premises offerings. The Cloud Edition offers the same management experience, interface, and integrations and InfiniVerse AIOps analytics capabilities. However, although this does offer both block and file, it is limited to Ethernet-based protocols only. This is based on AWS infrastructure. This solution is performance-limited by AWS cloud compute instance and has limited scalability as a single node only, with fixed capacity points and lower resiliency capabilities, compared with its proven, on-premises, three-controller architecture. Therefore, many of the guarantees around availability, performance, and data protection (e.g., the InfiniSafe recovery guarantee) are not available. InfuzeOS Cloud Edition is not available on public cloud environments other than AWS.

Although the Infinidat InfuzeOS performs well in its on-premises offerings and use cases outlined for InfiniBox, the InfuzeOS Cloud Edition may not be suitable for production workloads with a single-node implementation and ranked low across most use cases.

NetApp AFF A-Series

NetApp's AFF systems are all-flash storage appliances powered by the NetApp ONTAP storage OS, which provides enterprise data management services. The AFF A-series systems come in five different models, ranging from the AFF A250 to AFF A900 to address small, midsize and large deployments, with increasing capacity and performance limits. NetApp also offers hybrid (HDD/SSD) models and FAS arrays, including the FAS2720, FAS2750, FAS8300, FAS8700, and FAS9500, which are targeted at workloads with lower performance requirements. ONTAP One is a new offering that bundles all data services into a single license and is available across NetApp's AFF, ASA and FAS storage models.

NetApp ONTAP, the underlying storage OS, has been in the market for nearly three decades and has a rich set of data services for data protection, resiliency, security and cloud connectivity. In addition to FC, iSCSI, NVMe/FC and NVMe/TCP, NetApp ONTAP also supports File and Object protocols providing unified storage, regardless of the access protocols involved. The control plane for AFF is BlueXP, a SaaS-delivered global control plane that can discover, deploy and manage storage and data management resources across the hybrid multicloud.

For AIOps, NetApp has been offering Active IQ to automate the identification and resolution of potential problems, such as misconfigurations, security vulnerabilities, outdated firmware and best-practice optimizations. It is also the underlying technology for Keystone, NetApp's STaaS. Active IQ makes recommendations on which on-premises workloads are good candidates to move to the cloud, and enables customers to start the transition wizard with a single mouse click. It can also discover inactive data and start an intelligent workflow to tier that data to the cloud. During the past 12 months, NetApp introduced simplicity-based features, including BlueXP integrated control plane for simplified hybrid multicloud experience, ONTAP One comprehensive software license for simplicity. For cost savings, it introduced NetApp AFF A150 all-flash unified storage starting at 7.6TB raw capacity and the new Storage Lifecycle Program that future-proofs today's on-premises investment with a future controller refresh or cloud/Keystone credits. For security, it introduced tamper-proof snapshots for added protection from ransomware threats.

NetApp's AFF trails some of the leaders in this market on certain performance metrics, IOPS and latency. Also, initial installation, configuration and controller upgrades can be cumbersome and time-consuming, along with inconsistent first-level support and long response times, in solving an issue. Clients reported an elevated level of ONTAP bugs after version releases, resulting in frequent patching.

NetApp's AFF exceeds requirements for all use cases. It did particularly well with hybrid cloud

IT operations, due to its availability and integration with all major hyperscalers. It also did well for the containers use case, due to support for all major distributions of Kubernetes on-premises and in the cloud.

NetApp Cloud Volumes ONTAP

NetApp Cloud Volumes ONTAP (CVO) is a software-defined version of the same NetApp ONTAP software that runs on NetApp's AFF and FAS appliances. CVO is available as a VM in the marketplaces of AWS, Azure and Google Cloud Platform (GCP) for running in the public cloud. CVO provides the same set of NetApp data services for customers, regardless of whether the data is on-premises or in the cloud. Built-in features of CVO allow the replication of data among on-premises and multiple cloud providers, tiering or backup to low-cost object storage, end-to-end encryption in transit and at rest, and all storage efficiencies. CVO offers a minimum configuration of 10GB, enabling easy entry points. When paired with AWS S3, Azure Block Blob or Google Cloud Storage,

CVO can scale to 2PB. Dependence on cloud infrastructure may affect performance and availability, which can vary appreciably, depending on the workload.

