



Concepts

Cloud Volumes ONTAP

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Concepts

Cloud Volumes ONTAP licensing

Several licensing options are available for Cloud Volumes ONTAP. Each option enables you to choose a consumption model that meets your needs.

Licensing overview

The following licensing options are available for new customers.

Capacity-based licensing

Pay for multiple Cloud Volumes ONTAP systems in your NetApp account by provisioned capacity. Includes the ability to purchase add-on cloud data services.

Keystone Flex Subscription

A pay-as-you-grow subscription-based service that delivers a seamless hybrid cloud experience for HA pairs.

The previous by-node licensing model remains available for existing customers who have already purchased a license or who have an active marketplace subscription.

The following sections provide more details about each of these options.

Capacity-based licensing

Capacity-based licensing packages enable you to pay for Cloud Volumes ONTAP per TiB of capacity. The license is associated with your NetApp account and enables you to charge multiple systems against the license, as long as enough capacity is available through the license.

For example, you could purchase a single 20 TiB license, deploy four Cloud Volumes ONTAP systems, and then allocate a 5 TiB volume to each system, for a total of 20 TiB. The capacity is available to the volumes on each Cloud Volumes ONTAP system deployed in that account.

Capacity-based licensing is available in the form of a *package*. When you deploy a Cloud Volumes ONTAP system, you can choose from several licensing packages based on your business needs.

Packages

The following capacity-based packages are available for Cloud Volumes ONTAP.

Freemium

Provides all Cloud Volumes ONTAP features free of charge from NetApp (cloud provider charges still apply).

- No license or contract is needed.
- Support from NetApp is not included.
- You're limited to 500 GiB of provisioned capacity per Cloud Volumes ONTAP system.
- You can use up to 10 Cloud Volumes ONTAP systems with the Freemium offering per NetApp account, in any cloud provider.

- If the provisioned capacity for a Cloud Volumes ONTAP system exceeds 500 GiB, Cloud Manager converts the system to the Essentials package.

As soon as a system is converted to the Essentials package, the [minimum charge](#) applies.

Any other systems that have less than 500 GiB of provisioned capacity stay on Freemium (as long as they were deployed using the Freemium offering).

Optimized

Pay for provisioned capacity and I/O operations separately.

- Cloud Volumes ONTAP single node or HA
- Charging is based on two cost components: storage and usage (I/O)

Note that I/O for data replication does not count as charged I/O usage.

- Available only in the Azure Marketplace as a pay-as-you-go offering or as an annual contract
- Supported with selected VM types: E4s_v3, E4ds_v4, DS4_v2, DS13_v2, E8s_v3, and E8ds_v4
- Add on any of NetApp's cloud data services at extra cost

Essentials

Pay by capacity for Cloud Volumes ONTAP in a number of different configurations.

- Choose your Cloud Volumes ONTAP configuration:
 - A single node or HA system
 - File and block storage or secondary data for disaster recovery (DR)
- Add on any of NetApp's cloud data services at extra cost

Professional

Pay by capacity for any type of Cloud Volumes ONTAP configuration with unlimited backups.

- Provides licensing for any Cloud Volumes ONTAP configuration

Single node or HA with capacity charging for primary and secondary volumes at the same rate

- Includes unlimited volume backups using Cloud Backup, but only for Cloud Volumes ONTAP systems deployed with the Professional package
- Add on any of NetApp's cloud data services at extra cost

Edge Cache

Provides licensing for Cloud Volumes Edge Cache.

- The same capabilities as the Professional package with business continuity and data protection for a distributed enterprise
- Intelligent edge caching through a small-footprint Windows VM at each location
- 30 TiB minimum with six edge nodes included

- One edge node with every 3 TiBs of additional capacity purchased
- Available only in the Azure Marketplace as a pay-as-you-go offering or as an annual contract

[Learn more about how Cloud Volumes Edge Cache can help your business](#)

Consumption models

Capacity-based licensing packages are available with the following consumption models:

- **BYOL**: A license purchased from NetApp that can be used to deploy Cloud Volumes ONTAP in any cloud provider.

Note that the Optimized and Edge Cache packages are not available with BYOL.

- **PAYGO**: An hourly subscription from your cloud provider's marketplace.
- **Annual**: An annual contract from your cloud provider's marketplace.

Note the following:

- If you purchase a license from NetApp (BYOL), you also need to subscribe to the PAYGO offering from your cloud provider's marketplace.

Your license is always charged first, but you'll be charged from the hourly rate in the marketplace in these cases:

- If you exceed your licensed capacity
- If the term of your license expires
- If you have an annual contract from a marketplace, *all* Cloud Volumes ONTAP systems that you deploy are charged against that contract. You can't mix and match an annual marketplace contract with BYOL.

Changing packages

After deployment, you can change the package for a Cloud Volumes ONTAP system that uses capacity-based licensing. For example, if you deployed a Cloud Volumes ONTAP system with the Essentials package, you can change it to the Professional package if your business needs changed.

[Learn how to change charging methods.](#)

Pricing

For details about pricing, go to [NetApp Cloud Central](#).

Free trials

A 30-day free trial is available from the pay-as-you-go subscription in your cloud provider's marketplace. The free trial includes Cloud Volumes ONTAP and Cloud Backup. The trial starts when you subscribe to the offering in the marketplace.

There are no instance or capacity limitations. You can deploy as many Cloud Volumes ONTAP systems as you'd like and allocate as much capacity as needed, free of charge for 30 days. The free trial automatically converts to a paid hourly subscription after 30 days.

There are no hourly software license charges for Cloud Volumes ONTAP, but infrastructure charges from your

cloud provider still apply.

You will receive a notification in Cloud Manager when the free trial starts, when there are 7 days left, and when there is 1 day remaining. For example:



Your Cloud Manager free trial is almost over (7 days left)

23 minutes ago | Digital Wallet

Supported configurations

Capacity-based licensing packages are available with Cloud Volumes ONTAP 9.7 and later.

Capacity limit

With this licensing model, each individual Cloud Volumes ONTAP system supports up to 2 PiB of capacity through disks and tiering to object storage.

There is no maximum capacity limitation when it comes to the license itself.

Max number of systems

With capacity-based licensing, the maximum number of Cloud Volumes ONTAP systems is limited to 20 per NetApp account. A *system* is a Cloud Volumes ONTAP HA pair, a Cloud Volumes ONTAP single node system, or any additional storage VMs that you create. The default storage VM does not count against the limit. This limit applies to all licensing models.

For example, let's say you have three working environments:

- A single node Cloud Volumes ONTAP system with one storage VM (this is the default storage VM that's created when you deploy Cloud Volumes ONTAP)

This working environment counts as one system.

- A single node Cloud Volumes ONTAP system with two storage VMs (the default storage VM, plus one additional storage VM that you created)

This working environment counts as two systems: one for the single node system and one for the additional storage VM.

- A Cloud Volumes ONTAP HA pair with three storage VMs (the default storage VM, plus two additional storage VMs that you created)

This working environment counts as three systems: one for the HA pair and two for the additional storage VMs.

That's six systems in total. You would then have room for an additional 14 systems in your account.

If you have a large deployment that requires more than 20 systems, contact your account rep or sales team.

[Learn more about NetApp accounts.](#)

Notes about charging

The following details can help you understand how charging works with capacity-based licensing.

Minimum charge

There is a 4 TiB minimum charge for each data-serving storage VM that has least one primary (read-write) volume. If the sum of the primary volumes is less than 4 TiB, then Cloud Manager applies the 4 TiB minimum charge to that storage VM.

If you haven't provisioned any volumes yet, then the minimum charge doesn't apply.

The 4 TiB minimum capacity charge doesn't apply to storage VMs that contain secondary (data protection) volumes only. For example, if you have a storage VM with 1 TiB of secondary data, then you're charged just for that 1 TiB of data.

Overages

If you exceed your BYOL capacity or if your license expires, you'll be charged for overages at the hourly rate based on your marketplace subscription.

Essentials package

With the Essentials package, you're billed by the deployment type (HA or single node) and the volume type (primary or secondary). For example, *Essentials HA* has different pricing than *Essentials Secondary HA*.

If you purchased an Essentials license from NetApp (BYOL) and you exceed the licensed capacity for that deployment and volume type, the Digital Wallet charges overages against a higher priced Essentials license (if you have one). This happens because we first use the available capacity that you've already purchased as prepaid capacity before charging against the marketplace. Charging to the marketplace would add costs to your monthly bill.

Here's an example. Let's say you have the following licenses for the Essentials package:

- A 500 TiB *Essentials Secondary HA* license that has 500 TiB of committed capacity
- A 500 TiB *Essentials Single Node* license that only has 100 TiB of committed capacity

Another 50 TiB is provisioned on an HA pair with secondary volumes. Instead of charging that 50 TiB to PAYGO, the Digital Wallet charges the 50 TiB overage against the *Essentials Single Node* license. That license is priced higher than *Essentials Secondary HA*, but it's cheaper than the PAYGO rate.

In the Digital Wallet, that 50 TiB will be shown as charged against the *Essentials Single Node* license.

Storage VMs

- There are no extra licensing costs for additional data-serving storage VMs (SVMs), but there is a 4 TiB minimum capacity charge per data-serving SVM.
- Disaster recovery SVMs are charged according to the provisioned capacity.

HA pairs

For HA pairs, you're only charged for the provisioned capacity on a node. You aren't charged for data that is synchronously mirrored to the partner node.

FlexClone and FlexCache volumes

- You won't be charged for the capacity used by FlexClone volumes.
- Source and destination FlexCache volumes are considered primary data and charged according to the provisioned space.

