



# **Configure and manage backends**

Astra Trident

NetApp  
April 18, 2024

# Table of Contents

- Configure and manage backends ..... 1
  - Configure backends ..... 1
    - Azure NetApp Files ..... 1
    - Configure a Cloud Volumes Service for Google Cloud backend ..... 18
    - Configure a NetApp HCI or SolidFire backend ..... 34
    - ONTAP SAN drivers ..... 40
    - ONTAP NAS drivers ..... 63
    - Amazon FSx for NetApp ONTAP ..... 91
  - Create backends with kubectl ..... 108
  - Manage backends ..... 115

# Configure and manage backends

## Configure backends

A backend defines the relationship between Astra Trident and a storage system. It tells Astra Trident how to communicate with that storage system and how Astra Trident should provision volumes from it.

Astra Trident automatically offers up storage pools from backends that match the requirements defined by a storage class. Learn how to configure the backend for your storage system.

- [Configure an Azure NetApp Files backend](#)
- [Configure a Cloud Volumes Service for Google Cloud Platform backend](#)
- [Configure a NetApp HCI or SolidFire backend](#)
- [Configure a backend with ONTAP or Cloud Volumes ONTAP NAS drivers](#)
- [Configure a backend with ONTAP or Cloud Volumes ONTAP SAN drivers](#)
- [Use Astra Trident with Amazon FSx for NetApp ONTAP](#)

## Azure NetApp Files

### Configure an Azure NetApp Files backend

You can configure Azure NetApp Files as the backend for Astra Trident. You can attach NFS and SMB volumes using an Azure NetApp Files backend. Astra Trident also supports credential management using managed identities for Azure Kubernetes Services (AKS) clusters.

#### Azure NetApp Files driver details

Astra Trident provides the following Azure NetApp Files storage drivers to communicate with the cluster. Supported access modes are: *ReadWriteOnce* (RWO), *ReadOnlyMany* (ROX), *ReadWriteMany* (RWX), *ReadWriteOncePod* (RWOP).

Driver	Protocol	volumeMode	Access modes supported	File systems supported
azure-netapp-files	NFS SMB	Filesystem	RWO, ROX, RWX, RWOP	nfs, smb

#### Considerations

- The Azure NetApp Files service does not support volumes smaller than 100 GB. Astra Trident automatically creates 100-GiB volumes if a smaller volume is requested.
- Astra Trident supports SMB volumes mounted to pods running on Windows nodes only.

## Managed identities for AKS

Astra Trident supports [managed identities](#) for Azure Kubernetes Services clusters. To take advantage of streamlined credential management offered by managed identities, you must have:

- A Kubernetes cluster deployed using AKS
- Managed identities configured on the AKS kubernetes cluster
- Astra Trident installed that includes the `cloudProvider` to specify "Azure".

### Trident operator

To install Astra Trident using the Trident operator, edit `tridentorchestrator_cr.yaml` to set `cloudProvider` to "Azure". For example:

```
apiVersion: trident.netapp.io/v1
kind: TridentOrchestrator
metadata:
  name: trident
spec:
  debug: true
  namespace: trident
  imagePullPolicy: IfNotPresent
  cloudProvider: "Azure"
```

### Helm

The following example installs Astra Trident sets `cloudProvider` to Azure using the environment variable `$CP`:

```
helm install trident trident-operator-100.2402.0.tgz --create
--namespace --namespace <trident-namespace> --set cloudProvider=$CP
```

`tridentctl`

The following example installs Astra Trident and sets the `cloudProvider` flag to Azure:

```
tridentctl install --cloud-provider="Azure" -n trident
```

## Cloud identity for AKS

Cloud identity enables Kubernetes pods to access Azure resources by authenticating as a workload identity instead of by providing explicit Azure credentials.

To take advantage of cloud identity in Azure, you must have:

- A Kubernetes cluster deployed using AKS

- Workload identity and oidc-issuer configured on the AKS Kubernetes cluster
- Astra Trident installed that includes the `cloudProvider` to specify "Azure" and `cloudIdentity` specifying workload identity

## Trident operator

To install Astra Trident using the Trident operator, edit `tridentorchestrator_cr.yaml` to set `cloudProvider` to "Azure" and set `cloudIdentity` to `azure.workload.identity/client-id: xxxxxxxx-xxxx-xxxx-xxxx-xxxxxxxxxxxx`.

For example:

```
apiVersion: trident.netapp.io/v1
kind: TridentOrchestrator
metadata:
  name: trident
spec:
  debug: true
  namespace: trident
  imagePullPolicy: IfNotPresent
  cloudProvider: "Azure"
  *cloudIdentity: 'azure.workload.identity/client-id: xxxxxxxx-xxxx-
xxxx-xxxx-xxxxxxxxxxxx' *
```

## Helm

Set the values for **cloud-provider (CP)** and **cloud-identity (CI)** flags using the following environment variables:

```
export CP="Azure"
export CI="azure.workload.identity/client-id: xxxxxxxx-xxxx-xxxx-xxxx-
xxxxxxxxxxxx"
```

The following example installs Astra Trident and sets `cloudProvider` to Azure using the environment variable `$CP` and sets the `cloudIdentity` using the environment variable `$CI`:

```
helm install trident trident-operator-100.2402.0.tgz --set
cloudProvider=$CP --set cloudIdentity=$CI
```

`tridentctl`

Set the values for **cloud provider** and **cloud identity** flags using the following environment variables:

```
export CP="Azure"
export CI="azure.workload.identity/client-id: xxxxxxxx-xxxx-xxxx-xxxx-
xxxxxxxxxxxx"
```

The following example installs Astra Trident and sets the `cloud-provider` flag to `$CP`, and `cloud-identity` to `$CI`:

```
tridentctl install --cloud-provider=$CP --cloud-identity="$CI" -n
trident
```

## Prepare to configure an Azure NetApp Files backend

Before you can configure your Azure NetApp Files backend, you need to ensure the following requirements are met.

### Prerequisites for NFS and SMB volumes

If you are using Azure NetApp Files for the first time or in a new location, some initial configuration is required to set up Azure NetApp files and create an NFS volume. Refer to [Azure: Set up Azure NetApp Files and create an NFS volume](#).

To configure and use an [Azure NetApp Files](#) backend, you need the following:



- `subscriptionID`, `tenantID`, `clientID`, `location`, and `clientSecret` are optional when using managed identities on an AKS cluster.
- `tenantID`, `clientID`, and `clientSecret` are optional when using a cloud identity on an AKS cluster.

- A capacity pool. Refer to [Microsoft: Create a capacity pool for Azure NetApp Files](#).
- A subnet delegated to Azure NetApp Files. Refer to [Microsoft: Delegate a subnet to Azure NetApp Files](#).
- `subscriptionID` from an Azure subscription with Azure NetApp Files enabled.
- `tenantID`, `clientID`, and `clientSecret` from an [App Registration](#) in Azure Active Directory with sufficient permissions to the Azure NetApp Files service. The App Registration should use either:
  - The Owner or Contributor role [predefined by Azure](#).
  - A [custom Contributor role](#) at the subscription level (`assignableScopes`) with the following permissions that are limited to only what Astra Trident requires. After creating the custom role, [assign the role using the Azure portal](#).

## Custom contributor role

```
{
  "id": "/subscriptions/<subscription-id>/providers/Microsoft.Authorization/roleDefinitions/<role-definition-id>",
  "properties": {
    "roleName": "custom-role-with-limited-perms",
    "description": "custom role providing limited permissions",
    "assignableScopes": [
      "/subscriptions/<subscription-id>"
    ],
    "permissions": [
      {
        "actions": [

"Microsoft.NetApp/netAppAccounts/capacityPools/read",

"Microsoft.NetApp/netAppAccounts/capacityPools/write",

"Microsoft.NetApp/netAppAccounts/capacityPools/volumes/read",

"Microsoft.NetApp/netAppAccounts/capacityPools/volumes/write",

"Microsoft.NetApp/netAppAccounts/capacityPools/volumes/delete",

"Microsoft.NetApp/netAppAccounts/capacityPools/volumes/snapshots/read",

"Microsoft.NetApp/netAppAccounts/capacityPools/volumes/snapshots/write",

"Microsoft.NetApp/netAppAccounts/capacityPools/volumes/snapshots/delete",

"Microsoft.NetApp/netAppAccounts/capacityPools/volumes/MountTargets/read",

          "Microsoft.Network/virtualNetworks/read",

"Microsoft.Network/virtualNetworks/subnets/read",

"Microsoft.Features/featureProviders/subscriptionFeatureRegistrations/read",

"Microsoft.Features/featureProviders/subscriptionFeatureRegistrat
```

```

ions/write",

"Microsoft.Features/featureProviders/subscriptionFeatureRegistrat
ions/delete",
        "Microsoft.Features/features/read",
        "Microsoft.Features/operations/read",
        "Microsoft.Features/providers/features/read",

"Microsoft.Features/providers/features/register/action",

"Microsoft.Features/providers/features/unregister/action",

"Microsoft.Features/subscriptionFeatureRegistrations/read"
    ],
    "notActions": [],
    "dataActions": [],
    "notDataActions": []
  }
]
}
}

```

- The Azure location that contains at least one [delegated subnet](#). As of Trident 22.01, the location parameter is a required field at the top level of the backend configuration file. Location values specified in virtual pools are ignored.
- To use Cloud Identity, get the client ID from a [user-assigned managed identity](#) and specify that ID in `azure.workload.identity/client-id: xxxxxxxx-xxxx-xxxx-xxxx-xxxxxxxxxxxx`.

### Additional requirements for SMB volumes

To create an SMB volume, you must have:

- Active Directory configured and connected to Azure NetApp Files. Refer to [Microsoft: Create and manage Active Directory connections for Azure NetApp Files](#).
- A Kubernetes cluster with a Linux controller node and at least one Windows worker node running Windows Server 2019. Astra Trident supports SMB volumes mounted to pods running on Windows nodes only.
- At least one Astra Trident secret containing your Active Directory credentials so Azure NetApp Files can authenticate to Active Directory. To generate secret `smbcreds`:

```

kubectl create secret generic smbcreds --from-literal username=user
--from-literal password='password'

```

- A CSI proxy configured as a Windows service. To configure a `csi-proxy`, refer to [GitHub: CSI Proxy](#) or [GitHub: CSI Proxy for Windows](#) for Kubernetes nodes running on Windows.

## Azure NetApp Files backend configuration options and examples

Learn about NFS and SMB backend configuration options for Azure NetApp Files and review configuration examples.

### Backend configuration options

Astra Trident uses your backend configuration (subnet, virtual network, service level, and location), to create Azure NetApp Files volumes on capacity pools that are available in the requested location and match the requested service level and subnet.



Astra Trident does not support Manual QoS capacity pools.

Azure NetApp Files backends provide these configuration options.

Parameter	Description	Default
version		Always 1
storageDriverName	Name of the storage driver	"azure-netapp-files"
backendName	Custom name of the storage backend	Driver name + "_" + random characters
subscriptionID	The subscription ID from your Azure subscription  Optional when managed identities is enabled on an AKS cluster.	
tenantID	The tenant ID from an App Registration  Optional when managed identities or cloud identity is used on an AKS cluster.	
clientID	The client ID from an App Registration  Optional when managed identities or cloud identity is used on an AKS cluster.	
clientSecret	The client secret from an App Registration  Optional when managed identities or cloud identity is used on an AKS cluster.	
serviceLevel	One of Standard, Premium, or Ultra	"" (random)

Parameter	Description	Default
location	<p>Name of the Azure location where the new volumes will be created</p> <p>Optional when managed identities is enabled on an AKS cluster.</p>	
resourceGroups	List of resource groups for filtering discovered resources	[] (no filter)
netappAccounts	List of NetApp accounts for filtering discovered resources	[] (no filter)
capacityPools	List of capacity pools for filtering discovered resources	[] (no filter, random)
virtualNetwork	Name of a virtual network with a delegated subnet	""
subnet	Name of a subnet delegated to Microsoft.Netapp/volumes	""
networkFeatures	<p>Set of VNet features for a volume, may be Basic or Standard.</p> <p>Network Features is not available in all regions and might have to be enabled in a subscription. Specifying networkFeatures when the functionality is not enabled causes volume provisioning to fail.</p>	""
nfsMountOptions	<p>Fine-grained control of NFS mount options.</p> <p>Ignored for SMB volumes.</p> <p>To mount volumes using NFS version 4.1, include nfsvers=4 in the comma-delimited mount options list to choose NFS v4.1.</p> <p>Mount options set in a storage class definition override mount options set in backend configuration.</p>	"nfsvers=3"
limitVolumeSize	Fail provisioning if the requested volume size is above this value	"" (not enforced by default)

Parameter	Description	Default
debugTraceFlags	Debug flags to use when troubleshooting. Example, <code>\{"api": false, "method": true, "discovery": true\}</code> . Do not use this unless you are troubleshooting and require a detailed log dump.	null
nasType	Configure NFS or SMB volumes creation.  Options are <code>nfs</code> , <code>smb</code> or <code>null</code> . Setting to null defaults to NFS volumes.	<code>nfs</code>



For more information on Network Features, refer to [Configure network features for an Azure NetApp Files volume](#).

### Required permissions and resources

If you receive a “No capacity pools found” error when creating a PVC, it is likely your app registration doesn’t have the required permissions and resources (subnet, virtual network, capacity pool) associated. If debug is enabled, Astra Trident will log the Azure resources discovered when the backend is created. Verify an appropriate role is being used.

The values for `resourceGroups`, `netappAccounts`, `capacityPools`, `virtualNetwork`, and `subnet` can be specified using short or fully-qualified names. Fully-qualified names are recommended in most situations as short names can match multiple resources with the same name.

The `resourceGroups`, `netappAccounts`, and `capacityPools` values are filters that restrict the set of discovered resources to those available to this storage backend and may be specified in any combination. Fully-qualified names follow this format:

Type	Format
Resource group	<code>&lt;resource group&gt;</code>
NetApp account	<code>&lt;resource group&gt;/&lt;netapp account&gt;</code>
Capacity pool	<code>&lt;resource group&gt;/&lt;netapp account&gt;/&lt;capacity pool&gt;</code>
Virtual network	<code>&lt;resource group&gt;/&lt;virtual network&gt;</code>
Subnet	<code>&lt;resource group&gt;/&lt;virtual network&gt;/&lt;subnet&gt;</code>

### Volume provisioning

You can control default volume provisioning by specifying the following options in a special section of the configuration file. Refer to [Example configurations](#) for details.

Parameter	Description	Default
exportRule	Export rules for new volumes.  exportRule must be a comma-separated list of any combination of IPv4 addresses or IPv4 subnets in CIDR notation.  Ignored for SMB volumes.	"0.0.0.0/0"
snapshotDir	Controls visibility of the .snapshot directory	"false"
size	The default size of new volumes	"100G"
unixPermissions	The unix permissions of new volumes (4 octal digits).  Ignored for SMB volumes.	"" (preview feature, requires whitelisting in subscription)

## Example configurations

The following examples show basic configurations that leave most parameters to default. This is the easiest way to define a backend.

### Minimal configuration

This is the absolute minimum backend configuration. With this configuration, Astra Trident discovers all of your NetApp accounts, capacity pools, and subnets delegated to Azure NetApp Files in the configured location, and places new volumes on one of those pools and subnets randomly. Because `nasType` is omitted, the `nfs` default applies and the backend will provision for NFS volumes.

This configuration is ideal when you are just getting started with Azure NetApp Files and trying things out, but in practice you are going to want to provide additional scoping for the volumes you provision.

```
---
version: 1
storageDriverName: azure-netapp-files
subscriptionID: 9f87c765-4774-fake-ae98-a721add45451
tenantID: 68e4f836-edc1-fake-bff9-b2d865ee56cf
clientID: dd043f63-bf8e-fake-8076-8de91e5713aa
clientSecret: SECRET
location: eastus
```

## Managed identities for AKS

This backend configuration omits `subscriptionID`, `tenantID`, `clientID`, and `clientSecret`, which are optional when using managed identities.

```
apiVersion: trident.netapp.io/v1
kind: TridentBackendConfig
metadata:
  name: backend-tbc-anf-1
  namespace: trident
spec:
  version: 1
  storageDriverName: azure-netapp-files
  capacityPools: ["ultra-pool"]
  resourceGroups: ["aks-ami-eastus-rg"]
  netappAccounts: ["smb-na"]
  virtualNetwork: eastus-prod-vnet
  subnet: eastus-anf-subnet
```

## Cloud identity for AKS

This backend configuration omits `tenantID`, `clientID`, and `clientSecret`, which are optional when using a cloud identity.

```
apiVersion: trident.netapp.io/v1
kind: TridentBackendConfig
metadata:
  name: backend-tbc-anf-1
  namespace: trident
spec:
  version: 1
  storageDriverName: azure-netapp-files
  capacityPools: ["ultra-pool"]
  resourceGroups: ["aks-ami-eastus-rg"]
  netappAccounts: ["smb-na"]
  virtualNetwork: eastus-prod-vnet
  subnet: eastus-anf-subnet
  location: eastus
  subscriptionID: 9f87c765-4774-fake-ae98-a721add45451
```

### Specific service level configuration with capacity pool filters

This backend configuration places volumes in Azure's `eastus` location in an `Ultra` capacity pool. Astra Trident automatically discovers all of the subnets delegated to Azure NetApp Files in that location and places a new volume on one of them randomly.

```
---
version: 1
storageDriverName: azure-netapp-files
subscriptionID: 9f87c765-4774-fake-ae98-a721add45451
tenantID: 68e4f836-edc1-fake-bff9-b2d865ee56cf
clientID: dd043f63-bf8e-fake-8076-8de91e5713aa
clientSecret: SECRET
location: eastus
serviceLevel: Ultra
capacityPools:
- application-group-1/account-1/ultra-1
- application-group-1/account-1/ultra-2
```

## Advanced configuration

This backend configuration further reduces the scope of volume placement to a single subnet, and also modifies some volume provisioning defaults.

```
---
version: 1
storageDriverName: azure-netapp-files
subscriptionID: 9f87c765-4774-fake-ae98-a721add45451
tenantID: 68e4f836-edc1-fake-bff9-b2d865ee56cf
clientID: dd043f63-bf8e-fake-8076-8de91e5713aa
clientSecret: SECRET
location: eastus
serviceLevel: Ultra
capacityPools:
- application-group-1/account-1/ultra-1
- application-group-1/account-1/ultra-2
virtualNetwork: my-virtual-network
subnet: my-subnet
networkFeatures: Standard
nfsMountOptions: vers=3,proto=tcp,timeo=600
limitVolumeSize: 500Gi
defaults:
  exportRule: 10.0.0.0/24,10.0.1.0/24,10.0.2.100
  snapshotDir: 'true'
  size: 200Gi
  unixPermissions: '0777'
```

## Virtual pool configuration

This backend configuration defines multiple storage pools in a single file. This is useful when you have multiple capacity pools supporting different service levels and you want to create storage classes in Kubernetes that represent those. Virtual pool labels were used to differentiate the pools based on performance.

```
---
version: 1
storageDriverName: azure-netapp-files
subscriptionID: 9f87c765-4774-fake-ae98-a721add45451
tenantID: 68e4f836-edc1-fake-bff9-b2d865ee56cf
clientID: dd043f63-bf8e-fake-8076-8de91e5713aa
clientSecret: SECRET
location: eastus
resourceGroups:
- application-group-1
networkFeatures: Basic
nfsMountOptions: vers=3,proto=tcp,timeo=600
labels:
  cloud: azure
storage:
- labels:
    performance: gold
    serviceLevel: Ultra
    capacityPools:
    - ultra-1
    - ultra-2
    networkFeatures: Standard
- labels:
    performance: silver
    serviceLevel: Premium
    capacityPools:
    - premium-1
- labels:
    performance: bronze
    serviceLevel: Standard
    capacityPools:
    - standard-1
    - standard-2
```

## Storage Class definitions

The following StorageClass definitions refer to the storage pools above.

### Example definitions using `parameter.selector` field

Using `parameter.selector` you can specify for each `StorageClass` the virtual pool that is used to host a volume. The volume will have the aspects defined in the chosen pool.

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: gold
provisioner: csi.trident.netapp.io
parameters:
  selector: "performance=gold"
allowVolumeExpansion: true
---
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: silver
provisioner: csi.trident.netapp.io
parameters:
  selector: "performance=silver"
allowVolumeExpansion: true
---
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: bronze
provisioner: csi.trident.netapp.io
parameters:
  selector: "performance=bronze"
allowVolumeExpansion: true
```

### Example definitions for SMB volumes

Using `nasType`, `node-stage-secret-name`, and `node-stage-secret-namespace`, you can specify an SMB volume and provide the required Active Directory credentials.

## Basic configuration on default namespace

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: anf-sc-smb
provisioner: csi.trident.netapp.io
parameters:
  backendType: "azure-netapp-files"
  trident.netapp.io/nasType: "smb"
  csi.storage.k8s.io/node-stage-secret-name: "smbcreds"
  csi.storage.k8s.io/node-stage-secret-namespace: "default"
```

## Using different secrets per namespace

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: anf-sc-smb
provisioner: csi.trident.netapp.io
parameters:
  backendType: "azure-netapp-files"
  trident.netapp.io/nasType: "smb"
  csi.storage.k8s.io/node-stage-secret-name: "smbcreds"
  csi.storage.k8s.io/node-stage-secret-namespace: ${pvc.namespace}
```

## Using different secrets per volume

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: anf-sc-smb
provisioner: csi.trident.netapp.io
parameters:
  backendType: "azure-netapp-files"
  trident.netapp.io/nasType: "smb"
  csi.storage.k8s.io/node-stage-secret-name: ${pvc.name}
  csi.storage.k8s.io/node-stage-secret-namespace: ${pvc.namespace}
```



`nasType: smb` filters for pools which support SMB volumes. `nasType: nfs` or `nasType: null` filters for NFS pools.