The control plane for CVO is BlueXP, a SaaS-delivered global control plane that supports hybrid and multicloud architectures. Through this single interface, customers can discover, deploy and manage storage and data management resources across a multicloud environment from a single interface. It provides a single pane for easy control of workflow orchestration, automation, user and role management, and access control. It also integrates data management services, including backup and recovery, tiering, migration, and anti-ransomware capabilities. Astra Trident is NetApp's container storage interface (CSI), which presents ONTAP volumes as persistent storage for Kubernetes clusters in all three of the cloud providers mentioned previously. It is also the container provisioner and orchestrator.

The AIOps features, container support features of NetApp ONTAP, are equally applicable to CVO, including the API-driven workflows integrated with third-party automation tools. All software updates during the past 12 months, listed in the NetApp AFF sections of this research, are applicable to NetApp CVO as well. During the last 12 months, Cloud Volumes ONTAP LUN size increased to 128TB, volume size has increased to 300TB, vCPU count increased from 48 to 64, and FlashCache limits increased to 16TB. Additional updates include integration with hyperscaler native key manager as a service offering, snapshot copy locking, enhanced backup capability with immutable backup, fortification of MFA and in-transit encryption in AWS Nitro-based instances. Cloud Volumes ONTAP can now be deployed using multiple availability zones in Azure for better resiliency. NetApp CVO supports only a two-node configuration and does not support a scale-out configuration for scaling performance. It also does not offer guarantees on data reduction, unlike NetApp ONTAP running on AFF or FAS arrays.

NetApp CVO meets the requirements and did well for the hybrid cloud IT operations and containers use cases, compared with other SDS offerings evaluated in this research.

Pure Storage Cloud Block Store

Pure Storage's Cloud Block Store (CBS) is an SDS product based on the same Purity//FA OS that runs on FlashArray appliances. It can run as a VM in AWS and Azure in an active-active configuration. Although Cloud Block Store does not support scale-out deployments, it can be managed by Pure Storage's Pure Fusion to manage multiple instances of Cloud Block Store for scaling performance. Cloud Block Store on AWS can scale up to 95TB of raw capacity and, on Azure, as much as 137TB of raw capacity.

Cloud Block Store upgrades and expansion require a Pure Storage support person to perform. On average, CBS customers see 5:1 data reduction. Cloud Block Store in Azure uses Azure Ultra and now more cost-effective Premium SSD V2. Cloud Block Store in AWS uses a combination of io2 and instance store for I/O, which is backed by Amazon S3 for persistence. CBS allows offloading of snapshots to two AWS S3 or two Azure blob targets. CBS ensures that no two compute or storage

resources reside on the underlying hardware, thus improving resilience in the fault domain. Workloads can move back and forth between CBS running in the cloud and on-premises FlashArray//X models, with AIOps assistance from Pure Fusion. Fusion can also redistribute workloads between CBS running in different availability zones nondisruptively for rebalancing workloads, based on performance, snapshot/replication frequency and storage requirements.

Pure's cloud-based management platform, Pure1, and AI-driven workload planner, Meta, reduce operational complexity with policy-based proactive data management and placement with expansion recommendations. Ease of use and simplicity are hallmarks of the Purity OS that are further enhanced by its AIOps capabilities. Cloud Block Store does not run in GCP, does not support NVME-oF/TCP, and it only supports iSCSI. It does not support File Services or Rapid Data Locking. During the past 12 months, Cloud Block Store has improved VM performance with new Azure VM controller types with tight integration to Azure VMware Solution. Direct compression acceleration is now offered across cloud platforms, providing better storage efficiencies without compute overhead. Lastly, SafeMode support for CBS upgrades data protection and recovery abilities from ransomware attacks.

CBS meets the requirements for all of the use cases evaluated in this research. Given its lower scalability and performance scoring, compared with traditional storage arrays, it is best-suited to midsize workloads.

Pure Storage FlashArray//X Series

Pure Storage's FlashArray family consists of the newly announced FlashArray//E and upgrades to FlashArray//C, FlashArray//X and FlashArray//XL, all of which are based on a flash-only architecture. The architecture is predicated on the custom Direct Flash Modules, which are optimized for high capacity to challenge HDD economics or tuned to performance. All FlashArray models are powered by the Purity//FA Operating System and have the same set of software features. Purity//FA supports NVMe multiprotocol access to unified block and file data, always-on encryption, synchronous and asynchronous replication, and an average 5:1 data reduction. For capacity workloads, FlashArray//E is available in a 1PB minimum configuration, but can scale up to 3.6PB raw capacity. For high performance at scale, FlashArray//XL can reach as much as 1.4PB raw capacity.