How to get started

Learn how to get started with capacity-based licensing:

- [Set up licensing for Cloud Volumes ONTAP in AWS](#)
- [Set up licensing for Cloud Volumes ONTAP in Azure](#)
- [Set up licensing for Cloud Volumes ONTAP in Google Cloud](#)

Keystone Flex Subscription

A pay-as-you-grow subscription-based service that delivers a seamless hybrid cloud experience for those preferring OpEx consumption models to upfront CapEx or leasing.

Charging is based on the size of your committed capacity for one or more Cloud Volumes ONTAP HA pairs in your Keystone Flex Subscription.

The provisioned capacity for each volume is aggregated and compared to the committed capacity on your Keystone Flex Subscription periodically, and any overages are charged as burst on your Keystone Flex Subscription.

[Learn more about Keystone Flex Subscriptions.](#)

Supported configurations

Keystone Flex Subscriptions are supported with HA pairs. This licensing option isn't supported with single node systems at this time.

Capacity limit

Each individual Cloud Volumes ONTAP system supports up to 2 PiB of capacity through disks and tiering to object storage.

How to get started

Learn how to get started with a Keystone Flex Subscription:

- [Set up licensing for Cloud Volumes ONTAP in AWS](#)
- [Set up licensing for Cloud Volumes ONTAP in Azure](#)
- [Set up licensing for Cloud Volumes ONTAP in Google Cloud](#)

Node-based licensing

Node-based licensing is the previous generation licensing model that enabled you to license Cloud Volumes ONTAP by node. This licensing model is not available for new customers and no free trials are available. By-node charging has been replaced with the by-capacity charging methods described above.

Node-based licensing is still available for existing customers:

- If you have an active license, BYOL is available for license renewals only.
- If you have an active marketplace subscription, charging is still available through that subscription.

License conversions

Converting an existing Cloud Volumes ONTAP system to another licensing method isn't supported. The three current licensing methods are capacity-based licensing, Keystone Flex Subscriptions, and node-based licensing. For example, you can't convert a system from node-based licensing to capacity-based licensing (and vice versa).

If you want to transition to another licensing method, you can purchase a license, deploy a new Cloud Volumes ONTAP system using that license, and then replicate the data to that new system.

Note that converting a system from PAYGO by-node licensing to BYOL by-node licensing (and vice versa) isn't supported. You need to deploy a new system and then replicate data to that system. [Learn how to change between PAYGO and BYOL.](#)

Storage

Client protocols

Cloud Volumes ONTAP supports the iSCSI, NFS, SMB, and S3 client protocols.

iSCSI

iSCSI is a block protocol that can run on standard Ethernet networks. Most client operating systems offer a software initiator that runs over a standard Ethernet port.

NFS

NFS is the traditional file access protocol for UNIX and LINUX systems. Clients can access files in ONTAP volumes using the NFSv3, NFSv4, and NFSv4.1 protocols. You can control file access using UNIX-style permissions, NTFS-style permissions, or a mix of both.

Clients can access the same files using both NFS and SMB protocols.

SMB

SMB is the traditional file access protocol for Windows systems. Clients can access files in ONTAP volumes using the SMB 2.0, SMB 2.1, SMB 3.0, and SMB 3.1.1 protocols. Just like with NFS, a mix of permission styles are supported.

S3

Cloud Volumes ONTAP supports S3 as an option for scale-out storage in the following cloud providers:

- AWS
- Azure

S3 protocol support enables you to configure S3 client access to objects contained in a bucket in an SVM.

Disks and aggregates

Understanding how Cloud Volumes ONTAP uses cloud storage can help you understand your storage costs.



All disks and aggregates must be created and deleted directly from Cloud Manager. You should not perform these actions from another management tool. Doing so can impact system stability, hamper the ability to add disks in the future, and potentially generate redundant cloud provider fees.

Overview

Cloud Volumes ONTAP uses cloud provider storage as disks and groups them into one or more aggregates. Aggregates provide storage to one or more volumes.



Several types of cloud disks are supported. You choose the disk type when you create a volume and the default disk size when you deploy Cloud Volumes ONTAP.



The total amount of storage purchased from a cloud provider is the *raw capacity*. The *usable capacity* is less because approximately 12 to 14 percent is overhead that is reserved for Cloud Volumes ONTAP use. For example, if Cloud Manager creates a 500 GiB aggregate, the usable capacity is 442.94 GiB.

AWS storage

In AWS, Cloud Volumes ONTAP uses EBS storage for user data and local NVMe storage as Flash Cache on some EC2 instance types.

EBS storage

In AWS, an aggregate can contain up to 6 disks that are all the same size. But if you have a configuration that supports the Amazon EBS Elastic Volumes feature, then an aggregate can contain up to 8 disks. [Learn more about support for Elastic Volumes](#).

The maximum disk size is 16 TiB.

The underlying EBS disk type can be either General Purpose SSDs (gp3 or gp2), Provisioned IOPS SSD (io1), or Throughput Optimized HDD (st1). You can pair an EBS disk with Amazon S3 to [tier inactive data to low-cost object storage](#).



Tiering data to object storage is not recommended when using Throughput Optimized HDDs (st1).

Local NVMe storage

Some EC2 instance types include local NVMe storage, which Cloud Volumes ONTAP uses as [Flash Cache](#).

Related links

- [AWS documentation: EBS Volume Types](#)
- [Learn how to choose disk types and disk sizes for your systems in AWS](#)
- [Review storage limits for Cloud Volumes ONTAP in AWS](#)
- [Review supported configurations for Cloud Volumes ONTAP in AWS](#)

Azure storage

In Azure, an aggregate can contain up to 12 disks that are all the same size. The disk type and maximum disk size depends on whether you use a single node system or an HA pair:

Single node systems

Single node systems can use three types of Azure Managed Disks:

- *Premium SSD Managed Disks* provide high performance for I/O-intensive workloads at a higher cost.
- *Standard SSD Managed Disks* provide consistent performance for workloads that require low IOPS.
- *Standard HDD Managed Disks* are a good choice if you don't need high IOPS and want to reduce your costs.

Each managed disk type has a maximum disk size of 32 TiB.

You can pair a managed disk with Azure Blob storage to [tier inactive data to low-cost object storage](#).

HA pairs

HA pairs use Premium page blobs, which have a maximum disk size of 8 TiB.

Related links

- [Microsoft Azure documentation: Azure managed disk types](#)
- [Microsoft Azure documentation: Overview of Azure page blobs](#)
- [Learn how to choose disk types and disk sizes for your systems in Azure](#)
- [Review storage limits for Cloud Volumes ONTAP in Azure](#)

Google Cloud storage

In Google Cloud, an aggregate can contain up to 6 disks that are all the same size. The maximum disk size is 64 TiB.

The disk type can be either *Zonal SSD persistent disks*, *Zonal Balanced persistent disks*, or *Zonal standard persistent disks*. You can pair persistent disks with a Google Storage bucket to [tier inactive data to low-cost object storage](#).

Related links

- [Google Cloud documentation: Storage Options](#)
- [Review storage limits for Cloud Volumes ONTAP in Google Cloud](#)

RAID type

The RAID type for each Cloud Volumes ONTAP aggregate is RAID0 (striping). Cloud Volumes ONTAP relies on the cloud provider for disk availability and durability. No other RAID types are supported.

Hot spares

RAID0 doesn't support the use of hot spares for redundancy.

Creating unused disks (hot spares) attached to a Cloud Volumes ONTAP instance is an unnecessary expense and may prevent provisioning additional space as needed. Therefore, it's not recommended.

Elastic Volumes in AWS

Support for the Amazon EBS Elastic Volumes feature with a Cloud Volumes ONTAP aggregate provides better performance and additional capacity, while enabling Cloud Manager to automatically increase the underlying disk capacity as needed.

Benefits

- Dynamic disk growth

Cloud Manager can dynamically increase the size of disks while Cloud Volumes ONTAP is running and while disks are still attached.

- Better performance

Aggregates that are enabled with Elastic Volumes can have up to eight disks that are equally utilized across two RAID groups. This configuration provides more throughput and consistent performance.

- Larger aggregates

Support for eight disks provides a maximum aggregate capacity of 128 TiB. These limits are higher than

the six disk limit and 96 TiB limit for aggregates that aren't enabled with the Elastic Volumes feature.

Note that total system capacity limits remain the same.

[Learn more about Elastic Volumes from AWS](#)

Supported configurations

The Amazon EBS Elastic Volumes feature is supported with specific Cloud Volumes ONTAP versions and specific EBS disk types.

Cloud Volumes ONTAP version

The Elastic Volumes feature is supported with *new* Cloud Volumes ONTAP systems created from version 9.11.0 or later. The feature is *not* supported with existing Cloud Volumes ONTAP systems that were deployed prior to 9.11.0.

For example, the Elastic Volumes feature is not supported if you created a Cloud Volumes ONTAP 9.9.0 system and then later upgraded that system to version 9.11.0. It must be a new system deployed using version 9.11.0 or later.

EBS disk types

The Elastic Volumes feature is automatically enabled at the aggregate level when using General Purpose SSDs (gp3) or Provisioned IOPS SSDs (io1). The Elastic Volumes feature is not supported with aggregates that use any other disk type.

Required AWS permissions

Starting with the 3.9.19 release, the Connector requires the following permissions to enable and manage the Elastic Volumes feature on a Cloud Volumes ONTAP aggregate:

- ec2:DescribeVolumesModifications
- ec2:ModifyVolume

These permissions are included in [the policies provided by NetApp](#)

How support for Elastic Volumes works

An aggregate that has the Elastic Volumes feature enabled is comprised of one or two RAID groups. Each RAID group has four identical disks that have the same capacity. Here's an example of a 10 TiB aggregate that has four disks that are 2.5 TiB each:



When Cloud Manager creates an aggregate, it starts with one RAID group. If additional capacity is needed, Cloud Manager grows the aggregate by increasing the capacity of all disks in the RAID group by the same amount. The capacity increase is either a minimum of 256 GiB or 10% of the aggregate's size.

