Running at Light Speed: Cloud Native Security Patterns

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Hi, How is Everybody? Good. Great.

CEO @ nVisium since 2009

Doesn't mix coffee and sugar

Drinks beer the right way - never Budweis

Mostly codes in Scala + Go

Cloud Native Characteristics

Containerized

Microservices

Dynamically Managed Orchestration

Declarative

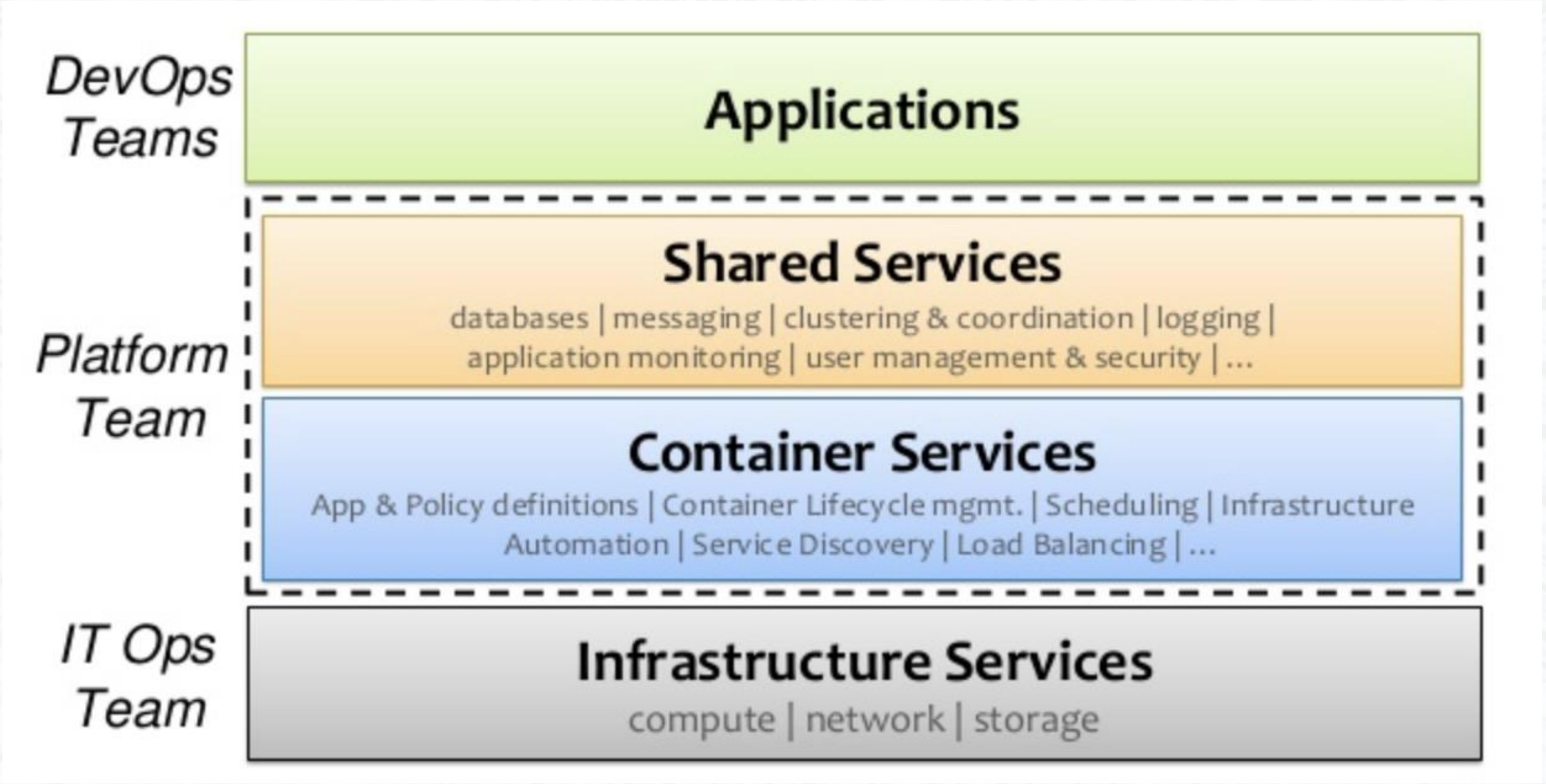
Telemetry & Health Reporting

Resiliency

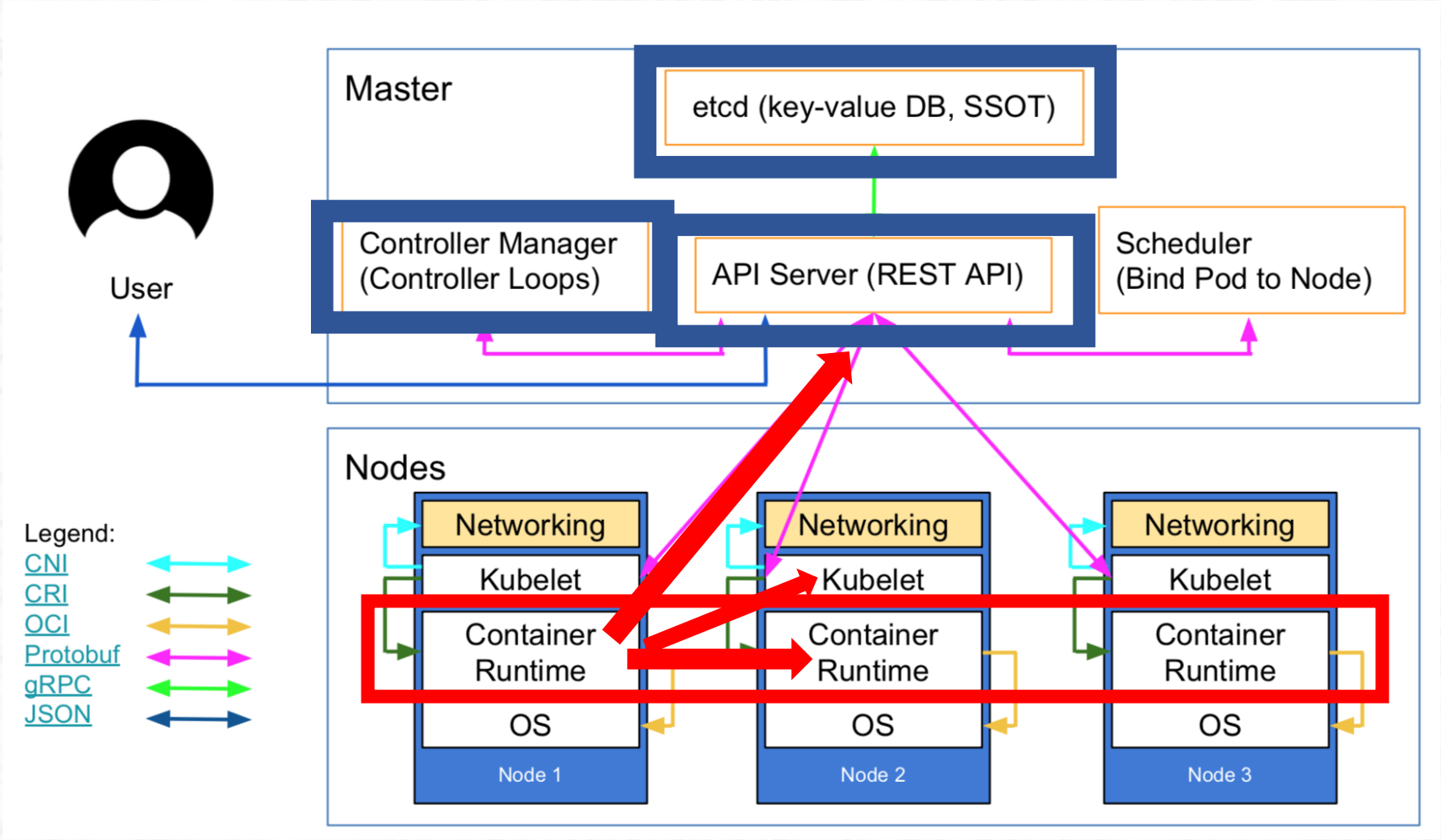
Cloud Native Secure Architecture

- ✓ Container Isolation
- ✓ Control Plane Hardening
- ✓ Network Segmentation