For containerized applications and modern databases, such as Kafka, Cassandra and Postgres, Pure Storage positions Portworx as a Kubernetes Data Platform. Portworx can be deployed as a stand-alone, multicloud-ready platform. It can also be an extension of FlashArray family to leverage the capacity from FlashArray to deploy Kubernetes workloads in production and at scale, with configurable availability, security, performance and reliability. Pure Storage's Evergreen//Forever provides hardware and software upgrades for customers with active subscriptions. Evergreen//One is Pure Storage's SLA-driven STaaS. Evergreen//Flex enables customers to pay for the subscription based on consumption, while retaining hardware asset ownership. Pure Storage's cloud-based monitoring and AIOps platform, Pure 1, provides proactive support, monitoring and analytics. It also

supports self-service upgrades, assessments for sustainability and safe-mode impact, as well as advanced fleet management.

FlashArray is 100% flash-based and does not support tiering to external hybrid storage to lower the total cost of ownership (TCO). Thus, it lacks an ultralow-cost sub-250TB capacity offering comparable to leading hybrid offerings. During the past 12 months, Pure Storage added FlashArray//E platform to the portfolio to compete with nearline HDD hybrid solutions, now available as a new service tier in Evergreen//One. Improvements to its file support coincided with Pure1 improvements around vulnerability management and data resiliency assessments to improve cyber resiliency. Pure Storage also introduced controller upgrades boosting performance in both the FlashArray//X R4 and FlashArray//C R4 by 40% and 30%, respectively, compared with prior models.

FlashArray meets and exceeds requirements and is ranked among the top five products for most of the use cases evaluated in this research. Powered by its Portworx platform, it did particularly well on the container and virtual desktop infrastructure (VDI) use cases.

Tintri TCE1000

The DDN Tintri Cloud Engine (TCE1000), is a new entrant this year as an SDS version of the VMstore 7000 for block storage and for use in the AWS public cloud. TCE1000 is a VM version on AWS as an EC2 instance for hybrid cloud storage that supports storage management of applications on AWS and seamless replication between VMstore T7000 on-premises and the AWS cloud. The capability enables customers to execute virtual Tintri VMstore TCE1000 instances in the public cloud and to transfer snapshot objects between the AWS cloud and on-premises.

The Tintri TCE1000 is designed to provide VM-aware storage at the VM level, with QoS capabilities and features, including in-line deduplication, compression and data protection features, such as snapshots, clones and replication. The TCE1000 integrates with VMware vSphere and supports native integrations with VMware vVols and vCenter. TCE1000 instances can be deployed on-premises or on AWS and managed with Tintri's single-pane-of-glass control plane for reporting, monitoring, analytics and orchestration. TCE1000 integrates with the Tintri cloud-based interactive analytics dashboard for historical analysis, service monitoring and event troubleshooting.

Overall, the TCE1000 meets requirements for each of the use cases. Performance, RAS and scalability are limited, due to public cloud constraints. Also, the TCE1000 is only available for use in the AWS public cloud. The TCE1000 is ideally suited for hybrid cloud use cases, where native public cloud integration is required to support hybrid cloud on-premises applications infrastructure.

Tintri VMstore T7000

The Tintri VMstore T7000 Series is the latest addition to Tintri's portfolio and is exclusively offered as an NVMe drive-only product that supports up to 7,500 VM applications in just two rack units. The T7000 all NVMe series includes the T7080, T7060 and T7040. The T7000 is unique with its VM-aware QoS architecture to solve the issues around virtualization, mixed workloads and the noisy neighbor

impacts of shared storage. VMstore uses its auto QoS feature to allocate desired performance behavior on a per-VM basis, with less than 1 ms performance.

Autonomous operations and advanced real-time and predictive analytics are used to drive down the costs of storage management and administration activities. The VMstore T7000 leverages the same storage hardware controller as the parent DDN At-Scale product, which is used for AI, analytics, deep learning and high-IOPS workload applications. Tintri offers a patented drive by drive expansion to optimize actual usage, allowing customers to acquire the capacity, when needed.

