



# Learn about Trident

## Trident

NetApp  
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# Learn about Trident

## Learn about Trident

Trident is a fully-supported open source project maintained by NetApp. It has been designed to help you meet your containerized application's persistence demands using industry-standard interfaces, such as the Container Storage Interface (CSI).

### What is Trident?

Netapp Trident enables consumption and management of storage resources across all popular NetApp storage platforms, in the public cloud or on premises, including ONTAP (AFF, FAS, Select, Cloud, Amazon FSx for NetApp ONTAP), Element software (NetApp HCI, SolidFire), Azure NetApp Files service, and Cloud Volumes Service on Google Cloud.

Trident is a Container Storage Interface (CSI) compliant dynamic storage orchestrator that natively integrates with [Kubernetes](#). Trident runs as a single Controller Pod plus a Node Pod on each worker node in the cluster. Refer to [Trident architecture](#) for details.

Trident also provides direct integration with the Docker ecosystem for NetApp storage platforms. The NetApp Docker Volume Plugin (nDVP) supports the provisioning and management of storage resources from the storage platform to Docker hosts. Refer to [Deploy Trident for Docker](#) for details.



If this is your first time using Kubernetes, you should familiarize yourself with the [Kubernetes concepts and tools](#).

### Kubernetes integration with NetApp products

The NetApp portfolio of storage products integrates with many aspects of a Kubernetes cluster, providing advanced data management capabilities, which enhance the functionality, capability, performance, and availability of the Kubernetes deployment.

#### Amazon FSx for NetApp ONTAP

[Amazon FSx for NetApp ONTAP](#) is a fully managed AWS service that lets you launch and run file systems powered by the NetApp ONTAP storage operating system.

#### Azure NetApp Files

[Azure NetApp Files](#) is an enterprise-grade Azure file share service, powered by NetApp. You can run your most demanding file-based workloads in Azure natively, with the performance and rich data management you expect from NetApp.

#### Cloud Volumes ONTAP

[Cloud Volumes ONTAP](#) is a software-only storage appliance that runs the ONTAP data management software in the cloud.

## Google Cloud NetApp Volumes

[Google Cloud NetApp Volumes](#) is a fully managed file storage service in Google Cloud that provides high-performance, enterprise-grade file storage.

## Element software

[Element](#) enables the storage administrator to consolidate workloads by guaranteeing performance and enabling a simplified and streamlined storage footprint.

## NetApp HCI

[NetApp HCI](#) simplifies the management and scale of the datacenter by automating routine tasks and enabling infrastructure administrators to focus on more important functions.

Trident can provision and manage storage devices for containerized applications directly against the underlying NetApp HCI storage platform.

## NetApp ONTAP

[NetApp ONTAP](#) is the NetApp multiprotocol, unified storage operating system that provides advanced data management capabilities for any application.

ONTAP systems have all-flash, hybrid, or all-HDD configurations and offer many different deployment models, including engineered hardware (FAS and AFF), white-box (ONTAP Select), and cloud-only (Cloud Volumes ONTAP). Trident supports these ONTAP deployment models.

