Abstract

Epic makes software for the healthcare industry. This technical report presents best practices for integrating NetApp® storage with Epic software environments.
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1 Introduction

1.1 Purpose
This document describes best practices for integrating NetApp storage into an Epic software environment. It contains the following sections:

- Section 2, “Integration Overview,” offers NetApp field engineers a technical understanding of the Epic software environment and its storage requirements across various configurations.
- Section 3, “Epic Storage Considerations,” describes important decision-making storage factors when architecting an Epic solution.
- Section 4, “Integration Overview,” details the Epic on NetApp reference architecture and sizing.
- Section 5, “NetApp AFF Overview,” describes the features of the NetApp AFF solution.
- Section 6, “NetApp Storage Recommendations,” describes NetApp storage configuration best practices for satisfying Epic storage requirements.
- Section 7, “Integration Tuning,” describes the host-side tuning required by Epic to enable the software to best integrate with NetApp storage.

1.2 Scope
The NetApp storage best practices provided in this document apply to environments with the following characteristics:

- Environments that use the NetApp ONTAP® data management software version 8.3 and later. Features that require specific ONTAP versions will be indicated.
- Environments that use the ONTAP software version 9.4 and later. Active Quality of Service (AQoS) can be used and the storage layout requirements are different.
- Environments that have multiple storage systems to provide mirror and/or disaster recovery capabilities.

This document does not cover the following subjects:

- Quantitative performance requirements and sizing guidance, which are addressed in TR-3930i: NetApp Sizing Guidelines for Epic.

  Note: NetApp Field Portal access is required.

1.3 Audience
This document is intended for NetApp and partner solution engineers (SEs) and professional services personnel. NetApp assumes that the reader has the following background knowledge:

- A solid understanding of SAN and NAS concepts
- Technical familiarity with NetApp ONTAP storage systems
- Technical familiarity with the configuration and administration of ONTAP software
2 Integration Overview

This section describes the Epic software environment and the key components that require storage. It provides key storage considerations from Epic to help guide storage design.

2.1 Epic Overview

Epic is a software company headquartered in Verona, Wisconsin. The following excerpt from the company’s website describes the span of functions supported by Epic software:

Epic makes software for midsize and large medical groups, hospitals, and integrated healthcare organizations—working with customers that include community hospitals, academic facilities, children’s organizations, safety net providers, and multi-hospital systems. Our integrated software spans clinical, access, and revenue functions and extends into the home.

It is beyond the scope of this document to cover the wide span of functions supported by Epic software. From the storage system point of view, however, for each deployment, all Epic software shares a single patient-centric database. Epic uses the InterSystems Caché database, which is available for operating systems AIX and Linux.

The primary focus of the best practices in this document is to enable NetApp storage systems to satisfy performance-driven requirements for the InterSystems Caché database used in an Epic software environment. Generally speaking, dedicated storage resources are provided for the production database, whereas mirror database instances share secondary storage resources with other Epic software-related components, such as Clarity reporting tools. Other software environment storage, such as that used for application and system files, is also provided by the secondary storage resources.

The remainder of this section identifies the various database servers used in an Epic software environment and describes their storage workload requirements.

InterSystems Caché

InterSystems Caché is the database that is used by the Epic application. In an InterSystems Caché database, the data server is the access point for persistently stored data. The application server handles database queries and makes data requests to the data server. For most Epic software environments, the use of the symmetric multiprocessor (SMP) architecture in a single database server suffices to service the Epic applications’ database requests. In large deployments, a distributed model can be supported by using InterSystems’ Enterprise Caché Protocol.

The use of failover-enabled clustered hardware enables a standby data server to access the same disks (that is, the same storage) as the primary data server and to take over the processing responsibilities during a hardware failure.

InterSystems also provides technologies to satisfy data replication, disaster recovery, and high-availability (HA) requirements. InterSystems’ replication technology can be used to asynchronously or synchronously replicate a Caché database from a primary data server to one or more secondary data servers. Asynchronous replication, commonly called a mirror copy, is the method NetApp recommends and the method most commonly deployed.

Caché Database Servers and Storage Usage

In Epic software environments, a single patient-centric database is deployed. In Epic’s hardware requirements, the physical server hosting the primary Caché data server is called the production database server. This server requires high-performance all flash storage for files belonging to the primary database instance. For HA, Epic supports the use of a failover database server that has access to the same files.
A reporting mirror database server is typically deployed to provide read-only access to production data. It hosts a Caché data server configured as a backup mirror of the production Caché data server. This database server has the same storage capacity requirements as the production database server, although the storage is sized differently from a performance perspective because the reporting read workload characteristics are different.

A mirror database server can also be deployed to support the Epic Supports Read-Only (SRO) functionality, in which access is provided to a copy of production in read-only mode. This type of database server can be switched to read/write mode for business continuity reasons.

To meet business continuity and disaster recovery objectives, a disaster recovery mirror database server is commonly deployed at a site geographically separate from the production and/or reporting mirror database servers. A disaster recovery mirror database server also hosts a Caché data server configured as a backup mirror of the production Caché data server. If the production site becomes unavailable for an extended time, this backup mirror database server can be configured to act as a mirror read/write (SRW) instance. The backup mirror database server has the same file storage requirements as the production database server. In contrast, for business continuity reasons, the backup mirror database storage is sized the same as the production storage from a performance perspective. Figure 1 shows the Caché database servers.

Figure 1) InterSystems Caché database servers.

Healthcare organizations often deploy development, testing, and staging environments. Additional Caché data servers for these environments also require storage, which can be accommodated by the storage system. Epic has specific requirements and constraints for providing additional storage from a shared storage system; these specific requirements are addressed generically by the best practices in this document.

In addition to Caché data servers, Epic software environments commonly include other components such as the following:

- An Oracle or Microsoft SQL Server database server as a backend to Epic’s Clarity business-reporting tools
  
  **Note:** Clarity is used to report on data extracted daily from the reporting Caché database.

- Web BLOB server (CIFS)

- Multipurpose database server
• Multipurpose virtual machines (VMs)
• Hyperspace for client access

The storage requirements of all these multiple workloads and multiple NAS and SAN protocols can be accommodated by a single NetApp ONTAP cluster.

Storage Workloads
Each Epic database server performs I/O on the following types of files:
• Database files
• Journal files
• Application files

The workload of an individual database server depends on its role in the Epic software environment. For example, production database files typically incur the most demanding workload, consisting of 100% random I/O requests. The workloads of any mirror database are typically less demanding and have fewer read requests. The workload of journal files consists mainly of sequential I/O.

Epic maintains a workload model for storage performance benchmarking and customer workload.

For more information about the Epic workload model, benchmark results, and guidance on using NetApp sizing tools to correctly size storage for Epic environments, see TR-3930i: NetApp Sizing Guidelines for Epic.

Note: NetApp Field Portal access is required.

Epic also provides each customer with a customized hardware configuration guide containing I/O projections and storage capacity requirements. The final storage requirements might include development, testing, and/or staging environments, and any other ancillary workloads that can be consolidated. The customer can use the hardware configuration guide to communicate the total storage requirements to NetApp. The hardware configuration guide contains all the data needed to size an Epic deployment.

During the deployment phase, Epic provides a database storage layout guide, which provides LUN-level details that can be used for an advanced storage design.

3 Epic Storage Considerations

3.1 Epic Comfort Rating
Epic publishes a quarterly document called Storage Products and Technology Status (SPATS). NetApp ONTAP is the highest rated storage platform by Epic.

Epic does not certify vendors, instead has a granular rating system: high, medium, low, or no. NetApp was the first all-flash array to achieve the Epic high-comfort rating. NetApp is the only vendor that has a large-scale, high-comfort rating for both NAS and SAN on the same platform. This leaves NetApp as the only high-comfort option for Epic to consolidate on an enterprise-class, single storage platform.

Epic’s high-comfort rating combined with the best practices outlined in this document will ensure that you make the Epic Honor Roll for infrastructure and realize significant savings on support costs.