The Tintri T7080 can scale up to 645 TB raw capacity with a single VMstore T7000 system and grow beyond 40PB in a scale-out configuration, all managed from a single Tintri Global Center console. The Tintri VMstore software suite offers a wide range of value-added services including predictive analytics with visibility across storage, network, and hosts on a per-VM or per-database basis. It also provides ReplicateVM for both asynchronous and synchronous on a VM level; SecureVM for data encryption at rest; VMstore Cloud Connector; always on and in-line deduplication and compression; SyncVM; copy data management; and SQL Integrated Storage.

Snapshots from a T7080 can be replicated to S3-compatible targets via Tintri Cloud Connector, a separately licensed feature. During the past 12 months, Tintri has added extended total raw capacity with a single VMstore T7000 and data services based on existing Tintri VMstore technologies to serve container and microservices applications. The T7000 series products do not support QLC flash, SCM media or HDD. Also, Tintri does not provide a branded Tintri STaaS block offering for use in a hybrid cloud solution.

The majority of Tintri VMstore involves virtualization use cases. Tintri VMstore meets or exceeds requirements in all use cases, and scores well in container and cloud IT operations use cases, due to its high levels of storage efficiency and scalability improvements.

Context

The adoption of SSAs to support demanding primary storage workloads associated with structured data continues to expand at a robust pace. Beyond the inherent performance advantage, compared with hybrid storage arrays deployed to support structured data workloads, SSAs also reduce operational costs related to host software license fees, data center space utilization, and power consumption and cooling. The performance and operating expenditure (opex) advantages enable SSAs to be used increasingly for application consolidation, further enhancing the TCO benefits.

To simplify the IT infrastructure and underpin hybrid-cloud architectures, modern SSA offerings provide an integrated function to seamlessly tier data to public cloud platforms. NVMe technology, in combination with higher-capacity NAND flash and SCM media, enables SSAs to consolidate the number of storage assets required to support an organization's primary storage workload, thereby streamlining storage administration.

SDS solutions, based on robust and mature storage OS stacks and tools, expanded IT operations into integration with public cloud infrastructure as part of an hybrid platform. Each of the primary storage vendors now offer an SDS solution as part of their hybrid cloud platform strategy, along with as-a-service, consumption-based offerings.

AIOPS client support software proactively analyzes capacity and performance telemetry, then predicts potential issues that may cause application disruption. The use of AIOPS can prevent and automatically resolve many Level 1 and Level 2 support issues and provide proactive, action-oriented advice to resolve problems and enhance storage capacity and asset utilization efficiency. SSA offerings come with a variety of flexible asset acquisition options, including capital expenditure (capex), opex, an as-a-service consumption model, a hybrid or both. Furthermore, vendors are offering capacity, efficiency and performance guarantees, along with ongoing flat support rates to expedite the business decision process. Collectively, these attributes make the overall value proposition of SSAs more compelling than mere speeds and feeds.

Product/Service Class Definition

An ECB primary storage array's foremost purpose is to support response time and IOPS-sensitive, structured data workloads. Typical use cases include mission-critical database workloads, application consolidation, virtualization and in-house-developed transactional applications. Primary storage platforms provide a broad library of data services that conserve capacity utilization, protect against data loss, and enhance recovery via local and remote replication. The form factor can be scaled up or scaled out. Host interface protocols can be block-based (FC, iSCSI, SAS and NVMe); file (NFS and SMB); or a combination of block-and-file protocols. We expect a growing number of NVMe-oF host interfaces to be deployed in primary storage infrastructure shipments to support the scale-out of capacity and performance with high-bandwidth connectivity and networking options.

SSA, Hybrid Flash Array, SDS

The SSAs featured in this research are designed to be deployed to support primary storage environments. The SSA category is a subcategory of the broader ECB storage market. SSAs are scalable, dedicated solutions based solely on solid-state semiconductor technology for data storage that can never be configured with HDD technology. The SSA category is distinct from SSD-only racks in ECB storage arrays. An SSA must be a stand-alone product denoted with a specific name and model number, which typically (but not always) includes an OS and data management software optimized for solid-state technology.

A hybrid flash array is a solid-state storage system that contains a mix of flash memory drives, typically for caching or separate storage tier, and HDD.