# Trident architecture

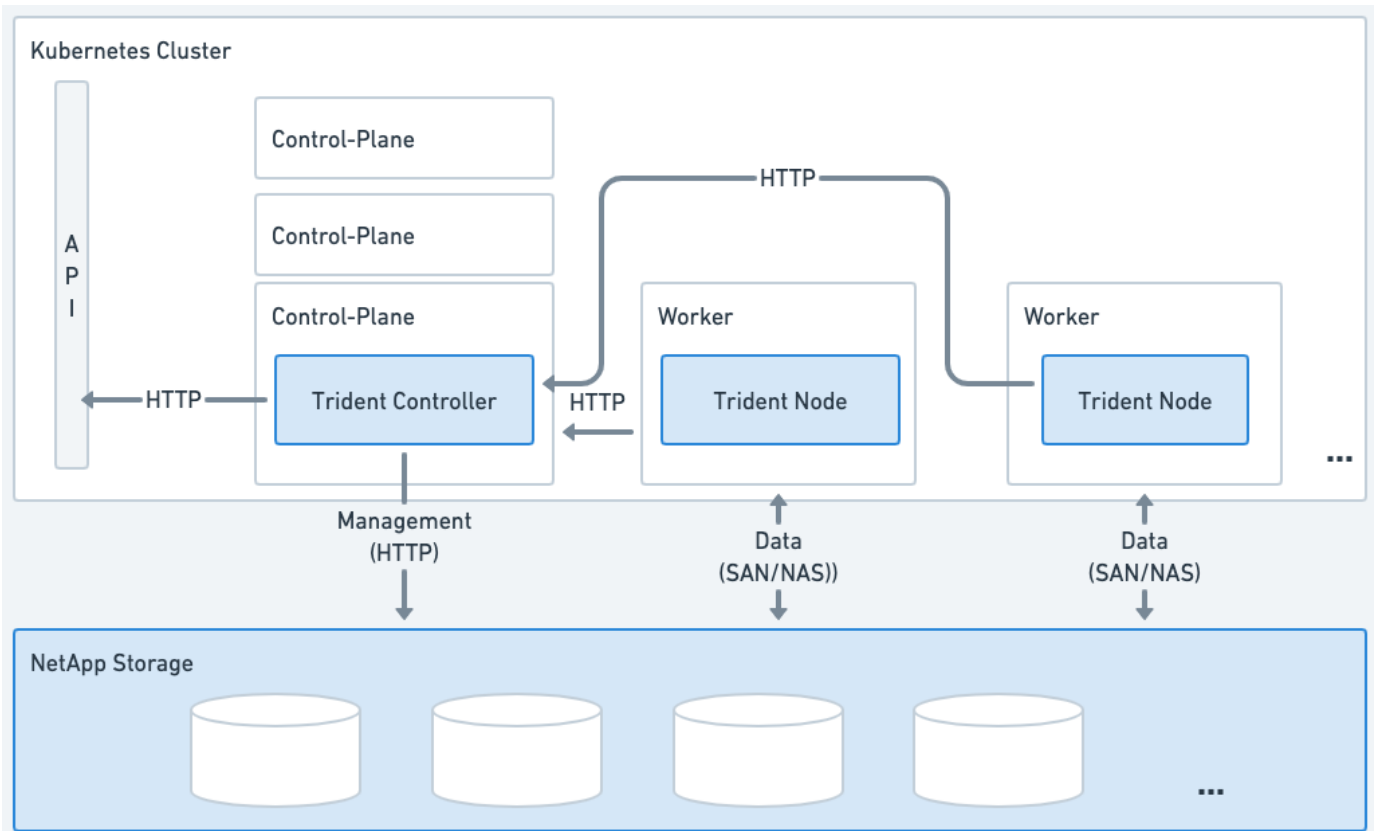
Trident runs as a single Controller Pod plus a Node Pod on each worker node in the cluster. The node pod must be running on any host where you want to potentially mount a Trident volume.

## Understanding controller pods and node pods

Trident deploys as a single [Trident Controller Pod](#) and one or more [Trident Node Pods](#) on the Kubernetes cluster and uses standard Kubernetes [CSI Sidecar Containers](#) to simplify the deployment of CSI plugins. [Kubernetes CSI Sidecar Containers](#) are maintained by the Kubernetes Storage community.

Kubernetes [node selectors](#) and [tolerations and taints](#) are used to constrain a pod to run on a specific or preferred node. You can configure node selectors and tolerations for controller and node pods during Trident installation.

- The controller plugin handles volume provisioning and management, such as snapshots and resizing.
- The node plugin handles attaching the storage to the node.