## Create the backend

After you create the backend configuration file, run the following command:

```
tridentctl create backend -f <backend-file>
```

If the backend creation fails, something is wrong with the backend configuration. You can view the logs to determine the cause by running the following command:

```
tridentctl logs
```

After you identify and correct the problem with the configuration file, you can run the create command again.

## Configure a Cloud Volumes Service for Google Cloud backend

Learn how to configure NetApp Cloud Volumes Service for Google Cloud as the backend for your Astra Trident installation using the sample configurations provided.

### Google Cloud driver details

Astra Trident provides the `gcp-cvs` driver to communicate with the cluster. Supported access modes are: *ReadWriteOnce* (RWO), *ReadOnlyMany* (ROX), *ReadWriteMany* (RWX), *ReadWriteOncePod* (RWOP).

Driver	Protocol	volumeMode	Access modes supported	File systems supported
<code>gcp-cvs</code>	NFS	Filesystem	RWO, ROX, RWX, RWOP	<code>nfs</code>

## Learn about Astra Trident support for Cloud Volumes Service for Google Cloud

Astra Trident can create Cloud Volumes Service volumes in one of two [service types](#):

- **CVS-Performance:** The default Astra Trident service type. This performance-optimized service type is best suited for production workloads that value performance. The CVS-Performance service type is a hardware option supporting volumes with a minimum 100 GiB size. You can choose one of [three service levels](#):
  - `standard`
  - `premium`
  - `extreme`
- **CVS:** The CVS service type provides high zonal availability with limited to moderate performance levels. The CVS service type is a software option that uses storage pools to support volumes as small as 1 GiB. The storage pool can contain up to 50 volumes where all volumes share the capacity and performance of the pool. You can choose one of [two service levels](#):

- `standardsw`
- `zoneredundantstandardsw`

## What you'll need

To configure and use the [Cloud Volumes Service for Google Cloud](#) backend, you need the following:

- A Google Cloud account configured with NetApp Cloud Volumes Service
- Project number of your Google Cloud account
- Google Cloud service account with the `netappcloudvolumes.admin` role
- API key file for your Cloud Volumes Service account

## Backend configuration options

Each backend provisions volumes in a single Google Cloud region. To create volumes in other regions, you can define additional backends.

Parameter	Description	Default
<code>version</code>		Always 1
<code>storageDriverName</code>	Name of the storage driver	"gcp-cvs"
<code>backendName</code>	Custom name or the storage backend	Driver name + "_" + part of API key
<code>storageClass</code>	Optional parameter used to specify the CVS service type.  Use <code>software</code> to select the CVS service type. Otherwise, Astra Trident assumes CVS-Performance service type ( <code>hardware</code> ).	
<code>storagePools</code>	CVS service type only. Optional parameter used to specify storage pools for volume creation.	
<code>projectNumber</code>	Google Cloud account project number. The value is found on the Google Cloud portal home page.	
<code>hostProjectNumber</code>	Required if using a shared VPC network. In this scenario, <code>projectNumber</code> is the service project, and <code>hostProjectNumber</code> is the host project.	
<code>apiRegion</code>	The Google Cloud region where Astra Trident creates Cloud Volumes Service volumes. When creating cross-region Kubernetes clusters, volumes created in an <code>apiRegion</code> can be used in workloads scheduled on nodes across multiple Google Cloud regions.  Cross-region traffic incurs an additional cost.	

Parameter	Description	Default
apiKey	<p>API key for the Google Cloud service account with the <code>netappcloudvolumes.admin</code> role.</p> <p>It includes the JSON-formatted contents of a Google Cloud service account's private key file (copied verbatim into the backend configuration file).</p>	
proxyURL	<p>Proxy URL if proxy server required to connect to CVS account. The proxy server can either be an HTTP proxy or an HTTPS proxy.</p> <p>For an HTTPS proxy, certificate validation is skipped to allow the usage of self-signed certificates in the proxy server.</p> <p>Proxy servers with authentication enabled are not supported.</p>	
nfsMountOptions	Fine-grained control of NFS mount options.	"nfsvers=3"
limitVolumeSize	Fail provisioning if the requested volume size is above this value.	"" (not enforced by default)
serviceLevel	<p>The CVS-Performance or CVS service level for new volumes.</p> <p>CVS-Performance values are <code>standard</code>, <code>premium</code>, or <code>extreme</code>.</p> <p>CVS values are <code>standardsw</code> or <code>zoneredundantstandardsw</code>.</p>	<p>CVS-Performance default is "standard".</p> <p>CVS default is "standardsw".</p>
network	Google Cloud network used for Cloud Volumes Service volumes.	"default"
debugTraceFlags	<p>Debug flags to use when troubleshooting. Example, <code>\{"api":false, "method":true\}</code>.</p> <p>Do not use this unless you are troubleshooting and require a detailed log dump.</p>	null
allowedTopologies	<p>To enable cross-region access, your <code>StorageClass</code> definition for <code>allowedTopologies</code> must include all regions.</p> <p>For example:</p> <ul style="list-style-type: none"> <li>- key: <code>topology.kubernetes.io/region</code></li> <li>values:</li> <li>- <code>us-east1</code></li> <li>- <code>europa-west1</code></li> </ul>	

## Volume provisioning options

You can control default volume provisioning in the `defaults` section of the configuration file.

Parameter	Description	Default
exportRule	The export rules for new volumes. Must be a comma-separated list of any combination of IPv4 addresses or IPv4 subnets in CIDR notation.	"0.0.0.0/0"
snapshotDir	Access to the .snapshot directory	"false"
snapshotReserve	Percentage of volume reserved for snapshots	"" (accept CVS default of 0)
size	The size of new volumes.  CVS-Performance minimum is 100 GiB.  CVS minimum is 1 GiB.	CVS-Performance service type defaults to "100GiB".  CVS service type does not set a default but requires a 1 GiB minimum.

## CVS-Performance service type examples

The following examples provide sample configurations for the CVS-Performance service type.

[illegible]

```
auth_uri: https://accounts.google.com/o/oauth2/auth
token_uri: https://oauth2.googleapis.com/token
auth_provider_x509_cert_url:
https://www.googleapis.com/oauth2/v1/certs
client_x509_cert_url:
https://www.googleapis.com/robot/v1/metadata/x509/cloudvolumes-admin-
sa%40my-gcp-project.iam.gserviceaccount.com
```

```
---
version: 1
storageDriverName: gcp-cvs
projectNumber: '012345678901'
apiRegion: us-west2
apiKey:
  type: service_account
  project_id: my-gcp-project
  private_key_id: "<id_value>"
  private_key: |
    -----BEGIN PRIVATE KEY-----
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    znHczZsr rtHisIsAbOguSaPIKeyAZNchRAGz lzZE4jK3bl /qp8B4Kws8zX5ojY9m
    XsYg6gyxy4zq7OlwWgLwGa==
    -----END PRIVATE KEY-----
  client_email: cloudvolumes-admin-sa@my-gcp-
project.iam.gserviceaccount.com
  client_id: '123456789012345678901'
  auth_uri: https://accounts.google.com/o/oauth2/auth
```

```
token_uri: https://oauth2.googleapis.com/token
auth_provider_x509_cert_url:
https://www.googleapis.com/oauth2/v1/certs
client_x509_cert_url:
https://www.googleapis.com/robot/v1/metadata/x509/cloudvolumes-admin-
sa%40my-gcp-project.iam.gserviceaccount.com
proxyURL: http://proxy-server-hostname/
nfsMountOptions: vers=3,proto=tcp,timeo=600
limitVolumeSize: 10Ti
serviceLevel: premium
defaults:
  snapshotDir: 'true'
  snapshotReserve: '5'
  exportRule: 10.0.0.0/24,10.0.1.0/24,10.0.2.100
  size: 5Ti
```

### Example 3: Virtual pool configuration

This sample uses `storage` to configure virtual pools and the `StorageClasses` that refer back to them. Refer to [Storage class definitions](#) to see how the storage classes were defined.

Here, specific defaults are set for all virtual pools, which set the `snapshotReserve` at 5% and the `exportRule` to 0.0.0.0/0. The virtual pools are defined in the `storage` section. Each individual virtual pool defines its own `serviceLevel`, and some pools overwrite the default values. Virtual pool labels were used to differentiate the pools based on performance and protection.

[illegible]

```

-----END PRIVATE KEY-----
client_email: cloudvolumes-admin-sa@my-gcp-
project.iam.gserviceaccount.com
client_id: '123456789012345678901'
auth_uri: https://accounts.google.com/o/oauth2/auth
token_uri: https://oauth2.googleapis.com/token
auth_provider_x509_cert_url:
https://www.googleapis.com/oauth2/v1/certs
client_x509_cert_url:
https://www.googleapis.com/robot/v1/metadata/x509/cloudvolumes-admin-
sa%40my-gcp-project.iam.gserviceaccount.com
nfsMountOptions: vers=3,proto=tcp,timeo=600
defaults:
  snapshotReserve: '5'
  exportRule: 0.0.0.0/0
labels:
  cloud: gcp
region: us-west2
storage:
- labels:
  performance: extreme
  protection: extra
  serviceLevel: extreme
  defaults:
    snapshotDir: 'true'
    snapshotReserve: '10'
    exportRule: 10.0.0.0/24
- labels:
  performance: extreme
  protection: standard
  serviceLevel: extreme
- labels:
  performance: premium
  protection: extra
  serviceLevel: premium
  defaults:
    snapshotDir: 'true'
    snapshotReserve: '10'
- labels:
  performance: premium
  protection: standard
  serviceLevel: premium
- labels:
  performance: standard
  serviceLevel: standard

```

## Storage class definitions

The following StorageClass definitions apply to the virtual pool configuration example. Using `parameters.selector`, you can specify for each StorageClass the virtual pool used to host a volume. The volume will have the aspects defined in the chosen pool.

## Storage class example

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: cvs-extreme-extra-protection
provisioner: csi.trident.netapp.io
parameters:
  selector: "performance=extreme; protection=extra"
allowVolumeExpansion: true
---
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: cvs-extreme-standard-protection
provisioner: csi.trident.netapp.io
parameters:
  selector: "performance=premium; protection=standard"
allowVolumeExpansion: true
---
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: cvs-premium-extra-protection
provisioner: csi.trident.netapp.io
parameters:
  selector: "performance=premium; protection=extra"
allowVolumeExpansion: true
---
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: cvs-premium
provisioner: csi.trident.netapp.io
parameters:
  selector: "performance=premium; protection=standard"
allowVolumeExpansion: true
---
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: cvs-standard
provisioner: csi.trident.netapp.io
parameters:
  selector: "performance=standard"
allowVolumeExpansion: true
```

```
---
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: cvs-extra-protection
provisioner: csi.trident.netapp.io
parameters:
  selector: "protection=extra"
allowVolumeExpansion: true
```

- The first StorageClass (`cvs-extreme-extra-protection`) maps to the first virtual pool. This is the only pool offering extreme performance with a snapshot reserve of 10%.
- The last StorageClass (`cvs-extra-protection`) calls out any storage pool which provides a snapshot reserve of 10%. Astra Trident decides which virtual pool is selected and ensures that the snapshot reserve requirement is met.

## CVS service type examples

The following examples provide sample configurations for the CVS service type.

[illegible]

```
client_id: '123456789012345678901'
auth_uri: https://accounts.google.com/o/oauth2/auth
token_uri: https://oauth2.googleapis.com/token
auth_provider_x509_cert_url:
https://www.googleapis.com/oauth2/v1/certs
client_x509_cert_url:
https://www.googleapis.com/robot/v1/metadata/x509/cloudvolumes-admin-
sa%40my-gcp-project.iam.gserviceaccount.com
serviceLevel: standardsw
```

## Example 2: Storage pool configuration

This sample backend configuration uses `storagePools` to configure a storage pool.

```
---
version: 1
storageDriverName: gcp-cvs
backendName: gcp-std-so-with-pool
projectNumber: '531265380079'
apiRegion: europe-west1
apiKey:
  type: service_account
  project_id: cloud-native-data
  private_key_id: "<id_value>"
  private_key: |-
    -----BEGIN PRIVATE KEY-----
    MIIIEvAIBADANBgkqhkiG9w0BAQEFAASCBywggSiAgEAAoIBAQDaT+Oui9FBAw19
    L1AGEkrYU5xd9K5NlO5jMkIFND5wCD+Nv+jd1GvtFRLaLK5RvXyF5wzvztmODNS+
    qtScpQ+5cFpQkuGtv9U9+N6qtuVYYO3b504Kp5CtqVPJCgMJaK2j8pZTIqUiMum/
    5/Y9oTbZrjAHSMsgJm2nHzFq2X0rqVMaHghI6ATm4DOuWx8XGWKTGIPlc0qPqJlqS
    LLaWOH4VIZQZCAyW5IUp9CAmwqHgdG0uhFNfCgMmED6PBUvVLsLvcq86X+QSWR9k
    ETqElj/sGCenPF7ti1DhGBFafd9hPnxg9PZY29ArEZwY9G/ZjZQX7WPgs0VvxiNR
    DxZRC3GXAgMBAAECggEACn5c59bG/qnVEVI1CwMAalM5M2z09JFhlL1ljKwntNPj
    Vilw2eTW2+UE7HbJru/S7KQgA5Dnn9kvCraEahPRuddUMrD0vG4kTl/IODV6uFuk
    Y0sZfbqd4jMUQ21smvGsqFzwloYWS5qzO1W83ivXH/HW/iqkmY2eW+EPRS/hwSSu
    SscR+SojI7PB0BWSJhlV4yqYf3vcD/D95el2CVHfRCkL85DKumeZ+yHENpiXGZAE
    t8xSs4a50OPm6NHhevCw2a/UQ95/foXNUR450HtbjieJo5o+FF6EYZQGfU2ZHZO8
    37FBKuaJkdGW5xqaI9TL7aqkGkFMF4F2qvOZM+vy8QKBgQD4oVuOkJDlhkTHP86W
    esFlwlkpWyJR9ZA7LI0g/rVpslnX+XdDq0WQf4umDLNau5hYEh9LU6ZSGs1Xk3/B
    NHwR6OXFuqEKNiu83d0zSlHhTy7PZpOZdj5a/vVvQfPDMz7OvsqLRd7YCAbdzuQ0
    +Ahq0Ztwvg0HQ64hdW0ukpYRRwKBgQDgyHj98oqswoYuIa+pPlYs0pPwLmjwKyNm
    /HayzCp+Qjiiyy7Tzg8AUqlH1Ou83XbV428jvg7kDh07PCCKFq+mMmfqHmTpb0Maq
    KpKnZg4ipsqPlyHNNEoRmcailXbWihCLewMqMrggUiLOmCw4PscL5nK+4GKu2XE1
    jLqjWAZFMQKBgFHkQ9XXRAJlK3XpGHOgn890pZOkCVSrqu6aUef/5KYlFCt8ew
    F/+aIxM2iQSVmWQYOvVCnhuY/F2GFAQ7d0om3decuwIOCX/xy7PjHMkLXa2uaZs4
    WR17sLduj62RqXRLX0c0QkwBiNFyHbRcpdkZJQujbYMhBa+7j7SxT4BtAoGAWMWT
    UucocRXZm/pdvz9wteNH3YDWNJLMxm1KC06qMXbBoYrliY4sm3ywJWMC+iCd/H8A
    Gecxd/xVu5mA2L2N3KMq18Zhz8Th0G5DwKyDRJgOQ0Q46yuNXOoYEjlo4Wjyk8Me
    +tlQ8iK98E0UmZnhTgfSpSNElbz2AqnzQ3MN9uECgYAqdvDVPnKGfvdTz2DjyMoJ
    E89UIC41WjjJGmHsd8W65+3X0RwMzKMT6aZc5tK9J5dHvmWIETnbM+1TImdBBFga
    NWOC6f3r2xbGXHhaWSl+nobpTuvlo56ZRJVvVk7lFMsidzMuHH8pxfgNJemwA4P
    ThDHcejv035NNV6Kyo00tA==
    -----END PRIVATE KEY-----
  client_email: cloudvolumes-admin-sa@cloud-native-
  data.iam.gserviceaccount.com
  client_id: '107071413297115343396'
```

```
auth_uri: https://accounts.google.com/o/oauth2/auth
token_uri: https://oauth2.googleapis.com/token
auth_provider_x509_cert_url:
https://www.googleapis.com/oauth2/v1/certs
client_x509_cert_url:
https://www.googleapis.com/robot/v1/metadata/x509/cloudvolumes-admin-
sa%40cloud-native-data.iam.gserviceaccount.com
storageClass: software
zone: europe-west1-b
network: default
storagePools:
- 1bc7f380-3314-6005-45e9-c7dc8c2d7509
serviceLevel: Standardsw
```

## What's next?

After you create the backend configuration file, run the following command:

```
tridentctl create backend -f <backend-file>
```

If the backend creation fails, something is wrong with the backend configuration. You can view the logs to determine the cause by running the following command:

```
tridentctl logs
```

After you identify and correct the problem with the configuration file, you can run the create command again.

## Configure a NetApp HCI or SolidFire backend

Learn how to create and use an Element backend with your Astra Trident installation.

### Element driver details

Astra Trident provides the `solidfire-san` storage driver to communicate with the cluster. Supported access modes are: *ReadWriteOnce* (RWO), *ReadOnlyMany* (ROX), *ReadWriteMany* (RWX), *ReadWriteOncePod* (RWOP).

The `solidfire-san` storage driver supports *file* and *block* volume modes. For the `Filesystem` volumeMode, Astra Trident creates a volume and creates a filesystem. The filesystem type is specified by the `StorageClass`.

Driver	Protocol	VolumeMode	Access modes supported	File systems supported
solidfire-san	iSCSI	Block	RWO, ROX, RWX, RWOP	No Filesystem. Raw block device.
solidfire-san	iSCSI	Filesystem	RWO, RWOP	xfs, ext3, ext4

## Before you begin

You'll need the following before creating an Element backend.

- A supported storage system that runs Element software.
- Credentials to a NetApp HCI/SolidFire cluster admin or tenant user that can manage volumes.
- All of your Kubernetes worker nodes should have the appropriate iSCSI tools installed. Refer to [worker node preparation information](#).

## Backend configuration options

See the following table for the backend configuration options:

Parameter	Description	Default
version		Always 1
storageDriverName	Name of the storage driver	Always "solidfire-san"
backendName	Custom name or the storage backend	"solidfire_" + storage (iSCSI) IP address
Endpoint	MVIP for the SolidFire cluster with tenant credentials	
SVIP	Storage (iSCSI) IP address and port	
labels	Set of arbitrary JSON-formatted labels to apply on volumes.	""
TenantName	Tenant name to use (created if not found)	
InitiatorIFace	Restrict iSCSI traffic to a specific host interface	"default"
UseCHAP	Use CHAP to authenticate iSCSI. Astra Trident uses CHAP.	true
AccessGroups	List of Access Group IDs to use	Finds the ID of an access group named "trident"
Types	QoS specifications	
limitVolumeSize	Fail provisioning if requested volume size is above this value	"" (not enforced by default)

Parameter	Description	Default
debugTraceFlags	Debug flags to use when troubleshooting. Example, {"api":false, "method":true}	null



Do not use debugTraceFlags unless you are troubleshooting and require a detailed log dump.

## Example 1: Backend configuration for solidfire-san driver with three volume types

This example shows a backend file using CHAP authentication and modeling three volume types with specific QoS guarantees. Most likely you would then define storage classes to consume each of these using the IOPS storage class parameter.

```
---
version: 1
storageDriverName: solidfire-san
Endpoint: https://<user>:<password>@<mvip>/json-rpc/8.0
SVIP: "<svip>:3260"
TenantName: "<tenant>"
labels:
  k8scluster: dev1
  backend: dev1-element-cluster
UseCHAP: true
Types:
- Type: Bronze
  Qos:
    minIOPS: 1000
    maxIOPS: 2000
    burstIOPS: 4000
- Type: Silver
  Qos:
    minIOPS: 4000
    maxIOPS: 6000
    burstIOPS: 8000
- Type: Gold
  Qos:
    minIOPS: 6000
    maxIOPS: 8000
    burstIOPS: 10000
```

## Example 2: Backend and storage class configuration for solidfire-san driver with virtual pools

This example shows the backend definition file configured with virtual pools along with StorageClasses that

refer back to them.

Astra Trident copies labels present on a storage pool to the backend storage LUN at provisioning. For convenience, storage administrators can define labels per virtual pool and group volumes by label.

In the sample backend definition file shown below, specific defaults are set for all storage pools, which set the type at Silver. The virtual pools are defined in the `storage` section. In this example, some of the storage pools set their own type, and some pools override the default values set above.

```
---
version: 1
storageDriverName: solidfire-san
Endpoint: https://<user>:<password>@<mvip>/json-rpc/8.0
SVIP: "<svip>:3260"
TenantName: "<tenant>"
UseCHAP: true
Types:
- Type: Bronze
  Qos:
    minIOPS: 1000
    maxIOPS: 2000
    burstIOPS: 4000
- Type: Silver
  Qos:
    minIOPS: 4000
    maxIOPS: 6000
    burstIOPS: 8000
- Type: Gold
  Qos:
    minIOPS: 6000
    maxIOPS: 8000
    burstIOPS: 10000
type: Silver
labels:
  store: solidfire
  k8scluster: dev-1-cluster
region: us-east-1
storage:
- labels:
    performance: gold
    cost: '4'
  zone: us-east-1a
  type: Gold
- labels:
    performance: silver
    cost: '3'
  zone: us-east-1b
```

```
type: Silver
- labels:
  performance: bronze
  cost: '2'
  zone: us-east-1c
type: Bronze
- labels:
  performance: silver
  cost: '1'
  zone: us-east-1d
```

The following StorageClass definitions refer to the above virtual pools. Using the `parameters.selector` field, each StorageClass calls out which virtual pool(s) can be used to host a volume. The volume will have the aspects defined in the chosen virtual pool.

The first StorageClass (`solidfire-gold-four`) will map to the first virtual pool. This is the only pool offering gold performance with a `Volume Type QoS` of Gold. The last StorageClass (`solidfire-silver`) calls out any storage pool which offers a silver performance. Astra Trident will decide which virtual pool is selected and will ensure the storage requirement is met.