For example, if you have a 1 TiB aggregate, each disk is 250 GiB. 10% of the aggregate's capacity is 100 GiB. That's lower than 256 GiB, so the size of the aggregate is increased by the 256 GiB minimum (or 64 GiB for each disk).

Cloud Manager increases the size of the disks while the Cloud Volumes ONTAP system is running and while the disks are still attached. The change is non-disruptive.

If an aggregate reaches 64 TiB (or 16 TiB on each disk), Cloud Manager creates a second RAID group for additional capacity. This second RAID group works just like the first one: it has four disks that have the exact same capacity and it can grow up to 64 TiB. That means an aggregate can have a maximum capacity of 128 TiB.

Here's an example of an aggregate with two RAID groups. The capacity limit has been reached on the first RAID group, while the disks in the second RAID group have plenty of free space.



What happens when you create a volume

If you create a volume that uses gp3 or io1 disks, Cloud Manager creates the volume on an aggregate as follows:

- If there is an existing gp3 or io1 aggregate that has Elastic Volumes enabled, Cloud Manager creates the volume on that aggregate.

- If there are multiple gp3 or io1 aggregates that have Elastic Volumes enabled, Cloud Manager creates the volume on the aggregate that requires the least amount of resources.
- If the system only has gp3 or io1 aggregates that aren't enabled for Elastic Volumes, then the volume is created on that aggregate.



While this scenario is unlikely, it's possible in two cases:

- You explicitly disabled the Elastic Volumes feature when creating an aggregate from the API.
- You created a new Cloud Volumes ONTAP system from the user interface, in which case the Elastic Volumes feature is disabled on the initial aggregate. Review [Limitations](#) below to learn more.

- If no existing aggregates have enough capacity, Cloud Manager creates the aggregate with Elastic Volumes enabled and then creates the volume on that new aggregate.

The size of the aggregate is based on the requested volume size plus an additional 10% capacity.

Capacity Management Mode

The Capacity Management Mode for a Connector works with Elastic Volumes similar to how it works with other types of aggregates:

- When Automatic mode is enabled (this is the default setting), Cloud Manager automatically increases the size of aggregates if additional capacity is needed.
- If you change the capacity management mode to Manual, Cloud Manager asks for your approval to purchase additional capacity.

[Learn more about the Capacity Management Mode.](#)

Limitations

Increasing the size of an aggregate can take up to 6 hours. During that time, Cloud Manager can't request any additional capacity for that aggregate.

How to work with Elastic Volumes

You can work with Elastic Volumes in Cloud Manager as follows:

- Create a new system that has Elastic Volumes enabled on the initial aggregate when using gp3 or io1 disks

[Learn how to create Cloud Volumes ONTAP system](#)

- Create a new volume on an aggregate that has Elastic Volumes enabled

If you create a volume that uses gp3 or io1 disks, Cloud Manager automatically creates the volume on an aggregate that has Elastic Volumes enabled. For more details, refer to [What happens when you create a volume](#).

[Learn how to create volumes.](#)

- Create a new aggregate that has Elastic Volumes enabled

Elastic Volumes is automatically enabled on new aggregates that use gp3 or io1 disks, as long as the Cloud Volumes ONTAP system was created from version 9.11.0 or later.

When you create the aggregate, Cloud Manager will prompt you for the aggregate's capacity size. This is different than other configurations where you choose a disk size and number of disks.

The following screenshot shows an example of a new aggregate comprised of gp3 disks.



[Learn how to create aggregates.](#)

- Identify aggregates that have Elastic Volumes enabled

When you go to the Advanced Allocation page, you can identify whether the Elastic Volumes feature is enabled on an aggregate. In the following example, aggr2 has Elastic Volumes enabled whereas aggr1 does not.



- Add capacity to an aggregate

While Cloud Manager automatically adds capacity to aggregates as needed, you can manually increase the capacity yourself.

[Learn how to increase aggregate capacity.](#)

- Replicate data to an aggregate that has Elastic Volumes enabled

If the destination Cloud Volumes ONTAP system supports Elastic Volumes, a destination volume will be placed on an aggregate that has Elastic Volumes enabled (as long as you choose a gp3 or io1 disk).

[Learn how to set up data replication](#)

Data tiering overview

Reduce your storage costs by enabling automated tiering of inactive data to low-cost object storage. Active data remains in high-performance SSDs or HDDs, while inactive data is tiered to low-cost object storage. This enables you to reclaim space on your primary storage and shrink secondary storage.



Data tiering is powered by FabricPool technology.



You don't need to install a feature license to enable data tiering (FabricPool).

Data tiering in AWS

When you enable data tiering in AWS, Cloud Volumes ONTAP uses EBS as a performance tier for hot data and AWS S3 as a capacity tier for inactive data.

Performance tier

The performance tier can be General Purpose SSDs (gp3 or gp2) or Provisioned IOPS SSDs (io1).

Tiering data to object storage is not recommended when using Throughput Optimized HDDs (st1).

Capacity tier

A Cloud Volumes ONTAP system tiers inactive data to a single S3 bucket.

Cloud Manager creates a single S3 bucket for each working environment and names it *fabric-pool-cluster unique identifier*. A different S3 bucket is not created for each volume.

When Cloud Manager creates the S3 bucket, it uses the following default settings:

- Storage class: Standard
- Default encryption: Disabled

- Block public access: Block all public access
- Object ownership: ACLs enabled
- Bucket versioning: Disabled
- Object lock: Disabled

Storage classes

The default storage class for tiered data in AWS is *Standard*. Standard is ideal for frequently accessed data stored across multiple Availability Zones.

If you don't plan to access the inactive data, you can reduce your storage costs by changing the storage class to one of the following: *Intelligent Tiering*, *One-Zone Infrequent Access*, *Standard-Infrequent Access*, or *S3 Glacier Instant Retrieval*. When you change the storage class, inactive data starts in the Standard storage class and transitions to the storage class that you selected, if the data is not accessed after 30 days.

The access costs are higher if you do access the data, so take that into consideration before you change the storage class. [Learn more about Amazon S3 storage classes](#).

You can select a storage class when you create the working environment and you can change it any time after. For details about changing the storage class, see [Tiering inactive data to low-cost object storage](#).

The storage class for data tiering is system wide—it's not per volume.

Data tiering in Azure

When you enable data tiering in Azure, Cloud Volumes ONTAP uses Azure managed disks as a performance tier for hot data and Azure Blob storage as a capacity tier for inactive data.

Performance tier

The performance tier can be either SSDs or HDDs.

Capacity tier

A Cloud Volumes ONTAP system tiers inactive data to a single Blob container.

Cloud Manager creates a new storage account with a container for each Cloud Volumes ONTAP working environment. The name of the storage account is random. A different container is not created for each volume.

Cloud Manager creates the storage account with the following settings:

- Access tier: Hot
- Performance: Standard
- Redundancy: Locally-redundant storage (LRS)
- Account: StorageV2 (general purpose v2)
- Require secure transfer for REST API operations: Enabled
- Storage account key access: Enabled
- Minimum TLS version: Version 1.2
- Infrastructure encryption: Disabled

Storage access tiers

The default storage access tier for tiered data in Azure is the *hot* tier. The hot tier is ideal for frequently accessed data.

If you don't plan to access the inactive data, you can reduce your storage costs by changing to the *cool* storage tier. When you change the storage tier, inactive data starts in the hot storage tier and transitions to the cool storage tier, if the data is not accessed after 30 days.

The access costs are higher if you do access the data, so take that into consideration before you change the storage tier. [Learn more about Azure Blob storage access tiers.](#)

You can select a storage tier when you create the working environment and you can change it any time after. For details about changing the storage tier, see [Tiering inactive data to low-cost object storage.](#)

The storage access tier for data tiering is system wide—it's not per volume.

Data tiering in Google Cloud

When you enable data tiering in Google Cloud, Cloud Volumes ONTAP uses persistent disks as a performance tier for hot data and a Google Cloud Storage bucket as a capacity tier for inactive data.

Performance tier

The performance tier can be either SSD persistent disks, balanced persistent disks, or standard persistent disks.

Capacity tier

A Cloud Volumes ONTAP system tiers inactive data to a single Google Cloud Storage bucket.

Cloud Manager creates a bucket for each working environment and names it *fabric-pool-cluster unique identifier*. A different bucket is not created for each volume.

When Cloud Manager creates the bucket, it uses the following default settings:

- Location type: Region
- Storage class: Standard
- Public access: Subject to object ACLs
- Access control: Fine-grained
- Protection: None
- Data encryption: Google-managed key

Storage classes

The default storage class for tiered data is the *Standard Storage* class. If the data is infrequently accessed, you can reduce your storage costs by changing to *Nearline Storage* or *Coldline Storage*. When you change the storage class, inactive data starts in the Standard Storage class and transitions to the storage class that you selected, if the data is not accessed after 30 days.

The access costs are higher if you do access the data, so take that into consideration before you change the storage class. [Learn more about storage classes for Google Cloud Storage.](#)

You can select a storage tier when you create the working environment and you can change it any time after. For details about changing the storage class, see [Tiering inactive data to low-cost object storage.](#)

The storage class for data tiering is system wide—it's not per volume.

Data tiering and capacity limits

If you enable data tiering, a system's capacity limit stays the same. The limit is spread across the performance tier and the capacity tier.

Volume tiering policies

To enable data tiering, you must select a volume tiering policy when you create, modify, or replicate a volume. You can select a different policy for each volume.