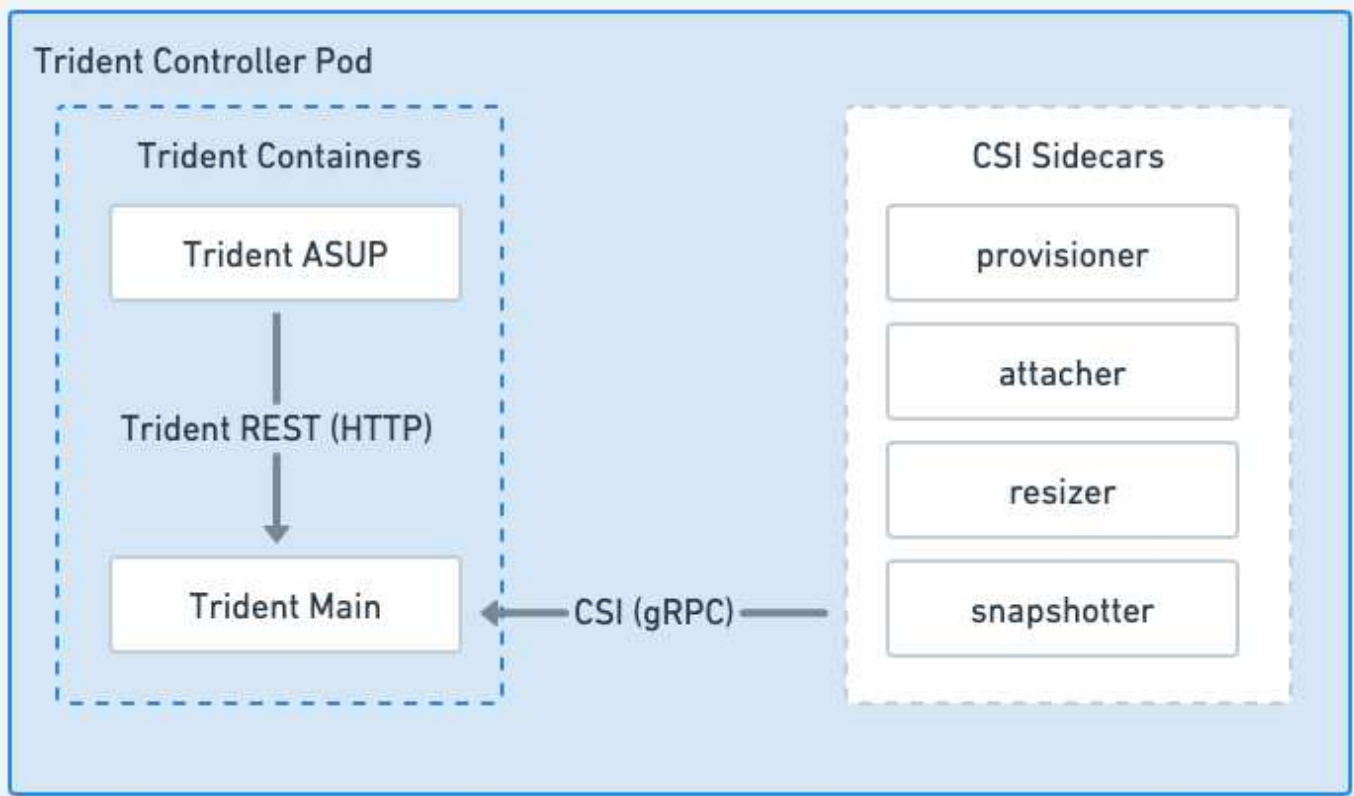


**Figure 1. Trident deployed on the Kubernetes cluster**

### Trident Controller Pod

The Trident Controller Pod is a single Pod running the CSI Controller plugin.

- Responsible for provisioning and managing volumes in NetApp storage
- Managed by a Kubernetes Deployment
- Can run on the control-plane or worker nodes, depending on installation parameters.



**Figure 2. Trident Controller Pod diagram**

### Trident Node Pods

Trident Node Pods are privileged Pods running the CSI Node plugin.

- Responsible for mounting and unmounting storage for Pods running on the host
- Managed by a Kubernetes DaemonSet
- Must run on any node that will mount NetApp storage