```

apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: solidfire-gold-four
provisioner: csi.trident.netapp.io
parameters:
  selector: "performance=gold; cost=4"
  fsType: "ext4"
---
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: solidfire-silver-three
provisioner: csi.trident.netapp.io
parameters:
  selector: "performance=silver; cost=3"
  fsType: "ext4"
---
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: solidfire-bronze-two
provisioner: csi.trident.netapp.io
parameters:
  selector: "performance=bronze; cost=2"
  fsType: "ext4"
---
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: solidfire-silver-one
provisioner: csi.trident.netapp.io
parameters:
  selector: "performance=silver; cost=1"
  fsType: "ext4"
---
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: solidfire-silver
provisioner: csi.trident.netapp.io
parameters:
  selector: "performance=silver"
  fsType: "ext4"

```

## Find more information

- [Volume access groups](#)

# ONTAP SAN drivers

## ONTAP SAN driver overview

Learn about configuring an ONTAP backend with ONTAP and Cloud Volumes ONTAP SAN drivers.

## ONTAP SAN driver details

Astra Trident provides the following SAN storage drivers to communicate with the ONTAP cluster. Supported access modes are: *ReadWriteOnce* (RWO), *ReadOnlyMany* (ROX), *ReadWriteMany* (RWX), *ReadWriteOncePod* (RWOP).



If you are using Astra Control for protection, recovery, and mobility, read [Astra Control driver compatibility](#).

Driver	Protocol	volumeMode	Access modes supported	File systems supported
ontap-san	iSCSI	Block	RWO, ROX, RWX, RWOP	No filesystem; raw block device
ontap-san	iSCSI	Filesystem	RWO, RWOP  ROX and RWX are not available in Filesystem volume mode.	xfs, ext3, ext4
ontap-san	NVMe/TCP  Refer to <a href="#">Additional considerations for NVMe/TCP</a> .	Block	RWO, ROX, RWX, RWOP	No filesystem; raw block device
ontap-san	NVMe/TCP  Refer to <a href="#">Additional considerations for NVMe/TCP</a> .	Filesystem	RWO, RWOP  ROX and RWX are not available in Filesystem volume mode.	xfs, ext3, ext4
ontap-san-economy	iSCSI	Block	RWO, ROX, RWX, RWOP	No filesystem; raw block device

Driver	Protocol	volumeMode	Access modes supported	File systems supported
ontap-san-economy	iSCSI	Filesystem	RWO, RWOP  ROX and RWX are not available in Filesystem volume mode.	xfs, ext3, ext4

### Astra Control driver compatibility

Astra Control provides seamless protection, disaster recovery, and mobility (moving volumes between Kubernetes clusters) for volumes created with the `ontap-nas`, `ontap-nas-flexgroup`, and `ontap-san` drivers. Refer to [Astra Control replication prerequisites](#) for details.



- Use `ontap-san-economy` only if persistent volume usage count is expected to be higher than [supported ONTAP volume limits](#).
- Use `ontap-nas-economy` only if persistent volume usage count is expected to be higher than [supported ONTAP volume limits](#) and the `ontap-san-economy` driver cannot be used.
- Do not use `ontap-nas-economy` if you anticipate the need for data protection, disaster recovery, or mobility.

### User permissions

Astra Trident expects to be run as either an ONTAP or SVM administrator, typically using the `admin` cluster user or a `vsadmin` SVM user, or a user with a different name that has the same role. For Amazon FSx for NetApp ONTAP deployments, Astra Trident expects to be run as either an ONTAP or SVM administrator, using the cluster `fsxadmin` user or a `vsadmin` SVM user, or a user with a different name that has the same role. The `fsxadmin` user is a limited replacement for the cluster admin user.



If you use the `limitAggregateUsage` parameter, cluster admin permissions are required. When using Amazon FSx for NetApp ONTAP with Astra Trident, the `limitAggregateUsage` parameter will not work with the `vsadmin` and `fsxadmin` user accounts. The configuration operation will fail if you specify this parameter.

While it is possible to create a more restrictive role within ONTAP that a Trident driver can use, we don't recommend it. Most new releases of Trident will call additional APIs that would have to be accounted for, making upgrades difficult and error-prone.

### Additional considerations for NVMe/TCP

Astra Trident supports the non-volatile memory express (NVMe) protocol using the `ontap-san` driver including:

- IPv6
- Snapshots and clones of NVMe volumes
- Resizing an NVMe volume
- Importing an NVMe volume that was created outside of Astra Trident so that its lifecycle can be managed by Astra Trident

- NVMe-native multipathing
- Graceful or ungraceful shutdown of the K8s nodes (24.02)

Astra Trident does not support:

- DH-HMAC-CHAP that is supported by natively by NVMe
- Device mapper (DM) multipathing
- LUKS encryption

## Prepare to configure backend with ONTAP SAN drivers

Understand the requirements and authentication options for configuring an ONTAP backend with ONTAP SAN drivers.

### Requirements

For all ONTAP backends, Astra Trident requires at least one aggregate assigned to the SVM.

Remember that you can also run more than one driver, and create storage classes that point to one or the other. For example, you could configure a `san-dev` class that uses the `ontap-san` driver and a `san-default` class that uses the `ontap-san-economy` one.

All your Kubernetes worker nodes must have the appropriate iSCSI tools installed. Refer to [Prepare the worker node](#) for details.

### Authenticate the ONTAP backend

Astra Trident offers two modes of authenticating an ONTAP backend.

- **Credential-based:** The username and password to an ONTAP user with the required permissions. It is recommended to use a pre-defined security login role, such as `admin` or `vsadmin` to ensure maximum compatibility with ONTAP versions.
- **Certificate-based:** Astra Trident can also communicate with an ONTAP cluster using a certificate installed on the backend. Here, the backend definition must contain Base64-encoded values of the client certificate, key, and the trusted CA certificate if used (recommended).

You can update existing backends to move between credential-based and certificate-based methods. However, only one authentication method is supported at a time. To switch to a different authentication method, you must remove the existing method from the backend configuration.



If you attempt to provide **both credentials and certificates**, backend creation will fail with an error that more than one authentication method was provided in the configuration file.

### Enable credential-based authentication

Astra Trident requires the credentials to an SVM-scoped/cluster-scoped admin to communicate with the ONTAP backend. It is recommended to make use of standard, pre-defined roles such as `admin` or `vsadmin`. This ensures forward compatibility with future ONTAP releases that might expose feature APIs to be used by future Astra Trident releases. A custom security login role can be created and used with Astra Trident, but is not recommended.

A sample backend definition will look like this:

## YAML

```
---
version: 1
backendName: ExampleBackend
storageDriverName: ontap-san
managementLIF: 10.0.0.1
svm: svm_nfs
username: vsadmin
password: password
```

## JSON

```
{
  "version": 1,
  "backendName": "ExampleBackend",
  "storageDriverName": "ontap-san",
  "managementLIF": "10.0.0.1",
  "svm": "svm_nfs",
  "username": "vsadmin",
  "password": "password"
}
```

Keep in mind that the backend definition is the only place the credentials are stored in plain text. After the backend is created, usernames/passwords are encoded with Base64 and stored as Kubernetes secrets. The creation or update of a backend is the only step that requires knowledge of the credentials. As such, it is an admin-only operation, to be performed by the Kubernetes/storage administrator.

### Enable certificate-based authentication

New and existing backends can use a certificate and communicate with the ONTAP backend. Three parameters are required in the backend definition.

- `clientCertificate`: Base64-encoded value of client certificate.
- `clientPrivateKey`: Base64-encoded value of associated private key.
- `trustedCACertificate`: Base64-encoded value of trusted CA certificate. If using a trusted CA, this parameter must be provided. This can be ignored if no trusted CA is used.

A typical workflow involves the following steps.

### Steps

1. Generate a client certificate and key. When generating, set Common Name (CN) to the ONTAP user to authenticate as.

```
openssl req -x509 -nodes -days 1095 -newkey rsa:2048 -keyout k8senv.key  
-out k8senv.pem -subj "/C=US/ST=NC/L=RTP/O=NetApp/CN=admin"
```

2. Add trusted CA certificate to the ONTAP cluster. This might be already handled by the storage administrator. Ignore if no trusted CA is used.

```
security certificate install -type server -cert-name <trusted-ca-cert-  
name> -vserver <vserver-name>  
ssl modify -vserver <vserver-name> -server-enabled true -client-enabled  
true -common-name <common-name> -serial <SN-from-trusted-CA-cert> -ca  
<cert-authority>
```

3. Install the client certificate and key (from step 1) on the ONTAP cluster.

```
security certificate install -type client-ca -cert-name <certificate-  
name> -vserver <vserver-name>  
security ssl modify -vserver <vserver-name> -client-enabled true
```

4. Confirm the ONTAP security login role supports cert authentication method.

```
security login create -user-or-group-name admin -application ontapi  
-authentication-method cert  
security login create -user-or-group-name admin -application http  
-authentication-method cert
```

5. Test authentication using certificate generated. Replace <ONTAP Management LIF> and <vserver name> with Management LIF IP and SVM name.

```
curl -X POST -Lk https://<ONTAP-Management-  
LIF>/servlets/netapp.servlets.admin.XMLrequest_filer --key k8senv.key  
--cert ~/k8senv.pem -d '<?xml version="1.0" encoding="UTF-8"?><netapp  
xmlns="http://www.netapp.com/filer/admin" version="1.21"  
vfiler="<vserver-name>"><vserver-get></vserver-get></netapp>'
```

6. Encode certificate, key and trusted CA certificate with Base64.

```
base64 -w 0 k8senv.pem >> cert_base64  
base64 -w 0 k8senv.key >> key_base64  
base64 -w 0 trustedca.pem >> trustedca_base64
```

7. Create backend using the values obtained from the previous step.

```
cat cert-backend.json
{
  "version": 1,
  "storageDriverName": "ontap-san",
  "backendName": "SanBackend",
  "managementLIF": "1.2.3.4",
  "svm": "vserver_test",
  "clientCertificate": "Faaaakkkkeeee...Vaaalllluuuuueeee",
  "clientPrivateKey": "LS0tFaKE...0VaLuES0tLS0K",
  "trustedCACertificate": "QNFinfO...SiqOyN",
  "storagePrefix": "myPrefix_"
}

tridentctl create backend -f cert-backend.json -n trident
+-----+-----+-----+-----+
+-----+-----+
|      NAME      | STORAGE DRIVER |                      UUID                      |
STATE | VOLUMES |
+-----+-----+-----+-----+
+-----+-----+
| SanBackend | ontap-san      | 586b1cd5-8cf8-428d-a76c-2872713612c1 |
online |          0 |
+-----+-----+-----+-----+
+-----+-----+
```

### Update authentication methods or rotate credentials

You can update an existing backend to use a different authentication method or to rotate their credentials. This works both ways: backends that make use of username/password can be updated to use certificates; backends that utilize certificates can be updated to username/password based. To do this, you must remove the existing authentication method and add the new authentication method. Then use the updated backend.json file containing the required parameters to execute `tridentctl backend update`.

```

cat cert-backend-updated.json
{
  "version": 1,
  "storageDriverName": "ontap-san",
  "backendName": "SanBackend",
  "managementLIF": "1.2.3.4",
  "svm": "vserver_test",
  "username": "vsadmin",
  "password": "password",
  "storagePrefix": "myPrefix_"
}

#Update backend with tridentctl
tridentctl update backend SanBackend -f cert-backend-updated.json -n
trident
+-----+-----+-----+
+-----+-----+
|      NAME      | STORAGE DRIVER |          UUID          |
STATE | VOLUMES |
+-----+-----+-----+
+-----+-----+
| SanBackend | ontap-san      | 586b1cd5-8cf8-428d-a76c-2872713612c1 |
online |      9 |
+-----+-----+-----+
+-----+-----+

```



When rotating passwords, the storage administrator must first update the password for the user on ONTAP. This is followed by a backend update. When rotating certificates, multiple certificates can be added to the user. The backend is then updated to use the new certificate, following which the old certificate can be deleted from the ONTAP cluster.

Updating a backend does not disrupt access to volumes that have already been created, nor impact volume connections made after. A successful backend update indicates that Astra Trident can communicate with the ONTAP backend and handle future volume operations.

### Authenticate connections with bidirectional CHAP

Astra Trident can authenticate iSCSI sessions with bidirectional CHAP for the `ontap-san` and `ontap-san-economy` drivers. This requires enabling the `useCHAP` option in your backend definition. When set to `true`, Astra Trident configures the SVM's default initiator security to bidirectional CHAP and set the username and secrets from the backend file. NetApp recommends using bidirectional CHAP to authenticate connections. See the following sample configuration:

```

---
version: 1
storageDriverName: ontap-san
backendName: ontap_san_chap
managementLIF: 192.168.0.135
svm: ontap_iscsi_svm
useCHAP: true
username: vsadmin
password: password
chapInitiatorSecret: cl9qxIm36DKyawxy
chapTargetInitiatorSecret: rqxigXgkesIpwxyz
chapTargetUsername: iJF4heBRT0TCwxyz
chapUsername: uh2aNCLSD6cNwxyz

```



The `useCHAP` parameter is a Boolean option that can be configured only once. It is set to `false` by default. After you set it to `true`, you cannot set it to `false`.

In addition to `useCHAP=true`, the `chapInitiatorSecret`, `chapTargetInitiatorSecret`, `chapTargetUsername`, and `chapUsername` fields must be included in the backend definition. The secrets can be changed after a backend is created by running `tridentctl update`.

### How it works

By setting `useCHAP` to `true`, the storage administrator instructs Astra Trident to configure CHAP on the storage backend. This includes the following:

- Setting up CHAP on the SVM:
  - If the SVM's default initiator security type is `none` (set by default) **and** there are no pre-existing LUNs already present in the volume, Astra Trident will set the default security type to `CHAP` and proceed to configuring the CHAP initiator and target username and secrets.
  - If the SVM contains LUNs, Astra Trident will not enable CHAP on the SVM. This ensures that access to LUNs that are already present on the SVM isn't restricted.
- Configuring the CHAP initiator and target username and secrets; these options must be specified in the backend configuration (as shown above).

After the backend is created, Astra Trident creates a corresponding `tridentbackend` CRD and stores the CHAP secrets and usernames as Kubernetes secrets. All PVs that are created by Astra Trident on this backend will be mounted and attached over CHAP.

### Rotate credentials and update backends

You can update the CHAP credentials by updating the CHAP parameters in the `backend.json` file. This will require updating the CHAP secrets and using the `tridentctl update` command to reflect these changes.



When updating the CHAP secrets for a backend, you must use `tridentctl` to update the backend. Do not update the credentials on the storage cluster through the CLI/ONTAP UI as Astra Trident will not be able to pick up these changes.

```
cat backend-san.json
{
  "version": 1,
  "storageDriverName": "ontap-san",
  "backendName": "ontap_san_chap",
  "managementLIF": "192.168.0.135",
  "svm": "ontap_iscsi_svm",
  "useCHAP": true,
  "username": "vsadmin",
  "password": "password",
  "chapInitiatorSecret": "cl9qxUpDaTeD",
  "chapTargetInitiatorSecret": "rqxigXgkeUpDaTeD",
  "chapTargetUsername": "iJF4heBRT0TCwxyz",
  "chapUsername": "uh2aNCLSD6cNwxyz",
}

./tridentctl update backend ontap_san_chap -f backend-san.json -n trident
+-----+-----+-----+-----+
+-----+-----+
| NAME | STORAGE DRIVER | UUID |
STATE | VOLUMES |
+-----+-----+-----+-----+
+-----+-----+
| ontap_san_chap | ontap-san | aa458f3b-ad2d-4378-8a33-1a472ffbeb5c |
online | 7 |
+-----+-----+-----+-----+
+-----+-----+
```

Existing connections will remain unaffected; they will continue to remain active if the credentials are updated by Astra Trident on the SVM. New connections will use the updated credentials and existing connections continue to remain active. Disconnecting and reconnecting old PVs will result in them using the updated credentials.

## ONTAP SAN configuration options and examples

Learn how to create and use ONTAP SAN drivers with your Astra Trident installation. This section provides backend configuration examples and details for mapping backends to StorageClasses.

### Backend configuration options

See the following table for the backend configuration options:

Parameter	Description	Default
version		Always 1

Parameter	Description	Default
storageDriverName	Name of the storage driver	ontap-nas, ontap-nas-economy, ontap-nas-flexgroup, ontap-san, ontap-san-economy
backendName	Custom name or the storage backend	Driver name + "_" + dataLIF
managementLIF	<p>IP address of a cluster or SVM management LIF.</p> <p>A fully-qualified domain name (FQDN) can be specified.</p> <p>Can be set to use IPv6 addresses if Astra Trident was installed using the IPv6 flag. IPv6 addresses must be defined in square brackets, such as [28e8:d9fb:a825:b7bf:69a8:d02f:9e7b:3555].</p> <p>For seamless MetroCluster switchover, see the <a href="#">MetroCluster example</a>.</p>	"10.0.0.1", "[2001:1234:abcd::fefe]"
dataLIF	<p>IP address of protocol LIF.</p> <p><b>Do not specify for iSCSI.</b> Astra Trident uses <a href="#">ONTAP Selective LUN Map</a> to discover the iSCSI LIFs needed to establish a multi path session. A warning is generated if dataLIF is explicitly defined.</p> <p><b>Omit for Metrocluster.</b> See the <a href="#">MetroCluster example</a>.</p>	Derived by the SVM
svm	<p>Storage virtual machine to use</p> <p><b>Omit for Metrocluster.</b> See the <a href="#">MetroCluster example</a>.</p>	Derived if an SVM managementLIF is specified
useCHAP	<p>Use CHAP to authenticate iSCSI for ONTAP SAN drivers [Boolean].</p> <p>Set to true for Astra Trident to configure and use bidirectional CHAP as the default authentication for the SVM given in the backend. Refer to <a href="#">Prepare to configure backend with ONTAP SAN drivers</a> for details.</p>	false
chapInitiatorSecret	CHAP initiator secret. Required if useCHAP=true	""
labels	Set of arbitrary JSON-formatted labels to apply on volumes	""
chapTargetInitiatorSecret	CHAP target initiator secret. Required if useCHAP=true	""

Parameter	Description	Default
chapUsername	Inbound username. Required if useCHAP=true	""
chapTargetUsername	Target username. Required if useCHAP=true	""
clientCertificate	Base64-encoded value of client certificate. Used for certificate-based auth	""
clientPrivateKey	Base64-encoded value of client private key. Used for certificate-based auth	""
trustedCACertificate	Base64-encoded value of trusted CA certificate. Optional. Used for certificate-based authentication.	""
username	Username needed to communicate with the ONTAP cluster. Used for credential-based authentication.	""
password	Password needed to communicate with the ONTAP cluster. Used for credential-based authentication.	""
svm	Storage virtual machine to use	Derived if an SVM managementLIF is specified
storagePrefix	Prefix used when provisioning new volumes in the SVM.  Cannot be modified later. To update this parameter, you will need to create a new backend.	trident
limitAggregateUsage	Fail provisioning if usage is above this percentage.  If you are using an Amazon FSx for NetApp ONTAP backend, do not specify limitAggregateUsage. The provided fsxadmin and vsadmin do not contain the permissions required to retrieve aggregate usage and limit it using Astra Trident.	"" (not enforced by default)
limitVolumeSize	Fail provisioning if requested volume size is above this value.  Also restricts the maximum size of the volumes it manages for qtrees and LUNs.	"" (not enforced by default)
lunsPerFlexvol	Maximum LUNs per Flexvol, must be in range [50, 200]	100
debugTraceFlags	Debug flags to use when troubleshooting. Example, {"api":false, "method":true}  Do not use unless you are troubleshooting and require a detailed log dump.	null

Parameter	Description	Default
useREST	<p>Boolean parameter to use ONTAP REST APIs. <b>Tech preview</b></p> <p>useREST is provided as a <b>tech preview</b> that is recommended for test environments and not for production workloads. When set to <code>true</code>, Astra Trident will use ONTAP REST APIs to communicate with the backend. This feature requires ONTAP 9.11.1 and later. In addition, the ONTAP login role used must have access to the <code>ontap</code> application. This is satisfied by the pre-defined <code>vsadmin</code> and <code>cluster-admin</code> roles.</p> <p>useREST is not supported with MetroCluster.</p> <p>useREST is fully qualified for NVMe/TCP.</p>	false
sanType	Use to select <code>iscsi</code> for iSCSI or <code>nvme</code> for NVMe/TCP.	iscsi if blank

### Backend configuration options for provisioning volumes

You can control default provisioning using these options in the `defaults` section of the configuration. For an example, see the configuration examples below.

Parameter	Description	Default
spaceAllocation	Space-allocation for LUNs	"true"
spaceReserve	Space reservation mode; "none" (thin) or "volume" (thick)	"none"
snapshotPolicy	Snapshot policy to use	"none"
qosPolicy	<p>QoS policy group to assign for volumes created. Choose one of <code>qosPolicy</code> or <code>adaptiveQosPolicy</code> per storage pool/backend.</p> <p>Using QoS policy groups with Astra Trident requires ONTAP 9.8 or later. We recommend using a non-shared QoS policy group and ensuring the policy group is applied to each constituent individually. A shared QoS policy group will enforce the ceiling for the total throughput of all workloads.</p>	""
adaptiveQosPolicy	Adaptive QoS policy group to assign for volumes created. Choose one of <code>qosPolicy</code> or <code>adaptiveQosPolicy</code> per storage pool/backend	""
snapshotReserve	Percentage of volume reserved for snapshots	"0" if <code>snapshotPolicy</code> is "none", otherwise ""

Parameter	Description	Default
splitOnClone	Split a clone from its parent upon creation	"false"
encryption	<p>Enable NetApp Volume Encryption (NVE) on the new volume; defaults to <code>false</code>. NVE must be licensed and enabled on the cluster to use this option.</p> <p>If NAE is enabled on the backend, any volume provisioned in Astra Trident will be NAE enabled.</p> <p>For more information, refer to: <a href="#">How Astra Trident works with NVE and NAE</a>.</p>	"false"
luksEncryption	<p>Enable LUKS encryption. Refer to <a href="#">Use Linux Unified Key Setup (LUKS)</a>.</p> <p>LUKS encryption is not supported for NVMe/TCP.</p>	""
securityStyle	Security style for new volumes	unix
tieringPolicy	Tiering policy to use "none"	"snapshot-only" for pre-ONTAP 9.5 SVM-DR configuration

### Volume provisioning examples

Here's an example with defaults defined:

```
---
version: 1
storageDriverName: ontap-san
managementLIF: 10.0.0.1
svm: trident_svm
username: admin
password: <password>
labels:
  k8scluster: dev2
  backend: dev2-sanbackend
storagePrefix: alternate-trident
debugTraceFlags:
  api: false
  method: true
defaults:
  spaceReserve: volume
  qosPolicy: standard
  spaceAllocation: 'false'
  snapshotPolicy: default
  snapshotReserve: '10'
```



For all volumes created using the `ontap-san` driver, Astra Trident adds an extra 10 percent capacity to the FlexVol to accommodate the LUN metadata. The LUN will be provisioned with the exact size that the user requests in the PVC. Astra Trident adds 10 percent to the FlexVol (shows as Available size in ONTAP). Users will now get the amount of usable capacity they requested. This change also prevents LUNs from becoming read-only unless the available space is fully utilized. This does not apply to `ontap-san-economy`.

For backends that define `snapshotReserve`, Astra Trident calculates the size of volumes as follows:

```
Total volume size = [(PVC requested size) / (1 - (snapshotReserve
percentage) / 100)] * 1.1
```

The 1.1 is the extra 10 percent Astra Trident adds to the FlexVol to accommodate the LUN metadata. For `snapshotReserve` = 5%, and PVC request = 5GiB, the total volume size is 5.79GiB and the available size is 5.50GiB. The `volume show` command should show results similar to this example:

Vserver	Volume	Aggregate	State	Type	Size	Available	Used%
		_pvc_89f1c156_3801_4de4_9f9d_034d54c395f4					
			online	RW	10GB	5.00GB	0%
		_pvc_e42ec6fe_3baa_4af6_996d_134adbbb8e6d					
			online	RW	5.79GB	5.50GB	0%
		_pvc_e8372153_9ad9_474a_951a_08ae15e1c0ba					
			online	RW	1GB	511.8MB	0%

3 entries were displayed.

Currently, resizing is the only way to use the new calculation for an existing volume.

### Minimal configuration examples

The following examples show basic configurations that leave most parameters to default. This is the easiest way to define a backend.



If you are using Amazon FSx on NetApp ONTAP with Astra Trident, we recommend you specify DNS names for LIFs instead of IP addresses.

## ONTAP SAN example

This is a basic configuration using the `ontap-san` driver.

```
---
version: 1
storageDriverName: ontap-san
managementLIF: 10.0.0.1
svm: svm_iscsi
labels:
  k8scluster: test-cluster-1
  backend: testcluster1-sanbackend
username: vsadmin
password: <password>
```

## ONTAP SAN economy example

```
---
version: 1
storageDriverName: ontap-san-economy
managementLIF: 10.0.0.1
svm: svm_iscsi_eco
username: vsadmin
password: <password>
```

## MetroCluster example

You can configure the backend to avoid having to manually update the backend definition after switchover and switchback during [SVM replication and recovery](#).

For seamless switchover and switchback, specify the SVM using `managementLIF` and omit the `dataLIF` and `svm` parameters. For example:

```
---
version: 1
storageDriverName: ontap-san
managementLIF: 192.168.1.66
username: vsadmin
password: password
```

## Certificate-based authentication example

In this basic configuration example `clientCertificate`, `clientPrivateKey`, and `trustedCACertificate` (optional, if using trusted CA) are populated in `backend.json` and take the base64-encoded values of the client certificate, private key, and trusted CA certificate, respectively.

```
---
version: 1
storageDriverName: ontap-san
backendName: DefaultSANBackend
managementLIF: 10.0.0.1
svm: svm_iscsi
useCHAP: true
chapInitiatorSecret: cl9qxIm36DKyawxy
chapTargetInitiatorSecret: rqxigXgkesIpwxyz
chapTargetUsername: iJF4heBRT0TCwxyz
chapUsername: uh2aNCLSD6cNwxyz
clientCertificate: ZXR0ZXJwYXB...ICMgJ3BhcGVyc2
clientPrivateKey: vciwKIyAgZG...0cnksIGRlc2NyaX
trustedCACertificate: zcyBbaG...b3Igb3duIGNsYXNz
```

## Bidirectional CHAP examples

These examples create a backend with `useCHAP` set to `true`.

### ONTAP SAN CHAP example

```
---
version: 1
storageDriverName: ontap-san
managementLIF: 10.0.0.1
svm: svm_iscsi
labels:
  k8scluster: test-cluster-1
  backend: testcluster1-sanbackend
useCHAP: true
chapInitiatorSecret: cl9qxIm36DKyawxy
chapTargetInitiatorSecret: rqxigXgkesIpwxyz
chapTargetUsername: iJF4heBRT0TCwxyz
chapUsername: uh2aNCLSD6cNwxyz
username: vsadmin
password: <password>
```

### ONTAP SAN economy CHAP example

```
---
version: 1
storageDriverName: ontap-san-economy
managementLIF: 10.0.0.1
svm: svm_iscsi_eco
useCHAP: true
chapInitiatorSecret: cl9qxIm36DKyawxy
chapTargetInitiatorSecret: rqxigXgkesIpwxyz
chapTargetUsername: iJF4heBRT0TCwxyz
chapUsername: uh2aNCLSD6cNwxyz
username: vsadmin
password: <password>
```

## NVMe/TCP example

You must have an SVM configured with NVMe on your ONTAP backend. This is a basic backend configuration for NVMe/TCP.

```
---
version: 1
backendName: NVMeBackend
storageDriverName: ontap-san
managementLIF: 10.0.0.1
svm: svm_nvme
username: vsadmin
password: password
sanType: nvme
useREST: true
```

## Examples of backends with virtual pools

In these sample backend definition files, specific defaults are set for all storage pools, such as `spaceReserve` at `none`, `spaceAllocation` at `false`, and `encryption` at `false`. The virtual pools are defined in the storage section.

Astra Trident sets provisioning labels in the "Comments" field. Comments are set on the FlexVol. Astra Trident copies all labels present on a virtual pool to the storage volume at provisioning. For convenience, storage administrators can define labels per virtual pool and group volumes by label.

In these examples, some of the storage pools set their own `spaceReserve`, `spaceAllocation`, and `encryption` values, and some pools override the default values.



```

---
version: 1
storageDriverName: ontap-san
managementLIF: 10.0.0.1
svm: svm_iscsi
useCHAP: true
chapInitiatorSecret: cl9qxIm36DKyawxy
chapTargetInitiatorSecret: rqxigXgkesIpwxyz
chapTargetUsername: iJF4heBRT0TCwxyz
chapUsername: uh2aNCLSD6cNwxyz
username: vsadmin
password: <password>
defaults:
  spaceAllocation: 'false'
  encryption: 'false'
  qosPolicy: standard
labels:
  store: san_store
  kubernetes-cluster: prod-cluster-1
region: us_east_1
storage:
- labels:
  protection: gold
  creditpoints: '40000'
  zone: us_east_1a
  defaults:
    spaceAllocation: 'true'
    encryption: 'true'
    adaptiveQosPolicy: adaptive-extreme
- labels:
  protection: silver
  creditpoints: '20000'
  zone: us_east_1b
  defaults:
    spaceAllocation: 'false'
    encryption: 'true'
    qosPolicy: premium
- labels:
  protection: bronze
  creditpoints: '5000'
  zone: us_east_1c
  defaults:
    spaceAllocation: 'true'
    encryption: 'false'

```

## ONTAP SAN economy example

```
---
version: 1
storageDriverName: ontap-san-economy
managementLIF: 10.0.0.1
svm: svm_iscsi_eco
useCHAP: true
chapInitiatorSecret: cl9qxIm36DKyawxy
chapTargetInitiatorSecret: rqxigXgkesIpwxyz
chapTargetUsername: iJF4heBRT0TCwxyz
chapUsername: uh2aNCLSd6cNwxyz
username: vsadmin
password: <password>
defaults:
  spaceAllocation: 'false'
  encryption: 'false'
labels:
  store: san_economy_store
region: us_east_1
storage:
- labels:
  app: oracledb
  cost: '30'
  zone: us_east_1a
  defaults:
    spaceAllocation: 'true'
    encryption: 'true'
- labels:
  app: postgresdb
  cost: '20'
  zone: us_east_1b
  defaults:
    spaceAllocation: 'false'
    encryption: 'true'
- labels:
  app: mysqldb
  cost: '10'
  zone: us_east_1c
  defaults:
    spaceAllocation: 'true'
    encryption: 'false'
- labels:
  department: legal
  creditpoints: '5000'
  zone: us_east_1c
```

```
defaults:
  spaceAllocation: 'true'
  encryption: 'false'
```

## NVMe/TCP example

```
---
version: 1
storageDriverName: ontap-san
sanType: nvme
managementLIF: 10.0.0.1
svm: nvme_svm
username: vsadmin
password: <password>
useREST: true
defaults:
  spaceAllocation: 'false'
  encryption: 'true'
storage:
- labels:
  app: testApp
  cost: '20'
  defaults:
    spaceAllocation: 'false'
    encryption: 'false'
```

## Map backends to StorageClasses

The following StorageClass definitions refer to the [Examples of backends with virtual pools](#). Using the `parameters.selector` field, each StorageClass calls out which virtual pools can be used to host a volume. The volume will have the aspects defined in the chosen virtual pool.

- The `protection-gold` StorageClass will map to the first virtual pool in the `ontap-san` backend. This is the only pool offering gold-level protection.

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: protection-gold
provisioner: csi.trident.netapp.io
parameters:
  selector: "protection=gold"
  fsType: "ext4"
```

- The `protection-not-gold` StorageClass will map to the second and third virtual pool in `ontap-san` backend. These are the only pools offering a protection level other than gold.

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: protection-not-gold
provisioner: csi.trident.netapp.io
parameters:
  selector: "protection!=gold"
  fsType: "ext4"
```

- The `app-mysqldb` StorageClass will map to the third virtual pool in `ontap-san-economy` backend. This is the only pool offering storage pool configuration for the `mysqldb` type app.

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: app-mysqldb
provisioner: csi.trident.netapp.io
parameters:
  selector: "app=mysqldb"
  fsType: "ext4"
```

- The `protection-silver-creditpoints-20k` StorageClass will map to the second virtual pool in `ontap-san` backend. This is the only pool offering silver-level protection and 20000 creditpoints.

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: protection-silver-creditpoints-20k
provisioner: csi.trident.netapp.io
parameters:
  selector: "protection=silver; creditpoints=20000"
  fsType: "ext4"
```

- The `creditpoints-5k` StorageClass will map to the third virtual pool in `ontap-san` backend and the fourth virtual pool in the `ontap-san-economy` backend. These are the only pool offerings with 5000 creditpoints.

```

apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: creditpoints-5k
provisioner: csi.trident.netapp.io
parameters:
  selector: "creditpoints=5000"
  fsType: "ext4"

```

- The my-test-app-sc StorageClass will map to the testAPP virtual pool in the ontap-san driver with sanType: nvme. This is the only pool offering testApp.

```

---
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: my-test-app-sc
provisioner: csi.trident.netapp.io
parameters:
  selector: "app=testApp"
  fsType: "ext4"

```

Astra Trident will decide which virtual pool is selected and will ensure the storage requirement is met.

## ONTAP NAS drivers

### ONTAP NAS driver overview

Learn about configuring an ONTAP backend with ONTAP and Cloud Volumes ONTAP NAS drivers.

### ONTAP NAS driver details

Astra Trident provides the following NAS storage drivers to communicate with the ONTAP cluster. Supported access modes are: *ReadWriteOnce* (RWO), *ReadOnlyMany* (ROX), *ReadWriteMany* (RWX), *ReadWriteOncePod* (RWOP).



If you are using Astra Control for protection, recovery, and mobility, read [Astra Control driver compatibility](#).

Driver	Protocol	volumeMode	Access modes supported	File systems supported
ontap-nas	NFS SMB	Filesystem	RWO, ROX, RWX, RWOP	"", nfs, smb
ontap-nas-economy	NFS SMB	Filesystem	RWO, ROX, RWX, RWOP	"", nfs, smb
ontap-nas-flexgroup	NFS SMB	Filesystem	RWO, ROX, RWX, RWOP	"", nfs, smb

### Astra Control driver compatibility

Astra Control provides seamless protection, disaster recovery, and mobility (moving volumes between Kubernetes clusters) for volumes created with the `ontap-nas`, `ontap-nas-flexgroup`, and `ontap-san` drivers. Refer to [Astra Control replication prerequisites](#) for details.



- Use `ontap-san-economy` only if persistent volume usage count is expected to be higher than [supported ONTAP volume limits](#).
- Use `ontap-nas-economy` only if persistent volume usage count is expected to be higher than [supported ONTAP volume limits](#) and the `ontap-san-economy` driver cannot be used.
- Do not use `ontap-nas-economy` if you anticipate the need for data protection, disaster recovery, or mobility.

### User permissions

Astra Trident expects to be run as either an ONTAP or SVM administrator, typically using the `admin` cluster user or a `vsadmin` SVM user, or a user with a different name that has the same role.

For Amazon FSx for NetApp ONTAP deployments, Astra Trident expects to be run as either an ONTAP or SVM administrator, using the cluster `fsxadmin` user or a `vsadmin` SVM user, or a user with a different name that has the same role. The `fsxadmin` user is a limited replacement for the cluster admin user.



If you use the `limitAggregateUsage` parameter, cluster admin permissions are required. When using Amazon FSx for NetApp ONTAP with Astra Trident, the `limitAggregateUsage` parameter will not work with the `vsadmin` and `fsxadmin` user accounts. The configuration operation will fail if you specify this parameter.

While it is possible to create a more restrictive role within ONTAP that a Trident driver can use, we don't recommend it. Most new releases of Trident will call additional APIs that would have to be accounted for, making upgrades difficult and error-prone.

## Prepare to configure a backend with ONTAP NAS drivers

Understand the requirements, authentication options, and export policies for configuring an ONTAP backend with ONTAP NAS drivers.

## Requirements

- For all ONTAP backends, Astra Trident requires at least one aggregate assigned to the SVM.
- You can run more than one driver, and create storage classes that point to one or the other. For example, you could configure a Gold class that uses the `ontap-nas` driver and a Bronze class that uses the `ontap-nas-economy` one.
- All your Kubernetes worker nodes must have the appropriate NFS tools installed. Refer to [here](#) for more details.
- Astra Trident supports SMB volumes mounted to pods running on Windows nodes only. Refer to [Prepare to provision SMB volumes](#) for details.

## Authenticate the ONTAP backend

Astra Trident offers two modes of authenticating an ONTAP backend.

- Credential-based: This mode requires sufficient permissions to the ONTAP backend. It is recommended to use an account associated with a pre-defined security login role, such as `admin` or `vsadmin` to ensure maximum compatibility with ONTAP versions.
- Certificate-based: This mode requires a certificate installed on the backend for Astra Trident to communicate with an ONTAP cluster. Here, the backend definition must contain Base64-encoded values of the client certificate, key, and the trusted CA certificate if used (recommended).

You can update existing backends to move between credential-based and certificate-based methods. However, only one authentication method is supported at a time. To switch to a different authentication method, you must remove the existing method from the backend configuration.



If you attempt to provide **both credentials and certificates**, backend creation will fail with an error that more than one authentication method was provided in the configuration file.

## Enable credential-based authentication

Astra Trident requires the credentials to an SVM-scoped/cluster-scoped admin to communicate with the ONTAP backend. It is recommended to make use of standard, pre-defined roles such as `admin` or `vsadmin`. This ensures forward compatibility with future ONTAP releases that might expose feature APIs to be used by future Astra Trident releases. A custom security login role can be created and used with Astra Trident, but is not recommended.

A sample backend definition will look like this:

## YAML

```
---
version: 1
backendName: ExampleBackend
storageDriverName: ontap-nas
managementLIF: 10.0.0.1
dataLIF: 10.0.0.2
svm: svm_nfs
username: vsadmin
password: password
```

## JSON

```
{
  "version": 1,
  "backendName": "ExampleBackend",
  "storageDriverName": "ontap-nas",
  "managementLIF": "10.0.0.1",
  "dataLIF": "10.0.0.2",
  "svm": "svm_nfs",
  "username": "vsadmin",
  "password": "password"
}
```

Keep in mind that the backend definition is the only place the credentials are stored in plain text. After the backend is created, usernames/passwords are encoded with Base64 and stored as Kubernetes secrets. The creation/updating of a backend is the only step that requires knowledge of the credentials. As such, it is an admin-only operation, to be performed by the Kubernetes/storage administrator.

### Enable certificate-based Authentication

New and existing backends can use a certificate and communicate with the ONTAP backend. Three parameters are required in the backend definition.

- `clientCertificate`: Base64-encoded value of client certificate.
- `clientPrivateKey`: Base64-encoded value of associated private key.
- `trustedCACertificate`: Base64-encoded value of trusted CA certificate. If using a trusted CA, this parameter must be provided. This can be ignored if no trusted CA is used.

A typical workflow involves the following steps.

### Steps

1. Generate a client certificate and key. When generating, set Common Name (CN) to the ONTAP user to authenticate as.

```
openssl req -x509 -nodes -days 1095 -newkey rsa:2048 -keyout k8senv.key  
-out k8senv.pem -subj "/C=US/ST=NC/L=RTP/O=NetApp/CN=vsadmin"
```

2. Add trusted CA certificate to the ONTAP cluster. This might be already handled by the storage administrator. Ignore if no trusted CA is used.

```
security certificate install -type server -cert-name <trusted-ca-cert-name> -vserver <vserver-name>  
ssl modify -vserver <vserver-name> -server-enabled true -client-enabled true -common-name <common-name> -serial <SN-from-trusted-CA-cert> -ca <cert-authority>
```

3. Install the client certificate and key (from step 1) on the ONTAP cluster.

```
security certificate install -type client-ca -cert-name <certificate-name> -vserver <vserver-name>  
security ssl modify -vserver <vserver-name> -client-enabled true
```

4. Confirm the ONTAP security login role supports cert authentication method.

```
security login create -user-or-group-name vsadmin -application ontapi -authentication-method cert -vserver <vserver-name>  
security login create -user-or-group-name vsadmin -application http -authentication-method cert -vserver <vserver-name>
```

5. Test authentication using certificate generated. Replace <ONTAP Management LIF> and <vserver name> with Management LIF IP and SVM name. You must ensure the LIF has its service policy set to default-data-management.

```
curl -X POST -Lk https://<ONTAP-Management-LIF>/servlets/netapp.servlets.admin.XMLrequest_filer --key k8senv.key  
--cert ~/k8senv.pem -d '<?xml version="1.0" encoding="UTF-8"?><netapp xmlns="http://www.netapp.com/filer/admin" version="1.21" vfiler="<vserver-name>"><vserver-get></vserver-get></netapp>'
```

6. Encode certificate, key and trusted CA certificate with Base64.

```
base64 -w 0 k8senv.pem >> cert_base64  
base64 -w 0 k8senv.key >> key_base64  
base64 -w 0 trustedca.pem >> trustedca_base64
```

## 7. Create backend using the values obtained from the previous step.

```
cat cert-backend-updated.json
{
  "version": 1,
  "storageDriverName": "ontap-nas",
  "backendName": "NasBackend",
  "managementLIF": "1.2.3.4",
  "dataLIF": "1.2.3.8",
  "svm": "vserver_test",
  "clientCertificate": "Faaaakkkkeeee...Vaaalllluuueeeee",
  "clientPrivateKey": "LS0tFaKE...0VaLuES0tLS0K",
  "storagePrefix": "myPrefix_"
}

#Update backend with tridentctl
tridentctl update backend NasBackend -f cert-backend-updated.json -n
trident
+-----+-----+-----+-----+
+-----+-----+
|      NAME      | STORAGE DRIVER |                UUID                |
STATE | VOLUMES |
+-----+-----+-----+-----+
+-----+-----+
| NasBackend | ontap-nas      | 98e19b74-aec7-4a3d-8dcf-128e5033b214 |
online |          9 |
+-----+-----+-----+-----+
+-----+-----+
```

### Update authentication methods or rotate credentials

You can update an existing backend to use a different authentication method or to rotate their credentials. This works both ways: backends that make use of username/password can be updated to use certificates; backends that utilize certificates can be updated to username/password based. To do this, you must remove the existing authentication method and add the new authentication method. Then use the updated backend.json file containing the required parameters to execute `tridentctl update backend`.