Some tiering policies have an associated minimum cooling period, which sets the time that user data in a volume must remain inactive for the data to be considered "cold" and moved to the capacity tier. The cooling period starts when data is written to the aggregate.



You can change the minimum cooling period and default aggregate threshold of 50% (more on that below). [Learn how to change the cooling period](#) and [learn how to change the threshold](#).

Cloud Manager enables you to choose from the following volume tiering policies when you create or modify a volume:

Snapshot Only

After an aggregate has reached 50% capacity, Cloud Volumes ONTAP tiers cold user data of Snapshot copies that are not associated with the active file system to the capacity tier. The cooling period is approximately 2 days.

If read, cold data blocks on the capacity tier become hot and are moved to the performance tier.

All

All data (not including metadata) is immediately marked as cold and tiered to object storage as soon as possible. There is no need to wait 48 hours for new blocks in a volume to become cold. Note that blocks located in the volume prior to the All policy being set require 48 hours to become cold.

If read, cold data blocks on the cloud tier stay cold and are not written back to the performance tier. This policy is available starting with ONTAP 9.6.

Auto

After an aggregate has reached 50% capacity, Cloud Volumes ONTAP tiers cold data blocks in a volume to a capacity tier. The cold data includes not just Snapshot copies but also cold user data from the active file system. The cooling period is approximately 31 days.

This policy is supported starting with Cloud Volumes ONTAP 9.4.

If read by random reads, the cold data blocks in the capacity tier become hot and move to the performance tier. If read by sequential reads, such as those associated with index and antivirus scans, the cold data blocks stay cold and do not move to the performance tier.

None

Keeps data of a volume in the performance tier, preventing it from being moved to the capacity tier.

When you replicate a volume, you can choose whether to tier the data to object storage. If you do, Cloud Manager applies the **Backup** policy to the data protection volume. Starting with Cloud Volumes ONTAP 9.6, the **All** tiering policy replaces the backup policy.

Turning off Cloud Volumes ONTAP impacts the cooling period

Data blocks are cooled by cooling scans. During this process, blocks that haven't been used have their block temperature moved (cooled) to the next lower value. The default cooling time depends on the volume tiering policy:

- Auto: 31 days
- Snapshot Only: 2 days

Cloud Volumes ONTAP must be running for the cooling scan to work. If Cloud Volumes ONTAP is turned off, cooling will stop, as well. As a result, you can experience longer cooling times.



When Cloud Volumes ONTAP is turned off, the temperature of each block is preserved until you restart the system. For example, if the temperature of a block is 5 when you turn the system off, the temp is still 5 when you turn the system back on.

Setting up data tiering

For instructions and a list of supported configurations, see [Tiering inactive data to low-cost object storage](#).

Storage management

Cloud Manager provides simplified and advanced management of Cloud Volumes ONTAP storage.



All disks and aggregates must be created and deleted directly from Cloud Manager. You should not perform these actions from another management tool. Doing so can impact system stability, hamper the ability to add disks in the future, and potentially generate redundant cloud provider fees.

Storage provisioning

Cloud Manager makes storage provisioning for Cloud Volumes ONTAP easy by purchasing disks and managing aggregates for you. You simply need to create volumes. You can use an advanced allocation option to provision aggregates yourself, if desired.

Simplified provisioning

Aggregates provide cloud storage to volumes. Cloud Manager creates aggregates for you when you launch an instance, and when you provision additional volumes.

When you create a volume, Cloud Manager does one of three things:

- It places the volume on an existing aggregate that has sufficient free space.
- It places the volume on an existing aggregate by purchasing more disks for that aggregate.

In the case of an aggregate in AWS that supports Elastic Volumes, Cloud Manager also increases the size of the disks in a RAID group. [Learn more about support for Elastic Volumes](#).

- It purchases disks for a new aggregate and places the volume on that aggregate.

Cloud Manager determines where to place a new volume by looking at several factors: an aggregate's maximum size, whether thin provisioning is enabled, and free space thresholds for aggregates.



The Account Admin can modify free space thresholds from the **Settings** page.

Disk size selection for aggregates in AWS

When Cloud Manager creates new aggregates for Cloud Volumes ONTAP in AWS, it gradually increases the disk size in an aggregate, as the number of aggregates in the system increases. Cloud Manager does this to ensure that you can utilize the system's maximum capacity before it reaches the maximum number of data disks allowed by AWS.

For example, Cloud Manager might choose the following disk sizes:

Aggregate number	Disk size	Max aggregate capacity
1	500 GiB	3 TiB
4	1 TiB	6 TiB
6	2 TiB	12 TiB



This behavior does not apply to aggregates that support the Amazon EBS Elastic Volumes feature. Aggregates that have Elastic Volumes enabled are comprised of one or two RAID groups. Each RAID group has four identical disks that have the same capacity. [Learn more about support for Elastic Volumes.](#)

You can choose the disk size yourself by using the advanced allocation option.

Advanced allocation

Rather than let Cloud Manager manage aggregates for you, you can do it yourself. [From the Advanced allocation page](#), you can create new aggregates that include a specific number of disks, add disks to an existing aggregate, and create volumes in specific aggregates.

Capacity management

The Account Admin can choose whether Cloud Manager notifies you of storage capacity decisions or whether Cloud Manager automatically manages capacity requirements for you.

This behavior is determined by the *Capacity Management Mode* on a Connector. The Capacity Management Mode affects all Cloud Volumes ONTAP systems managed by that Connector. If you have another Connector, it can be configured differently.

Automatic capacity management

The Capacity Management Mode is set to automatic by default. In this mode, Cloud Manager automatically purchases new disks for Cloud Volumes ONTAP instances when more capacity is needed, deletes unused collections of disks (aggregates), moves volumes between aggregates when needed, and attempts to unfail disks.

The following examples illustrate how this mode works:

- If an aggregate reaches the capacity threshold and it has room for more disks, Cloud Manager automatically purchases new disks for that aggregate so volumes can continue to grow.

Cloud Manager checks the free space ratio every 15 minutes to determine if it needs to purchase

additional disks.

In the case of an aggregate in AWS that supports Elastic Volumes, Cloud Manager also increases the size of the disks in a RAID group. [Learn more about support for Elastic Volumes](#).

- If an aggregate reaches the capacity threshold and it can't support any additional disks, Cloud Manager automatically moves a volume from that aggregate to an aggregate with available capacity or to a new aggregate.

If Cloud Manager creates a new aggregate for the volume, it chooses a disk size that accommodates the size of that volume.

Note that free space is now available on the original aggregate. Existing volumes or new volumes can use that space. The space can't be returned to the cloud provider in this scenario.

- If an aggregate contains no volumes for more than 12 hours, Cloud Manager deletes it.

Management of LUNs with automatic capacity management

Cloud Manager's automatic capacity management doesn't apply to LUNs. When Cloud Manager creates a LUN, it disables the autogrow feature.

Manual capacity management

If the Account Admin set the Capacity Management Mode to manual, Cloud Manager displays Action Required messages when capacity decisions must be made. The same examples described in the automatic mode apply to the manual mode, but it is up to you to accept the actions.

Learn more

[Learn how to modify the capacity management mode](#).

Write speed

Cloud Manager enables you to choose normal or high write speed for most Cloud Volumes ONTAP configurations. Before you choose a write speed, you should understand the differences between the normal and high settings and risks and recommendations when using high write speed.

Normal write speed

When you choose normal write speed, data is written directly to disk. When data is written directly to disk, reduces the likelihood of data loss in the event of an unplanned system outage, or a cascading failure involving an unplanned system outage (HA pairs only).

Normal write speed is the default option.

High write speed

When you choose high write speed, data is buffered in memory before it is written to disk, which provides faster write performance. Due to this caching, there is the potential for data loss if an unplanned system outage occurs.

The amount of data that can be lost in the event of an unplanned system outage is the span of the last two

consistency points. A consistency point is the act of writing buffered data to disk. A consistency point occurs when the write log is full or after 10 seconds (whichever comes first). However, the performance of the storage provided by your cloud provider can affect consistency point processing time.

When to use high write speed

High write speed is a good choice if fast write performance is required for your workload and you can withstand the risk of data loss in the event of an unplanned system outage, or a cascading failure involving an unplanned system outage (HA pairs only).

Recommendations when using high write speed

If you enable high write speed, you should ensure write protection at the application layer, or that the applications can tolerate data loss, if it occurs.

High write speed with an HA pair in AWS

If you plan to enable high write speed on an HA pair in AWS, you should understand the difference in protection levels between a multiple Availability Zone (AZ) deployment and a single AZ deployment. Deploying an HA pair across multiple AZs provides more resiliency and can help to mitigate the chance of data loss.

[Learn more about HA pairs in AWS.](#)

Configurations that support high write speed

Not all Cloud Volumes ONTAP configurations support high write speed. Those configurations use normal write speed by default.

AWS

If you use a single node system, Cloud Volumes ONTAP supports high write speed with all instance types.

Starting with the 9.8 release, Cloud Volumes ONTAP supports high write speed with HA pairs when using almost all supported EC2 instance types, except for m5.xlarge and r5.xlarge.

[Learn more about the Amazon EC2 instances that Cloud Volumes ONTAP supports.](#)

Azure

If you use a single node system, Cloud Volumes ONTAP supports high write speed with all VM types.

If you use an HA pair, Cloud Volumes ONTAP supports high write speed with several VM types, starting with the 9.8 release. Go to the [Cloud Volumes ONTAP Release Notes](#) to view the VM types that support high write speed.

Google Cloud

If you use a single node system, Cloud Volumes ONTAP supports high write speed with all machine types.