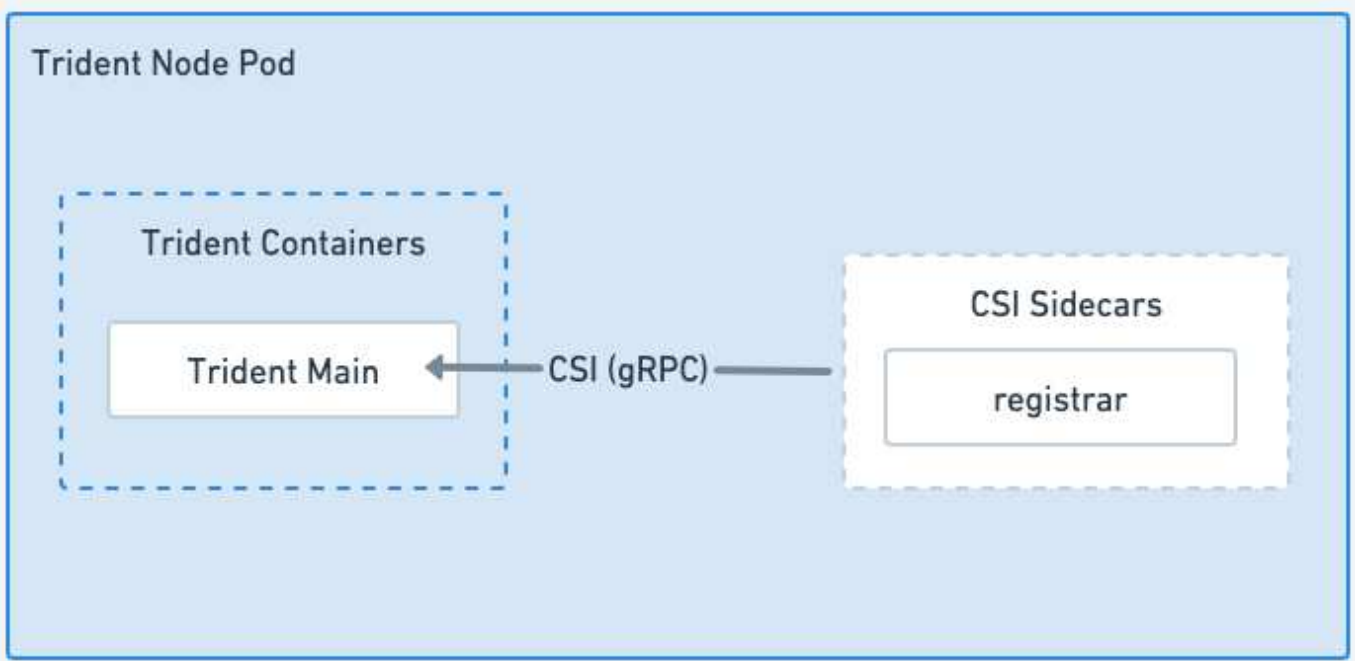


Figure 3. Trident Node Pod diagram

## Supported Kubernetes cluster architectures

Trident is supported with the following Kubernetes architectures:

Kubernetes cluster architectures	Supported	Default install
Single master, compute	Yes	Yes
Multiple master, compute	Yes	Yes
Master, etcd, compute	Yes	Yes
Master, infrastructure, compute	Yes	Yes

## Concepts

### Provisioning

Provisioning in Trident has two primary phases. The first phase associates a storage class with the set of suitable backend storage pools and occurs as a necessary preparation before provisioning. The second phase includes the volume creation itself and requires choosing a storage pool from those associated with the pending volume's storage class.

### Storage class association

Associating backend storage pools with a storage class relies on both the storage class's requested attributes and its `storagePools`, `additionalStoragePools`, and `excludeStoragePools` lists. When you create a

storage class, Trident compares the attributes and pools offered by each of its backends to those requested by the storage class. If a storage pool's attributes and name match all of the requested attributes and pool names, Trident adds that storage pool to the set of suitable storage pools for that storage class. In addition, Trident adds all storage pools listed in the `additionalStoragePools` list to that set, even if their attributes do not fulfill all or any of the storage class's requested attributes. You should use the `excludeStoragePools` list to override and remove storage pools from use for a storage class. Trident performs a similar process every time you add a new backend, checking whether its storage pools satisfy those of the existing storage classes and removing any that have been marked as excluded.

## Volume creation

Trident then uses the associations between storage classes and storage pools to determine where to provision volumes. When you create a volume, Trident first gets the set of storage pools for that volume's storage class, and, if you specify a protocol for the volume, Trident removes those storage pools that cannot provide the requested protocol (for example, a NetApp HCI/SolidFire backend cannot provide a file-based volume while an ONTAP NAS backend cannot provide a block-based volume). Trident randomizes the order of this resulting set, to facilitate an even distribution of volumes, and then iterates through it, attempting to provision the volume on each storage pool in turn. If it succeeds on one, it returns successfully, logging any failures encountered in the process. Trident returns a failure **only if** it fails to provision on **all** the storage pools available for the requested storage class and protocol.