- ✓ Encrypted Communications
- ✓ Authentication (container & cluster-level)
- ✓ Authorization & Access Control
- ✓ Secrets Management
- ✓ Logging & Monitoring

Who's Job is it Anyway?



Isolating Containerized Workloads



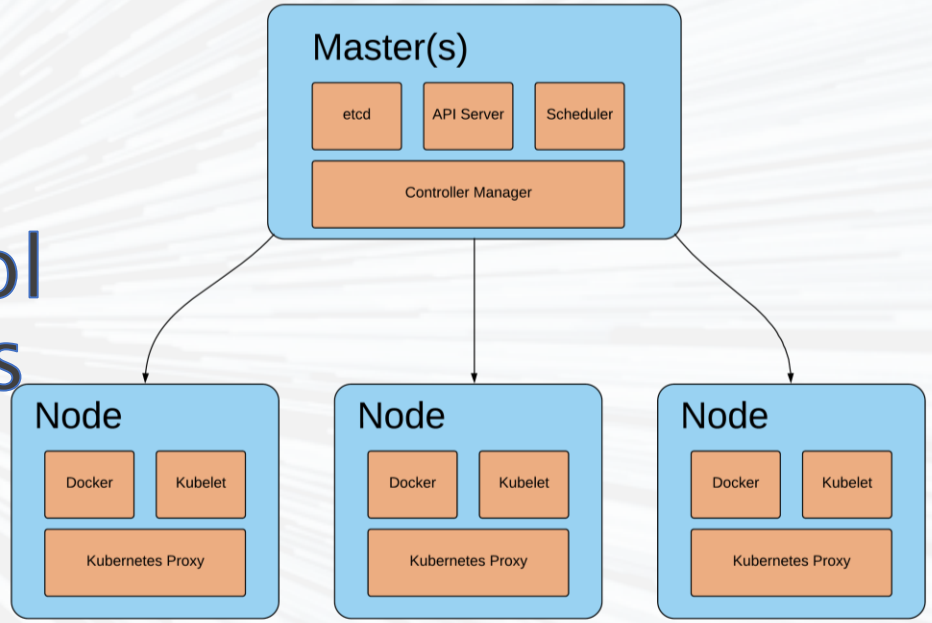
https://kubernetes.io/blog/2018/07/18/11-ways-not-to-get-hacked/

Control Plane & Core Components

Control Plane manages the cluster's state and schedules containers.

A privileged attack against a control plane node or pod can have serious consequences.

Managed container orchestration services generally abstract away the control plane for you.