Cloud Volumes ONTAP doesn't support high write speed with HA pairs in Google Cloud.

[Learn more about the Google Cloud machine types that Cloud Volumes ONTAP supports.](#)

How to select a write speed

You can choose a write speed when you create a new working environment and you can [change the write speed for an existing system](#).

What to expect if data loss occurs

If data loss occurs due to high write speed, the Event Management System (EMS) reports the following two events:

- Cloud Volumes ONTAP 9.11.0 or later

```
DEBUG nv.check.failed: NVRAM check failed with error "NVRAM disabled due to dirty shutdown with High Write Speed mode"
```

```
ERROR wafl.root.content.changed: Contents of the root volume '' might have changed. Verify that all recent configuration changes are still in effect.
```

- Cloud Volumes ONTAP 9.8 to 9.10.1

```
DEBUG nv.check.failed: NVRAM check failed with error "NVRAM disabled due to dirty shutdown"
```

```
ERROR wafl.root.content.changed: Contents of the root volume '' might have changed. Verify that all recent configuration changes are still in effect.
```

When this happens, Cloud Volumes ONTAP should be able to boot up and continue to serve data without user intervention.

How to stop data access if data loss occurs

If you are concerned about data loss, want the applications to stop running upon data loss, and the data access to be resumed after the data loss issue is properly addressed, you can use the NVFAIL option from the CLI to achieve that goal.

To enable the NVFAIL option

```
vol modify -volume <vol-name> -nvfail on
```

To check NVFAIL settings

```
vol show -volume <vol-name> -fields nvfail
```

To disable the NVFAIL option

```
vol modify -volume <vol-name> -nvfail off
```

When data loss occurs, an NFS or iSCSI volume with NVFAIL enabled should stop serving data (there's no impact to CIFS which is a stateless protocol). For more details, refer to [How NVFAIL impacts access to NFS volumes or LUNs](#).

To check the NVFAIL state

```
vol show -fields in-nvfailed-state
```

After the data loss issue is properly addressed, you can clear the NVFAIL state and the volume will be available for data access.

To clear the NVFAIL state

```
vol modify -volume <vol-name> -in-nvfailed-state false
```

Flash Cache

Some Cloud Volumes ONTAP configurations include local NVMe storage, which Cloud Volumes ONTAP uses as *Flash Cache* for better performance.

What's Flash Cache?

Flash Cache speeds access to data through real-time intelligent caching of recently read user data and NetApp metadata. It's effective for random read-intensive workloads, including databases, email, and file services.

Supported configurations

Flash Cache is supported with specific Cloud Volumes ONTAP configurations. View supported configurations in the [Cloud Volumes ONTAP Release Notes](#)

Limitations

- Compression must be disabled on all volumes to take advantage of the Flash Cache performance improvements.

Choose no storage efficiency when creating a volume from Cloud Manager, or create a volume and then [disable data compression by using the CLI](#).

- Cache rewarming after a reboot is not supported with Cloud Volumes ONTAP.

WORM storage

You can activate write once, read many (WORM) storage on a Cloud Volumes ONTAP system to retain files in unmodified form for a specified retention period. Cloud WORM storage is powered by SnapLock technology, which means WORM files are protected at the file level.

How WORM storage works

Once a file has been committed to WORM storage, it can't be modified, even after the retention period has expired. A tamper-proof clock determines when the retention period for a WORM file has elapsed.

After the retention period has elapsed, you are responsible for deleting any files that you no longer need.

Charging

Charging for WORM storage is hourly, according to the total provisioned capacity of WORM volumes.

[Learn about pricing for WORM storage.](#)

Activating WORM storage

You can activate WORM storage on a Cloud Volumes ONTAP system when you create a new working environment. This includes setting the default retention period for files.



You can't activate WORM storage on individual volumes—WORM must be activated at the system level.

The following image shows how to activate WORM storage when creating a working environment:

The screenshot shows the 'Create a New Working Environment' wizard in the Cloud Manager interface. The current step is 'WORM (write once, read many)'. On the left, under 'Write Speed', there are two options: 'Normal' (selected) and 'High'. The 'Normal' option description states: 'Data is written directly to disk, reducing the likelihood of data loss in the event of an unplanned system outage.' The 'High' option description states: 'Data is buffered in memory before it is written to disk, which provides faster write performance. Due to this caching, there is the potential for data loss in the event of an unplanned system outage.' On the right, under 'WORM', there is a description: 'You can use write once, read many (WORM) storage to retain critical files in unmodified form for regulatory and governance purposes and to protect from malware attacks. WORM files are protected at the file level. [Learn More](#)'. Below this, there are two radio buttons: 'Disable WORM' and 'Activate WORM' (selected). A notice states: 'Notice: If you activate WORM storage, data tiering to object storage will be disabled on the system.' At the bottom, there is a 'Retention Period' field set to '15' years. A 'Continue' button is at the bottom center. The footer shows 'Cloud Manager 3.9.9 Build: 0 Jun 30, 2021 02:52:27 pm UTC Environment: staging'.

Committing files to WORM

You can use an application to commit files to WORM over NFS or CIFS, or use the ONTAP CLI to autocommit files to WORM automatically. You can also use a WORM appendable file to retain data that is written incrementally, like log information.

After you activate WORM storage on a Cloud Volumes ONTAP system, you must use the ONTAP CLI for all management of WORM storage. For instructions, refer to [ONTAP documentation](#).

Limitations

- WORM storage in Cloud Volumes ONTAP operates under a "trusted storage administrator" model. While WORM files are protected from alteration or modification, volumes can be deleted by a cluster administrator even if those volumes contain unexpired WORM data.
- In addition to the trusted storage administrator model, WORM storage in Cloud Volumes ONTAP also implicitly operates under a "trusted cloud administrator" model. A cloud administrator could delete WORM

data before its expiry date by removing or editing cloud storage directly from the cloud provider.

- When WORM storage is activated, data tiering to object storage can't be enabled.

High-availability pairs

High-availability pairs in AWS

A Cloud Volumes ONTAP high availability (HA) configuration provides nondisruptive operations and fault tolerance. In AWS, data is synchronously mirrored between the two nodes.

HA components

In AWS, Cloud Volumes ONTAP HA configurations include the following components:

- Two Cloud Volumes ONTAP nodes whose data is synchronously mirrored between each other.
- A mediator instance that provides a communication channel between the nodes to assist in storage takeover and giveback processes.

Mediator

Here are some key details about the mediator instance in AWS:

Instance type

t2-micro

Disks

One EBS magnetic disk that is approximately 8 GiB.

Operating system

Debian 11



For Cloud Volumes ONTAP 9.10.0 and earlier, Debian 10 was installed on the mediator.

Upgrades

When you upgrade Cloud Volumes ONTAP, Cloud Manager also updates the mediator instance as needed.

Access to the instance

When you create a Cloud Volumes ONTAP HA pair from Cloud Manager, you're prompted to provide a key pair for the mediator instance. You can use that key pair for SSH access using the `admin` user.

Third-party agents

Third-party agents or VM extensions are not supported on the mediator instance.

Storage takeover and giveback

If a node goes down, the other node can serve data for its partner to provide continued data service. Clients can access the same data from the partner node because the data was synchronously mirrored to the partner.

After the node reboots, the partner must resync data before it can return the storage. The time that it takes to resync data depends on how much data was changed while the node was down.

Storage takeover, resync, and giveback are all automatic by default. No user action is required.

RPO and RTO

An HA configuration maintains high availability of your data as follows:

- The recovery point objective (RPO) is 0 seconds.
Your data is transactionally consistent with no data loss.
- The recovery time objective (RTO) is 60 seconds.
In the event of an outage, data should be available in 60 seconds or less.

HA deployment models

You can ensure the high availability of your data by deploying an HA configuration across multiple Availability Zones (AZs) or in a single AZ. You should review more details about each configuration to choose which best fits your needs.

Multiple Availability Zones

Deploying an HA configuration in multiple Availability Zones (AZs) ensures high availability of your data if a failure occurs with an AZ or an instance that runs a Cloud Volumes ONTAP node. You should understand how NAS IP addresses impact data access and storage failover.

NFS and CIFS data access

When an HA configuration is spread across multiple Availability Zones, *floating IP addresses* enable NAS client access. The floating IP addresses, which must be outside of the CIDR blocks for all VPCs in the region, can migrate between nodes when failures occur. They aren't natively accessible to clients that are outside of the VPC, unless you [set up an AWS transit gateway](#).

If you can't set up a transit gateway, private IP addresses are available for NAS clients that are outside the VPC. However, these IP addresses are static—they can't failover between nodes.

You should review requirements for floating IP addresses and route tables before you deploy an HA configuration across multiple Availability Zones. You must specify the floating IP addresses when you deploy the configuration. The private IP addresses are automatically created by Cloud Manager.

For details, see [AWS networking requirements for Cloud Volumes ONTAP HA in multiple AZs](#).

iSCSI data access

Cross-VPC data communication is not an issue since iSCSI does not use floating IP addresses.

Takeover and giveback for iSCSI

For iSCSI, Cloud Volumes ONTAP uses multipath I/O (MPIO) and Asymmetric Logical Unit Access (ALUA) to manage path failover between the active-optimized and non-optimized paths.



For information about which specific host configurations support ALUA, see the [NetApp Interoperability Matrix Tool](#) and the Host Utilities Installation and Setup Guide for your host operating system.

Takeover and giveback for NAS

When takeover occurs in a NAS configuration using floating IPs, the node's floating IP address that clients use to access data moves to the other node. The following image depicts storage takeover in a NAS configuration using floating IPs. If node 2 goes down, the floating IP address for node 2 moves to node 1.