The SDS product is a functional-equivalent storage OS derivative of the individual vendor's primary storage array. SDS separates the software from the vendor's proprietary hardware for use on any industry-standard x86 system, removing the software's dependence on proprietary hardware

capabilities. It's used for on-premises or hybrid cloud storage, and must integrate with one or multiple cloud platforms. It must be accessible (via a public cloud marketplace) and integrated with cloud providers' server, storage, networking hardware with similar functionality and capabilities, including management, as found in its on-premises appliance solution. SDS solutions integrate with the vendor's control plane, AIOps and data services capabilities.

To be considered an SSA, the storage software management layer should enable most, if not all, of the following benefits:

- High availability
- Enhanced-capacity efficiency — perhaps through thin provisioning, compression or data deduplication
- Data management
- Automated tiering within and external to the vendor's cluster
- Other advanced software capabilities, such as application-specific and OS-specific acceleration, based on the unique workload requirements of the data type being processed

Scale-Up Architectures

- Front-end connectivity, internal and back-end bandwidth are fixed or scaled to packaging constraints, independent of capacity, which may vary, based on drive type and capacity.
- Logical volumes, files or objects are fragmented and spread across user-defined collections, such as solid-state pools, groups or RAID sets.
- Capacity, performance and throughput are limited by physical packaging constraints, such as the number of slots in a backplane and/or interconnectivity (e.g., Ethernet and InfiniBand) constraints.

Scale-Out Architectures

- Capacity, performance, throughput and connectivity scale with the number of storage and compute nodes in the system.
- Logical volumes, files or objects are fragmented and spread across multiple storage nodes to protect against hardware failure and to provide higher performance in relation to additional capacity.
- Scalability is limited by software and networking architectural constraints, not physical packaging or interconnect limitations.

Unified Architectures

- These can simultaneously support one or more block, file and/or object protocol — such as FC, iSCSI, nonvolatile memory express over fabric (NVMe-oF), NFS, SMB (aka CIFS), Fibre Channel over Ethernet (FCoE) and InfiniBand.
- Gateway and integrated data flow implementations are included.
- These architectures can be implemented as scale-up or scale-out arrays.

Critical Capabilities Definition

Performance

This is the collective term that is often used to describe IOPS, bandwidth (GB/second) and response times (latency in milliseconds or microseconds per I/O) that are visible to attached servers.

This involves overall system performance and the ability to scale performance via controller bandwidth, network bandwidth, plus other areas such as front- and back-end array design and use of media type such as NVMe. This is not the performance of individual components.

Storage Efficiency

This refers to the ability of the platform to support storage efficiency technologies, such as compression, deduplication, thin provisioning and auto tiering to improve utilization rates, while reducing storage acquisition and TCO.

The difference (ratio) between raw capacity and usable capacity will contribute to storage efficiency effectiveness and overall storage costs.

RAS

Reliability, availability and serviceability (RAS) refers to a design philosophy that consistently delivers high availability by building systems with reliable components and “derating” components to increase their mean time between failure (MTBF).

Systems are designed to be resilient. They must reduce the number of critical failure modes, implement serviceability features that enable nondisruptive microcode or hardware updates, protect against and recover from data corruption, and embody diagnostics that enhance performance and minimize human errors. User-visible features include tolerance of multiple disk and/or node failures, fault isolation techniques, built-in protection against data corruption, and other techniques (e.g., snapshots and replication) to meet customers’ RPOs and recovery time objectives (RTOs).

Scalability

This refers to the storage system’s ability to grow capacity, as well as performance and host connectivity. The concept of usable scalability links capacity growth and system performance to

SLAs and application needs.

This collective term is often used to describe IOPS, bandwidth (MB/second) and response times (milliseconds per I/O) that are visible to attached servers.

Ecosystem

This refers to the ability of the platform to support multiple OSs, hypervisors, third-party independent software vendors (ISVs), applications (such as databases and backup/archiving products and management tools), and public cloud vendors.

Multitenancy and Security

This refers to the ability of a storage system to support diverse workloads, isolate workloads from each other, and provide user access controls and auditing capabilities that log changes to the system configuration.

Operations Management

This refers to the use of AIOps, automation, management, monitoring, and reporting tools and programs supported by the platform.

These tools and programs can include single-pane management consoles, monitoring and reporting tools designed to assist IT operations and support personnel in seamlessly managing systems, and monitoring system use and efficiency. They can also be used, in conjunction with SLAs, to anticipate and automatically correct system alarms and fault conditions in advance of the incident or soon after it occurs.