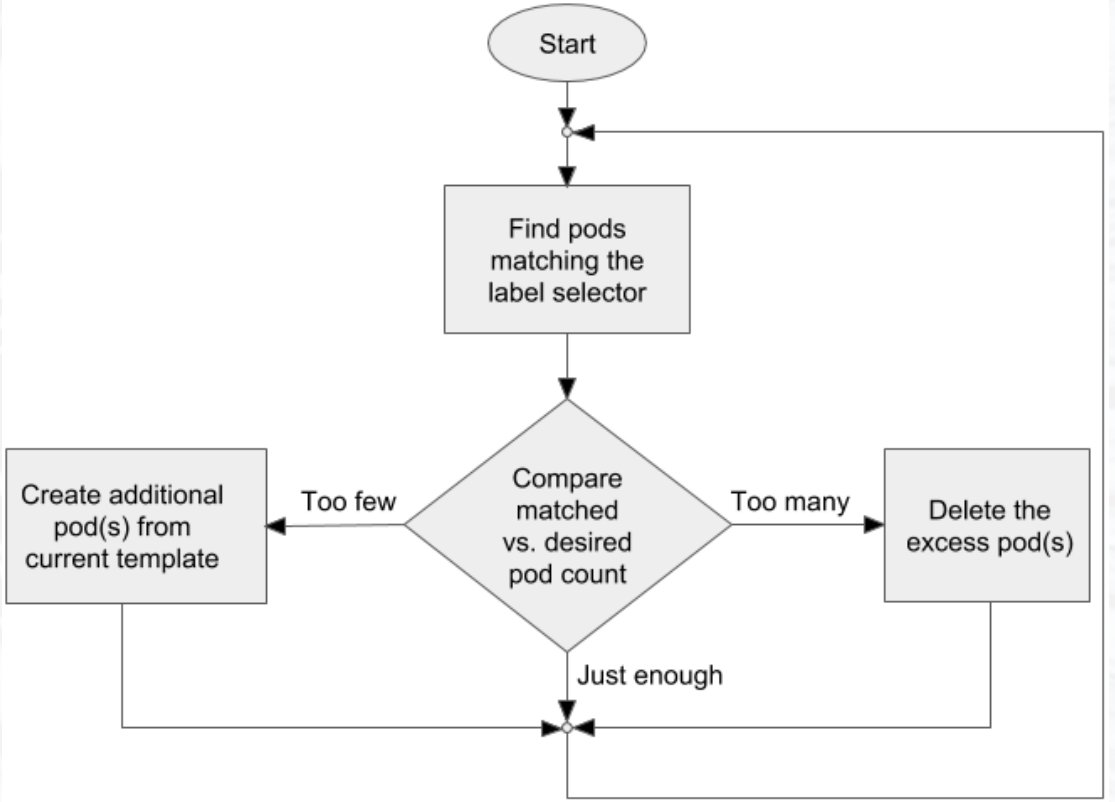
Reconciler Pattern

Fix configuration drift

Event-driven model for updating/patching

Decrease the mean-time-to-fix (MTTF)

Kubernetes controller loops & scheduler handle updates

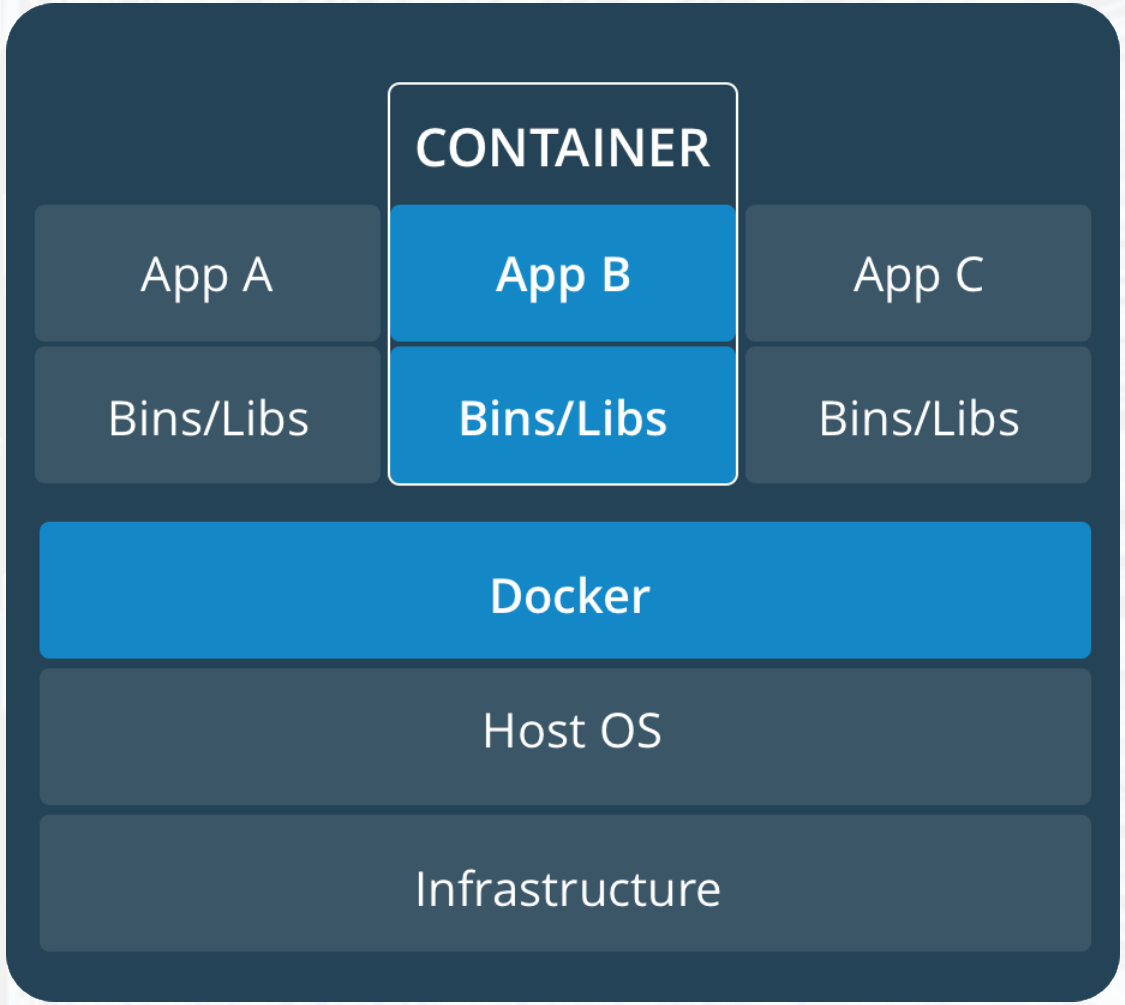


https://freecontent.manning.com/wp-content/uploads/Luksa_IRC_02.png

Spoiler: Containers Aren't Sandboxes

Shared host resources & kernel

Often relies on rule-based execution policies (Seccomp, SELinux, AppArmor) for isolation