NAS data IPs used for external VPC access cannot migrate between nodes if failures occur. If a node goes offline, you must manually remount volumes to clients outside the VPC by using the IP address on the other node.

After the failed node comes back online, remount clients to volumes using the original IP address. This step is needed to avoid transferring unnecessary data between two HA nodes, which can cause significant performance and stability impact.

You can easily identify the correct IP address from Cloud Manager by selecting the volume and clicking **Mount Command**.

Single Availability Zone

Deploying an HA configuration in a single Availability Zone (AZ) can ensure high availability of your data if an instance that runs a Cloud Volumes ONTAP node fails. All data is natively accessible from outside of the VPC.



Cloud Manager creates an [AWS spread placement group](#) and launches the two HA nodes in that placement group. The placement group reduces the risk of simultaneous failures by spreading the instances across distinct underlying hardware. This feature improves redundancy from a compute perspective and not from disk failure perspective.

Data access

Because this configuration is in a single AZ, it does not require floating IP addresses. You can use the same IP

address for data access from within the VPC and from outside the VPC.

The following image shows an HA configuration in a single AZ. Data is accessible from within the VPC and from outside the VPC.

VPC in AWS



Takeover and giveback

For iSCSI, Cloud Volumes ONTAP uses multipath I/O (MPIO) and Asymmetric Logical Unit Access (ALUA) to manage path failover between the active-optimized and non-optimized paths.



For information about which specific host configurations support ALUA, see the [NetApp Interoperability Matrix Tool](#) and the Host Utilities Installation and Setup Guide for your host operating system.

For NAS configurations, the data IP addresses can migrate between HA nodes if failures occur. This ensures client access to storage.

How storage works in an HA pair

Unlike an ONTAP cluster, storage in a Cloud Volumes ONTAP HA pair is not shared between nodes. Instead, data is synchronously mirrored between the nodes so that the data is available in the event of failure.

Storage allocation

When you create a new volume and additional disks are required, Cloud Manager allocates the same number of disks to both nodes, creates a mirrored aggregate, and then creates the new volume. For example, if two disks are required for the volume, Cloud Manager allocates two disks per node for a total of four disks.

Storage configurations

You can use an HA pair as an active-active configuration, in which both nodes serve data to clients, or as an active-passive configuration, in which the passive node responds to data requests only if it has taken over storage for the active node.



You can set up an active-active configuration only when using Cloud Manager in the Storage System View.

Performance expectations

A Cloud Volumes ONTAP HA configuration synchronously replicates data between nodes, which consumes network bandwidth. As a result, you can expect the following performance in comparison to a single-node Cloud Volumes ONTAP configuration:

- For HA configurations that serve data from only one node, read performance is comparable to the read performance of a single-node configuration, whereas write performance is lower.
- For HA configurations that serve data from both nodes, read performance is higher than the read performance of a single-node configuration, and write performance is the same or higher.

For more details about Cloud Volumes ONTAP performance, see [Performance](#).

Client access to storage

Clients should access NFS and CIFS volumes by using the data IP address of the node on which the volume resides. If NAS clients access a volume by using the IP address of the partner node, traffic goes between both nodes, which reduces performance.

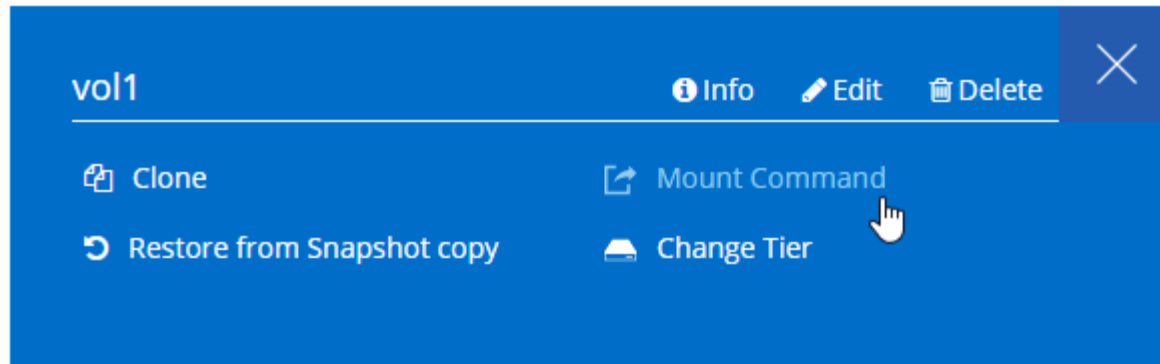


If you move a volume between nodes in an HA pair, you should remount the volume by using the IP address of the other node. Otherwise, you can experience reduced performance. If clients support NFSv4 referrals or folder redirection for CIFS, you can enable those features on the Cloud Volumes ONTAP systems to avoid remounting the volume. For details, see ONTAP documentation.

You can easily identify the correct IP address from Cloud Manager:

Volumes

2 Volumes | 0.22 TB Allocated | < 0.01 TB Used (0 TB in S3)



High-availability pairs in Azure

A Cloud Volumes ONTAP high availability (HA) pair provides enterprise reliability and continuous operations in case of failures in your cloud environment. In Azure, storage is shared between the two nodes.

HA components

A Cloud Volumes ONTAP HA configuration in Azure includes the following components:



Note the following about the Azure components that Cloud Manager deploys for you:

Azure Standard Load Balancer

The load balancer manages incoming traffic to the Cloud Volumes ONTAP HA pair.

Availability Set

The Azure Availability Set is a logical grouping of the Cloud Volumes ONTAP nodes. The Availability Set ensures that the nodes are in different fault and update domains to provide redundancy and availability.

[Learn more about Availability Sets in the Azure docs.](#)

Disks

Customer data resides on Premium Storage page blobs. Each node has access to the other node's storage. Additional storage is also required for [boot, root, and core data](#).

Storage accounts

- One storage account is required for managed disks.
- One or more storage accounts are required for the Premium Storage page blobs, as the disk capacity limit per storage account is reached.

[Azure documentation: Azure Storage scalability and performance targets for storage accounts.](#)

- One storage account is required for data tiering to Azure Blob storage.
- Starting with Cloud Volumes ONTAP 9.7, the storage accounts that Cloud Manager creates for HA pairs are general-purpose v2 storage accounts.
- You can enable an HTTPS connection from a Cloud Volumes ONTAP 9.7 HA pair to Azure storage accounts when creating a working environment. Note that enabling this option can impact write performance. You can't change the setting after you create the working environment.

RPO and RTO

An HA configuration maintains high availability of your data as follows:

- The recovery point objective (RPO) is 0 seconds.
Your data is transactionally consistent with no data loss.
- The recovery time objective (RTO) is 60 seconds.
In the event of an outage, data should be available in 60 seconds or less.

Storage takeover and giveback

Similar to a physical ONTAP cluster, storage in an Azure HA pair is shared between nodes. Connections to the partner's storage allows each node to access the other's storage in the event of a *takeover*. Network path failover mechanisms ensure that clients and hosts continue to communicate with the surviving node. The partner *gives back* storage when the node is brought back on line.

For NAS configurations, data IP addresses automatically migrate between HA nodes if failures occur.

For iSCSI, Cloud Volumes ONTAP uses multipath I/O (MPIO) and Asymmetric Logical Unit Access (ALUA) to manage path failover between the active-optimized and non-optimized paths.



For information about which specific host configurations support ALUA, see the [NetApp Interoperability Matrix Tool](#) and the Host Utilities Installation and Setup Guide for your host operating system.

Storage takeover, resync, and giveback are all automatic by default. No user action is required.

Storage configurations

You can use an HA pair as an active-active configuration, in which both nodes serve data to clients, or as an active-passive configuration, in which the passive node responds to data requests only if it has taken over storage for the active node.

High-availability pairs in Google Cloud

A Cloud Volumes ONTAP high availability (HA) configuration provides nondisruptive operations and fault tolerance. In Google Cloud, data is synchronously mirrored between the two nodes.

HA components

Cloud Volumes ONTAP HA configurations in Google Cloud include the following components:

- Two Cloud Volumes ONTAP nodes whose data is synchronously mirrored between each other.
- A mediator instance that provides a communication channel between the nodes to assist in storage takeover and giveback processes.

The mediator runs the Linux operating system on a f1-micro instance and uses two standard persistent disks that are 10 GB each.

- One zone or three zones (recommended).

If you choose three zones, the two nodes and mediator are in separate Google Cloud zones.

- Four Virtual Private Clouds (VPCs).

The configuration uses four VPCs because GCP requires that each network interface resides in a separate VPC network.

- Four Google Cloud internal load balancers (TCP/UDP) that manage incoming traffic to the Cloud Volumes ONTAP HA pair.

[Learn about networking requirements](#), including more details about load balancers, VPCs, internal IP addresses, subnets, and more.

The following conceptual image shows a Cloud Volumes ONTAP HA pair and its components:



Mediator

Here are some key details about the mediator instance in Google Cloud:

Instance type

f1-micro

Disks

Two standard persistent disks that are 10 GiB each.

Operating system

Debian 11



For Cloud Volumes ONTAP 9.10.0 and earlier, Debian 10 was installed on the mediator.

Upgrades

When you upgrade Cloud Volumes ONTAP, Cloud Manager also updates the mediator instance as needed.

Access to the instance

For Debian, the default cloud user is `admin`. Google Cloud creates and adds a certificate for the `admin` user when SSH access is requested through the Google Cloud console or `gcloud` command line. You can specify `sudo` to gain root privileges.

Third-party agents

Third-party agents or VM extensions are not supported on the mediator instance.

Storage takeover and giveback

If a node goes down, the other node can serve data for its partner to provide continued data service. Clients can access the same data from the partner node because the data was synchronously mirrored to the partner.