## Volume snapshots

Learn more about how Trident handles the creation of volume snapshots for its drivers.

### Learn about volume snapshot creation

- For the `ontap-nas`, `ontap-san`, `gcp-cvs`, and `azure-netapp-files` drivers, each Persistent Volume (PV) maps to a FlexVol. As a result, volume snapshots are created as NetApp snapshots. NetApp snapshot technology delivers more stability, scalability, recoverability, and performance than competing snapshot technologies. These snapshot copies are extremely efficient both in the time needed to create them and in storage space.
- For the `ontap-nas-flexgroup` driver, each Persistent Volume (PV) maps to a FlexGroup. As a result, volume snapshots are created as NetApp FlexGroup snapshots. NetApp snapshot technology delivers more stability, scalability, recoverability, and performance than competing snapshot technologies. These snapshot copies are extremely efficient both in the time needed to create them and in storage space.
- For the `ontap-san-economy` driver, PVs map to LUNs created on shared FlexVols. VolumeSnapshots of PVs are achieved by performing FlexClones of the associated LUN. ONTAP FlexClone technology makes it possible to create copies of even the largest datasets almost instantaneously. Copies share data blocks with their parents, consuming no storage except what is required for metadata.
- For the `solidfire-san` driver, each PV maps to a LUN created on the NetApp Element software/NetApp HCI cluster. VolumeSnapshots are represented by Element snapshots of the underlying LUN. These snapshots are point-in-time copies and only take up a small amount of system resources and space.
- When working with the `ontap-nas` and `ontap-san` drivers, ONTAP snapshots are point-in-time copies of the FlexVol and consume space on the FlexVol itself. This can result in the amount of writable space in the volume to reduce with time as snapshots are created/scheduled. One simple way of addressing this is to grow the volume by resizing through Kubernetes. Another option is to delete snapshots that are no longer required. When a VolumeSnapshot created through Kubernetes is deleted, Trident will delete the associated ONTAP snapshot. ONTAP snapshots that were not created through Kubernetes can also be deleted.

With Trident, you can use VolumeSnapshots to create new PVs from them. Creating PVs from these snapshots



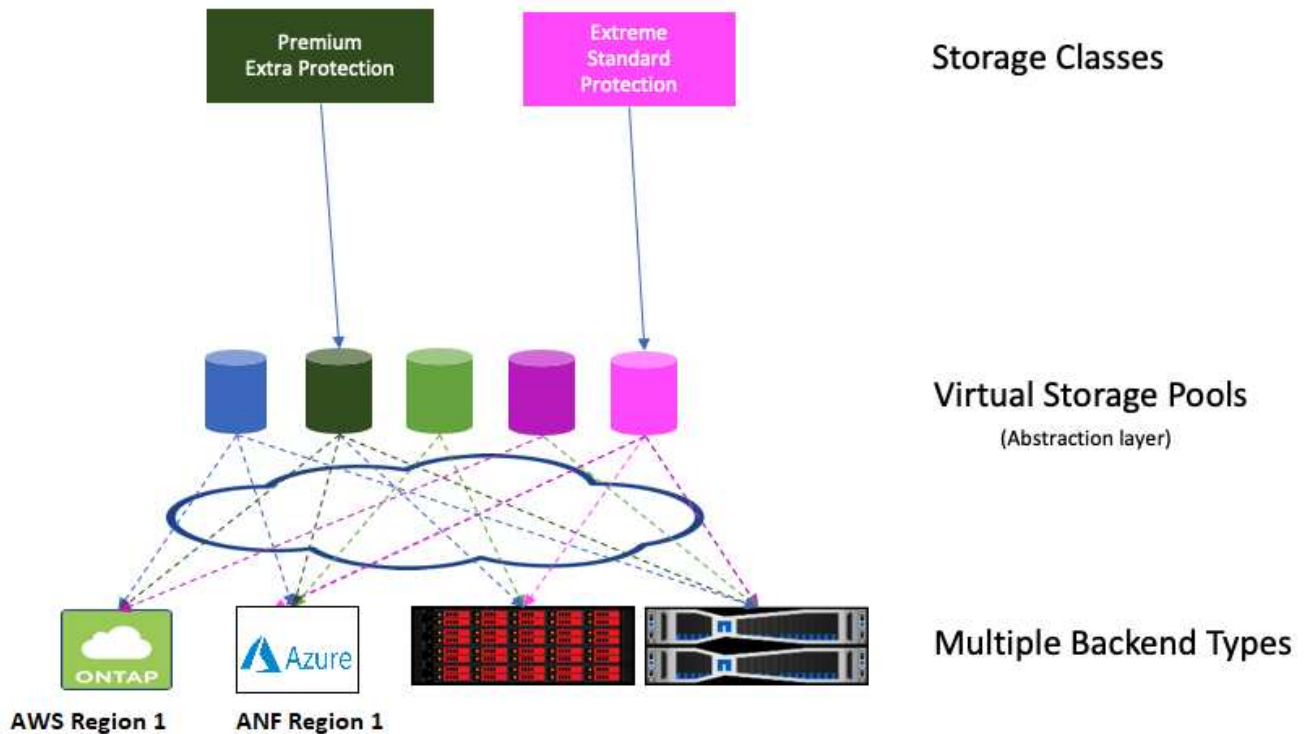
is performed by using the FlexClone technology for supported ONTAP and CVS backends. When creating a PV from a snapshot, the backing volume is a FlexClone of the snapshot's parent volume. The `solidfire-san` driver uses Element software volume clones to create PVs from snapshots. Here it creates a clone from the Element snapshot.