3.2 Simplicity
Reduced storage deployment and operation times have a direct impact on how many full-time employees (FTEs) are required to manage storage. The NetApp portfolio of products have the capabilities to modernize storage that is managed more efficiently and allow you to transition to next-generation data
management. The NetApp products and enterprise-class capabilities provide a comprehensive toolbox to solve the most complex challenges presented by running an Epic environment:

- **Consolidate and run all Epic workloads on a single platform:**
  - NetApp can run multiple NAS and SAN protocols on the same cluster (FCP, NVMe/FC, FCoE, iSCSI, CIFS and NFS).
  - NetApp can scale to 12 nodes in the same single cluster.
- **Your data fabric powered by NetApp delivers solutions to real healthcare business problems.** Epic has approved running Epic Production, disaster recovery, and backup or tiering workloads to anywhere in the data fabric (ONTAP, NetApp HCI, or Cloud)
- **Nondisruptively move workloads between nodes with zero impact to the business.** Never perform a data migration again, even onto new, future technology.
- **NetApp ActiveIQ Call Home and ActiveIQ Unified Manager use machine learning to proactively monitor storage;** they are proven to detect and resolve issues before they have an impact on your business.
- **With ONTAP 9.4 and later, NetApp Service Level Manager (NSLM) and AQoS illuminate performance issues and allow you to manage latency.**
- **NetApp delivers fully automated workflows for Epic backup and refresh of full-copy test environments such as SUP (Support) and REL (Release).** The Epic Environment On-Demand tool was built specifically for Epic database administrators (DBAs) to solve the biggest challenges with Epic infrastructure management through automation.

### 3.3 Consolidation or Workload Isolation?

Consolidating workloads into a simple platform to improve efficiencies is the goal of most organizations. Epic requires each pool of storage to be on separate physical hardware, pool1, pool2, pool3, NAS1 and NAS2. The main reason for these silos is to protect critical workload performance such as Epic Production, Report, and Clarity and disrupting the business.

NetApp has the ability to guarantee performance of all workloads with AQoS. This capability provides a consistent performance based on IOPs/TB. With AQoS, you can consolidate all workloads onto less hardware on a single cluster and simplify storage with more efficiency.

**Note:** The native NSLM automatically manages and monitors AQoS and is part of ActiveIQ Unified Manger.

### 3.4 Scale

Epic typically Hardware Configuration Guide accounts for ~20% growth per year and sizing is performed to accommodate three years of growth. However, environments can and frequently do grow unexpectedly. NetApp can seamlessly scale performance and capacity up to 12 nodes for both SAN and NAS clusters. You can nondisruptively and linearly grow the cluster as your business grows.

You can scale up nondisruptively by upgrading controllers or adding disks. You can scale out nondisruptively by adding HA pairs to the cluster. Both NAS and SAN data can be nondisruptively moved between nodes in the cluster.

Balance your workloads across the cluster and maximize your storage investment.

Epic runs better with the NetApp product portfolio, leveraging the data fabric with NetApp HCI, NetApp StorageGrid®, or the cloud. These products provide options for disaster recovery, archiving, analytics, tiering, and more.
3.5 Performance

By year 2020, all Epic operational database (ODB) workloads will be required to be on all-flash storage. Epic workloads typically operate at approximately 1,000–1,500 IOPs per terabyte of storage (8k block, 75%/25% read and write ratio, and 100% random). This is not an extreme workload requirement, but Epic is latency sensitive, and high latency has an impact on the end-user experience and operation tasks such as running reports, backup, integrity checks, and environment refresh times. Here are some performance related considerations:

- NetApp offers a <500µs performance guarantee with ONTAP all flash. This is realized by using AQoS and automatically configured and managed by NSLM.
- NetApp has no single point of failure and is fully active-active. Most importantly, for performance, both nodes in each HA pair in the cluster write to disk. This has proven to be the fastest architecture maximizing CPU utilization, which is the single most important factor in any all-flash array architectures.
- Epic recognizes the value that NetApp RAID DP®, Advanced Disk Partitioning (ADP), and WAFL® technologies deliver, which exceed the Epic-defined requirements. All workloads share the performance across all the disks.
- ONTAP data management software is write-optimized; writes are acknowledged in NVRAM before they are written to disk at inline memory speed.
- WAFL, NVRAM, and the modular architecture allow NetApp to use software to innovate with inline efficiencies, encryption, performance and to introduce new features and functionality without impacting performance.
- Performance is easily measured; it’s based on numbers. Based on independent testing from SPC, NetApp has the world’s fastest and lowest cost per gigabyte all-flash arrays. NetApp has industry-leading GenIO testing results at the lowest latencies.
- NetApp innovates using software. Historically, with each new version of ONTAP (approximately every six months), there is an increase in performance and efficiency in the range of 30–50%, extending the life of your investment.

3.6 Efficiency

Epic runs on all-flash arrays; therefore, storage efficiency is critical for cost savings. NetApp offers a written efficiency guarantee with the all-flash arrays. When calculating storage efficiency, it’s important to measure raw to usable to effective capacity. Figure 2 illustrates how NetApp inline storage efficiency (by default) achieves industry-leading savings on storage with no impact to performance:

- RAW capacity: before any RAID is applied, size of disk by number of disks
- Usable capacity: after RAID is applied, how much usable storage is available
- Effective capacity: how much storage is provisioned and presented to the host or client

Figure 2 is a sample efficiency calculation of a typical Epic deployment including all workloads with 477TB required effective storage.

Note: Based on the number of disks, raw-to-usable capacity varies slightly.
Note: NetApp does not use snapshots or thin provisioning to calculate efficiencies. Doing so would show unrealistic efficiencies of 30–100:1, which do not mean anything to sizing storage capacity.

3.7 Reliability

At the core of ONTAP is nondisruptive operations that allow you to avoid costly disruption to business operations. NetApp offers 99.9999% availability and is delivering over 99.99995% availability based on production data call home to ActiveIQ. Each HA pair in the cluster has no single point of failure. ONTAP dates back to 1992; ONTAP is the most widely deployed data management software in the world with an exceptional history of delivering reliable storage. Now, with ActiveIQ proactively monitoring and automatically resolving issues, availability is higher and with significantly less support cases.

Epic recommends the use of HA storage systems to mitigate hardware component failure. This recommendation extends from basic hardware, such as redundant power supplies, to networking, such as multipath networking.

NetApp has a 100% written availability guarantee. Rest assured, when you need to upgrade storage, scale up, scale out, or rebalance workloads across the cluster, there will be no impact to the business. You might move data, but you will never need to disruptively migrate data again. Move to next generation technology, future proof, and avoid hardware lock-in.

3.8 Monitoring and Reporting

Epic recommends the use of effective monitoring tools to identify or predict any storage system bottlenecks. Each ONTAP cluster comes with System Manager built in to manage the single cluster. NetApp also provides ActiveIQ Unified Manager to manage capacity, performance, security, and provisioning across all clusters in your organization in a single pain of glass.

All NetApp devices from each customer call back (when allowed) to a central repository called ActiveIQ. NetApp built machine-learning capabilities into the tool with dashboards and accessible by mobile device. ActiveIQ capabilities go beyond just implementing best practices to improve performance and efficiency. Analyzing trends and anomalies has proven to reduce support cases, automatically fix 97% of issues before they have an impact and increase availability.

NetApp OnCommand® Insight is a licensed product that provides a complete view to monitor your entire infrastructure across storage, network, and compute for all vendors in your environment. An Insight dashboard was specifically developed for Epic; it provides complete visibility into storage, network, and compute beyond what the host-side only Epic Pulse monitoring tool provides. Although Pulse can detect an issue, Insight can proactively identify the issue early, before it has an impact. When issues are detected OnCommand Insight reduces the time to determine root cause.
3.9 Security

Security is the number one concern for organizations and healthcare executives today. Security has never been more difficult to manage, and organizations are challenged by compliance, data governance, antivirus protection, and ransomware.

Security is beyond the scope of this document; however, TR-4569: Security Hardening Guide for NetApp ONTAP 9 details all the extensive and advanced security features available with ONTAP software.