After the node reboots, the partner must resync data before it can return the storage. The time that it takes to resync data depends on how much data was changed while the node was down.

Storage takeover, resync, and giveback are all automatic by default. No user action is required.

RPO and RTO

An HA configuration maintains high availability of your data as follows:

- The recovery point objective (RPO) is 0 seconds.

Your data is transactionally consistent with no data loss.

- The recovery time objective (RTO) is 60 seconds.

In the event of an outage, data should be available in 60 seconds or less.

HA deployment models

You can ensure the high availability of your data by deploying an HA configuration in multiple zones or in a single zone.

Multiple zones (recommended)

Deploying an HA configuration across three zones ensures continuous data availability if a failure occurs within a zone. Note that write performance is slightly lower compared to using a single zone, but it's minimal.

Single zone

When deployed in a single zone, a Cloud Volumes ONTAP HA configuration uses a spread placement policy. This policy ensures that an HA configuration is protected from a single point of failure within the zone, without having to use separate zones to achieve fault isolation.

This deployment model does lower your costs because there are no data egress charges between zones.

How storage works in an HA pair

Unlike an ONTAP cluster, storage in a Cloud Volumes ONTAP HA pair in GCP is not shared between nodes. Instead, data is synchronously mirrored between the nodes so that the data is available in the event of failure.

Storage allocation

When you create a new volume and additional disks are required, Cloud Manager allocates the same number of disks to both nodes, creates a mirrored aggregate, and then creates the new volume. For example, if two disks are required for the volume, Cloud Manager allocates two disks per node for a total of four disks.

Storage configurations

You can use an HA pair as an active-active configuration, in which both nodes serve data to clients, or as an active-passive configuration, in which the passive node responds to data requests only if it has taken over storage for the active node.

Performance expectations for an HA configuration

A Cloud Volumes ONTAP HA configuration synchronously replicates data between nodes, which consumes network bandwidth. As a result, you can expect the following performance in comparison to a single-node Cloud Volumes ONTAP configuration:

- For HA configurations that serve data from only one node, read performance is comparable to the read performance of a single-node configuration, whereas write performance is lower.
- For HA configurations that serve data from both nodes, read performance is higher than the read performance of a single-node configuration, and write performance is the same or higher.

For more details about Cloud Volumes ONTAP performance, see [Performance](#).

Client access to storage

Clients should access NFS and CIFS volumes by using the data IP address of the node on which the volume resides. If NAS clients access a volume by using the IP address of the partner node, traffic goes between both nodes, which reduces performance.



If you move a volume between nodes in an HA pair, you should remount the volume by using the IP address of the other node. Otherwise, you can experience reduced performance. If clients support NFSv4 referrals or folder redirection for CIFS, you can enable those features on the Cloud Volumes ONTAP systems to avoid remounting the volume. For details, see ONTAP documentation.

You can easily identify the correct IP address from Cloud Manager:

Volumes

2 Volumes | 0.22 TB Allocated | < 0.01 TB Used (0 TB in S3)



Related links

- [Learn about networking requirements](#)
- [Learn how to get started in GCP](#)

Actions unavailable during takeover

When a node in an HA pair isn't available, the other node serves data for its partner to provide continued data service. This is called *storage takeover*. Several actions are unavailable until in storage giveback is complete.



When a node in an HA pair is unavailable, the state of the working environment in Cloud Manager is *Degraded*.

The following actions are unavailable from Cloud Manager during storage takeover:

- Support registration
- License changes
- Instance or VM type changes
- Write speed changes
- CIFS setup
- Changing the location of configuration backups
- Setting the cluster password
- Managing disks and aggregates (advanced allocation)

These actions are available again after storage giveback completes and the state of the working environment changes back to normal.

Security

Cloud Volumes ONTAP supports data encryption and provides protection against viruses and ransomware.

Encryption of data at rest

Cloud Volumes ONTAP supports the following encryption technologies:

- NetApp encryption solutions (NVE and NAE)
- AWS Key Management Service
- Azure Storage Service Encryption
- Google Cloud Platform default encryption

You can use NetApp encryption solutions with native encryption from your cloud provider, which encrypts data at the hypervisor level. Doing so would provide double encryption, which might be desired for very sensitive data. When the encrypted data is accessed, it's unencrypted twice—once at the hypervisor-level (using keys from the cloud provider) and then again using NetApp encryption solutions (using keys from an external key manager).

NetApp encryption solutions (NVE and NAE)

Cloud Volumes ONTAP supports [NetApp Volume Encryption \(NVE\)](#) and [NetApp Aggregate Encryption \(NAE\)](#). NVE and NAE are software-based solutions that enable (FIPS) 140-2-compliant data-at-rest encryption of volumes. Both NVE and NAE use AES 256-bit encryption.

- NVE encrypts data at rest one volume at a time. Each data volume has its own unique encryption key.
- NAE is an extension of NVE—it encrypts data for each volume, and the volumes share a key across the aggregate. NAE also allows common blocks across all volumes in the aggregate to be deduplicated.

Both NVE and NAE are supported with an external key manager.

If you use NVE, you have the option to use your cloud provider's key vault to protect ONTAP encryption keys:

- Azure Key Vault (AKV)
- Google Cloud Key Management Service

New aggregates have NetApp Aggregate Encryption (NAE) enabled by default after you set up an external key manager. New volumes that aren't part of an NAE aggregate will have NetApp Volume Encryption (NVE) enabled by default (for example, if you have existing aggregates that were created before setting up an external key manager).

Setting up a supported key manager is the only required step. For set up instructions, refer to [Encrypting volumes with NetApp encryption solutions](#).

AWS Key Management Service

When you launch a Cloud Volumes ONTAP system in AWS, you can enable data encryption using the [AWS Key Management Service \(KMS\)](#). Cloud Manager requests data keys using a customer master key (CMK).



You can't change the AWS data encryption method after you create a Cloud Volumes ONTAP system.

If you want to use this encryption option, then you must ensure that the AWS KMS is set up appropriately. For details, see [Setting up the AWS KMS](#).

Azure Storage Service Encryption

Data is automatically encrypted on Cloud Volumes ONTAP in Azure using [Azure Storage Service Encryption](#) with a Microsoft-managed key.

You can use your own encryption keys if you prefer. [Learn how to set up Cloud Volumes ONTAP to use a customer-managed key in Azure](#).

Google Cloud Platform default encryption

[Google Cloud Platform data-at-rest encryption](#) is enabled by default for Cloud Volumes ONTAP. No setup is required.

While Google Cloud Storage always encrypts your data before it's written to disk, you can use Cloud Manager APIs to create a Cloud Volumes ONTAP system that uses *customer-managed encryption keys*. These are keys that you generate and manage in GCP using the Cloud Key Management Service. [Learn more](#).

ONTAP virus scanning

You can use integrated antivirus functionality on ONTAP systems to protect data from being compromised by viruses or other malicious code.

ONTAP virus scanning, called *Vscan*, combines best-in-class third-party antivirus software with ONTAP features that give you the flexibility you need to control which files get scanned and when.

For information about the vendors, software, and versions supported by Vscan, see the [NetApp Interoperability Matrix](#).

For information about how to configure and manage the antivirus functionality on ONTAP systems, see the [ONTAP 9 Antivirus Configuration Guide](#).

Ransomware protection

Ransomware attacks can cost a business time, resources, and reputation. Cloud Manager enables you to implement the NetApp solution for ransomware, which provides effective tools for visibility, detection, and remediation.

- Cloud Manager identifies volumes that are not protected by a Snapshot policy and enables you to activate the default Snapshot policy on those volumes.


Snapshot copies are read-only, which prevents ransomware corruption. They can also provide the granularity to create images of a single file copy or a complete disaster recovery solution.

- Cloud Manager also enables you to block common ransomware file extensions by enabling ONTAP's FPolicy solution.

Ransomware Protection

Ransomware attacks can cost a business time, resources, and reputation. The NetApp solution for ransomware provides effective tools for visibility, detection, and remediation. [Learn More](#)

1 Enable Snapshot Copy Protection ⓘ




50 %
Protection

1 Volumes without a Snapshot Policy

To protect your data, activate the default Snapshot policy for these volumes ⓘ

Activate Snapshot Policy

2 Block Ransomware File Extensions ⓘ



ONTAP's native FPolicy configuration monitors and blocks file operations based on a file's extension.

View Denied File Names ⓘ

Activate FPolicy

[Learn how to implement the NetApp solution for ransomware.](#)

Performance

You can review performance results to help you decide which workloads are appropriate for Cloud Volumes ONTAP.

Performance technical reports

- Cloud Volumes ONTAP for AWS

[NetApp Technical Report 4383: Performance Characterization of Cloud Volumes ONTAP in Amazon Web Services with Application Workloads](#)

- Cloud Volumes ONTAP for Microsoft Azure

[NetApp Technical Report 4671: Performance Characterization of Cloud Volumes ONTAP in Azure with Application Workloads](#)

- Cloud Volumes ONTAP for Google Cloud

[NetApp Technical Report 4816: Performance Characterization of Cloud Volumes ONTAP for Google Cloud](#)

CPU performance

Cloud Volumes ONTAP nodes show as highly utilized (over 90%) from your cloud provider's monitoring tools. This is because ONTAP reserves all vCPUs presented to the virtual machine so that they are available when needed.

[Learn how to monitor Cloud Volumes ONTAP performance](#), or check out this [NetApp knowledgebase article](#) about how to monitor ONTAP CPU utilization using the CLI

License management for node-based BYOL

Each Cloud Volumes ONTAP system that has a node-based BYOL must have a system

license installed with an active subscription. Cloud Manager simplifies the process by managing licenses for you and by displaying a warning before they expire.