```
cat cert-backend-updated.json
{
  "version": 1,
  "storageDriverName": "ontap-nas",
  "backendName": "NasBackend",
  "managementLIF": "1.2.3.4",
  "dataLIF": "1.2.3.8",
  "svm": "vserver_test",
  "username": "vsadmin",
  "password": "password",
  "storagePrefix": "myPrefix_"
}

#Update backend with tridentctl
tridentctl update backend NasBackend -f cert-backend-updated.json -n
trident

+-----+-----+-----+
+-----+-----+
|      NAME      | STORAGE DRIVER |          UUID          |
STATE | VOLUMES |
+-----+-----+-----+
+-----+-----+
| NasBackend | ontap-nas      | 98e19b74-aec7-4a3d-8dcf-128e5033b214 |
online |          9 |
+-----+-----+-----+
+-----+-----+
```



When rotating passwords, the storage administrator must first update the password for the user on ONTAP. This is followed by a backend update. When rotating certificates, multiple certificates can be added to the user. The backend is then updated to use the new certificate, following which the old certificate can be deleted from the ONTAP cluster.

Updating a backend does not disrupt access to volumes that have already been created, nor impact volume connections made after. A successful backend update indicates that Astra Trident can communicate with the ONTAP backend and handle future volume operations.

## Manage NFS export policies

Astra Trident uses NFS export policies to control access to the volumes that it provisions.

Astra Trident provides two options when working with export policies:

- Astra Trident can dynamically manage the export policy itself; in this mode of operation, the storage administrator specifies a list of CIDR blocks that represent admissible IP addresses. Astra Trident adds node IPs that fall in these ranges to the export policy automatically. Alternatively, when no CIDRs are specified, any global-scoped unicast IP found on the nodes will be added to the export policy.
- Storage administrators can create an export policy and add rules manually. Astra Trident uses the default

export policy unless a different export policy name is specified in the configuration.

### Dynamically manage export policies

Astra Trident provides the ability to dynamically manage export policies for ONTAP backends. This provides the storage administrator the ability to specify a permissible address space for worker node IPs, rather than defining explicit rules manually. It greatly simplifies export policy management; modifications to the export policy no longer require manual intervention on the storage cluster. Moreover, this helps restrict access to the storage cluster only to worker nodes that have IPs in the range specified, supporting a fine-grained and automated management.



Do not use Network Address Translation (NAT) when using dynamic export policies. With NAT, the storage controller sees the frontend NAT address and not the actual IP host address, so access will be denied when no match is found in the export rules.

### Example

There are two configuration options that must be used. Here's an example backend definition:

```
---
version: 1
storageDriverName: ontap-nas
backendName: ontap_nas_auto_export
managementLIF: 192.168.0.135
svm: svm1
username: vsadmin
password: password
autoExportCIDRs:
- 192.168.0.0/24
autoExportPolicy: true
```



When using this feature, you must ensure that the root junction in your SVM has a previously created export policy with an export rule that permits the node CIDR block (such as the default export policy). Always follow NetApp recommended best practice to dedicate an SVM for Astra Trident.

Here is an explanation of how this feature works using the example above:

- `autoExportPolicy` is set to `true`. This indicates that Astra Trident will create an export policy for the `svm1` SVM and handle the addition and deletion of rules using `autoExportCIDRs` address blocks. For example, a backend with UUID `403b5326-8482-40db-96d0-d83fb3f4daec` and `autoExportPolicy` set to `true` creates an export policy named `trident-403b5326-8482-40db-96d0-d83fb3f4daec` on the SVM.
- `autoExportCIDRs` contains a list of address blocks. This field is optional and it defaults to `["0.0.0.0/0", "::/0"]`. If not defined, Astra Trident adds all globally-scoped unicast addresses found on the worker nodes.

In this example, the `192.168.0.0/24` address space is provided. This indicates that Kubernetes node IPs that fall within this address range will be added to the export policy that Astra Trident creates. When Astra Trident registers a node it runs on, it retrieves the IP addresses of the node and checks them against the

address blocks provided in `autoExportCIDRs`. After filtering the IPs, Astra Trident creates export policy rules for the client IPs it discovers, with one rule for each node it identifies.

You can update `autoExportPolicy` and `autoExportCIDRs` for backends after you create them. You can append new CIDRs for a backend that is automatically managed or delete existing CIDRs. Exercise care when deleting CIDRs to ensure that existing connections are not dropped. You can also choose to disable `autoExportPolicy` for a backend and fall back to a manually created export policy. This will require setting the `exportPolicy` parameter in your backend config.

After Astra Trident creates or updates a backend, you can check the backend using `tridentctl` or the corresponding `tridentbackend` CRD:

```
./tridentctl get backends ontap_nas_auto_export -n trident -o yaml
items:
- backendUUID: 403b5326-8482-40db-96d0-d83fb3f4daec
  config:
    aggregate: ""
    autoExportCIDRs:
    - 192.168.0.0/24
    autoExportPolicy: true
    backendName: ontap_nas_auto_export
    chapInitiatorSecret: ""
    chapTargetInitiatorSecret: ""
    chapTargetUsername: ""
    chapUsername: ""
    dataLIF: 192.168.0.135
    debug: false
    debugTraceFlags: null
    defaults:
      encryption: "false"
      exportPolicy: <automatic>
      fileType: ext4
```

As nodes are added to a Kubernetes cluster and registered with the Astra Trident controller, export policies of existing backends are updated (provided they fall in the address range specified in `autoExportCIDRs` for the backend).

When a node is removed, Astra Trident checks all backends that are online to remove the access rule for the node. By removing this node IP from the export policies of managed backends, Astra Trident prevents rogue mounts, unless this IP is reused by a new node in the cluster.

For previously existing backends, updating the backend with `tridentctl update backend` will ensure that Astra Trident manages the export policies automatically. This will create a new export policy named after the backend's UUID and volumes that are present on the backend will use the newly created export policy when they are mounted again.



Deleting a backend with auto-managed export policies will delete the dynamically created export policy. If the backend is re-created, it is treated as a new backend and will result in the creation of a new export policy.

If the IP address of a live node is updated, you must restart the Astra Trident pod on the node. Astra Trident will then update the export policy for backends it manages to reflect this IP change.

## Prepare to provision SMB volumes

With a little additional preparation, you can provision SMB volumes using `ontap-nas` drivers.



You must configure both NFS and SMB/CIFS protocols on the SVM to create an `ontap-nas-economy` SMB volume for ONTAP on-premises. Failure to configure either of these protocols will cause SMB volume creation to fail.

## Before you begin

Before you can provision SMB volumes, you must have the following.

- A Kubernetes cluster with a Linux controller node and at least one Windows worker node running Windows Server 2019. Astra Trident supports SMB volumes mounted to pods running on Windows nodes only.
- At least one Astra Trident secret containing your Active Directory credentials. To generate secret `smbcreds`:

```
kubectl create secret generic smbcreds --from-literal username=user
--from-literal password='password'
```

- A CSI proxy configured as a Windows service. To configure a `csi-proxy`, refer to [GitHub: CSI Proxy](#) or [GitHub: CSI Proxy for Windows](#) for Kubernetes nodes running on Windows.

## Steps

1. For on-premises ONTAP, you can optionally create an SMB share or Astra Trident can create one for you.



SMB shares are required for Amazon FSx for ONTAP.

You can create the SMB admin shares in one of two ways either using the [Microsoft Management Console](#) Shared Folders snap-in or using the ONTAP CLI. To create the SMB shares using the ONTAP CLI:

- a. If necessary, create the directory path structure for the share.

The `vserver cifs share create` command checks the path specified in the `-path` option during share creation. If the specified path does not exist, the command fails.

- b. Create an SMB share associated with the specified SVM:

```
vserver cifs share create -vserver vserver_name -share-name
share_name -path path [-share-properties share_properties,...]
[other_attributes] [-comment text]
```

c. Verify that the share was created:

```
vserver cifs share show -share-name share_name
```



Refer to [Create an SMB share](#) for full details.

2. When creating the backend, you must configure the following to specify SMB volumes. For all FSx for ONTAP backend configuration options, refer to [FSx for ONTAP configuration options and examples](#).

Parameter	Description	Example
smbShare	You can specify one of the following: the name of an SMB share created using the Microsoft Management Console or ONTAP CLI; a name to allow Astra Trident to create the SMB share; or you can leave the parameter blank to prevent common share access to volumes.  This parameter is optional for on-premises ONTAP.  This parameter is required for Amazon FSx for ONTAP backends and cannot be blank.	smb-share
nasType	<b>Must set to smb.</b> If null, defaults to nfs.	smb
securityStyle	Security style for new volumes.  <b>Must be set to ntfs or mixed for SMB volumes.</b>	ntfs or mixed for SMB volumes
unixPermissions	Mode for new volumes. <b>Must be left empty for SMB volumes.</b>	""

## ONTAP NAS configuration options and examples

Learn to create and use ONTAP NAS drivers with your Astra Trident installation. This section provides backend configuration examples and details for mapping backends to StorageClasses.

### Backend configuration options

See the following table for the backend configuration options:

Parameter	Description	Default
version		Always 1
storageDriverName	Name of the storage driver	"ontap-nas", "ontap-nas-economy", "ontap-nas-flexgroup", "ontap-san", "ontap-san-economy"
backendName	Custom name or the storage backend	Driver name + "_" + dataLIF

Parameter	Description	Default
managementLIF	<p>IP address of a cluster or SVM management LIF</p> <p>A fully-qualified domain name (FQDN) can be specified.</p> <p>Can be set to use IPv6 addresses if Astra Trident was installed using the IPv6 flag. IPv6 addresses must be defined in square brackets, such as [28e8:d9fb:a825:b7bf:69a8:d02f:9e7b:3555].</p> <p>For seamless MetroCluster switchover, see the <a href="#">MetroCluster example</a>.</p>	"10.0.0.1", "[2001:1234:abcd::fefe]"
dataLIF	<p>IP address of protocol LIF.</p> <p>We recommend specifying dataLIF. If not provided, Astra Trident fetches data LIFs from the SVM. You can specify a fully-qualified domain name (FQDN) to be used for the NFS mount operations, allowing you to create a round-robin DNS to load-balance across multiple data LIFs.</p> <p>Can be changed after initial setting. Refer to <a href="#">Update dataLIF after initial configuration</a>.</p> <p>Can be set to use IPv6 addresses if Astra Trident was installed using the IPv6 flag. IPv6 addresses must be defined in square brackets, such as [28e8:d9fb:a825:b7bf:69a8:d02f:9e7b:3555].</p> <p><b>Omit for Metrocluster.</b> See the <a href="#">MetroCluster example</a>.</p>	Specified address or derived from SVM, if not specified (not recommended)
svm	<p>Storage virtual machine to use</p> <p><b>Omit for Metrocluster.</b> See the <a href="#">MetroCluster example</a>.</p>	Derived if an SVM managementLIF is specified
autoExportPolicy	<p>Enable automatic export policy creation and updating [Boolean].</p> <p>Using the autoExportPolicy and autoExportCIDRs options, Astra Trident can manage export policies automatically.</p>	false
autoExportCIDRs	<p>List of CIDRs to filter Kubernetes' node IPs against when autoExportPolicy is enabled.</p> <p>Using the autoExportPolicy and autoExportCIDRs options, Astra Trident can manage export policies automatically.</p>	["0.0.0.0/0", ":::0"]

Parameter	Description	Default
labels	Set of arbitrary JSON-formatted labels to apply on volumes	""
clientCertificate	Base64-encoded value of client certificate. Used for certificate-based auth	""
clientPrivateKey	Base64-encoded value of client private key. Used for certificate-based auth	""
trustedCACertificate	Base64-encoded value of trusted CA certificate. Optional. Used for certificate-based auth	""
username	Username to connect to the cluster/SVM. Used for credential-based auth	
password	Password to connect to the cluster/SVM. Used for credential-based auth	
storagePrefix	Prefix used when provisioning new volumes in the SVM. Cannot be updated after you set it	"trident"
limitAggregateUsage	Fail provisioning if usage is above this percentage.  <b>Does not apply to Amazon FSx for ONTAP</b>	"" (not enforced by default)
limitVolumeSize	Fail provisioning if requested volume size is above this value.  Also restricts the maximum size of the volumes it manages for qtrees and LUNs, and the qtreesPerFlexvol option allows customizing the maximum number of qtrees per FlexVol.	"" (not enforced by default)
lunsPerFlexvol	Maximum LUNs per Flexvol, must be in range [50, 200]	"100"
debugTraceFlags	Debug flags to use when troubleshooting. Example, {"api":false, "method":true}  Do not use debugTraceFlags unless you are troubleshooting and require a detailed log dump.	null
nasType	Configure NFS or SMB volumes creation.  Options are nfs, smb or null. Setting to null defaults to NFS volumes.	nfs

Parameter	Description	Default
nfsMountOptions	<p>Comma-separated list of NFS mount options.</p> <p>The mount options for Kubernetes-persistent volumes are normally specified in storage classes, but if no mount options are specified in a storage class, Astra Trident will fall back to using the mount options specified in the storage backend's configuration file.</p> <p>If no mount options are specified in the storage class or the configuration file, Astra Trident will not set any mount options on an associated persistent volume.</p>	""
qtreesPerFlexvol	Maximum Qtrees per FlexVol, must be in range [50, 300]	"200"
smbShare	<p>You can specify one of the following: the name of an SMB share created using the Microsoft Management Console or ONTAP CLI; a name to allow Astra Trident to create the SMB share; or you can leave the parameter blank to prevent common share access to volumes.</p> <p>This parameter is optional for on-premises ONTAP.</p> <p>This parameter is required for Amazon FSx for ONTAP backends and cannot be blank.</p>	smb-share
useREST	<p>Boolean parameter to use ONTAP REST APIs. <b>Tech preview</b></p> <p>useREST is provided as a <b>tech preview</b> that is recommended for test environments and not for production workloads. When set to <code>true</code>, Astra Trident will use ONTAP REST APIs to communicate with the backend. This feature requires ONTAP 9.11.1 and later. In addition, the ONTAP login role used must have access to the <code>ontap</code> application. This is satisfied by the pre-defined <code>vsadmin</code> and <code>cluster-admin</code> roles.</p> <p>useREST is not supported with MetroCluster.</p>	false

## Backend configuration options for provisioning volumes

You can control default provisioning using these options in the `defaults` section of the configuration. For an example, see the configuration examples below.

Parameter	Description	Default
spaceAllocation	Space-allocation for LUNs	"true"

Parameter	Description	Default
spaceReserve	Space reservation mode; "none" (thin) or "volume" (thick)	"none"
snapshotPolicy	Snapshot policy to use	"none"
qosPolicy	QoS policy group to assign for volumes created. Choose one of qosPolicy or adaptiveQosPolicy per storage pool/backend	""
adaptiveQosPolicy	Adaptive QoS policy group to assign for volumes created. Choose one of qosPolicy or adaptiveQosPolicy per storage pool/backend.  Not supported by ontap-nas-economy.	""
snapshotReserve	Percentage of volume reserved for snapshots	"0" if snapshotPolicy is "none", otherwise ""
splitOnClone	Split a clone from its parent upon creation	"false"
encryption	Enable NetApp Volume Encryption (NVE) on the new volume; defaults to false. NVE must be licensed and enabled on the cluster to use this option.  If NAE is enabled on the backend, any volume provisioned in Astra Trident will be NAE enabled.  For more information, refer to: <a href="#">How Astra Trident works with NVE and NAE</a> .	"false"
tieringPolicy	Tiering policy to use "none"	"snapshot-only" for pre-ONTAP 9.5 SVM-DR configuration
unixPermissions	Mode for new volumes	"777" for NFS volumes; empty (not applicable) for SMB volumes
snapshotDir	Controls access to the .snapshot directory	"false"
exportPolicy	Export policy to use	"default"
securityStyle	Security style for new volumes.  NFS supports mixed and unix security styles.  SMB supports mixed and ntfs security styles.	NFS default is unix.  SMB default is ntfs.



Using QoS policy groups with Astra Trident requires ONTAP 9.8 or later. It is recommended to use a non-shared QoS policy group and ensure the policy group is applied to each constituent individually. A shared QoS policy group will enforce the ceiling for the total throughput of all workloads.

### Volume provisioning examples

Here's an example with defaults defined:

```

---
version: 1
storageDriverName: ontap-nas
backendName: customBackendName
managementLIF: 10.0.0.1
dataLIF: 10.0.0.2
labels:
  k8scluster: dev1
  backend: dev1-nasbackend
svm: trident_svm
username: cluster-admin
password: <password>
limitAggregateUsage: 80%
limitVolumeSize: 50Gi
nfsMountOptions: nfsvers=4
debugTraceFlags:
  api: false
  method: true
defaults:
  spaceReserve: volume
  qosPolicy: premium
  exportPolicy: myk8scluster
  snapshotPolicy: default
  snapshotReserve: '10'

```

For `ontap-nas` and `ontap-nas-flexgroups`, Astra Trident now uses a new calculation to ensure that the FlexVol is sized correctly with the `snapshotReserve` percentage and PVC. When the user requests a PVC, Astra Trident creates the original FlexVol with more space by using the new calculation. This calculation ensures that the user receives the writable space they requested for in the PVC, and not lesser space than what they requested. Before v21.07, when the user requests a PVC (for example, 5GiB), with the `snapshotReserve` to 50 percent, they get only 2.5GiB of writeable space. This is because what the user requested for is the whole volume and `snapshotReserve` is a percentage of that. With Trident 21.07, what the user requests for is the writeable space and Astra Trident defines the `snapshotReserve` number as the percentage of the whole volume. This does not apply to `ontap-nas-economy`. See the following example to see how this works:

The calculation is as follows:

```

Total volume size = (PVC requested size) / (1 - (snapshotReserve
percentage) / 100)

```

For `snapshotReserve` = 50%, and PVC request = 5GiB, the total volume size is  $2/.5 = 10\text{GiB}$  and the available size is 5GiB, which is what the user requested in the PVC request. The `volume show` command should show results similar to this example:

Vserver	Volume	Aggregate	State	Type	Size	Available	Used%
		_pvc_89f1c156_3801_4de4_9f9d_034d54c395f4	online	RW	10GB	5.00GB	0%
		_pvc_e8372153_9ad9_474a_951a_08ae15e1c0ba	online	RW	1GB	511.8MB	0%

2 entries were displayed.

Existing backends from previous installs will provision volumes as explained above when upgrading Astra Trident. For volumes that you created before upgrading, you should resize their volumes for the change to be observed. For example, a 2GiB PVC with `snapshotReserve=50` earlier resulted in a volume that provides 1GiB of writable space. Resizing the volume to 3GiB, for example, provides the application with 3GiB of writable space on a 6 GiB volume.

### Minimal configuration examples

The following examples show basic configurations that leave most parameters to default. This is the easiest way to define a backend.



If you are using Amazon FSx on NetApp ONTAP with Trident, the recommendation is to specify DNS names for LIFs instead of IP addresses.

#### ONTAP NAS economy example

```
---
version: 1
storageDriverName: ontap-nas-economy
managementLIF: 10.0.0.1
dataLIF: 10.0.0.2
svm: svm_nfs
username: vsadmin
password: password
```

#### ONTAP NAS Flexgroup example

```
---
version: 1
storageDriverName: ontap-nas-flexgroup
managementLIF: 10.0.0.1
dataLIF: 10.0.0.2
svm: svm_nfs
username: vsadmin
password: password
```

## MetroCluster example

You can configure the backend to avoid having to manually update the backend definition after switchover and switchback during [SVM replication and recovery](#).

For seamless switchover and switchback, specify the SVM using `managementLIF` and omit the `dataLIF` and `svm` parameters. For example:

```
---
version: 1
storageDriverName: ontap-nas
managementLIF: 192.168.1.66
username: vsadmin
password: password
```

## SMB volumes example

```
---
version: 1
backendName: ExampleBackend
storageDriverName: ontap-nas
managementLIF: 10.0.0.1
nasType: smb
securityStyle: ntfs
unixPermissions: ""
dataLIF: 10.0.0.2
svm: svm_nfs
username: vsadmin
password: password
```

## Certificate-based authentication example

This is a minimal backend configuration example. `clientCertificate`, `clientPrivateKey`, and `trustedCACertificate` (optional, if using trusted CA) are populated in `backend.json` and take the base64-encoded values of the client certificate, private key, and trusted CA certificate, respectively.

```
---
version: 1
backendName: DefaultNASBackend
storageDriverName: ontap-nas
managementLIF: 10.0.0.1
dataLIF: 10.0.0.15
svm: nfs_svm
clientCertificate: ZXR0ZXJwYXB...ICMgJ3BhcGVyc2
clientPrivateKey: vciwKIyAgZG...0cnksIGRlc2NyaX
trustedCACertificate: zcyBbaG...b3Igb3duIGNsYXNz
storagePrefix: myPrefix_
```

## Auto export policy example

This example shows you how you can instruct Astra Trident to use dynamic export policies to create and manage the export policy automatically. This works the same for the `ontap-nas-economy` and `ontap-nas-flexgroup` drivers.

```
---
version: 1
storageDriverName: ontap-nas
managementLIF: 10.0.0.1
dataLIF: 10.0.0.2
svm: svm_nfs
labels:
  k8scluster: test-cluster-east-1a
  backend: test1-nasbackend
autoExportPolicy: true
autoExportCIDRs:
- 10.0.0.0/24
username: admin
password: password
nfsMountOptions: nfsvers=4
```

## IPv6 addresses example

This example shows managementLIF using an IPv6 address.

```
---
version: 1
storageDriverName: ontap-nas
backendName: nas_ipv6_backend
managementLIF: "[5c5d:5edf:8f:7657:bef8:109b:1b41:d491]"
labels:
  k8scluster: test-cluster-east-1a
  backend: test1-ontap-ipv6
svm: nas_ipv6_svm
username: vsadmin
password: password
```

## Amazon FSx for ONTAP using SMB volumes example

The smbShare parameter is required for FSx for ONTAP using SMB volumes.