**Note:** NetApp Active IQ Unified Manager (formerly OnCommand Unified Manager) monitors for security violations based on the information included in TR-4569 and reports them in the dashboard to simplify managing security. These tools can help your organization meet your security goals to protect, detect, and remediate against attacks.

NetApp has partnered with security vendors to provide integration through NetApp FPolicy™ software to enhance your security offering.

NetApp ONTAP native SnapShot™ and SnapLock® technologies offer a unique air gap capability to protect your patient records against ransomware.

3.10 Cloud and NetApp HCI

More organizations are looking to enterprise applications such as Epic to the cloud. Your data fabric powered by NetApp provides a common framework to grow your business. Enable your business to grow by creating a competitive advantage based on the most critical asset to the business, data.

Your data fabric powered by NetApp includes ONTAP, NetApp HCI, and cloud offerings such as NetApp Cloud Volumes ONTAP. Epic has approved Hyperspace/W&SS, ODB, and Cogito Analytics to run anywhere in your data fabric powered by NetApp.

For details about Epic comfort ratings, see the Storage Products and Technology Status document.

The major advantage to the NetApp cloud integration and the data fabric powered by NetApp is the flexibility to move workloads between all platforms closer to the users that need the data. Each location can be used for production, disaster recovery, archiving, or tiering workloads. Replication technology is built into the fabric. Figure 3 illustrates Epic on your data fabric powered by NetApp.

**Figure 3** Epic on your data fabric powered by NetApp.
3.11 Future Proof

The WAFL file system created in 1992 is even more relevant today than ever before. ONTAP is a true software-defined storage platform with a modular architecture. Emerging hardware technology can be introduced quickly and nondisruptively. New faster Ethernet ports, FC ports, larger drives, and new protocols will always be tested and available on NetApp storage first. NetApp has a long history of innovation that redefines how storage is managed. With each software upgrade, customers get enhanced performance, lower efficiency, with new features and functionality.

3.12 Large-Scale Enterprise Class Storage

For any critical electronic health record (EHR) deployment such as Epic, there are complex requirements to ensure meeting Epic Honor Roll. ONTAP is the most capable enterprise-class data management software with vast capabilities that collectively accelerate and exceed business requirements. ONTAP software includes native tools that are cloud-capable and provide application integration, security, data protection, NDO, storage tiering, monitoring, and much more.

3.13 Epic Storage Requirements

Beyond sizing considerations, Epic has additional storage layout rules and key considerations:

- By year 2020, all ODB workloads must be on all-flash arrays.
- Epic requires each pool of storage to be on separate physical hardware, pool1, pool2, pool3, NAS1 and NAS2. With ONTAP 9.4 or later and AQoS, you can consolidate workloads and protect performance.
- For large sites, where the production OLTP database is expected to exceed 15,000,000 global references per second, Cogito workloads must be on separate physical hardware. With ONTAP 9.4 or later and AQoS, you can consolidate all workloads, and separation is not required.

For more information about storage requirements, see the following Epic guides:

- Storage Area Network Considerations
- Storage Products and Technology Status (SPATS)
- Hardware Configuration Guide

3.14 Snapshot and Clone Technology

Epic recognizes that the storage-node-based NetApp Snapshot technology can minimize performance impacts on production workloads compared to traditional file-based backups. When Snapshot backups are intended for use as a recovery source for the production database, the backup method must be implemented with database consistency in mind.

NetApp FlexClone® volumes provide a great value taking read-only, application-consistent Snapshot copies and creating writable FlexClone volumes from production data. This native capability has a significant impact of storage savings, operations time, and automation capabilities.

3.15 SAN leadership

NetApp has been known as the leader in NAS from its inception and still is today. Even though NetApp introduced the first multiprotocol NAS and SAN platform in 2002, some still see NetApp as a NAS storage vendor. A few important points on NetApp SAN leadership include:

- NetApp is the fastest growing SAN vendor of all the major SAN vendors.
- NetApp is the number one all-flash vendor in the world.
- NetApp has grown to the number two SAN vendor in the world.
- 68% of NetApp flash sales are SAN.
• ONTAP is the first all-flash vendor to get Epic High Comport.

Any all-flash vendor without a file system such as WAFL is just a bunch of disks (JBOD). Modern SAN vendors that have inline efficiencies, encryption, and data management have a file system. ONTAP is the number one data management software in the world with a long history of innovation. The ONTAP modular architecture has always allowed NetApp to introduce new innovation first and seamlessly:

• For hardware, NetApp was the first to add 100GB Ethernet, 32GB FCP, end-to-end NVMe/FC, and 30TB drives. Whatever technological advances come next, it can be installed and tested on ONTAP first and made available.
• Each software upgrade of ONTAP provides better performance, efficiency, and new features.

4 Reference Architectures

Given the storage requirements for Epic software environments, NetApp has three reference architectures based on the size of the environment and the version of ONTAP. For more information, see TR-3930i: NetApp Sizing Guidelines for Epic.

Note: NetApp Field Portal access is required.

Before you read this section, review the following resources:

• Storage Area Network Considerations
• Epic Hardware Configuration Guide

The three reference architectures are:

• Small. This architecture includes a 4-node architecture with a 2-node HA pair in the production data center and a 2-node HA pair in the disaster recovery data center using A220.
• Medium. This architecture includes a 4-node architecture with a 2-node HA pair in the production data center and a 2-node HA pair in the disaster recovery data center using A400.
• Large. This architecture includes a 6-node architecture with four nodes in production and two nodes in disaster recovery (more than 15M global references).
• Epic on ONTAP 9.3 or earlier. If you are running ONTAP 9.3 or earlier, you must put each Epic storage pool on a separate node.

The number of nodes depends on the sizing requirements. For more information, see TR-3930i: NetApp Sizing Guidelines for Epic.

The architecture considerations include:

• Scale. ONTAP allows easy, nondisruptive scale up and scale out. Disks and nodes can be upgraded, added, or removed by using ONTAP nondisruptive operations. Customers can start with four nodes and move to six nodes or upgrade to larger controllers nondisruptively.
• Consolidation. Isolation of critical workloads from potential bully workloads is a key design objective of Epic. A storage pool is a fault domain in which workload performance must be isolated and protected. Without AQoS, each node in an ONTAP cluster is a fault domain and is considered a pool of storage. However, with ONTAP 9.4 and later, you can achieve the same isolation with a more consistent performance for critical workloads by implementing adaptive AQoS. With AQoS, there is no need for physical separation.
• Data management. How can your storage vendor solve the challenges for Epic DBAs to manage Epic complex backup and numerous refreshes of test environments? The NetApp Epic fully automated workflow solution can back up and refresh Epic full-copy test environments in minutes instead of hours. This solution simplifies the architecture and saves on storage capacity with integrated efficiencies. The architectures in this document factor in the backup solution for Epic and leverage storage integration to integrate with any backup solution, as shown in 4 and 5.
• The disaster recovery mirror database server is part of a customer’s business continuity strategy (used to support SRO functionality and potentially configured to be an SRW instance). Therefore, the placement and sizing of the third storage system are usually the same as in the production database storage system. Ideally, Epic disaster recovery should be placed in a separate data center.
• Database consistency requires some consideration. If NetApp SnapMirror® backup copies are used in relation to business continuity, see the Epic document Business Continuity Technical Solutions Guide.

4.1 Small to Medium: 4-Node Reference Architecture with AQoS

The 4-node architecture for small and medium deployments have the exact same storage layout but uses different size controllers. For small deployments, the NetApp AFF A220 all-flash storage system is used; for medium deployments, the NetApp AFF A400 all-flash storage system is used. Depending on the fusion sizing, you might be able to consolidate larger environments into four nodes.

As a starting point, you can determine the architecture based on the database (DB) size:

**Note:** To perform more detailed sizing, contact the NetApp Epic alliance team.

- Small Epic architecture with Epic DB less than 10TB
- Medium Epic architecture with Epic DB from 10TB to 30TB
- Medium Epic architecture with Epic DB from greater than 30TB

NetApp guarantees a minimum performance level by using AQoS; therefore, Epic supports consolidating pools of storage onto less hardware. For more information, see the SPATS document. Basically, pool1, pool2, and NAS1 (listed in the Epic Hardware Configuration Guide) can all be run on a single HA pair with the workloads spread evenly across the two controllers. In disaster recovery, Epic pool 3 and NAS 3 are also split between the two controllers in the HA pair.