A node-based license is the previous generation BYOL for Cloud Volumes ONTAP. A node-based license is available for license renewals only.

[Learn more about Cloud Volumes ONTAP licensing options.](#)

BYOL system licenses

A node-based license provides up to 368 TiB of capacity for a single node or HA pair.

You can purchase multiple licenses for a Cloud Volumes ONTAP BYOL system to allocate more than 368 TiB of capacity. For example, you might purchase two licenses to allocate up to 736 TiB of capacity to Cloud Volumes ONTAP. Or you could purchase four licenses to get up to 1.4 PiB.

The number of licenses that you can purchase for a single node system or HA pair is unlimited.



Some on-premises ONTAP storage systems that you purchased may have included a free Cloud Volumes ONTAP license. You can use the license to create a new Cloud Volumes ONTAP system, or you can apply the license to an existing Cloud Volumes ONTAP system to expand the capacity. [See if you have any available licenses to use.](#)

Be aware that disk limits can prevent you from reaching the capacity limit by using disks alone. You can go beyond the disk limit by [tiering inactive data to object storage](#). For information about disk limits, refer to [storage limits in the Cloud Volumes ONTAP Release Notes](#).

License management for a new system

When you create a node-based BYOL system, Cloud Manager prompts you for the serial number of your license and your NetApp Support Site account. Cloud Manager uses the account to download the license file from NetApp and to install it on the Cloud Volumes ONTAP system.

[Learn how to add NetApp Support Site accounts to Cloud Manager.](#)

If Cloud Manager can't access the license file over the secure internet connection, you can [obtain the file yourself and then manually upload the file to Cloud Manager](#).

License expiration

Cloud Manager displays a warning 30 days before a node-based license is due to expire and again when the license expires. The following image shows a 30-day expiration warning that appears in the user interface:



You can select the working environment to review the message.

Cloud Manager includes a license expiration warning in the Cloud Volumes ONTAP report that's emailed to you, if you are an Account Admin and you enabled the option:



The emailed report includes the license expiration warning every 2 weeks.

If you don't renew the license in time, the Cloud Volumes ONTAP system shuts itself down. If you restart it, it shuts itself down again.

License renewal

When you renew a node-based BYOL subscription by contacting a NetApp representative, Cloud Manager automatically obtains the new license from NetApp and installs it on the Cloud Volumes ONTAP system.

If Cloud Manager can't access the license file over the secure internet connection, you can [obtain the file yourself and then manually upload the file to Cloud Manager](#).

License transfer to a new system

A node-based BYOL license is transferable between Cloud Volumes ONTAP systems when you delete an existing system and then create a new one using the same license.

For example, you might want to delete an existing licensed system and then use the license with a new BYOL system in a different VPC/VNet or cloud provider. Note that only *cloud-agnostic* serial numbers work in any cloud provider. Cloud-agnostic serial numbers start with the *908xxxx* prefix.

It's important to note that your BYOL license is tied to your company and a specific set of NetApp Support Site credentials.

AutoSupport and Active IQ Digital Advisor

The AutoSupport component of ONTAP collects telemetry and sends it for analysis. Active IQ Digital Advisor analyzes the data from AutoSupport and provides proactive care and optimization. Using artificial intelligence, Active IQ can identify potential problems and help you resolve them before they impact your business.

Active IQ enables you to optimize your data infrastructure across your global hybrid cloud by delivering actionable predictive analytics and proactive support through a cloud-based portal and mobile app. Data-driven insights and recommendations from Active IQ are available to all NetApp customers with an active SupportEdge contract (features vary by product and support tier).

Here are some things you can do with Active IQ:

- Plan upgrades.

Active IQ identifies issues in your environment that can be resolved by upgrading to a newer version of ONTAP and the Upgrade Advisor component helps you plan for a successful upgrade.

- View system wellness.

Your Active IQ dashboard reports any issues with wellness and helps you correct those issues. Monitor system capacity to make sure you never run out of storage space. View support cases for your system.

- Manage performance.

Active IQ shows system performance over a longer period than you can see in ONTAP System Manager. Identify configuration and system issues that are impacting your performance. Maximize efficiency. View storage efficiency metrics and identify ways to store more data in less space.

- View inventory and configuration.

Active IQ displays complete inventory and software and hardware configuration information. See when service contracts are expiring and renew them to ensure you remain supported.

Related information

- [NetApp Documentation: Active IQ Digital Advisor](#)
- [Launch Active IQ](#)
- [SupportEdge Services](#)

Default configuration for Cloud Volumes ONTAP

Understanding how Cloud Volumes ONTAP is configured by default can help you set up and administer your systems, especially if you are familiar with ONTAP because the default setup for Cloud Volumes ONTAP is different than ONTAP.

Default setup

- Cloud Manager creates one data-serving storage VM when it deploys Cloud Volumes ONTAP. Some configurations support additional storage VMs. [Learn more about managing storage VMs.](#)

Starting with the Cloud Manager 3.9.5 release, logical space reporting is enabled on the initial storage VM. When space is reported logically, ONTAP reports the volume space such that all the physical space saved by the storage efficiency features are also reported as used.

- Cloud Manager automatically installs the following ONTAP feature licenses on Cloud Volumes ONTAP:
 - CIFS
 - FlexCache
 - FlexClone
 - iSCSI
 - Multi-tenant Encryption Key Management (MTEKM), starting with Cloud Volumes ONTAP 9.11.1
 - NetApp Volume Encryption (only for BYOL or registered PAYGO systems)
 - NFS
 - ONTAP S3

Starting with Cloud Volumes ONTAP 9.11.0 in AWS

Starting with Cloud Volumes ONTAP 9.9.1 in Azure

- SnapMirror
- SnapRestore
- SnapVault
- Several network interfaces are created by default:
 - A cluster management LIF
 - An intercluster LIF
 - An SVM management LIF on HA systems in Azure
 - An SVM management LIF on HA systems in Google Cloud
 - An SVM management LIF on single node systems in AWS
 - A node management LIF

In Google Cloud, this LIF is combined with the intercluster LIF.

- An iSCSI data LIF
- A CIFS and NFS data LIF




LIF failover is disabled by default for Cloud Volumes ONTAP due to cloud provider requirements. Migrating a LIF to a different port breaks the external mapping between IP addresses and network interfaces on the instance, making the LIF inaccessible.

- Cloud Volumes ONTAP sends configuration backups to the Connector using HTTPS.

The backups are accessible from <https://ipaddress/occm/offboxconfig/> where *ipaddress* is the IP address of the Connector host.

- Cloud Manager sets a few volume attributes differently than other management tools (System Manager or the CLI, for example).

The following table lists the volume attributes that Cloud Manager sets differently from the defaults:

Attribute	Value set by Cloud Manager
Autosize mode	grow
Maximum autosize	1,000 percent  The Account Admin can modify this value from the Settings page.
Security style	NTFS for CIFS volumes UNIX for NFS volumes
Space guarantee style	none
UNIX permissions (NFS only)	777

See the *volume create* man page for information about these attributes.

Internal disks for system data

In addition to the storage for user data, Cloud Manager also purchases cloud storage for system data.

AWS

- Three disks per node for boot, root, and core data:
 - 45 GiB io1 disk for boot data
 - 140 GiB gp3 disk for root data
 - 540 GiB gp2 disk for core data
- One EBS snapshot for each boot disk and root disk
- For HA pairs, one EBS volume for the Mediator instance, which is approximately 8 GiB
- When you enable data encryption in AWS using the Key Management Service (KMS), the boot and root disks for Cloud Volumes ONTAP are encrypted, as well. This includes the boot disk for the mediator instance in an HA pair. The disks are encrypted using the CMK that you select when you create the working environment.



In AWS, NVRAM is on the boot disk.

Azure (single node)

- Three Premium SSD disks:
 - One 10 GiB disk for boot data
 - One 140 GiB disk for root data
 - One 512 GiB disk for NVRAM

If the virtual machine that you chose for Cloud Volumes ONTAP supports Ultra SSDs, then the system uses a 32 GiB Ultra SSD for NVRAM, rather than a Premium SSD.

- One 1024 GiB Standard HDD disk for saving cores
- One Azure snapshot for each boot disk and root disk
- Boot and root disks are encrypted by default.

Azure (HA pair)

- Two 10 GiB Premium SSD disks for the boot volume (one per node)
- Two 140 GiB Premium Storage page blobs for the root volume (one per node)
- Two 1024 GiB Standard HDD disks for saving cores (one per node)
- Two 512 GiB Premium SSD disks for NVRAM (one per node)
- One Azure snapshot for each boot disk and root disk
- Boot and root disks are encrypted by default.

Google Cloud (single node)

- One 10 GiB SSD persistent disk for boot data
- One 64 GiB SSD persistent disk for root data
- One 500 GiB SSD persistent disk for NVRAM
- One 315 GiB Standard persistent disk for saving cores
- Snapshots for boot and root data
- Boot and root disks are encrypted by default.

Google Cloud (HA pair)

- Two 10 GiB SSD persistent disks for boot data
- Four 64 GiB SSD persistent disk for root data
- Two 500 GiB SSD persistent disk for NVRAM
- Two 315 GiB Standard persistent disk for saving cores
- One 10 GiB Standard persistent disk for mediator data
- Snapshots for boot and root data
- Boot and root disks are encrypted by default.

Where the disks reside

Cloud Manager lays out the storage as follows:

- Boot data resides on a disk attached to the instance or virtual machine.

This disk, which contains the boot image, is not available to Cloud Volumes ONTAP.

- Root data, which contains the system configuration and logs, resides in aggr0.
- The storage virtual machine (SVM) root volume resides in aggr1.
- Data volumes also reside in aggr1.

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