https://www.docker.com/sites/default/files/Container%402x.png

Container Privilege Escalation

CVE-2018-1000400
Kubernetes' Container Runtime Interface (CRI) was vulnerable to a privilege context switching error due to a capability granting issue

CVE-2016-3697
runC was vulnerable to privilege escalation by starting a Docker container with an arbitrary UID

The Gateway Drug

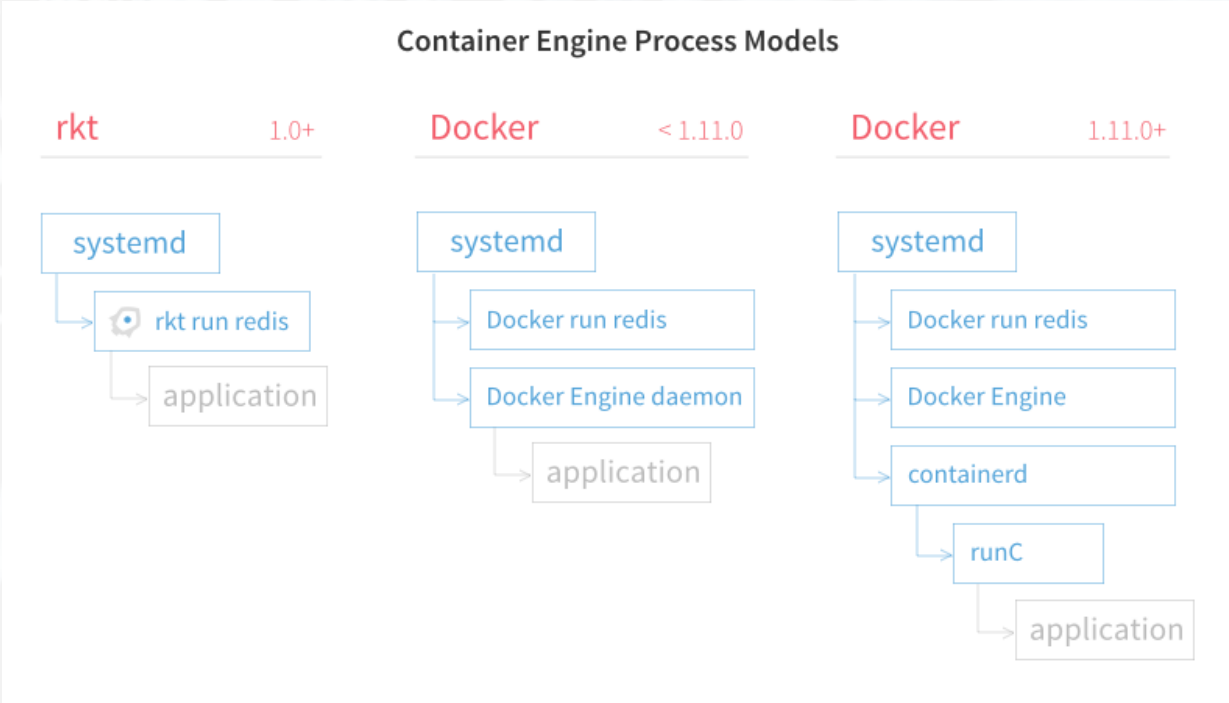
```
FROM golang:1.10.2
MAINTAINER Jack Mannino <jack@nvisium.com>

USER root

ENV password s3curitah1

RUN apt-get update && apt-get install -y
apt-transport-https

RUN mkdir /app
ADD . /app/
WORKDIR /app
RUN go build main -o main .
CMD ["/app/main"]
```