**Data Management**

As part of the solution, NetApp delivers a fully automated backup and test refresh solution using native ONTAP tools. This solution was designed to simplify Epic data management specifically for the large community of Epic DBAs:

- Epic Mirror is used to replicate data to disaster recovery and Report (indicated with green).
- Daily data dumps from Report to Clarity.
- NetApp automated backups (indicated with yellow).
- NetApp automated test refresh of SUP, REP, and other (indicated with blue).
- The test environments are for full-copy environments, not smaller squash copies.

For more information, reach out to the NetApp Epic alliance team.
Best Practice

To make sure that the required performance is delivered constantly, NetApp recommends using AQoS managed by NSLM when consolidating Epic workloads.

Best Practice

NetApp recommends balancing all workloads evenly across the HA pair.

4.2 Large: 6-Node Reference Architecture

Customers with an Epic DB 30TB might need to scale out to four nodes in the production site and two nodes in disaster recovery. This decision is determined during sizing. For more information, see TR-3930i: NetApp Sizing Guidelines for Epic.

Customers might want to go to six nodes for reasons other than sizing (optional and not recommended or required), such as:

- Offload backup archive process from production storage
- Offload all test environments from production storage

In this architecture, Epic Production, Epic Report, and Epic Test all run on prod-n01/02 HA pair. Test environments such as SUP, REL, and PJX can be cloned from either Epic Production, Epic Report, or Epic Disaster recovery. Disaster recovery is the same as for the 4-node architecture in the previous section.

For information about Epic backup and refresh, see the section titled "Data Management."
Figure 5 shows the clones made from production for full-copy test environments. The second HA pair is used for Clarity, Hyperspace, VMware, NAS1, and the remaining Epic workloads. Disaster recovery is the same as for the 4-node architecture in the previous section.

For information about Epic backup and refresh, see the section titled "Data Management."

Figure 5) 6-node reference architecture.

4.3 ONTAP 9.3 or Earlier (No AQoS or NSLM)

With ONTAP 9.3 or earlier, Epic pools of storage must be placed on separate nodes. A NetApp node provides the physical separation that is required for each pool of storage. Epic Production and Epic Report must be separate nodes. For customers > 15,000,000 global references, more nodes are required—and Clarity also must be on a separate HA pair from production and report. Figure 6 is a 4-node design on ONTAP 9.3 or earlier with < 15,000,000 global references.

For information about Epic backup and refresh, see the “Data Management” section.
4.4 Storage Design and Layout

With ONTAP 9.4 or later, NetApp recommends using AQoS. Depending on the sizing, you might need a 4-node or 6-node design. Epic workloads can be consolidated into less nodes and there is no need to build inefficiency silos for each pool listed in the Epic Hardware Configuration Guide.

If you are not using AQoS, then each node in the cluster can be considered a storage pool. Each workload pool should be placed in a separate node on the same cluster.

Figure 7, Figure 8, and Figure 9 detail the 4-node, 6-node, and 4-node without AQoS layout of Epic on NetApp storage.
Figure 7) 4-node, high-level storage design and layout (with ONTAP 9.4 and AQoS).

Figure 8) 6-node, high-level storage design and layout (with ONTAP 9.4 and AQoS).
5 NetApp AFF Overview

Built on more than 25 years of innovation, NetApp ONTAP has evolved to meet the changing needs of customers and help drive their success. ONTAP provides a rich set of data management features and clustering for scale-out, operational efficiency, and nondisruptive operations to offer customers the most compelling value propositions in the industry. The IT landscape is undergoing a fundamental shift to IT as a service (ITaaS). This model requires a pool of compute, network, and storage resources to serve a wide range of applications and deliver a wide range of services. NetApp ONTAP innovations fuel this revolution.

5.1 Consolidation of workloads

NetApp ONTAP is the only platform to provide an Epic rated large-scale, high-comfort solution for both NAS and SAN on a single platform. Consolidate all your workloads onto a simple ONTAP cluster.

Additionally, only NetApp has been approved by Epic to use AQoS policies to protect critical workloads instead of building physically separate pools of storage. Deploy Epic on less storage hardware and maximize your investment by consolidation.

Move away from the traditional complexities and inefficiencies of building multiple silos and transition into a next-generation data center with significant saving on hardware, number of FTEs, and operations run by IT generalists.

5.2 Performance

ONTAP introduced flash technologies in 2009 and has supported solid-state drives (SSDs) since 2010. This long experience with flash storage allows NetApp to tune ONTAP features to optimize SSD performance and enhance flash media endurance while keeping the feature-rich capabilities of ONTAP.
ONTAP acknowledges writes after they are in DRAM and logged to NVRAM; SSDs are not in the critical write path. Therefore, write latencies are extremely low. ONTAP also enables efficient use of SSDs during the destaging of write memory buffers by coalescing writes into a single sequential stripe across all SSDs simultaneously. ONTAP writes only to free space, minimizing overwrites for every dataset, not only for deduplicated or compressed data.

Here are some key performance related features for Epic:

- NetApp offers a <500µs performance guarantee with ONTAP all flash. This is realized by using AQoS and automatically configured and managed by NSLM.
- NetApp has no single point of failure and is fully active-active. Most importantly, for performance, both nodes in each HA pair in the cluster write to disk. This has proven to be the fastest architecture maximizing CPU utilization which is the single most important factor in any all-flash array.
- Epic recognizes the value of NetApp RAID DP, ADP, and WAFL technologies delivers and exceeds Epic-defined requirements. All workloads share the performance across all the disk.
- ONTAP comes write optimized and writes are acknowledged in NVRAM before written to disk at inline memory speed.
- WAFL, NVRAM, and the modular architecture allow NetApp to use software to innovate with inline efficiencies, encryption, performance and introduce new features and functionality and not impact to performance. With every six-month upgrade comes improvements in all of the latter.
- Performance is not based on opinions: it’s based on numbers. Based on independent testing from SPC, NetApp has the world’s fastest all-flash, but least $/GB, arrays. NetApp has industry-leading GenIO testing results at the lowest latencies.
- NetApp innovates using software. By simply upgrading the version of ONTAP, NetApp has historically shown increases in performance and efficiency in the range of 30–50% extending the life of your investment.
- NetApp is the number one selling all-flash vendor in the world with SPC forwarded number one highest performing all flash at the lowest $/GB. These tests were performed with all efficiencies turned on, with over 80% load, and with a mixed workload.

Quarantined Performance with AQoS

Most all-flash arrays can deliver the performance required for Epic workloads. The NetApp differentiator is its ability to set performance levels using policies and guarantee a consistent performance level for each application. Now you can add workloads to your cluster, knowing the headroom, without concern of effecting other workloads and select performance level through policy.

NetApp recommends using AQoS managed by NSLM. Benefits of AQoS and NSLM include:

- Considerable cost saving:
  - Fewer nodes are required for physical separation.
  - Much higher utilization by spreading workloads.
  - Less disk required with more consolidation of nodes and aggregates.
- Guaranteed consistent performance for the life of the workload on the cluster by setting a minimum floor performance level to protect the workload.
- A simplified and more flexible design with AQoS enabled:
  - Simplified deployment of workloads by using adaptive QoS policies.
  - Application deployments and auto balancing of workloads.
  - Design based on storage not restrictions; Epic storage pools are no longer required.
  - Creation of storage silos avoided.
  - Performance and allocation management through software.
- NSLM:
− Uses NSLM 1.3 to manage AQoS policies with ONTAP 9.4 or later. NSLM is built into ActiveIQ Unified Manger 9.7.
− Automatically analyzes workloads through machine learning and recommends performance policies. Simply accept recommended policies to lock in guaranteed performance level.
− Calculates headroom on storage controllers and allows you to get more from your storage.
− Adds workload without risk of effecting existing workloads.
− Provides and I/O budget for your ONTAP cluster.
− Creates a catalog of services to simplify policy-based provisioning of storage.
− Delivers predictable service levels; consistently meets utilization goals.