Use Cases

Online Transaction Processing

Online transaction processing (OLTP) is closely affiliated with business-critical applications, such as database management systems (DBMSs).

DBMSs require 24/7 availability and subsecond transaction response times; hence, there's a higher emphasis on performance and RAS features. Manageability and storage efficiency are important, because they enable the storage system to scale with data growth, while staying within budgetary constraints.

Virtualization

This use case encompasses business-critical applications, as well as test and development workloads.

The need to deliver low I/O response times to large numbers of VMs that generate cache-unfriendly workloads, while providing 24/7 availability, heavily weighs performance and storage efficiency, followed closely by RAS.

Containers

Containers are increasingly being viewed as viable alternatives to server virtualization for developing and hosting applications.

This use case assesses the storage system's capabilities to provide persistent storage to container environments through plug-ins, such as container storage interface.

Application Consolidation

The increase in overall performance, coupled with improvements in SSD and HDD capacity, has resulted in storage vendors offering high-capacity storage systems.

These are being provided in denser rack unit form factors, with a higher ratio of performance to power (watts) consumed. High-density storage drives and scale-out storage architectures in combination with data reduction technologies (such as compression and deduplication) can help enterprises consolidate most of the applications onto a single platform.

Hybrid Cloud IT Operations

This use case evaluates storage vendor capabilities to provide platform services and STaaS offerings.

Key attributes must include a centralized operations and storage services control plane and data services plan for onboarding, provisioning and storage life cycle management. Integrated control plane AIOps capabilities are needed to proactively operate, manage and support the platform.

Virtual Desktop Infrastructure

This use case encompasses business-critical applications, as well as test and development workloads.

The need to deliver low I/O response times to large numbers of VMs that generate cache-unfriendly workloads, while providing 24/7 availability, heavily weighs performance and storage efficiency, followed closely by RAS.

Vendors Added and Dropped

Dropped

Fujitsu, Lenovo and Zadara were unable to meet one or more inclusion criteria.

Inclusion Criteria

The Critical Capabilities inclusion criteria include:

- Produced and released its own storage controller OS product (sometimes referred to as data management software), and an SDS product that decouples controller software from its hardware, for general availability during the period July 2022 through May 2023 to support all use cases.

- Products must not depend on a third-party or OEM license.
- Be serviceable in “three” of the major primary storage market geographies — the Asia/Pacific (APAC) region, Japan; Europe, the Middle East and Africa (EMEA); and North America by either direct, service provider or channel sales.
- Generated a minimum of \$100 million in recognized primary storage billings and or bookings revenue (GAAP) during the past four quarters as of March 31, 2023, excluding support revenue. Criteria also includes generating more than \$100 million in total ARR contract value as of 31 March 2023; or have an installed base of at least 500 active customers in the midsize and large enterprise markets. Gartner defines the midmarket as being 500 to 999 employees, and the large enterprise as being 1,000 employees or more. Products must be sold under its brand as a stand-alone product, without the requirement to bundle it with other vendors’ storage products for the product to be commercially usable in mission or business-critical production use cases.
- Produced and have released a managed hybrid platform block storage as a service and at least one data services infrastructure offering in at least two of the major primary storage market geographies. This can be used with on-premises and public cloud infrastructure, along with integrated AIOps capabilities for use in the vendor’s central control and data plane.

Just a bunch of flash or SSDs (JBOF/S) will not be included in this Critical Capabilities research. It covers arrays and SDS products. Hence, it includes only SSAs with internal controllers providing storage features or high-level data services (e.g., thin provisioning, data reduction features, replication and snapshots).

The primary storage SSAs evaluated in this research include scale-up, scale-out and unified storage architectures. Because these arrays have different availability characteristics, performance profiles, scalability, ecosystem support, pricing and warranties, they enable users to tailor solutions against operational needs, planned new application deployments, forecast growth rates and asset management strategies.

Although this primary storage SSA Critical Capabilities research represents vendors with dedicated systems that meet our inclusion criteria, the application workload ultimately governs which solutions should be considered, regardless of the criteria involved. Some vendors may still warrant investigation based on application workload needs for their SSD-only offerings.