https://coreos.com/rkt/docs/latest/rkt-vs-docker-process-model.png

Container Isolation Models

Via cgroups & namespaces

- Docker, Rkt, LXC

User-space kernels

- gVisor

Hypervisor/VM

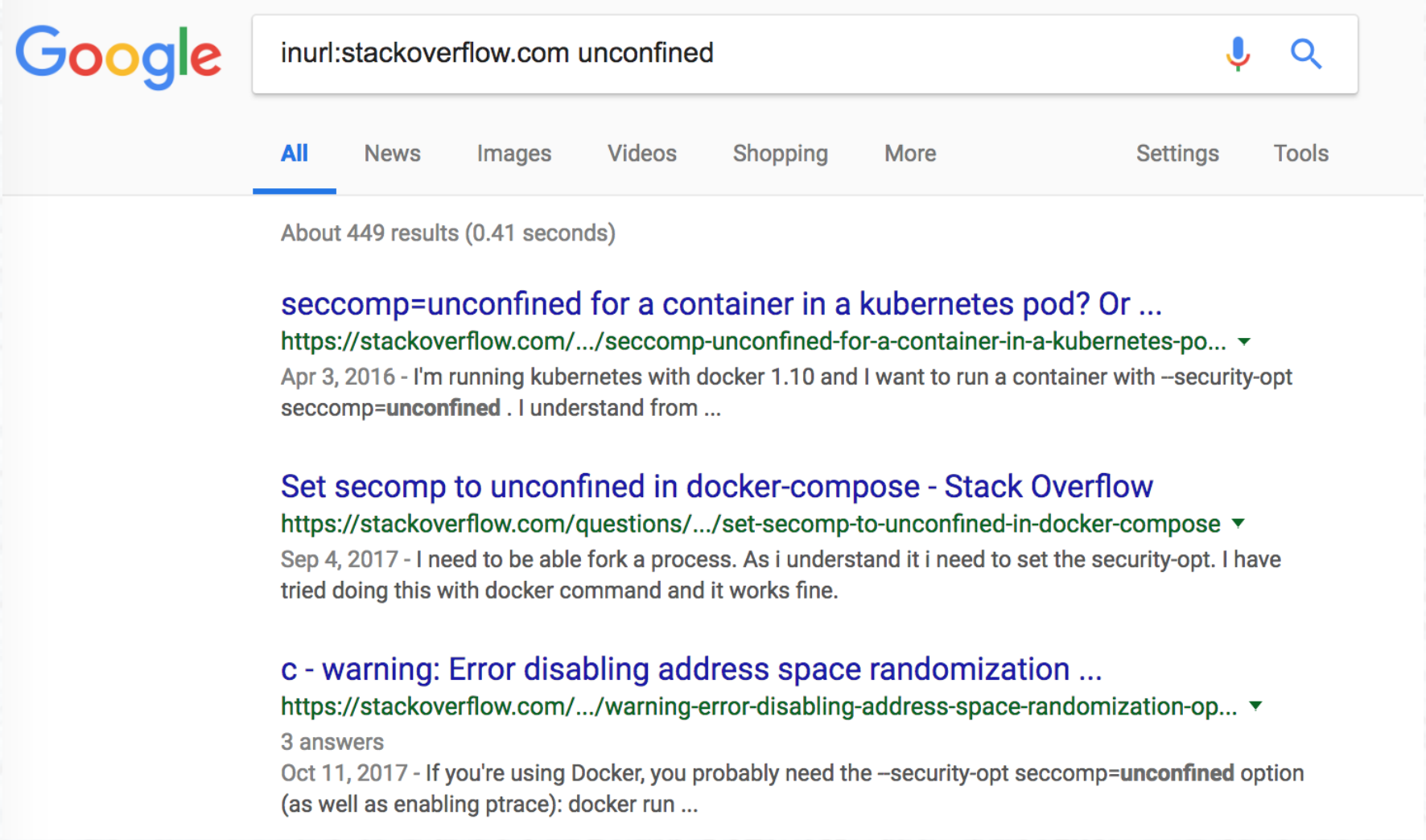
- Kata Containers, Clear Containers

How They Stack Up

Available Container Security Features, Requirements and Defaults			
Security Feature	**LXC 2.0**	**Docker 1.11**	**CoreOS Rkt 1.3**
User Namespaces	Default	Optional	Experimental
Root Capability Dropping	Weak Defaults	Strong Defaults	Weak Defaults
Procfs and Sysfs Limits	Default	Default	Weak Defaults
Cgroup Defaults	Default	Default	Weak Defaults
Seccomp Filtering	Weak Defaults	Strong Defaults	Optional
Custom Seccomp Filters	Optional	Optional	Optional
Bridge Networking	Default	Default	Default
Hypervisor Isolation	Coming Soon	Coming Soon	Optional
MAC: AppArmor	Strong Defaults	Strong Defaults	Not Possible
MAC: SELinux	Optional	Optional	Optional
No New Privileges	Not Possible	Optional	Not Possible
Container Image Signing	Default	Strong Defaults	Default
Root Interation Optional	True	False	Mostly False