If adaptive QoS is part of the design, sizing can be performed based on storage requirements in the Epic Hardware Configuration Guide. The need to separate workloads into pools is not required on NetApp storage and AQoS enabled.

<table>
<thead>
<tr>
<th>Best Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>• When consolidating Epic workloads to ensure that the required performance is constantly delivered, use AQoS managed by NSLM.</td>
</tr>
<tr>
<td>• No not apply any AQoS policies during the GenIO tests; the IOPs/TB is not consistent and does not reflect a production workload.</td>
</tr>
<tr>
<td>• Only use NSLM to apply recommended policies after the workloads have been running for at least a week on storage.</td>
</tr>
</tbody>
</table>

Some small LUNs such as journals might require customer AQoS policies since the IOPs/TB is excessive. If you set up a policy using the settings listed in Table 1, NSLM will recommend these policies for such LUNs.

Table 1) Customer AQoS policy for small LUNs.

<table>
<thead>
<tr>
<th>AQoS Name</th>
<th>Absolute Minimum</th>
<th>Expected IOPs</th>
<th>Peak IOPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>aqos_burst</td>
<td>1,000</td>
<td>22,528</td>
<td>22,528</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Best Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>NetApp recommends setting up this custom policy to make sure all Epic workloads have the performance requirements.</td>
</tr>
</tbody>
</table>

5.3 Storage Efficiencies

The NetApp AFF solution includes built-in thin provisioning, inline data deduplication, inline compression, inline compaction, and zero-cost cloning with FlexClone technology that offers multilevel storage efficiency across database, installed applications, and user data. Aggregate-level inline deduplication is available in ONTAP 9.2, and postprocess aggregate deduplication is available in ONTAP 9.3.

ONTAP Inline efficiencies are on by default and work regardless of storage protocol, application, or storage tier. Efficiencies reduce the amount of data written to disk saving on wear and tear on the disk, the number of disks required and even preserves efficiencies with replication. Each of the efficiencies have little to no impact on performance, even for a latency sensitive application like Epic.
Best Practice

To maximize disk utilization, NetApp recommends turning on all efficiency settings. These settings are on by default.

Inline Efficiencies

The following features make this storage efficiency possible:

- **Deduplication** saves space on primary storage by removing redundant copies of blocks in a volume that hosts LUNs. This recommended option is on by default.
- **Inline compression** reduces the amount of data to be written to disk and considers saving in space is realized with Epic workloads. This recommended option is on by default.
- **Inline compaction** takes 4k blocks that are less than half full and combines them into a single block. This recommended option is on by default.

Operational Efficiencies

- **NetApp Snapshot copies and FlexClone volumes.** A snapshot is a point-in-time backup of a volume that is read-only. A snapshot puts a lock on all the blocks in the active file system at that point in time. Snapshots are near instant, and they do not use any additional storage. WAFL is a write-only file system; it does not do copy on writes. No data is ever moved; therefore, Snapshot copies have zero impact on storage capacity or performance. Snapshot copies provide tremendous savings in storage while augmenting the backup solution.

  A FlexClone volume is a read- and write-able Snapshot copy; it can write data to new available empty blocks. Epic requires 10 to 30 copies of the production databases for various operational requirements such as streaming backups, integrity checks, and staging upgrade environments. The need for a solution built on FlexClone volumes has increased with the move from 18-month upgrades to quarterly upgrades.

  **Note:** A fully automated Epic backup solution and Epic refresh solution is provided by NetApp as part of the solution using native NetApp tools.

- **Thin replication** is at the center of the NetApp data protection software portfolio, which includes NetApp SnapMirror and NetApp SnapVault® software. SnapVault thin replication enables more frequent backups that use less storage capacity because no redundant data is moved or stored. SnapMirror thin replication protects business-critical data while minimizing storage capacity requirements. NetApp recommends turning this option on.

- **Aggregate deduplication.** Deduplication has always been at the volume level. With ONTAP 9.2, aggregate deduplication became available, providing additional disk reduction savings. Postprocess aggregate deduplication was added with ONTAP 9.3. NetApp recommends turning this option on.

Best Practice

NetApp recommends using FlexClone volumes for each of the full copy environments.

Advanced Disk Partitioning

ADP distributes the root file system across multiple disks in an HA pair. By removing the need for dedicated root and spare disks, this partitioning enables higher overall capacity utilization. This feature became available in ONTAP 8.3. New AFF systems ordered with ONTAP 8.3 and later come with root-data partitioning configured. The cost per gigabyte is much lower, with a higher raw to usable storage percentage.

The root-data-data partitioning feature that is available in ONTAP 9.0 provides even higher raw-to-usable capacity by using three partitions per disk, on small partition for ONTAP, and two data partitions for each node. This reduces the number of party disk.
Figure 10 shows how disk is partitioned for an active-active HA pair with a shelf of 24 disks. The NetApp cluster comes configured with ADP—no configuration is required.

Figure 10) ADP disk layout.

5.4 NAS
Combining NAS and SAN on the same all-flash array is supported. If a document management application is not being used can cause many small files to be written to WebBLOB and the size of WebBLOB to grow faster. FlexGroup volumes eliminate any issues with scale and high file count or directory count issues and recommended with a supported version of ONTAP.

Most of the feature gaps between FlexVol volumes and FlexGroup volumes have been removed but check to make sure if any gaps with the version of ONTAP you are running to make sure required features are not available.

Best Practice
NetApp recommends using FlexGroup volumes for NAS shares such as WebBLOB (when available).

6 NetApp Storage Recommendations
This section provides recommendations for configuring NetApp storage in Epic environments.

6.1 Storage Sizing
For information about how to use NetApp sizing tools to determine the correct RAID group size and number of RAID groups for Epic software environment storage needs, see TR-3930i: NetApp Sizing Guidelines for Epic.

Note: NetApp Field Portal access is required.

6.2 Storage Node Configuration

High Availability
Storage systems configured with nodes in an HA pair mitigate the effect of node failure and enable nondisruptive upgrades of the storage system. There is no single point of failure.

Each node in the HA pair is active-active writing to disk to maximize overall utilization. Disk shelves connected to nodes with multiple paths increase storage resiliency by protecting against a single-path failure while providing improved performance consistency during a node failover.
6.3 Aggregate Configuration

Advanced Disk Partitioning

ADP enables capacity sharing of physical drives between aggregates and controllers in an HA pair. ADP can be implemented by two methods, as shown in Figure 11.

- A root aggregate and a data aggregate; supported with HDDs and SSDs
- A root aggregate and two data aggregates; supported with SSDs only

**Best Practice**

To maximize disk raw-to-useful efficiency, NetApp recommends using a root partition and two data partition RD2 when possible.

Figure 11) ADP.

RAID DP

RAID DP is a double-parity RAID implementation designed with NVRAM and NetApp WAFL technologies in mind. By caching write requests in memory and writing to disk in stripes, RAID DP offers double-parity data protection without the significant decreases in performance that are synonymous with traditional double-parity schemes. RAID DP should be used for all aggregates in a NetApp storage system.

Aggregate Snapshot Copies

Set the aggregate-level Snapshot copy reserve to zero and disable the aggregate Snapshot schedule. For greater flexibility and fine-grained control, manage Snapshot copies at the volume level when you implement a backup and restore solution.

6.4 LUN and Volume Configuration

Attain a copy of the “Epic Database Storage Layout Recommendations” that details the size and number of LUNs for each ODB database. It is important to review that with the Epic DBA and Epic support and finalize the number of LUNs and LUN sizes; they might need to be adjusted slightly.

For the server OS q-depth consideration, use a minimum of eight LUNs in a volume group for the Epic cache DB. Increase the number of LUNs by multiples of eight. For larger environments, more LUNs might be required; use the same number of volumes (eight, four per node) and add LUNs in multiples of eight,
as shown in Figure 12, Figure 13, and Figure 14. Epic recommends keeping the LUNs <8TB and the number of LUNs <32. This approach allows you to scale to any size Epic environment.