Table 1: Weighting for Critical Capabilities in Use Cases

Critical Capabilities ↓	Online Transaction Processing ↓	Virtualization ↓	Containers ↓	Application Consolidation
Performance	30%	14%	10%	20%
Storage Efficiency	13%	15%	12%	10%
RAS	20%	20%	9%	12%
Scalability	7%	15%	15%	17%
Ecosystem	10%	8%	22%	14%
Multitenancy and Security	5%	13%	12%	13%
Operations Management	15%	15%	20%	14%
As of 15 September, 2023				

Source: Gartner (September 2023)

This methodology requires analysts to identify the critical capabilities for a class of products/services. Each capability is then weighted in terms of its relative importance for specific product/service use cases.

Critical Capabilities Rating

Each of the products/services that meet our inclusion criteria has been evaluated on the critical capabilities on a scale from 1.0 to 5.0.

Table 2: Product/Service Rating on Critical Capabilities

Critical Capabilities ↓	Dell Technologies PowerFlex ↓	Dell Technologies PowerMax ↓	Hitachi Vantara VSP 5600 ↓	Hitachi Vantara VSS Block ↓
Performance	4.1	4.6	4.6	3.5
Storage Efficiency	3.8	4.3	4.3	3.1
RAS	4.1	4.5	4.6	4.1
Scalability	4.3	4.4	4.1	3.7
Ecosystem	4.0	4.2	4.1	3.5
Multitenancy and Security	3.9	4.3	4.1	3.8
Operations Management	3.9	3.8	4.1	3.7
As of 15 September 2023				

Source: Gartner (September 2023)

Table 3 shows the product/service scores for each use case. The scores, which are generated by multiplying the use-case weightings by the product/service ratings, summarize how well the critical capabilities are met for each use case.

Table 3: Product Score in Use Cases

Use Cases ↓	Dell Technologies PowerFlex ↓	Dell Technologies PowerMax ↓	Hitachi Vantara VSP 5600 ↓	Hitachi Vantara VSS Block ↓	HP AI 9060 and 50
Online Transaction Processing	4.03	4.35	4.38	3.63	4.
Virtualization	4.02	4.31	4.30	3.66	4.
Containers	4.01	4.24	4.22	3.61	4.
Application Consolidation	4.04	4.32	4.28	3.63	4.
Hybrid Cloud IT Operations	4.00	4.22	4.22	3.63	4.
Virtual Desktop Infrastructure	4.02	4.26	4.24	3.66	4.
As of 15 September 2023					

Source: Gartner (September 2023)

To determine an overall score for each product/service in the use cases, multiply the ratings in Table 2 by the weightings shown in Table 1.

Critical Capabilities Methodology

This methodology requires analysts to identify the critical capabilities for a class of products or services. Each capability is then weighted in terms of its relative importance for specific product or service use cases. Next, products/services are rated in terms of how well they achieve each of the

critical capabilities. A score that summarizes how well they meet the critical capabilities for each use case is then calculated for each product/service.

"Critical capabilities" are attributes that differentiate products/services in a class in terms of their quality and performance. Gartner recommends that users consider the set of critical capabilities as some of the most important criteria for acquisition decisions.

In defining the product/service category for evaluation, the analyst first identifies the leading uses for the products/services in this market. What needs are end-users looking to fulfill, when considering products/services in this market? Use cases should match common client deployment scenarios. These distinct client scenarios define the Use Cases.

The analyst then identifies the critical capabilities. These capabilities are generalized groups of features commonly required by this class of products/services. Each capability is assigned a level of importance in fulfilling that particular need; some sets of features are more important than others, depending on the use case being evaluated.

Each vendor's product or service is evaluated in terms of how well it delivers each capability, on a five-point scale. These ratings are displayed side-by-side for all vendors, allowing easy comparisons between the different sets of features.

Ratings and summary scores range from 1.0 to 5.0:

1 = Poor or Absent: most or all defined requirements for a capability are not achieved

2 = Fair: some requirements are not achieved

3 = Good: meets requirements

4 = Excellent: meets or exceeds some requirements

5 = Outstanding: significantly exceeds requirements

To determine an overall score for each product in the use cases, the product ratings are multiplied by the weightings to come up with the product score in use cases.

The critical capabilities Gartner has selected do not represent all capabilities for any product; therefore, may not represent those most important for a specific use situation or business objective. Clients should use a critical capabilities analysis as one of several sources of input about a product before making a product/service decision.

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