https://blog.jessfraz.com/post/containers-security-and-echo-chambers/

Just Use the Defaults != Turn It Off



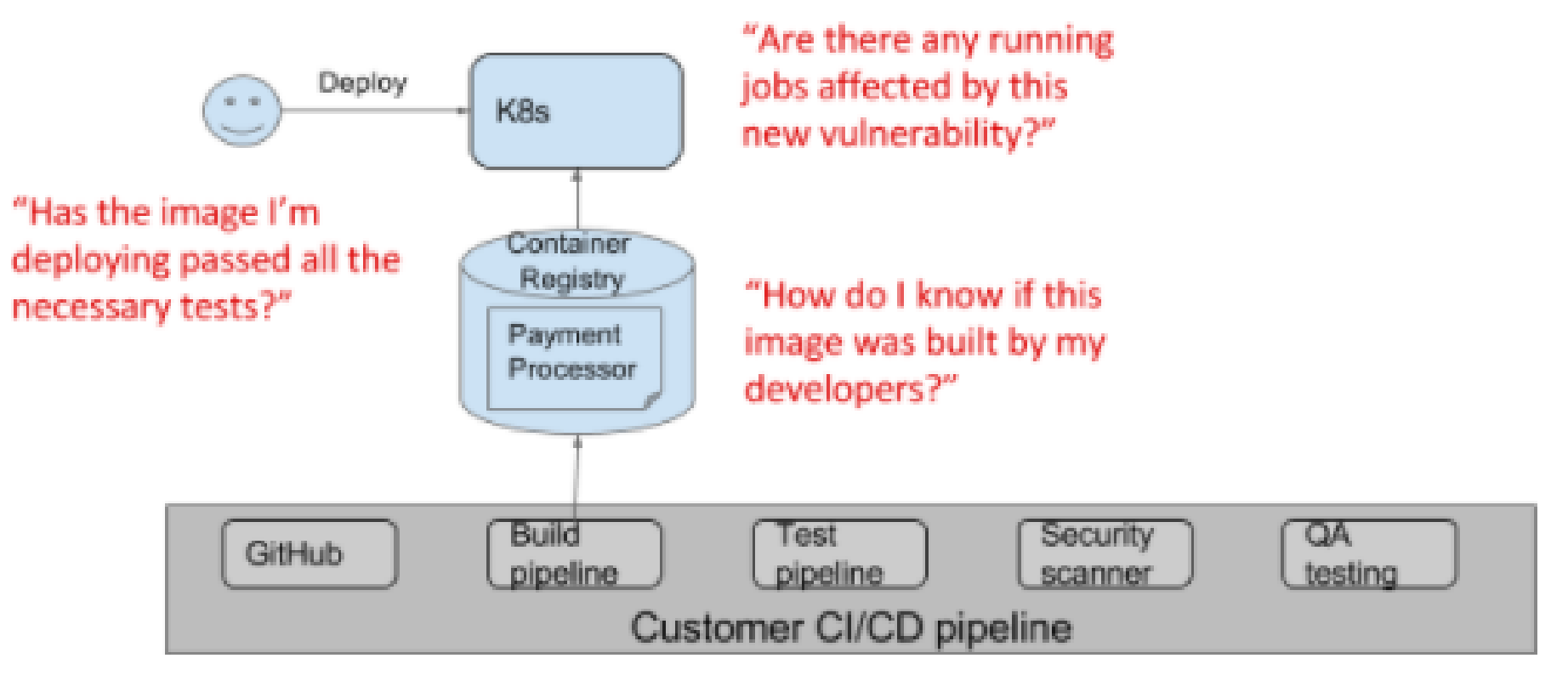
Control Groups & Namespaces

By UID, GID, and PID

Isolation for what you can use (cgroups) and what you can see (namespaces)

Not all objects are namespaced (time, keyctl), however default seccomp profiles blocks these syscalls

What Am I Shipping?



https://kubernetes.io/blog/2017/11/securing-software-supply-chain-grafeas/

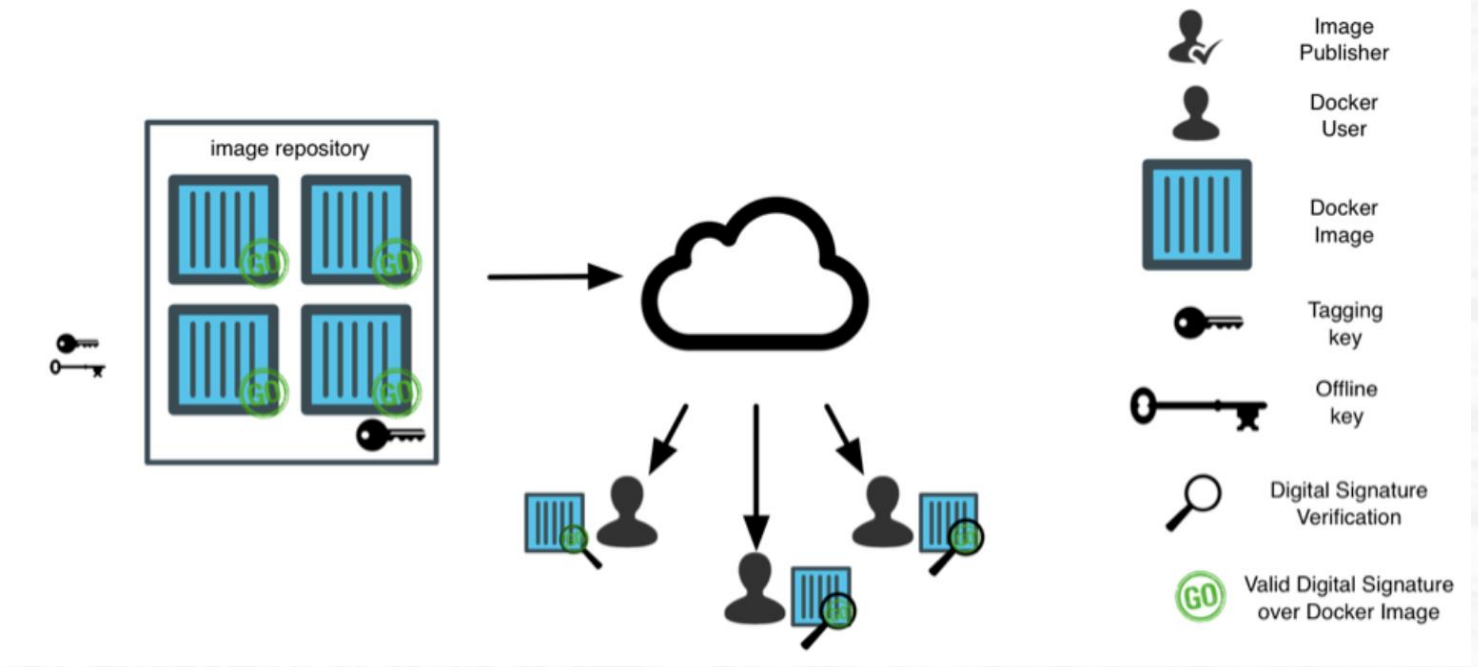
Base Image Management

- Focus on keeping the attack surface small
- Use base images that ship with minimal installed packages and dependencies
- Use version tags vs. image:latest
- Use images that support security kernel features (Seccomp, AppArmor, SELinux)

```
$ grep CONFIG_SECCOMP= /boot/config-$(uname -r)
$ cat /sys/module/apparmor/parameters/enabled
```

Build Integrity & Attestation

- Ensures integrity of the images and publisher attestation
- Sign to validate pipeline phases
- Example – Docker Content Trust & Notary, GCP's Binary Authorization
- Consume only trusted content for tagged builds



Seccomp

Linux kernel feature that reduces the attack surface by filtering dangerous syscalls

Applied via metadata annotations at the pod or container level

Docker provides a reasonably secure default profile to leverage (security quick win!)