To maximize performance for a workload such as Epic or Clarity, the layout in Figure 12, Figure 13, and Figure 14 works best also for NetApp storage. By using eight volumes, volume affinity is spread evenly across the controllers to maximizing access to CPU utilization. For replication and backup, its best to keep the number of volumes to eight to simplify operations.

Scaling Options

If more storage is required by the server, the easiest option is to grow the LUNs and containing volumes. The second option is to add LUNs to the volume groups in multiples of eight at a time. Adding just one or two LUNs can create a hot spot and impact performance.

Figure 12 illustrates the best-practice storage layout for volumes and LUNs.

Figure 12) Volume and 8-LUN layout.
Figure 13) Volume and 16-LUN layout.

Figure 14) Volume and 24-LUN layout.
Best Practices

- Use eight LUNs for each Epic workload, four per node.
- Use either 8, 16, 24, or 32 LUNs in 8 volumes, as shown in Figure 12, Figure 13, Figure 14, and Figure 15.
- Balance the workloads across the HA pair to maximize performance and efficiency.
- Create LUNs at the size expected for three years of growth to avoid hitting 10x LUN expansion limitations.
- Use thin-provisioned volumes and LUNs.
- Use a minimum of eight DB LUNs, two journal LUNs, and two app LUNs. This configuration maximizes storage performance and OS q-depth. More can be used if needed for capacity or other reasons.
- If you do need to add LUNs to volume groups, add eight LUNs at a time.

LUNs can only grow to 10 times their initial size. For ease of operation, make sure that the number of LUNs and initial size can grow well beyond expected requirements after three years. Growing LUNs is much easier to manage than adding LUNs when scaling. With thin provisioning on the LUN and volume only, storage used shows in the aggregate, and starting with larger LUNs is highly recommended and no cost to storage.

Snapshot Copies

A nightly volume-level Snapshot schedule should be set for volumes that provide storage for the production database. Volume-level Snapshot copies can also be used as the source for cloning the production database for use in nonproduction environments such as development, test, and staging. NetApp has developed workflows for Epic that automate the backup of production databases and the refresh of test environments.
Snapshot copies can be used to support the restore operations of Epic’s production database. You can use SnapMirror or SnapVault technology to maintain Snapshot copies on storage systems separate from production.

For SAN volumes, disable the default Snapshot policy on each volume. These Snapshot copies are typically managed by a backup application or by OnCommand WFA. NetApp recommends turning on all efficiency settings to maximize disk utilization. See section 5.3, Storage Efficiencies.

Presentation

FCP is the preferred protocol for presenting LUNs. NetApp recommends single initiator zoning. One initiator per zone with all the required target ports on storage using WWPNs.

After the LUN is created, map the LUN to the igroup containing the WWPNs of the host to enable access.

6.5 Sample Epic Deployment

This section takes you through a complete advanced configuration of an ONTAP cluster and provisioning and presenting storage to an Epic server. For the purpose of capturing details and for easier documentation, the command line is used. If the GUI is preferred, you can provision all the settings in System Manager.

Historically, the initial bulk setup for larger projects is usually faster by using the commands listed in Table 2, especially if you concatenate the commands in a worksheet. This also serves as excellent build documentation.

The GUI also works great with a simple, single-page LUN and shared provisioning. GUI is best used for operations when adding, modifying, or deleting storage. Either preference is fine as long as you apply the best-practice storage settings in Table 2.

The complete cluster setup and storage/host provisioning should not take more than an hour once staged.

Table 2) Best-practice storage settings.

<table>
<thead>
<tr>
<th>Setting Type</th>
<th>Setting Values</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate settings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>auto-provision</td>
<td>*Default settings are best practice</td>
<td>The auto-provision creates one aggregate per node with ADP and RAID-DP</td>
</tr>
<tr>
<td>Storage virtual machine (SVM)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>-vserver</td>
<td>epic_fcp</td>
<td>SVM names</td>
</tr>
<tr>
<td></td>
<td>epic_cifs</td>
<td>Note: In the command line, vServer is referred to as SVM.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Setting Type</td>
<td>Setting Values</td>
<td>Description</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-----------------------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>aggregate</td>
<td>a800_3_n1_aggr1</td>
<td>SVM root volume aggregate</td>
</tr>
<tr>
<td>vserver create</td>
<td>vserver epic_fcp -aggregate a800_3_n1_aggr1 -</td>
<td></td>
</tr>
<tr>
<td></td>
<td>rootvolume epic_fcp_vol0 -</td>
<td></td>
</tr>
<tr>
<td></td>
<td>rootvolume-security-style unix vserver modify</td>
<td></td>
</tr>
<tr>
<td></td>
<td>vserver svm_epicprod -aggr-list a800_3_n1_aggr1,a800_3_n2_aggr1 -allowed-protocols fcp</td>
<td></td>
</tr>
<tr>
<td>rootvolume</td>
<td>epic_fcp_vol0</td>
<td>Root volume name</td>
</tr>
<tr>
<td></td>
<td>epic_cifs_vol0</td>
<td></td>
</tr>
<tr>
<td>rootvolume-security-style</td>
<td>UNIX NTFS</td>
<td>For SAN, use UNIX. For the CFIS SVM, use NTFS.</td>
</tr>
<tr>
<td>aggr-list</td>
<td>a800_3_n1_aggr1, a800_3_n2_aggr1</td>
<td>SVM data aggregates (remove any root aggregate from this list).</td>
</tr>
<tr>
<td>allowed-protocols</td>
<td>FCP CIFS</td>
<td>Use an SVM for each protocol.</td>
</tr>
</tbody>
</table>

**Volume settings**

<table>
<thead>
<tr>
<th>Setting</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume size</td>
<td>375Gb</td>
<td>&quot;1.5 times the size of the LUN</td>
</tr>
<tr>
<td>space-guarantee</td>
<td>&quot;None&quot;</td>
<td>Thin provision the volume.</td>
</tr>
<tr>
<td>snapshot-policy</td>
<td>&quot;None&quot;</td>
<td>Remove the default Snapshot policy.</td>
</tr>
<tr>
<td>autosize-mode</td>
<td>&quot;Grow&quot;</td>
<td>To protect the volume when full, its easiest to grow the volume first</td>
</tr>
<tr>
<td>max-autosize</td>
<td>500g</td>
<td>&quot;Max. autosize is set to two times the LUN size</td>
</tr>
<tr>
<td>volume snapshot autodelete</td>
<td>&quot;Enabled&quot;</td>
<td>If max. autosize is reached, Snapshot copies are deleted, starting with oldest first. This ensures that the volume and LUN stay online.</td>
</tr>
<tr>
<td>aggregate</td>
<td>N1_aggr1, N2_aggr2</td>
<td>&quot;Balance volumes evenly across the HA pair.</td>
</tr>
<tr>
<td>fractional reserve</td>
<td>0</td>
<td>This option is no longer required with autosize and autodelete.</td>
</tr>
</tbody>
</table>

**LUN settings**
<table>
<thead>
<tr>
<th>Setting Type</th>
<th>Setting Values</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>LUN size</td>
<td>250Gb</td>
<td>*Use full size after three years of growth</td>
</tr>
<tr>
<td>-space reserve</td>
<td>*disabled</td>
<td>Thin provision the LUN.</td>
</tr>
<tr>
<td>-ostype</td>
<td>Linux</td>
<td>Depending on the host OS, use either AIX or Linux.</td>
</tr>
</tbody>
</table>

**Ingroup settings**

<table>
<thead>
<tr>
<th>-protocol</th>
<th>*FCP</th>
<th>LUNs can be mounted by using iSCSI or FCP protocol.</th>
</tr>
</thead>
<tbody>
<tr>
<td>-ostype</td>
<td>VMware</td>
<td>If virtual is not the host, use the hypervisor OS type. For physical servers, use the host OS such as AIX.</td>
</tr>
</tbody>
</table>

*Default settings

**Provision Aggregates**

To provision aggregates, run the following single command:

Note: The default settings optimize performance and capacity. One large aggregate is created per node.

```
aggr auto-provision
```

**Set Up SVM**

NetApp virtualizes storage, and user access is provided by SVM. For Epic, there is an FCP SVM and a CIFS SVM. Depending on how you want to manage your storage, and possibly multitenancy, you can use more SVMs.