## Virtual pools

Virtual pools provide a layer of abstraction between Trident storage backends and Kubernetes `StorageClasses`. They allow an administrator to define aspects, such as location, performance, and protection for each backend in a common, backend-agnostic way without making a `StorageClass` specify which physical backend, backend pool, or backend type to use to meet desired criteria.

### Learn about virtual pools

The storage administrator can define virtual pools on any of the Trident backends in a JSON or YAML definition file.



Any aspect specified outside the virtual pools list is global to the backend and will apply to all the virtual pools, while each virtual pool might specify one or more aspects individually (overriding any backend-global aspects).



- When defining virtual pools, do not attempt to rearrange the order of existing virtual pools in a backend definition.
- We advise against modifying attributes for an existing virtual pool. You should define a new virtual pool to make changes.

Most aspects are specified in backend-specific terms. Crucially, the aspect values are not exposed outside the backend's driver and are not available for matching in `StorageClasses`. Instead, the administrator defines one or more labels for each virtual pool. Each label is a `key:value` pair, and labels might be common across unique backends. Like aspects, labels can be specified per-pool or global to the backend. Unlike aspects, which have predefined names and values, the administrator has full discretion to define label keys and values as needed. For convenience, storage administrators can define labels per virtual pool and group volumes by label.

A `StorageClass` identifies which virtual pool to use by referencing the labels within a selector parameter. Virtual pool selectors support the following operators:

Operator	Example	A pool's label value must:
=	performance=premium	Match
!=	performance!=extreme	Not match
in	location in (east, west)	Be in the set of values
notin	performance notin (silver, bronze)	Not be in the set of values
<key>	protection	Exist with any value
!<key>	!protection	Not exist

## Volume access groups

Learn more about how Trident uses [volume access groups](#).



Ignore this section if you are using CHAP, which is recommended to simplify management and avoid the scaling limit described below. In addition, if you are using Trident in CSI mode, you can ignore this section. Trident uses CHAP when installed as an enhanced CSI provisioner.

### Learn about volume access groups

Trident can use volume access groups to control access to the volumes that it provisions. If CHAP is disabled, it expects to find an access group called `trident` unless you specify one or more access group IDs in the configuration.

While Trident associates new volumes with the configured access groups, it does not create or otherwise manage access groups themselves. The access groups must exist before the storage backend is added to Trident, and they need to contain the iSCSI IQNs from every node in the Kubernetes cluster that could potentially mount the volumes provisioned by that backend. In most installations, that includes every worker node in the cluster.

For Kubernetes clusters with more than 64 nodes, you should use multiple access groups. Each access group may contain up to 64 IQNs, and each volume can belong to four access groups. With the maximum four access groups configured, any node in a cluster up to 256 nodes in size will be able to access any volume. For latest limits on volume access groups, refer to [here](#).

If you're modifying the configuration from one that is using the default `trident` access group to one that uses others as well, include the ID for the `trident` access group in the list.

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