AppArmor

Mandatory access control (MAC) for Linux.

Reduces the attack surface by whitelisting capabilities, restricting network access, file permissions, and more.

Similar to Seccomp, container runtimes provide default profiles with quick wins (especially Docker and LXC).

```
cat > /etc/apparmor.d/no_raw_net <<EOF
#include <tunables/global>

profile no-ping flags=(attach_disconnected,mediate_deleted) {
  #include <abstractions/base>

  network inet tcp,
  network inet udp,
  network inet icmp,

  deny network raw,
  deny network packet,
  file,
  mount,
}
```

Deny Network Traffic

```
root@6da5a2a930b9:~# ping 8.8.8.8
ping: Lacking privilege for raw socket.
```

Restricting Capabilities

- Circa 2003, root privileges were broken into a subset of capabilities.
- This feature enables us to reduce the damage a compromised root account can do.
- Docker default profile allows 14 of 40+ capabilities.
- Open Container Initiative (OCI) spec restricts this this even further:
  - AUDIT_WRITE
  - KILL
  - NET_BIND_SERVICE

Docker Default Capabilities

- CHOWN
- DAC_OVERRIDE
- FOWNER
- FSETID
- KILL
- SETGID
- SETUID
- SETPCAP
- NET_BIND_SERVICE
- NET_RAW
- SYS_CHROOT
- MKNOD
- AUDIT_WRITE
- SETFCAP

Limiting Privileges

More often than not, your container does not need root!!!

Limit access to underlying host resources (network, storage, or IPC)

Example – Ping command requires CAP_NET_RAW

We can drop everything else.

```
docker run -d --cap-drop=all --cap-add=net_raw my-image
```

```
securityContext:
  allowPrivilegeEscalation: false
  capabilities:
    drop:
      - ALL
    add: ["NET_RAW"]
  runAsNonRoot: true
  runAsUser: 1000
```

User Namespaces

Supported by modern kernels and leading container tech

Remaps UID from the container to an unprivileged high-number UID on the host

Enable ***ExperimentalHostUserNamespaceDefaultingGate***

```
dockerd –userns-remap=“someuser:someuser”
```

Rootless Containers

Unprivileged user that can't ask for more privileges

Cannot install packages

Rootless containers are built via filesystem snapshots

runC and others support rootless, but upstream support has been limited

Upstream Orchestration Support

Cool story, how do I actually use this?

Kubernetes 1.12 supports the procMount security context attribute

Allows paths in the container's */proc* to not be masked

```
type ContainerSecurityContextAccessor interface {
    Capabilities() *api.Capabilities
    Privileged() *bool
    ProcMount() api.ProcMountType
    SELinuxOptions() *api.SELinuxOptions
    RunAsUser() *int64
    RunAsNonRoot() *bool
    ReadOnlyRootFilesystem() *bool
    AllowPrivilegeEscalation() *bool
}
```

No New Privileges

Introduced in Linux 3.5, uses the **no_new_privs** kernel flag

Breaks setuid and setgid

Docker ***--no-new-privileges***
K8s via the **allowPrivilegeEscalation** security context constraint

Authentication

- Authentication occurs at several layers
  - Authenticating API users.
  - Authenticating nodes to the cluster.
  - Authenticating services to each other.
  - Webhook endpoints should authenticate requests.
- Kubernetes provides several authenticator options, each with their own strengths and tradeoffs.
- *By default, Kubernetes uses a self-signed certificate infrastructure*

Implementation Flaw - Account Reuse

By default, K8s uses the namespace default service account if you don't define one for your pod.

Elevate privileges against other services in the same namespace or potentially at the cluster level.

Run Commands via K8s API

Even if network traffic is blocked, K8s API lets us execute shell commands.

This is allowed across shared accounts or users with **create** privileges for **pods/exec**

https://k8s/api/v1/namespaces/owned1/pods/pod-xyz-xyz/exec?command=/bin/bash&stdin=true&stderr=true&stdout=true&tty=true

Fixing the Problem

Always use a unique service account per pod!

```
kubectl create serviceaccount s1 --
namespace=”prod”
```

This can be set at the orchestration level

```yaml
apiVersion: v1
kind: Pod
metadata:
  name: my-pod
spec:
  serviceAccountName: s1
```

Don’t Share Anything From the Host

- ✓ Mounts & Volumes
- ✓ Host namespaces
- ✓ Host Network
- ✓ Host PID

```yaml
apiVersion: extensions/v1beta1
kind: PodSecurityPolicy
metadata:
  name: restrictive-pod-security-policy
  annotations:
    seccomp.security.alpha.kubernetes.io/defaultProfileName: docker/default
    apparmor.security.beta.kubernetes.io/allowedProfileNames: 'runtime/default'
    seccomp.security.alpha.kubernetes.io/allowedProfileNames: docker/default
    apparmor.security.beta.kubernetes.io/defaultProfileName:  'runtime/default'
spec:
  privileged: false
  allowPrivilegeEscalation: false
  requiredDropCapabilities:
    - ALL
  volumes:
    - 'configMap'
    - 'emptyDir'
    - 'projected'
    - 'secret'
    - 'downwardAPI'
    - 'persistentVolumeClaim'
  hostNetwork: false
  hostIPC: false
  hostPID: false
  runAsUser:
    rule: MustRunAsNonRoot
  seLinux:
    rule: RunAsAny
  fsGroup:
    rule: RunAsAny
  supplementalGroups:
    rule: 'MustRunAs'
    ranges:
      # Forbid adding the root group.
      - min: 1
        max: 65535
  fsGroup:
    rule: 'MustRunAs'
    ranges:
      # Forbid adding the root group.
      - min: 1
        max: 65535
  readOnlyRootFilesystem: true
```

Authorization

- After we've authenticated a subject, we need to limit the resources they can view or manipulate.
- Kubernetes provides two approaches to authorizing apiserver cluster actions for users and services.
  - Role-Based Access Control (RBAC)
  - Attribute-Based Access Control (ABAC)
- Kubelet API uses the Node Authorizer to control access.
- Webhook endpoints can also be authorized independently.