To set up SVM, run the following commands:

```
vserver create -vserver epic_fcp -aggregate a800_3_n1_aggr1 -rootvolume epic_fcp_vol0 -rootvolume-security-style unix
vserver modify -vserver svm_epicprod -aggr-list a800_3_n1_aggr1,a800_3_n2_aggr1 -allowed-protocols fcp
vserver create -vserver epic_cifs -aggregate a800_3_n1_aggr1 -rootvolume epic_cifs_vol0 -rootvolume-security-style unix
vserver modify -vserver svm_epicprod -aggr-list a800_3_n1_aggr1,a800_3_n2_aggr1 -allowed-protocols cifs
```

**Create FCP Data LIFs**

To create FCP data LIFs, run the following commands:

```
network interface create -vserver epic_fcp -lif a800_3-01_0c -data-protocol fcp -home-node a800_3-01 -home-port 0c
network interface create -vserver epic_fcp -lif a800_3-01_0d -data-protocol fcp -home-node a800_3-01 -home-port 0d
network interface create -vserver epic_fcp -lif a800_3-01_0e -data-protocol fcp -home-node a800_3-01 -home-port 0e
network interface create -vserver epic_fcp -lif a800_3-01_0f -data-protocol fcp -home-node a800_3-01 -home-port 0f
network interface create -vserver epic_fcp -lif a800_3-02_0c -data-protocol fcp -home-node a800_3-02 -home-port 0c
```
network interface create -vserver epic_fcp -lif a800_3-02_0d -data-protocol fc -home-node a800_3-02 -home-port 0d
network interface create -vserver epic_fcp -lif a800_3-02_0e -data-protocol fc -home-node a800_3-02 -home-port 0e
network interface create -vserver epic_fcp -lif a800_3-02_0f -data-protocol fc -home-node a800_3-02 -home-port 0f

Start FCP on the SVM
To start FCP on the SVM, run the following command:

vserver fcp start -vserver epic_fcp

Create igroup
Igroups are used to allow server access to LUNs. To create an igroup, run the following commands:

Note: This example is a 4-node VMWare cluster and includes all the initiator WWPN for each server in the cluster.

igroup create -igroup ESX_Cluster_01 -protocol fcp -ostype vmware -initiator 10:00:00:10:9b:40:17:e1, 10:00:00:10:9b:40:17:e2, 10:00:00:90:fa:94:36:a3, 10:00:00:90:fa:94:36:a4, 10:00:00:90:fa:d1:43:8b, 10:00:00:90:fa:d1:43:8c, 10:00:00:90:fa:f0:77:a8, 10:00:00:90:fa:f0:77:a9

Create Volumes
To create volumes, run the following commands:


Autodelete Volumes
To autodelete volumes, run the following commands:

volume snapshot autodelete modify -vserver svm_epicprod -volume epic_7_db_1 -enable true volume snapshot autodelete modify -vserver svm_epicprod -volume epic_7_db_2 -enable true volume snapshot autodelete modify -vserver svm_epicprod -volume epic_7_db_3 -enable true
Create LUN

To create a LUN, run the following commands:

```bash
lun create -vserver svm_epicprod -path /vol/epic_7_db_1/epic_7_db_1 -size 250g -ostype linux -space-reserve disabled
lun create -vserver svm_epicprod -path /vol/epic_7_db_2/epic_7_db_2 -size 250g -ostype linux -space-reserve disabled
lun create -vserver svm_epicprod -path /vol/epic_7_db_3/epic_7_db_3 -size 250g -ostype linux -space-reserve disabled
lun create -vserver svm_epicprod -path /vol/epic_7_db_4/epic_7_db_4 -size 250g -ostype linux -space-reserve disabled
lun create -vserver svm_epicprod -path /vol/epic_7_db_5/epic_7_db_5 -size 250g -ostype linux -space-reserve disabled
lun create -vserver svm_epicprod -path /vol/epic_7_db_6/epic_7_db_6 -size 250g -ostype linux -space-reserve disabled
lun create -vserver svm_epicprod -path /vol/epic_7_db_7/epic_7_db_7 -size 250g -ostype linux -space-reserve disabled
lun create -vserver svm_epicprod -path /vol/epic_7_db_8/epic_7_db_8 -size 250g -ostype linux -space-reserve disabled
lun create -vserver svm_epicprod -path /vol/epic_7_jrn_9/epic_7_jrn_9 -size 250g -ostype linux -space-reserve disabled
lun create -vserver svm_epicprod -path /vol/epic_7_jrn_10/epic_7_jrn_10 -size 250g -ostype linux -space-reserve disabled
lun create -vserver svm_epicprod -path /vol/epic_7_inst_11/epic_7_inst_11 -size 250g -ostype linux -space-reserve disabled
lun create -vserver svm_epicprod -path /vol/epic_7_inst_12/epic_7_inst_12 -size 250g -ostype linux -space-reserve disabled
```

Map LUN

To map the LUN, run the following commands:

```bash
lun map -vserver svm_epicprod -path /vol/epic_7_db_1/epic_7_db_1 -igroup ESX_Cluster_01 -lun-id 50
lun map -vserver svm_epicprod -path /vol/epic_7_db_2/epic_7_db_2 -igroup ESX_Cluster_01 -lun-id 51
lun map -vserver svm_epicprod -path /vol/epic_7_db_3/epic_7_db_3 -igroup ESX_Cluster_01 -lun-id 52
lun map -vserver svm_epicprod -path /vol/epic_7_db_4/epic_7_db_4 -igroup ESX_Cluster_01 -lun-id 53
lun map -vserver svm_epicprod -path /vol/epic_7_db_5/epic_7_db_5 -igroup ESX_Cluster_01 -lun-id 54
lun map -vserver svm_epicprod -path /vol/epic_7_db_6/epic_7_db_6 -igroup ESX_Cluster_01 -lun-id 55
lun map -vserver svm_epicprod -path /vol/epic_7_db_7/epic_7_db_7 -igroup ESX_Cluster_01 -lun-id 56
lun map -vserver svm_epicprod -path /vol/epic_7_db_8/epic_7_db_8 -igroup ESX_Cluster_01 -lun-id 57
lun map -vserver svm_epicprod -path /vol/epic_7_jrn_9/epic_7_jrn_9 -igroup ESX_Cluster_01 -lun-id 58
lun map -vserver svm_epicprod -path /vol/epic_7_jrn_10/epic_7_jrn_10 -igroup ESX_Cluster_01 -lun-id 59
lun map -vserver svm_epicprod -path /vol/epic_7_inst_11/epic_7_inst_11 -igroup ESX_Cluster_01 -lun-id 60
lun map -vserver svm_epicprod -path /vol/epic_7_inst_12/epic_7_inst_12 -igroup ESX_Cluster_01 -lun-id 61
```
Depending on the version of ONTAP, the default setting for Fractional Reserve on the volume can be 100%. This configuration should be set to 0.

### 6.6 Presentation

For Epic ODB databases, journal, and application workloads, Epic recommends presenting storage to servers as FCP LUNs. NetApp also supports using NVMe/FC as soon as AIX and RHEL server operating systems are capable and will enhance the performance.

NetApp customers have successfully run all Epic workloads in the Azure cloud. AWS is also capable of running Epic workloads. With Cloud Volumes ONTAP and Cloud Volumes Services, NetApp provides the enterprise-class capabilities and the performance required to effectively run Epic in the cloud. NetApp provides block over iSCSI and file over NFS or SMB.

### 7 Integration Tuning

This section describes host integration for various operating systems. Use the NetApp Interoperability Matrix Tool (IMT) to validate all versions of software and firmware.