```
---
version: 1
backendName: SMBBackend
storageDriverName: ontap-nas
managementLIF: example.mgmt.fqdn.aws.com
nasType: smb
dataLIF: 10.0.0.15
svm: nfs_svm
smbShare: smb-share
clientCertificate: ZXR0ZXJwYXB...ICMgJ3BhcGVyc2
clientPrivateKey: vciwKIyAgZG...0cnksIGRlc2NyaX
trustedCACertificate: zcyBbaG...b3Igb3duIGNsYXNz
storagePrefix: myPrefix_
```

## Examples of backends with virtual pools

In the sample backend definition files shown below, specific defaults are set for all storage pools, such as spaceReserve at none, spaceAllocation at false, and encryption at false. The virtual pools are defined in the storage section.

Astra Trident sets provisioning labels in the "Comments" field. Comments are set on FlexVol for ontap-nas or FlexGroup for ontap-nas-flexgroup. Astra Trident copies all labels present on a virtual pool to the storage volume at provisioning. For convenience, storage administrators can define labels per virtual pool and group volumes by label.

In these examples, some of the storage pools set their own `spaceReserve`, `spaceAllocation`, and `encryption` values, and some pools override the default values.

## ONTAP NAS example

```
---
version: 1
storageDriverName: ontap-nas
managementLIF: 10.0.0.1
svm: svm_nfs
username: admin
password: <password>
nfsMountOptions: nfsvers=4
defaults:
  spaceReserve: none
  encryption: 'false'
  qosPolicy: standard
labels:
  store: nas_store
  k8scluster: prod-cluster-1
region: us_east_1
storage:
- labels:
  app: msoffice
  cost: '100'
  zone: us_east_1a
  defaults:
    spaceReserve: volume
    encryption: 'true'
    unixPermissions: '0755'
    adaptiveQosPolicy: adaptive-premium
- labels:
  app: slack
  cost: '75'
  zone: us_east_1b
  defaults:
    spaceReserve: none
    encryption: 'true'
    unixPermissions: '0755'
- labels:
  department: legal
  creditpoints: '5000'
  zone: us_east_1b
  defaults:
    spaceReserve: none
    encryption: 'true'
    unixPermissions: '0755'
- labels:
  app: wordpress
```

```
    cost: '50'
  zone: us_east_1c
  defaults:
    spaceReserve: none
    encryption: 'true'
    unixPermissions: '0775'
- labels:
  app: mysqldb
  cost: '25'
  zone: us_east_1d
  defaults:
    spaceReserve: volume
    encryption: 'false'
    unixPermissions: '0775'
```

## ONTAP NAS FlexGroup example

```
---
version: 1
storageDriverName: ontap-nas-flexgroup
managementLIF: 10.0.0.1
svm: svm_nfs
username: vsadmin
password: <password>
defaults:
  spaceReserve: none
  encryption: 'false'
labels:
  store: flexgroup_store
  k8scluster: prod-cluster-1
region: us_east_1
storage:
- labels:
  protection: gold
  creditpoints: '50000'
  zone: us_east_1a
  defaults:
    spaceReserve: volume
    encryption: 'true'
    unixPermissions: '0755'
- labels:
  protection: gold
  creditpoints: '30000'
  zone: us_east_1b
  defaults:
    spaceReserve: none
    encryption: 'true'
    unixPermissions: '0755'
- labels:
  protection: silver
  creditpoints: '20000'
  zone: us_east_1c
  defaults:
    spaceReserve: none
    encryption: 'true'
    unixPermissions: '0775'
- labels:
  protection: bronze
  creditpoints: '10000'
  zone: us_east_1d
  defaults:
```

```
spaceReserve: volume  
encryption: 'false'  
unixPermissions: '0775'
```

## ONTAP NAS economy example

```
---
version: 1
storageDriverName: ontap-nas-economy
managementLIF: 10.0.0.1
svm: svm_nfs
username: vsadmin
password: <password>
defaults:
  spaceReserve: none
  encryption: 'false'
labels:
  store: nas_economy_store
region: us_east_1
storage:
- labels:
  department: finance
  creditpoints: '6000'
  zone: us_east_1a
  defaults:
    spaceReserve: volume
    encryption: 'true'
    unixPermissions: '0755'
- labels:
  protection: bronze
  creditpoints: '5000'
  zone: us_east_1b
  defaults:
    spaceReserve: none
    encryption: 'true'
    unixPermissions: '0755'
- labels:
  department: engineering
  creditpoints: '3000'
  zone: us_east_1c
  defaults:
    spaceReserve: none
    encryption: 'true'
    unixPermissions: '0775'
- labels:
  department: humanresource
  creditpoints: '2000'
  zone: us_east_1d
  defaults:
    spaceReserve: volume
```

```
encryption: 'false'
unixPermissions: '0775'
```

## Map backends to StorageClasses

The following StorageClass definitions refer to [Examples of backends with virtual pools](#). Using the `parameters.selector` field, each StorageClass calls out which virtual pools can be used to host a volume. The volume will have the aspects defined in the chosen virtual pool.

- The `protection-gold` StorageClass will map to the first and second virtual pool in the `ontap-nas-flexgroup` backend. These are the only pools offering gold level protection.

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: protection-gold
provisioner: csi.trident.netapp.io
parameters:
  selector: "protection=gold"
  fsType: "ext4"
```

- The `protection-not-gold` StorageClass will map to the third and fourth virtual pool in the `ontap-nas-flexgroup` backend. These are the only pools offering protection level other than gold.

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: protection-not-gold
provisioner: csi.trident.netapp.io
parameters:
  selector: "protection!=gold"
  fsType: "ext4"
```

- The `app-mysqldb` StorageClass will map to the fourth virtual pool in the `ontap-nas` backend. This is the only pool offering storage pool configuration for `mysqldb` type app.

```

apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: app-mysqldb
provisioner: csi.trident.netapp.io
parameters:
  selector: "app=mysqldb"
  fsType: "ext4"

```

- The protection-silver-creditpoints-20k StorageClass will map to the third virtual pool in the ontap-nas-flexgroup backend. This is the only pool offering silver-level protection and 20000 creditpoints.

```

apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: protection-silver-creditpoints-20k
provisioner: csi.trident.netapp.io
parameters:
  selector: "protection=silver; creditpoints=20000"
  fsType: "ext4"

```

- The creditpoints-5k StorageClass will map to the third virtual pool in the ontap-nas backend and the second virtual pool in the ontap-nas-economy backend. These are the only pool offerings with 5000 creditpoints.

```

apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: creditpoints-5k
provisioner: csi.trident.netapp.io
parameters:
  selector: "creditpoints=5000"
  fsType: "ext4"

```

Astra Trident will decide which virtual pool is selected and will ensure the storage requirement is met.

### Update dataLIF after initial configuration

You can change the data LIF after initial configuration by running the following command to provide the new backend JSON file with updated data LIF.

```
tridentctl update backend <backend-name> -f <path-to-backend-json-file-with-updated-dataLIF>
```



If PVCs are attached to one or multiple pods, you must bring down all corresponding pods and then bring them back up in order for the new data LIF to take effect.

## Amazon FSx for NetApp ONTAP

### Use Astra Trident with Amazon FSx for NetApp ONTAP

[Amazon FSx for NetApp ONTAP](#) is a fully managed AWS service that enables customers to launch and run file systems powered by the NetApp ONTAP storage operating system. FSx for ONTAP enables you to leverage NetApp features, performance, and administrative capabilities you are familiar with, while taking advantage of the simplicity, agility, security, and scalability of storing data on AWS. FSx for ONTAP supports ONTAP file system features and administration APIs.

#### Overview

A file system is the primary resource in Amazon FSx, analogous to an ONTAP cluster on premises. Within each SVM you can create one or multiple volumes, which are data containers that store the files and folders in your file system. With Amazon FSx for NetApp ONTAP, Data ONTAP will be provided as a managed file system in the cloud. The new file system type is called **NetApp ONTAP**.

Using Astra Trident with Amazon FSx for NetApp ONTAP, you can ensure Kubernetes clusters running in Amazon Elastic Kubernetes Service (EKS) can provision block and file persistent volumes backed by ONTAP.

#### Considerations

- SMB volumes:
  - SMB volumes are supported using the `ontap-nas` driver only.
  - SMB volumes are not supported with Astra Trident EKS add-on.
  - Astra Trident supports SMB volumes mounted to pods running on Windows nodes only.
- Prior to Astra Trident 24.02, volumes created on Amazon FSx file systems that have automatic backups enabled, could not be deleted by Trident. To prevent this issue in Astra Trident 24.02 or later, specify the `fsxFileSystemID`, `AWS apiRegion`, `AWS apikey`, and `AWS secretKey` in the backend configuration file for AWS FSx for ONTAP.



If you are specifying an IAM role to Astra Trident, then you can omit specifying the `apiRegion`, `apiKey`, and `secretKey` fields to Astra Trident explicitly. For more information, refer to [FSx for ONTAP configuration options and examples](#).

#### FSx for ONTAP driver details

You can integrate Astra Trident with Amazon FSx for NetApp ONTAP using the following drivers:

- `ontap-san`: Each PV provisioned is a LUN within its own Amazon FSx for NetApp ONTAP volume.
- `ontap-san-economy`: Each PV provisioned is a LUN with a configurable number of LUNs per Amazon FSx for NetApp ONTAP volume.
- `ontap-nas`: Each PV provisioned is a full Amazon FSx for NetApp ONTAP volume.
- `ontap-nas-economy`: Each PV provisioned is a qtree, with a configurable number of qtrees per Amazon FSx for NetApp ONTAP volume.
- `ontap-nas-flexgroup`: Each PV provisioned is a full Amazon FSx for NetApp ONTAP FlexGroup volume.

For driver details, refer to [NAS drivers](#) and [SAN drivers](#).

## Authentication

Astra Trident offers two modes of authentication.

- **Certificate-based**: Astra Trident will communicate with the SVM on your FSx file system using a certificate installed on your SVM.
- **Credential-based**: You can use the `fsxadmin` user for your file system or the `vsadmin` user configured for your SVM.



Astra Trident expects to be run as a `vsadmin` SVM user or as a user with a different name that has the same role. Amazon FSx for NetApp ONTAP has an `fsxadmin` user that is a limited replacement of the ONTAP `admin` cluster user. We strongly recommend using `vsadmin` with Astra Trident.

You can update backends to move between credential-based and certificate-based methods. However, if you attempt to provide **credentials and certificates**, backend creation will fail. To switch to a different authentication method, you must remove the existing method from the backend configuration.

For details on enabling authentication, refer to the authentication for your driver type:

- [ONTAP NAS authentication](#)
- [ONTAP SAN authentication](#)

## Cloud identity for EKS

Cloud identity enables Kubernetes pods to access AWS resources by authenticating as an AWS IAM role instead of by providing explicit AWS credentials.

To take advantage of cloud identity in AWS, you must have:

- A Kubernetes cluster deployed using EKS
- Astra Trident installed that includes the `cloudProvider` specifying "AWS" and `cloudIdentity` specifying AWS IAM role.

## Trident operator

To install Astra Trident using the Trident operator, edit `tridentorchestrator_cr.yaml` to set `cloudProvider` to "AWS" and set `cloudIdentity` to AWS IAM role.

For example:

```
apiVersion: trident.netapp.io/v1
kind: TridentOrchestrator
metadata:
  name: trident
spec:
  debug: true
  namespace: trident
  imagePullPolicy: IfNotPresent
  cloudProvider: "AWS"
  cloudIdentity: "'eks.amazonaws.com/role-arn:
arn:aws:iam::123456:role/astratrident-role'"
```

## Helm

Set the values for **cloud provider** and **cloud identity** flags using the following environment variables:

```
export CP="AWS"
export CI="'eks.amazonaws.com/role-arn:
arn:aws:iam::123456:role/astratrident-role'"
```

The following example installs Astra Trident and sets `cloudProvider` to AWS using the environment variable `$CP` and sets the 'cloudIdentity' using the environment variable `$CI`:

```
helm install trident trident-operator-100.2402.0.tgz --set
cloudProvider=$CP --set cloudIdentity=$CI
```

`tridentctl`

Set the values for **cloud provider** and **cloud identity** flags using the following environment variables:

```
export CP="AWS"
export CI="'eks.amazonaws.com/role-arn:
arn:aws:iam::123456:role/astratrident-role'"
```

The following example installs Astra Trident and sets the `cloud-provider` flag to `$CP`, and `cloud-identity` to `$CI`:

```
tridentctl install --cloud-provider=$CP --cloud-identity="$CI" -n
trident
```

## Find more information

- [Amazon FSx for NetApp ONTAP documentation](#)
- [Blog post on Amazon FSx for NetApp ONTAP](#)

## Integrate Amazon FSx for NetApp ONTAP

You can integrate your Amazon FSx for NetApp ONTAP file system with Astra Trident to ensure Kubernetes clusters running in Amazon Elastic Kubernetes Service (EKS) can provision block and file persistent volumes backed by ONTAP.

### Requirements

In addition to [Astra Trident requirements](#), to integrate FSx for ONTAP with Astra Trident, you need:

- An existing Amazon EKS cluster or self-managed Kubernetes cluster with `kubectl` installed.
- An existing Amazon FSx for NetApp ONTAP file system and storage virtual machine (SVM) that is reachable from your cluster's worker nodes.
- Worker nodes that are prepared for [NFS or iSCSI](#).



Ensure you follow the node preparation steps required for Amazon Linux and Ubuntu [Amazon Machine Images](#) (AMIs) depending on your EKS AMI type.

- Astra Trident supports SMB volumes mounted to pods running on Windows nodes only. Refer to [Prepare to provision SMB volumes](#) for details.

### ONTAP SAN and NAS driver integration



If you are configuring for SMB volumes, you must read [Prepare to provision SMB volumes](#) before creating the backend.

### Steps

1. Deploy Astra Trident using one of the [deployment methods](#).
2. Collect your SVM management LIF DNS name. For example, using the AWS CLI, find the `DNSName` entry under `Endpoints` → `Management` after running the following command:

```
aws fsx describe-storage-virtual-machines --region <file system region>
```

3. Create and install certificates for [NAS backend authentication](#) or [SAN backend authentication](#).



You can log in to your file system (for example to install certificates) using SSH from anywhere that can reach your file system. Use the `fsxadmin` user, the password you configured when you created your file system, and the management DNS name from `aws fsx describe-file-systems`.

4. Create a backend file using your certificates and the DNS name of your management LIF, as shown in the sample below:

## YAML

```
version: 1
storageDriverName: ontap-san
backendName: customBackendName
managementLIF: svm-XXXXXXXXXXXXXXXXXX.fs-XXXXXXXXXXXXXXXXXXXX.fsx.us-
east-2.aws.internal
svm: svm01
clientCertificate: ZXR0ZXJwYXB...ICMgJ3BhcGVyc2
clientPrivateKey: vciwKIyAgZG...0cnksIGRlc2NyaX
trustedCACertificate: zcyBbaG...b3Igb3duIGNsYXNz
```

## JSON

```
{
  "version": 1,
  "storageDriverName": "ontap-san",
  "backendName": "customBackendName",
  "managementLIF": "svm-XXXXXXXXXXXXXXXXXX.fs-
XXXXXXXXXXXXXXXXXXXX.fsx.us-east-2.aws.internal",
  "svm": "svm01",
  "clientCertificate": "ZXR0ZXJwYXB...ICMgJ3BhcGVyc2",
  "clientPrivateKey": "vciwKIyAgZG...0cnksIGRlc2NyaX",
  "trustedCACertificate": "zcyBbaG...b3Igb3duIGNsYXNz"
}
```

Alternatively, you can create a backend file using the SVM credentials (username and password) stored in AWS Secret Manager as shown in this example:

## YAML

```
apiVersion: trident.netapp.io/v1
kind: TridentBackendConfig
metadata:
  name: backend-tbc-ontap-nas
spec:
  version: 1
  storageDriverName: ontap-nas
  backendName: tbc-ontap-nas
  svm: svm-name
  aws:
    fsxFileSystemID: fs-xxxxxxxxxx
  managementLIF:
  credentials:
    name: "arn:aws:secretsmanager:us-west-2:xxxxxxx:secret:secret-
name"
    type: awsarn
```

## JSON

```
{
  "apiVersion": "trident.netapp.io/v1",
  "kind": "TridentBackendConfig",
  "metadata": {
    "name": "backend-tbc-ontap-nas"
  },
  "spec": {
    "version": 1,
    "storageDriverName": "ontap-nas",
    "backendName": "tbc-ontap-nas",
    "svm": "svm-name",
    "aws": {
      "fsxFileSystemID": "fs-xxxxxxxxxx"
    },
    "managementLIF": null,
    "credentials": {
      "name": "arn:aws:secretsmanager:us-west-
2:xxxxxxx:secret:secret-name",
      "type": "awsarn"
    }
  }
}
```

For information about creating backends, see these links:

- [Configure a backend with ONTAP NAS drivers](#)
- [Configure a backend with ONTAP SAN drivers](#)

## Prepare to provision SMB volumes

You can provision SMB volumes using the `ontap-nas` driver. Before you complete [ONTAP SAN and NAS driver integration](#) complete the following steps.

### Before you begin

Before you can provision SMB volumes using the `ontap-nas` driver, you must have the following.

- A Kubernetes cluster with a Linux controller node and at least one Windows worker node running Windows Server 2019. Astra Trident supports SMB volumes mounted to pods running on Windows nodes only.
- At least one Astra Trident secret containing your Active Directory credentials. To generate secret `smbcreds`:

```
kubectl create secret generic smbcreds --from-literal username=user
--from-literal password='password'
```

- A CSI proxy configured as a Windows service. To configure a `csi-proxy`, refer to [GitHub: CSI Proxy](#) or [GitHub: CSI Proxy for Windows](#) for Kubernetes nodes running on Windows.

### Steps

1. Create SMB shares. You can create the SMB admin shares in one of two ways either using the [Microsoft Management Console](#) Shared Folders snap-in or using the ONTAP CLI. To create the SMB shares using the ONTAP CLI:

- a. If necessary, create the directory path structure for the share.

The `vserver cifs share create` command checks the path specified in the `-path` option during share creation. If the specified path does not exist, the command fails.

- b. Create an SMB share associated with the specified SVM:

```
vserver cifs share create -vserver vserver_name -share-name
share_name -path path [-share-properties share_properties,...]
[other_attributes] [-comment text]
```

- c. Verify that the share was created:

```
vserver cifs share show -share-name share_name
```



Refer to [Create an SMB share](#) for full details.

2. When creating the backend, you must configure the following to specify SMB volumes. For all FSx for

ONTAP backend configuration options, refer to [FSx for ONTAP configuration options and examples](#).

Parameter	Description	Example
smbShare	You can specify one of the following: the name of an SMB share created using the Microsoft Management Console or ONTAP CLI or a name to allow Astra Trident to create the SMB share.  This parameter is required for Amazon FSx for ONTAP backends.	smb-share
nasType	<b>Must set to smb.</b> If null, defaults to nfs.	smb
securityStyle	Security style for new volumes.  <b>Must be set to ntfs or mixed for SMB volumes.</b>	ntfs or mixed for SMB volumes
unixPermissions	Mode for new volumes. <b>Must be left empty for SMB volumes.</b>	""

## FSx for ONTAP configuration options and examples

Learn about backend configuration options for Amazon FSx for ONTAP. This section provides backend configuration examples.

### Backend configuration options

See the following table for the backend configuration options:

Parameter	Description	Example
version		Always 1
storageDriverName	Name of the storage driver	ontap-nas, ontap-nas-economy, ontap-nas-flexgroup, ontap-san, ontap-san-economy
backendName	Custom name or the storage backend	Driver name + “_” + dataLIF

Parameter	Description	Example
managementLIF	<p>IP address of a cluster or SVM management LIF</p> <p>A fully-qualified domain name (FQDN) can be specified.</p> <p>Can be set to use IPv6 addresses if Astra Trident was installed using the IPv6 flag. IPv6 addresses must be defined in square brackets, such as [28e8:d9fb:a825:b7bf:69a8:d02f:9e7b:3555].</p>	"10.0.0.1", "[2001:1234:abcd::fefe]"
dataLIF	<p>IP address of protocol LIF.</p> <p><b>ONTAP NAS drivers:</b> We recommend specifying dataLIF. If not provided, Astra Trident fetches data LIFs from the SVM. You can specify a fully-qualified domain name (FQDN) to be used for the NFS mount operations, allowing you to create a round-robin DNS to load-balance across multiple data LIFs. Can be changed after initial setting. Refer to <a href="#">Update dataLIF after initial configuration</a>.</p> <p><b>ONTAP SAN drivers:</b> Do not specify for iSCSI. Astra Trident uses ONTAP Selective LUN Map to discover the iSCSI LIFs needed to establish a multi path session. A warning is generated if dataLIF is explicitly defined.</p> <p>Can be set to use IPv6 addresses if Astra Trident was installed using the IPv6 flag. IPv6 addresses must be defined in square brackets, such as [28e8:d9fb:a825:b7bf:69a8:d02f:9e7b:3555].</p>	
autoExportPolicy	<p>Enable automatic export policy creation and updating [Boolean].</p> <p>Using the <code>autoExportPolicy</code> and <code>autoExportCIDRs</code> options, Astra Trident can manage export policies automatically.</p>	false

Parameter	Description	Example
autoExportCIDRs	<p>List of CIDRs to filter Kubernetes' node IPs against when <code>autoExportPolicy</code> is enabled.</p> <p>Using the <code>autoExportPolicy</code> and <code>autoExportCIDRs</code> options, Astra Trident can manage export policies automatically.</p>	<code>"["0.0.0.0/0", "::/0"]"</code>
labels	Set of arbitrary JSON-formatted labels to apply on volumes	<code>""</code>
clientCertificate	Base64-encoded value of client certificate. Used for certificate-based auth	<code>""</code>
clientPrivateKey	Base64-encoded value of client private key. Used for certificate-based auth	<code>""</code>
trustedCACertificate	Base64-encoded value of trusted CA certificate. Optional. Used for certificate-based authentication.	<code>""</code>
username	Username to connect to the cluster or SVM. Used for credential-based authentication. For example, <code>vsadmin</code> .	
password	Password to connect to the cluster or SVM. Used for credential-based authentication.	
svm	Storage virtual machine to use	Derived if an SVM managementLIF is specified.
storagePrefix	<p>Prefix used when provisioning new volumes in the SVM.</p> <p>Cannot be modified after creation. To update this parameter, you will need to create a new backend.</p>	<code>trident</code>
limitAggregateUsage	<p><b>Do not specify for Amazon FSx for NetApp ONTAP.</b></p> <p>The provided <code>fsxadmin</code> and <code>vsadmin</code> do not contain the permissions required to retrieve aggregate usage and limit it using Astra Trident.</p>	Do not use.

Parameter	Description	Example
limitVolumeSize	<p>Fail provisioning if requested volume size is above this value.</p> <p>Also restricts the maximum size of the volumes it manages for qtrees and LUNs, and the <code>qtreesPerFlexvol</code> option allows customizing the maximum number of qtrees per FlexVol.</p>	"" (not enforced by default)
lunsPerFlexvol	<p>Maximum LUNs per Flexvol, must be in range [50, 200].</p> <p>SAN only.</p>	100
debugTraceFlags	<p>Debug flags to use when troubleshooting. Example, <code>{"api":false, "method":true}</code></p> <p>Do not use <code>debugTraceFlags</code> unless you are troubleshooting and require a detailed log dump.</p>	null
nfsMountOptions	<p>Comma-separated list of NFS mount options.</p> <p>The mount options for Kubernetes-persistent volumes are normally specified in storage classes, but if no mount options are specified in a storage class, Astra Trident will fall back to using the mount options specified in the storage backend's configuration file.</p> <p>If no mount options are specified in the storage class or the configuration file, Astra Trident will not set any mount options on an associated persistent volume.</p>	""
nasType	<p>Configure NFS or SMB volumes creation.</p> <p>Options are <code>nfs</code>, <code>smb</code>, or <code>null</code>.</p> <p><b>Must set to <code>smb</code> for SMB volumes.</b> Setting to null defaults to NFS volumes.</p>	nfs
qtreesPerFlexvol	Maximum Qtrees per FlexVol, must be in range [50, 300]	200

Parameter	Description	Example
smbShare	<p>You can specify one of the following: the name of an SMB share created using the Microsoft Management Console or ONTAP CLI or a name to allow Astra Trident to create the SMB share.</p> <p>This parameter is required for Amazon FSx for ONTAP backends.</p>	smb-share
useREST	<p>Boolean parameter to use ONTAP REST APIs. <b>Tech preview</b></p> <p>useREST is provided as a <b>tech preview</b> that is recommended for test environments and not for production workloads. When set to <code>true</code>, Astra Trident will use ONTAP REST APIs to communicate with the backend.</p> <p>This feature requires ONTAP 9.11.1 and later. In addition, the ONTAP login role used must have access to the <code>ontap</code> application. This is satisfied by the pre-defined <code>vsadmin</code> and <code>cluster-admin</code> roles.</p>	false
aws	<p>You can specify the following in the configuration file for AWS FSx for ONTAP:</p> <ul style="list-style-type: none"> <li>- <code>fsxFilesystemID</code>: Specify the ID of the AWS FSx file system.</li> <li>- <code>apiRegion</code>: AWS API region name.</li> <li>- <code>apiKey</code>: AWS API key.</li> <li>- <code>secretKey</code>: AWS secret key.</li> </ul>	<pre>"" "" ""</pre>
credentials	<p>Specify the FSx SVM credentials to store in AWS Secret Manager.</p> <ul style="list-style-type: none"> <li>- <code>name</code>: Amazon Resource Name (ARN) of the secret, which contains the credentials of SVM.</li> <li>- <code>type</code>: Set to <code>awsarn</code>.</li> </ul> <p>Refer to <a href="#">Create an AWS Secrets Manager secret</a> for more information.</p>	

#### Update dataLIF after initial configuration

You can change the data LIF after initial configuration by running the following command to provide the new backend JSON file with updated data LIF.

```
tridentctl update backend <backend-name> -f <path-to-backend-json-file-with-updated-dataLIF>
```



If PVCs are attached to one or multiple pods, you must bring down all corresponding pods and then bring them back up in order for the new data LIF to take effect.

## Backend configuration options for provisioning volumes

You can control default provisioning using these options in the `defaults` section of the configuration. For an example, see the configuration examples below.

Parameter	Description	Default
<code>spaceAllocation</code>	Space-allocation for LUNs	<code>true</code>
<code>spaceReserve</code>	Space reservation mode; “none” (thin) or “volume” (thick)	<code>none</code>
<code>snapshotPolicy</code>	Snapshot policy to use	<code>none</code>
<code>qosPolicy</code>	<p>QoS policy group to assign for volumes created. Choose one of <code>qosPolicy</code> or <code>adaptiveQosPolicy</code> per storage pool or backend.</p> <p>Using QoS policy groups with Astra Trident requires ONTAP 9.8 or later.</p> <p>We recommend using a non-shared QoS policy group and ensuring the policy group is applied to each constituent individually. A shared QoS policy group will enforce the ceiling for the total throughput of all workloads.</p>	<code>“”</code>
<code>adaptiveQosPolicy</code>	<p>Adaptive QoS policy group to assign for volumes created. Choose one of <code>qosPolicy</code> or <code>adaptiveQosPolicy</code> per storage pool or backend.</p> <p>Not supported by <code>ontap-nas-economy</code>.</p>	<code>“”</code>
<code>snapshotReserve</code>	Percentage of volume reserved for snapshots “0”	If <code>snapshotPolicy</code> is <code>none</code> , else <code>“”</code>
<code>splitOnClone</code>	Split a clone from its parent upon creation	<code>false</code>

Parameter	Description	Default
encryption	<p>Enable NetApp Volume Encryption (NVE) on the new volume; defaults to <code>false</code>. NVE must be licensed and enabled on the cluster to use this option.</p> <p>If NAE is enabled on the backend, any volume provisioned in Astra Trident will be NAE enabled.</p> <p>For more information, refer to: <a href="#">How Astra Trident works with NVE and NAE</a>.</p>	<code>false</code>
luksEncryption	<p>Enable LUKS encryption. Refer to <a href="#">Use Linux Unified Key Setup (LUKS)</a>.</p> <p>SAN only.</p>	<code>""</code>
tieringPolicy	Tiering policy to use <code>none</code>	<code>snapshot-only</code> for pre-ONTAP 9.5 SVM-DR configuration
unixPermissions	<p>Mode for new volumes.</p> <p><b>Leave empty for SMB volumes.</b></p>	<code>""</code>
securityStyle	<p>Security style for new volumes.</p> <p>NFS supports <code>mixed</code> and <code>unix</code> security styles.</p> <p>SMB supports <code>mixed</code> and <code>ntfs</code> security styles.</p>	<p>NFS default is <code>unix</code>.</p> <p>SMB default is <code>ntfs</code>.</p>

## Example configurations

## Configuration of storage class for SMB volumes

Using `nasType`, `node-stage-secret-name`, and `node-stage-secret-namespace`, you can specify an SMB volume and provide the required Active Directory credentials. SMB volumes are supported using the `ontap-nas` driver only.

```
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: nas-smb-sc
provisioner: csi.trident.netapp.io
parameters:
  backendType: "ontap-nas"
  trident.netapp.io/nasType: "smb"
  csi.storage.k8s.io/node-stage-secret-name: "smbcreds"
  csi.storage.k8s.io/node-stage-secret-namespace: "default"
```

## Configuration for AWS FSx for ONTAP with secret manager

```
apiVersion: trident.netapp.io/v1
kind: TridentBackendConfig
metadata:
  name: backend-tbc-ontap-nas
spec:
  version: 1
  storageDriverName: ontap-nas
  backendName: tbc-ontap-nas
  svm: svm-name
  aws:
    fsxFileSystemID: fs-xxxxxxxxxx
  managementLIF:
  credentials:
    name: "arn:aws:secretsmanager:us-west-2:xxxxxxx:secret:secret-
name"
    type: awsarn
```

## Configure the Astra Trident EKS add-on version 23.10 on EKS cluster

Astra Trident streamlines Amazon FSx for NetApp ONTAP storage management in Kubernetes to enable your developers and administrators focus on application deployment. The Astra Trident EKS add-on includes the latest security patches, bug fixes, and is validated by AWS to work with Amazon EKS. The EKS add-on enables you to consistently ensure that your Amazon EKS clusters are secure and stable and reduce

the amount of work that you need to do in order to install, configure, and update add-ons.

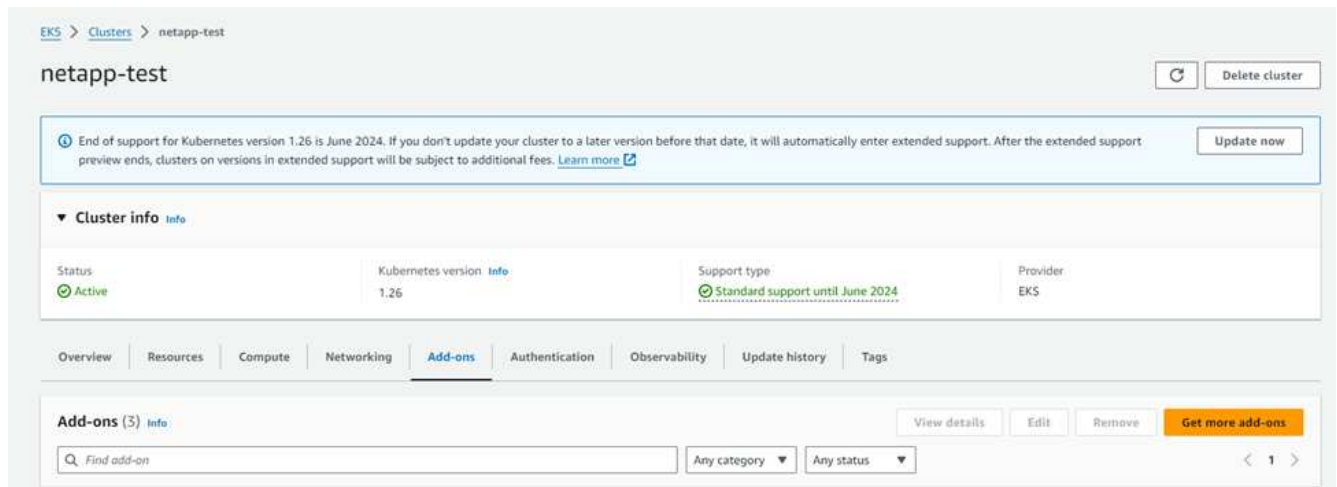
## Prerequisites

Ensure that you have the following before configuring the Astra Trident add-on for AWS EKS:

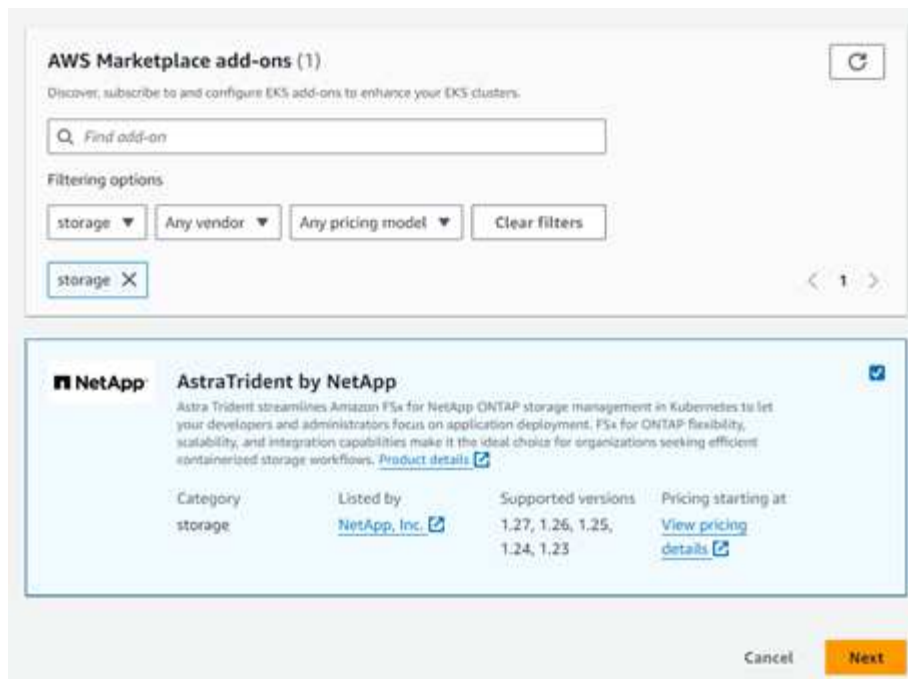
- An Amazon EKS cluster account with add-on subscription
- AWS permissions to the AWS marketplace:  
"aws-marketplace:ViewSubscriptions",  
"aws-marketplace:Subscribe",  
"aws-marketplace:Unsubscribe"
- AMI type: Amazon Linux 2 (AL2\_x86\_64) or Amazon Linux 2 Arm(AL2\_ARM\_64)
- Node type: AMD or ARM
- An existing Amazon FSx for NetApp ONTAP file system

## Steps

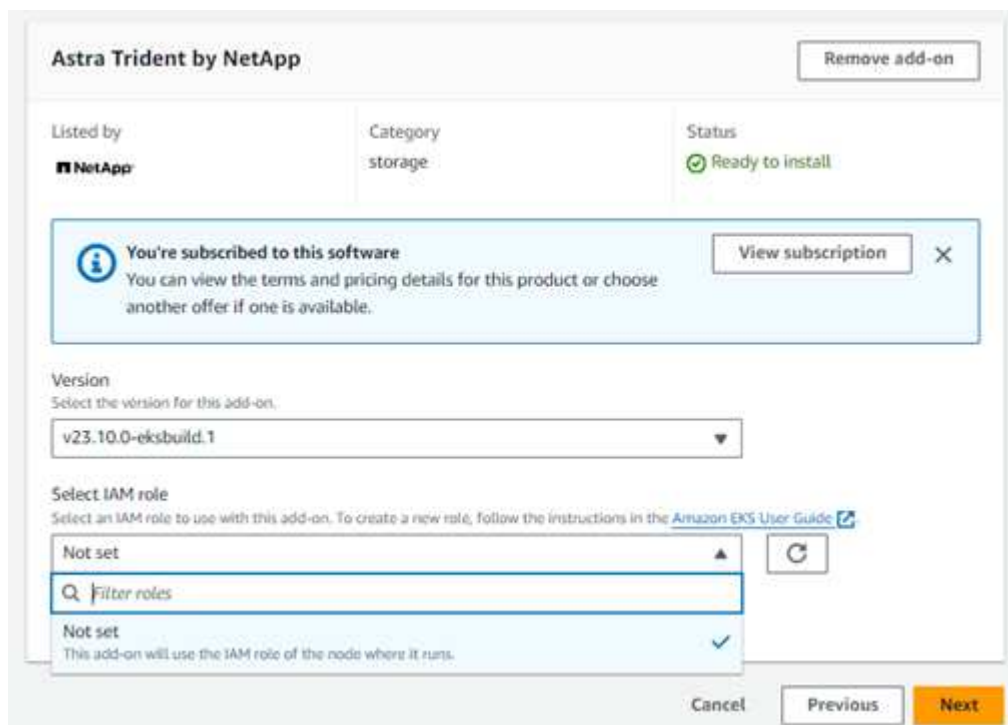
1. On your your EKS Kubernetes cluster, navigate to the **Add-ons** tab.



2. Go to **AWS Marketplace add-ons** and choose the *storage* category.



3. Locate **AstraTrident by NetApp** and select the checkbox for the Astra Trident add-on.
4. Choose the desired version of the add-on.



5. Select the IAM role option to inherit from the node.
6. Configure any optional settings as required and select **Next**.

## Review and add

**Step 1: Select add-ons**
Edit

Selected add-ons

Find add-on

Add-on name	Type	Status
netapp_trident-operator	storage	Ready to install

**Step 2: Configure selected add-ons settings**
Edit

Selected add-ons version

Add-on name	Version	IAM role
netapp_trident-operator	v23.10.0-eksbuild.1	Inherit from node

Cancel
Previous
Create

7. Select **Create**.
8. Verify that the status of the add-on is *Active*.

Add-ons (1) [info](#)

[View details](#)
[Edit](#)
[Remove](#)
[Add more add-ons](#)

Any category

Any status

< >

**AstraTrident by NetApp**

Astra Trident is a storage management solution for Kubernetes that allows you to manage and administer your storage infrastructure. It is a fully managed service that provides a simple and efficient way to manage your storage infrastructure.
 [Learn more](#)

Category	Status	Version	IAM role	Used by
Storage	Active	v23.10.0-eksbuild.1	Inherited from node	<a href="#">NetApp, Inc.</a>

## Install/uninstall the Astra Trident EKS add-on using CLI

### Install the Astra Trident EKS add-on using CLI:

The following example commands install the Astra Trident EKS add-on:

```
eksctl create addon --cluster K8s-arm --name netapp_trident-operator --version v23.10.0-eksbuild.
eksctl create addon --cluster K8s-arm --name netapp_trident-operator --version v23.10.0-eksbuild.1 (with a dedicated version)
```

### Uninstall the Astra Trident EKS add-on using CLI:

The following command uninstalls the Astra Trident EKS add-on:

```
eksctl delete addon --cluster K8s-arm --name netapp_trident-operator
```

## Create backends with kubectl

A backend defines the relationship between Astra Trident and a storage system. It tells Astra Trident how to communicate with that storage system and how Astra Trident should provision volumes from it. After Astra Trident is installed, the next step is to create a backend. The `TridentBackendConfig` Custom Resource Definition (CRD) enables

you to create and manage Trident backends directly through the Kubernetes interface. You can do this by using `kubectl` or the equivalent CLI tool for your Kubernetes distribution.

## TridentBackendConfig

`TridentBackendConfig` (tbc, tbconfig, tbackendconfig) is a frontend, namespaced CRD that enables you to manage Astra Trident backends using `kubectl`. Kubernetes and storage admins can now create and manage backends directly through the Kubernetes CLI without requiring a dedicated command-line utility (`tridentctl`).

Upon the creation of a `TridentBackendConfig` object, the following happens:

- A backend is created automatically by Astra Trident based on the configuration you provide. This is represented internally as a `TridentBackend` (tbe, tridentbackend) CR.
- The `TridentBackendConfig` is uniquely bound to a `TridentBackend` that was created by Astra Trident.

Each `TridentBackendConfig` maintains a one-to-one mapping with a `TridentBackend`. The former is the interface provided to the user to design and configure backends; the latter is how Trident represents the actual backend object.



`TridentBackend` CRs are created automatically by Astra Trident. You **should not** modify them. If you want to make updates to backends, do this by modifying the `TridentBackendConfig` object.

See the following example for the format of the `TridentBackendConfig` CR:

```
apiVersion: trident.netapp.io/v1
kind: TridentBackendConfig
metadata:
  name: backend-tbc-ontap-san
spec:
  version: 1
  backendName: ontap-san-backend
  storageDriverName: ontap-san
  managementLIF: 10.0.0.1
  dataLIF: 10.0.0.2
  svm: trident_svm
  credentials:
    name: backend-tbc-ontap-san-secret
```

You can also take a look at the examples in the [trident-installer](#) directory for sample configurations for the desired storage platform/service.

The `spec` takes backend-specific configuration parameters. In this example, the backend uses the `ontap-san` storage driver and uses the configuration parameters that are tabulated here. For the list of configuration options for your desired storage driver, refer to the [backend configuration information for your storage driver](#).

The `spec` section also includes `credentials` and `deletionPolicy` fields, which are newly introduced in the `TridentBackendConfig` CR:

- `credentials`: This parameter is a required field and contains the credentials used to authenticate with the storage system/service. This is set to a user-created Kubernetes Secret. The credentials cannot be passed in plain text and will result in an error.
- `deletionPolicy`: This field defines what should happen when the `TridentBackendConfig` is deleted. It can take one of two possible values:
  - `delete`: This results in the deletion of both `TridentBackendConfig` CR and the associated backend. This is the default value.
  - `retain`: When a `TridentBackendConfig` CR is deleted, the backend definition will still be present and can be managed with `tridentctl`. Setting the deletion policy to `retain` lets users downgrade to an earlier release (pre-21.04) and retain the created backends. The value for this field can be updated after a `TridentBackendConfig` is created.



The name of a backend is set using `spec.backendName`. If unspecified, the name of the backend is set to the name of the `TridentBackendConfig` object (`metadata.name`). It is recommended to explicitly set backend names using `spec.backendName`.



Backends that were created with `tridentctl` do not have an associated `TridentBackendConfig` object. You can choose to manage such backends with `kubectl` by creating a `TridentBackendConfig` CR. Care must be taken to specify identical config parameters (such as `spec.backendName`, `spec.storagePrefix`, `spec.storageDriverName`, and so on). Astra Trident will automatically bind the newly-created `TridentBackendConfig` with the pre-existing backend.

## Steps overview

To create a new backend by using `kubectl`, you should do the following:

1. Create a [Kubernetes Secret](#). The secret contains the credentials Astra Trident needs to communicate with the storage cluster/service.
2. Create a `TridentBackendConfig` object. This contains specifics about the storage cluster/service and references the secret created in the previous step.

After you create a backend, you can observe its status by using `kubectl get tbc <tbc-name> -n <trident-namespace>` and gather additional details.

## Step 1: Create a Kubernetes Secret

Create a Secret that contains the access credentials for the backend. This is unique to each storage service/platform. Here's an example:

```
kubectl -n trident create -f backend-tbc-ontap-san-secret.yaml
apiVersion: v1
kind: Secret
metadata:
  name: backend-tbc-ontap-san-secret
type: Opaque
stringData:
  username: cluster-admin
  password: t@Ax@7q(>
```

This table summarizes the fields that must be included in the Secret for each storage platform:

Storage platform Secret Fields description	Secret	Fields description
Azure NetApp Files	clientID	The client ID from an app registration
Cloud Volumes Service for GCP	private_key_id	ID of the private key. Part of API key for GCP Service Account with CVS admin role
Cloud Volumes Service for GCP	private_key	Private key. Part of API key for GCP Service Account with CVS admin role
Element (NetApp HCI/SolidFire)	Endpoint	MVIP for the SolidFire cluster with tenant credentials
ONTAP	username	Username to connect to the cluster/SVM. Used for credential-based authentication
ONTAP	password	Password to connect to the cluster/SVM. Used for credential-based authentication
ONTAP	clientPrivateKey	Base64-encoded value of client private key. Used for certificate-based authentication
ONTAP	chapUsername	Inbound username. Required if useCHAP=true. For <code>ontap-san</code> and <code>ontap-san-economy</code>

Storage platform Secret Fields description	Secret	Fields description
ONTAP	chapInitiatorSecret	CHAP initiator secret. Required if useCHAP=true. For ontap-san and ontap-san-economy
ONTAP	chapTargetUsername	Target username. Required if useCHAP=true. For ontap-san and ontap-san-economy
ONTAP	chapTargetInitiatorSecret	CHAP target initiator secret. Required if useCHAP=true. For ontap-san and ontap-san-economy

The Secret created in this step will be referenced in the `spec.credentials` field of the `TridentBackendConfig` object that is created in the next step.

## Step 2: Create the `TridentBackendConfig` CR

You are now ready to create your `TridentBackendConfig` CR. In this example, a backend that uses the `ontap-san` driver is created by using the `TridentBackendConfig` object shown below:

```
kubectl -n trident create -f backend-tbc-ontap-san.yaml
```

```
apiVersion: trident.netapp.io/v1
kind: TridentBackendConfig
metadata:
  name: backend-tbc-ontap-san
spec:
  version: 1
  backendName: ontap-san-backend
  storageDriverName: ontap-san
  managementLIF: 10.0.0.1
  dataLIF: 10.0.0.2
  svm: trident_svm
  credentials:
    name: backend-tbc-ontap-san-secret
```

## Step 3: Verify the status of the `TridentBackendConfig` CR

Now that you created the `TridentBackendConfig` CR, you can verify the status. See the following example:

```
kubectl -n trident get tbc backend-tbc-ontap-san
```

NAME	BACKEND NAME	BACKEND UUID
backend-tbc-ontap-san	ontap-san-backend	8d24fce7-6f60-4d4a-8ef6-bab2699e6ab8
Bound	Success	

A backend was successfully created and bound to the `TridentBackendConfig` CR.

Phase can take one of the following values:

- **Bound:** The `TridentBackendConfig` CR is associated with a backend, and that backend contains `configRef` set to the `TridentBackendConfig` CR's uid.
- **Unbound:** Represented using `""`. The `TridentBackendConfig` object is not bound to a backend. All newly created `TridentBackendConfig` CRs are in this phase by default. After the phase changes, it cannot revert to Unbound again.
- **Deleting:** The `TridentBackendConfig` CR's `deletionPolicy` was set to delete. When the `TridentBackendConfig` CR is deleted, it transitions to the Deleting state.
  - If no persistent volume claims (PVCs) exist on the backend, deleting the `TridentBackendConfig` will result in Astra Trident deleting the backend as well as the `TridentBackendConfig` CR.
  - If one or more PVCs are present on the backend, it goes to a deleting state. The `TridentBackendConfig` CR subsequently also enters deleting phase. The backend and `TridentBackendConfig` are deleted only after all PVCs are deleted.
- **Lost:** The backend associated with the `TridentBackendConfig` CR was accidentally or deliberately deleted and the `TridentBackendConfig` CR still has a reference to the deleted backend. The `TridentBackendConfig` CR can still be deleted irrespective of the `deletionPolicy` value.
- **Unknown:** Astra Trident is unable to determine the state or existence of the backend associated with the `TridentBackendConfig` CR. For example, if the API server is not responding or if the `tridentbackends.trident.netapp.io` CRD is missing. This might require intervention.

At this stage, a backend is successfully created! There are several operations that can additionally be handled, such as [backend updates and backend deletions](#).

## (Optional) Step 4: Get more details

You can run the following command to get more information about your backend:

```
kubectl -n trident get tbc backend-tbc-ontap-san -o wide
```

NAME	BACKEND NAME	BACKEND UUID
backend-tbc-ontap-san	ontap-san-backend	8d24fce7-6f60-4d4a-8ef6-bab2699e6ab8
Bound	Success	

In addition, you can also obtain a YAML/JSON dump of `TridentBackendConfig`.

```
kubectl -n trident get tbc backend-tbc-ontap-san -o yaml
```

```
apiVersion: trident.netapp.io/v1
kind: TridentBackendConfig
metadata:
  creationTimestamp: "2021-04-21T20:45:11Z"
  finalizers:
    - trident.netapp.io
  generation: 1
  name: backend-tbc-ontap-san
  namespace: trident
  resourceVersion: "947143"
  uid: 35b9d777-109f-43d5-8077-c74a4559d09c
spec:
  backendName: ontap-san-backend
  credentials:
    name: backend-tbc-ontap-san-secret
  managementLIF: 10.0.0.1
  dataLIF: 10.0.0.2
  storageDriverName: ontap-san
  svm: trident_svm
  version: 1
status:
  backendInfo:
    backendName: ontap-san-backend
    backendUUID: 8d24fce7-6f60-4d4a-8ef6-bab2699e6ab8
  deletionPolicy: delete
  lastOperationStatus: Success
  message: Backend 'ontap-san-backend' created
  phase: Bound
```

`backendInfo` contains the `backendName` and the `backendUUID` of the backend that got created in response to the `TridentBackendConfig` CR. The `lastOperationStatus` field represents the status of the last operation of the `TridentBackendConfig` CR, which can be user-triggered (for example, user changed something in `spec`) or triggered by Astra Trident (for example, during Astra Trident restarts). It can either be `Success` or `Failed`. `phase` represents the status of the relation between the `TridentBackendConfig` CR and the backend. In the example above, `phase` has the value `Bound`, which means that the `TridentBackendConfig` CR is associated with the backend.

You can run the `kubectl -n trident describe tbc <tbc-cr-name>` command to get details of the event logs.



You cannot update or delete a backend which contains an associated `TridentBackendConfig` object using `tridentctl`. To understand the steps involved in switching between `tridentctl` and `TridentBackendConfig`, [see here](#).

## Manage backends

### Perform backend management with kubectl

Learn about how to perform backend management operations by using `kubectl`.

#### Delete a backend

By deleting a `TridentBackendConfig`, you instruct Astra Trident to delete/retain backends (based on `deletionPolicy`). To delete a backend, ensure that `deletionPolicy` is set to `delete`. To delete just the `TridentBackendConfig`, ensure that `deletionPolicy` is set to `retain`. This will ensure the backend is still present and can be managed by using `tridentctl`.

Run the following command:

```
kubectl delete tbc <tbc-name> -n trident
```

Astra Trident does not delete the Kubernetes Secrets that were in use by `TridentBackendConfig`. The Kubernetes user is responsible for cleaning up secrets. Care must be taken when deleting secrets. You should delete secrets only if they are not in use by the backends.

#### View the existing backends

Run the following command:

```
kubectl get tbc -n trident
```

You can also run `tridentctl get backend -n trident` or `tridentctl get backend -o yaml -n trident` to obtain a list of all backends that exist. This list will also include backends that were created with `tridentctl`.

#### Update a backend

There can be multiple reasons to update a backend:

- Credentials to the storage system have changed. To update credentials, the Kubernetes Secret that is used in the `TridentBackendConfig` object must be updated. Astra Trident will automatically update the backend with the latest credentials provided. Run the following command to update the Kubernetes Secret:

```
kubectl apply -f <updated-secret-file.yaml> -n trident
```

- Parameters (such as the name of the ONTAP SVM being used) need to be updated.

- You can update `TridentBackendConfig` objects directly through Kubernetes using the following command:

```
kubectl apply -f <updated-backend-file.yaml>
```

- Alternatively, you can make changes to the existing `TridentBackendConfig` CR using the following command:

```
kubectl edit tbc <tbc-name> -n trident
```



- If a backend update fails, the backend continues to remain in its last known configuration. You can view the logs to determine the cause by running `kubectl get tbc <tbc-name> -o yaml -n trident` or `kubectl describe tbc <tbc-name> -n trident`.
- After you identify and correct the problem with the configuration file, you can re-run the update command.

## Perform backend management with `tridentctl`

Learn about how to perform backend management operations by using `tridentctl`.

### Create a backend

After you create a [backend configuration file](#), run the following command:

```
tridentctl create backend -f <backend-file> -n trident
```

If backend creation fails, something was wrong with the backend configuration. You can view the logs to determine the cause by running the following command:

```
tridentctl logs -n trident
```

After you identify and correct the problem with the configuration file, you can simply run the `create` command again.

### Delete a backend

To delete a backend from Astra Trident, do the following:

1. Retrieve the backend name:

```
tridentctl get backend -n trident
```

2. Delete the backend:

```
tridentctl delete backend <backend-name> -n trident
```



If Astra Trident has provisioned volumes and snapshots from this backend that still exist, deleting the backend prevents new volumes from being provisioned by it. The backend will continue to exist in a “Deleting” state and Trident will continue to manage those volumes and snapshots until they are deleted.

## View the existing backends

To view the backends that Trident knows about, do the following:

- To get a summary, run the following command:

```
tridentctl get backend -n trident
```

- To get all the details, run the following command:

```
tridentctl get backend -o json -n trident
```

## Update a backend

After you create a new backend configuration file, run the following command:

```
tridentctl update backend <backend-name> -f <backend-file> -n trident
```

If backend update fails, something was wrong with the backend configuration or you attempted an invalid update. You can view the logs to determine the cause by running the following command:

```
tridentctl logs -n trident
```

After you identify and correct the problem with the configuration file, you can simply run the update command again.

## Identify the storage classes that use a backend

This is an example of the kind of questions you can answer with the JSON that `tridentctl` outputs for backend objects. This uses the `jq` utility, which you need to install.

```
tridentctl get backend -o json | jq '[.items[] | {backend: .name, storageClasses: [.storage[].storageClasses]|unique}]'
```

This also applies for backends that were created by using `TridentBackendConfig`.

## Move between backend management options

Learn about the different ways of managing backends in Astra Trident.

### Options for managing backends

With the introduction of `TridentBackendConfig`, administrators now have two unique ways of managing backends. This poses the following questions:

- Can backends created using `tridentctl` be managed with `TridentBackendConfig`?
- Can backends created using `TridentBackendConfig` be managed using `tridentctl`?

### Manage `tridentctl` backends using `TridentBackendConfig`

This section covers the steps required to manage backends that were created using `tridentctl` directly through the Kubernetes interface by creating `TridentBackendConfig` objects.

This will apply to the following scenarios:

- Pre-existing backends, that don't have a `TridentBackendConfig` because they were created with `tridentctl`.
- New backends that were created with `tridentctl`, while other `TridentBackendConfig` objects exist.

In both scenarios, backends will continue to be present, with Astra Trident scheduling volumes and operating on them. Administrators have one of two choices here:

- Continue using `tridentctl` to manage backends that were created using it.
- Bind backends created using `tridentctl` to a new `TridentBackendConfig` object. Doing so would mean the backends will be managed using `kubectl` and not `tridentctl`.

To manage a pre-existing backend using `kubectl`, you will need to create a `TridentBackendConfig` that binds to the existing backend. Here is an overview of how that works:

1. Create a Kubernetes Secret. The secret contains the credentials Astra Trident needs to communicate with the storage cluster/service.
2. Create a `TridentBackendConfig` object. This contains specifics about the storage cluster/service and references the secret created in the previous step. Care must be taken to specify identical config parameters (such as `spec.backendName`, `spec.storagePrefix`, `spec.storageDriverName`, and so on). `spec.backendName` must be set to the name of the existing backend.

#### Step 0: Identify the backend

To create a `TridentBackendConfig` that binds to an existing backend, you will need to obtain the backend configuration. In this example, let us assume a backend was created using the following JSON definition:

```
tridentctl get backend ontap-nas-backend -n trident
+-----+-----+
+-----+-----+-----+-----+
|          NAME          | STORAGE DRIVER |          UUID          |
```

STATE	VOLUMES	
ontap-nas-backend	ontap-nas	52f2eb10-e4c6-4160-99fc-96b3be5ab5d7   online   25

```
cat ontap-nas-backend.json
```

```
{
  "version": 1,
  "storageDriverName": "ontap-nas",
  "managementLIF": "10.10.10.1",
  "dataLIF": "10.10.10.2",
  "backendName": "ontap-nas-backend",
  "svm": "trident_svm",
  "username": "cluster-admin",
  "password": "admin-password",

  "defaults": {
    "spaceReserve": "none",
    "encryption": "false"
  },
  "labels": {"store": "nas_store"},
  "region": "us_east_1",
  "storage": [
    {
      "labels": {"app": "msoffice", "cost": "100"},
      "zone": "us_east_1a",
      "defaults": {
        "spaceReserve": "volume",
        "encryption": "true",
        "unixPermissions": "0755"
      }
    },
    {
      "labels": {"app": "mysqldb", "cost": "25"},
      "zone": "us_east_1d",
      "defaults": {
        "spaceReserve": "volume",
        "encryption": "false",
        "unixPermissions": "0775"
      }
    }
  ]
}
```

```
}
```

### Step 1: Create a Kubernetes Secret

Create a Secret that contains the credentials for the backend, as shown in this example:

```
cat tbc-ontap-nas-backend-secret.yaml

apiVersion: v1
kind: Secret
metadata:
  name: ontap-nas-backend-secret
type: Opaque
stringData:
  username: cluster-admin
  password: admin-password

kubectl create -f tbc-ontap-nas-backend-secret.yaml -n trident
secret/backend-tbc-ontap-san-secret created
```

### Step 2: Create a `TridentBackendConfig` CR

The next step is to create a `TridentBackendConfig` CR that will automatically bind to the pre-existing `ontap-nas-backend` (as in this example). Ensure the following requirements are met:

- The same backend name is defined in `spec.backendName`.
- Configuration parameters are identical to the original backend.
- Virtual pools (if present) must retain the same order as in the original backend.
- Credentials are provided through a Kubernetes Secret and not in plain text.

In this case, the `TridentBackendConfig` will look like this:

```

cat backend-tbc-ontap-nas.yaml
apiVersion: trident.netapp.io/v1
kind: TridentBackendConfig
metadata:
  name: tbc-ontap-nas-backend
spec:
  version: 1
  storageDriverName: ontap-nas
  managementLIF: 10.10.10.1
  dataLIF: 10.10.10.2
  backendName: ontap-nas-backend
  svm: trident_svm
  credentials:
    name: mysecret
  defaults:
    spaceReserve: none
    encryption: 'false'
  labels:
    store: nas_store
  region: us_east_1
  storage:
  - labels:
      app: msoffice
      cost: '100'
      zone: us_east_1a
      defaults:
        spaceReserve: volume
        encryption: 'true'
        unixPermissions: '0755'
  - labels:
      app: mysqldb
      cost: '25'
      zone: us_east_1d
      defaults:
        spaceReserve: volume
        encryption: 'false'
        unixPermissions: '0775'

kubectl create -f backend-tbc-ontap-nas.yaml -n trident
tridentbackendconfig.trident.netapp.io/tbc-ontap-nas-backend created

```

### Step 3: Verify the status of the `TridentBackendConfig` CR

After the `TridentBackendConfig` has been created, its phase must be `Bound`. It should also reflect the same backend name and UUID as that of the existing backend.

```
kubectl get tbc tbc-ontap-nas-backend -n trident
```

NAME	BACKEND NAME	BACKEND UUID
tbc-ontap-nas-backend	ontap-nas-backend	52f2eb10-e4c6-4160-99fc-96b3be5ab5d7
Bound	Success	

#confirm that no new backends were created (i.e., TridentBackendConfig did not end up creating a new backend)

```
tridentctl get backend -n trident
```

NAME	STATE	VOLUMES	STORAGE DRIVER	UUID
ontap-nas-backend	online	25	ontap-nas	52f2eb10-e4c6-4160-99fc-96b3be5ab5d7

The backend will now be completely managed using the `tbc-ontap-nas-backend` `TridentBackendConfig` object.

### Manage `TridentBackendConfig` backends using `tridentctl`

`tridentctl` can be used to list backends that were created using `TridentBackendConfig`. In addition, administrators can also choose to completely manage such backends through `tridentctl` by deleting `TridentBackendConfig` and making sure `spec.deletionPolicy` is set to `retain`.

#### Step 0: Identify the backend

For example, let us assume the following backend was created using `TridentBackendConfig`:

```
kubectl get tbc backend-tbc-ontap-san -n trident -o wide
```

NAME	BACKEND NAME	BACKEND UUID
backend-tbc-ontap-san	ontap-san-backend	81abcb27-ea63-49bb-b606-0a5315ac5f82

```
tridentctl get backend ontap-san-backend -n trident
```

NAME	STORAGE DRIVER	UUID
ontap-san-backend	ontap-san	81abcb27-ea63-49bb-b606-0a5315ac5f82

From the output, it is seen that `TridentBackendConfig` was created successfully and is bound to a backend [observe the backend's UUID].

#### Step 1: Confirm `deletionPolicy` is set to `retain`

Let us take a look at the value of `deletionPolicy`. This needs to be set to `retain`. This will ensure that when a `TridentBackendConfig` CR is deleted, the backend definition will still be present and can be managed with `tridentctl`.

```
kubectl get tbc backend-tbc-ontap-san -n trident -o wide
```

NAME	BACKEND NAME	BACKEND UUID
backend-tbc-ontap-san	ontap-san-backend	81abcb27-ea63-49bb-b606-0a5315ac5f82

```
# Patch value of deletionPolicy to retain
kubectl patch tbc backend-tbc-ontap-san --type=merge -p
'{"spec":{"deletionPolicy":"retain"}}' -n trident
tridentbackendconfig.trident.netapp.io/backend-tbc-ontap-san patched

#Confirm the value of deletionPolicy
kubectl get tbc backend-tbc-ontap-san -n trident -o wide
```

NAME	BACKEND NAME	BACKEND UUID
backend-tbc-ontap-san	ontap-san-backend	81abcb27-ea63-49bb-b606-0a5315ac5f82



Do not proceed to the next step unless `deletionPolicy` is set to `retain`.

## Step 2: Delete the `TridentBackendConfig` CR

The final step is to delete the `TridentBackendConfig` CR. After confirming the `deletionPolicy` is set to `retain`, you can go ahead with the deletion:

```
kubectl delete tbc backend-tbc-ontap-san -n trident
tridentbackendconfig.trident.netapp.io "backend-tbc-ontap-san" deleted

tridentctl get backend ontap-san-backend -n trident
+-----+-----+
+-----+-----+-----+-----+
|      NAME      | STORAGE DRIVER |                               UUID
| STATE  | VOLUMES |
+-----+-----+
+-----+-----+-----+-----+
| ontap-san-backend | ontap-san      | 81abcb27-ea63-49bb-b606-
0a5315ac5f82 | online |      33 |
+-----+-----+
+-----+-----+-----+-----+
```

Upon the deletion of the `TridentBackendConfig` object, Astra Trident simply removes it without actually deleting the backend itself.

## Copyright information

Copyright © 2024 NetApp, Inc. All Rights Reserved. Printed in the U.S. No part of this document covered by copyright may be reproduced in any form or by any means—graphic, electronic, or mechanical, including photocopying, recording, taping, or storage in an electronic retrieval system—without prior written permission of the copyright owner.

Software derived from copyrighted NetApp material is subject to the following license and disclaimer:

THIS SOFTWARE IS PROVIDED BY NETAPP “AS IS” AND WITHOUT ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, WHICH ARE HEREBY DISCLAIMED. IN NO EVENT SHALL NETAPP BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

NetApp reserves the right to change any products described herein at any time, and without notice. NetApp assumes no responsibility or liability arising from the use of products described herein, except as expressly agreed to in writing by NetApp. The use or purchase of this product does not convey a license under any patent rights, trademark rights, or any other intellectual property rights of NetApp.

The product described in this manual may be protected by one or more U.S. patents, foreign patents, or pending applications.

LIMITED RIGHTS LEGEND: Use, duplication, or disclosure by the government is subject to restrictions as set forth in subparagraph (b)(3) of the Rights in Technical Data -Noncommercial Items at DFARS 252.227-7013 (FEB 2014) and FAR 52.227-19 (DEC 2007).

Data contained herein pertains to a commercial product and/or commercial service (as defined in FAR 2.101) and is proprietary to NetApp, Inc. All NetApp technical data and computer software provided under this Agreement is commercial in nature and developed solely at private expense. The U.S. Government has a non-exclusive, non-transferrable, nonsublicensable, worldwide, limited irrevocable license to use the Data only in connection with and in support of the U.S. Government contract under which the Data was delivered. Except as provided herein, the Data may not be used, disclosed, reproduced, modified, performed, or displayed without the prior written approval of NetApp, Inc. United States Government license rights for the Department of Defense are limited to those rights identified in DFARS clause 252.227-7015(b) (FEB 2014).

## Trademark information

NETAPP, the NETAPP logo, and the marks listed at <http://www.netapp.com/TM> are trademarks of NetApp, Inc. Other company and product names may be trademarks of their respective owners.