#### 7.1 NetApp Host Utility

NetApp recommends installing the NetApp Host Utility Kit (HUK) on the operating systems of hosts that are connected to and accessing NetApp storage systems. Native Microsoft Multipath I/O (MPIO) can be used and is supported. The OS must be ALUA capable for multipathing. Installing the HUK configures the host bus adapter (HBA) settings for NetApp storage. For more information, see the Interoperability Matrix Tool.

#### 7.2 Mount Options

**Asynchronous I/O**

A copy of the Epic SAN Considerations whitepaper and the Storage Configuration Quick Reference document provide details about how to configure the hosts and connect to storage. This section reviews how to set up a Red Hat Enterprise Linux host. AIX details can be found in the referenced documents.

**File System and Mount Options**

For information about mounting LUNs, creating volume groups and logical volumes, and configuring the file systems, see the Epic Storage Configuration Quick Reference Guide. Use the following sample commands to set up Epic Production servers for Red Hat Enterprise Linux.

After the LUNs have been created and mapped, and the zoning is complete, use the following procedure to attach storage to the server.

**Note:** In this example, we used 8x 250Gb LUNs for the DB, 2x 250Gb LUNs for journals, and 2x 250Gb LUNs for application installations.

**Discover Storage**

```
[root@rhel01 ~]# lsblk -do KNAME,TYPE,SIZE,MODEL
KNAME TYPE  SIZE MODEL
sdb disk  250G LUN C-Mode
sdc disk  250G LUN C-Mode
sdd disk  250G LUN C-Mode
sde disk  250G LUN C-Mode
sdf disk  250G LUN C-Mode
sdg disk  250G LUN C-Mode
sdh disk  250G LUN C-Mode
sdi disk  250G LUN C-Mode
```
sdj disk 250G LUN C-Mode
sdk disk 250G LUN C-Mode
sdl disk 250G LUN C-Mode
sdm disk 250G LUN C-Mode

Create Physical Disk

```
pvcreate /dev/sdb
pvcreate /dev/sdc
pvcreate /dev/sdd
pvcreate /dev/sdf
pvcreate /dev/sdg
pvcreate /dev/sdh
pvcreate /dev/sdj
pvcreate /dev/sdk
pvcreate /dev/sdl
pvcreate /dev/sdm
```

Create the Volume Groups

```
vgcreate -s 16M prodvg /dev/sd[b-i]
vgcreate -s 16M jrnvg /dev/sd[j-k]
vgcreate -s 16M instvg /dev/sd[l-m]
```

Create Logical Volume

```
lvcreate -n prod01 -l 100%FREE -i 4 -l 16M prodvg
lvcreate -n jrn -l 100%FREE -i 2 -l 16M jrnvg
lvcreate -n prd -l 100%FREE instvg
```

Mike the File System

```
mkfs.xfs -K /dev/prodvg/prod01
mkfs.xfs -K /dev/jrnvg/jrn
mkfs.xfs -K /dev/instvg/prd
```

Make Folder to Mount

```
mkdir /prod01
mkdir /jrn
mkdir /prd
```

Set Permissions

```
chmod 755 /prod01
chmod 755 /jrn
chmod 755 /prd
chown root:root /prod01
chown root:root /jrn
chown root:root /prd
```

Add Mounts to /etc/fstab so Mounts are Maintained Through Reboot

```
/dev/mapper/prodvg-prod01 /prod01 xfs defaults 0 0
/dev/mapper/jrnvg-jrn /jrn xfs defaults 0 0
/dev/mapper/instvg-prd /prd xfs defaults 0 0
```

Mount Storage

```
mount -a
```
8 Cloud Extensibility and Scaling

This section discusses the various cloud solutions provided by NetApp. NetApp offers Epic approved solutions to run in the cloud leveraging NetApp and Cloud Volumes Service. NetApp provides on prem speed with enterprise class features and functionality needed to run all of Epic in the cloud.

8.1 Cloud

NetApp Cloud Volumes ONTAP® is a data management software solution that runs NetApp ONTAP storage software, offering you control of your data with the power of an enterprise storage software solution. It provides nondisruptive, secure, and proven NFS, CIFS, and ISCSI data management for the cloud.

Cloud Volumes ONTAP is deployed and managed from OnCommand® Cloud Manager giving you a simple point-and-click environment to manage the software and underlying cloud infrastructure for your cloud storage solution. For a nondisruptive environment, Cloud Volumes ONTAP HA allows you to build a two-node solution with failover support in the case that one node fails (whether unplanned or for planned upgrade purposes).

Cloud Volumes ONTAP HA requires two Cloud Volumes ONTAP instances and a failover controller in order to operate. As with a single instance of Cloud Volumes ONTAP, OnCommand Cloud Manager is required for setup, configuration, and management of the environment. Cloud Volumes ONTAP takes the EBS storage, manages it with the ONTAP storage operating system, and provides numerous advanced features on top of the storage advanced features that Cloud Volumes ONTAP offers:

- Multiprotocol (NFS, CIFS, iSCSI)
- Data protection (snapshot copies, SnapMirror, SnapVault)
- Storage efficiency (data deduplication, compression, thin provisioning) can reduce the amount of EBS storage you must purchase
- FlexClone® volumes
- Management (Unified Manager, System Manager, WFA, Insight, and so on)

Cloud Manager software is a centralized management environment for ONTAP software-based hybrid cloud storage environment, including the Cloud Volumes ONTAP, AFF, and FAS storage systems. Cloud Manager is the deployment environment for Cloud Volumes ONTAP and provides installation, resource assignment, and provisioning of data.

Where to Find Additional Information

To learn more about the information described in this document, refer to the following documents and/or websites:

- NetApp Product Documentation
- ONTAP 9 Documentation Center
  [https://docs.netapp.com/ontap-9/index.jsp](https://docs.netapp.com/ontap-9/index.jsp)
- ONTAP and ONTAP System Manager Documentation Resources

NetApp Technical Reports

- TR-3930i: NetApp Sizing Guidelines for Epic
- TR-4684: Implementing and Configuring Modern SANs with NVMe/FC
- TR-4080: Best Practices for Modern SAN and ONTAP 9
Epic Customer Guidance Documents

Epic provides customers the following documents to its customers for guidance on server, storage, and network. These documents are referenced in this technical report.

- Storage Area Network Considerations
- Business Continuity Technical Solutions Guide
- All-Flash Reference Architecture Strategy Handbook
- Storage Products and Technology Status
- Epic Cloud Considerations
- Hardware Configuration Guide (customer-specific)
- Database Storage Layout Recommendations (customer-specific)

NetApp Support Tools and Services

NetApp offers a complete set of support tools and services. The NetApp Active IQ tool should be enabled and configured on NetApp storage systems to call home in case of hardware failure or system misconfiguration. For mission-critical environments, NetApp also recommends the SupportEdge Premium package, which provides access to operational expertise, extended support hours, and fast response times on parts replacement.

Version History

<table>
<thead>
<tr>
<th>Date</th>
<th>Authors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>February 2020</td>
<td>Brian O'Mahony</td>
<td>Complete rewrite of the document based on requirement changes.</td>
</tr>
<tr>
<td>May 2018</td>
<td>Brian O'Mahony</td>
<td>Added Adaptive Quality of Service options for Epic deployments.</td>
</tr>
<tr>
<td>May 2018</td>
<td>Brian O'Mahony</td>
<td>Updated text and diagrams based on new ONTAP features.</td>
</tr>
<tr>
<td>January 2018</td>
<td>Brian O'Mahony</td>
<td>Added AFF A700 and AFF A300 considerations.</td>
</tr>
<tr>
<td>October 2017</td>
<td>Brian O'Mahony</td>
<td>Updated requirements for all-flash arrays. Added volume affinity considerations. Added new reference architectures.</td>
</tr>
</tbody>
</table>


Refer to the Interoperability Matrix Tool (IMT) on the NetApp Support site to validate that the exact product and feature versions described in this document are supported for your specific environment. The NetApp IMT defines the product components and versions that can be used to construct configurations that are supported by NetApp. Specific results depend on each customer’s installation in accordance with published specifications.

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