Role-Based Access Control

- Our goal is to restrict what each user and service can do against a running cluster.
- Roles can be granted at the cluster-level or namespace-level.
  - *ClusterRoleBinding* – applies to all namespaces across the cluster
  - *RoleBinding* – applies only within a single namespace
- Kubernetes also enables default roles for common role types and for system services.
- RBAC policies are cumulative; Nothing is taken away, only given.

Create Roles & Bindings

```yaml
kind: Role
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  namespace: production
  name: read-pods
rules:
- apiGroups: [""] # "" indicates the core API group
  resources: ["pods"]
  verbs: ["get", "watch", "list"]
```

Create a role

```yaml
kind: RoleBinding
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  name: read-pods
  namespace: production
subjects:
- kind: ServiceAccount
  name: joe-dev # Name is case sensitive
roleRef:
  kind: Role #this must be Role or ClusterRole
  name: read-pods # name of the Role or ClusterRole
  apiGroup: rbac.authorization.k8s.io
```

Bind the role to an explicit namespace

Controller Pattern

Used to read an object's specification and mutate its status

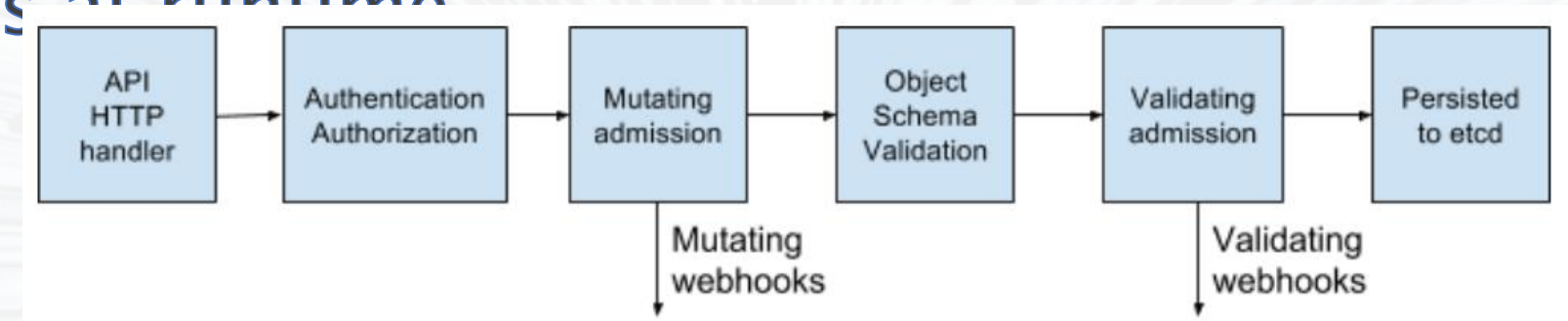
Enforce security at cluster admission boundaries

Pluggable architecture

Kubernetes implements a controller for most objects

Admission Controllers

Kubernetes provides hooks to check & fix containers at runtime



PodSecurityPolicy enforces a set of security constraints at the cluster level for pods being admitted

Enable the *PodSecurityPolicy* admission controller via kube-apiserver: ***–admission-***

Designing a PodSecurityPolicy

One or more policies can be applied per cluster

When multiple policies are defined, K8s selects a policy in the following order:

1. Policies that validate the pod without altering it are used first.
2. If it is a new pod, the policy is selected alphabetically.
3. The policy is rejected if it's a pod update and mutation is required.

Designing a PodSecurityPolicy

```yaml
apiVersion: extensions/v1beta1
kind: PodSecurityPolicy
metadata:
  name: restrictive-pod-security-policy
  annotations:
    seccomp.security.alpha.kubernetes.io/defaultProfileName: docker/default
    apparmor.security.beta.kubernetes.io/allowedProfileNames: 'runtime/default'
    seccomp.security.alpha.kubernetes.io/allowedProfileNames: docker/default
    apparmor.security.beta.kubernetes.io/defaultProfileName:  'runtime/default'
spec:
  privileged: false
  allowPrivilegeEscalation: false
  requiredDropCapabilities:
    - ALL
  volumes:
    - 'configMap'
    - 'emptyDir'
    - 'projected'
    - 'secret'
    - 'downwardAPI'
    - 'persistentVolumeClaim'
  hostNetwork: false
  hostIPC: false
  hostPID: false
  runAsUser:
    rule: MustRunAsNonRoot
  seLinux:
    rule: RunAsAny
  supplementalGroups:
    rule: 'MustRunAs'
    ranges:
      # Forbid adding the root group.
      - min: 1
        max: 65535
  fsGroup:
    rule: 'MustRunAs'
    ranges:
      # Forbid adding the root group.
      - min: 1
        max: 65535
  readOnlyRootFilesystem: true
```

PodSecurityPolicy components

- AppArmor
- Capabilities
- Host Namespaces
- Privilege Escalation
- Seccomp
- SELinux
- Users and Groups
- Volumes and Filesystems

Apply a PodSecurityPolicy

To ensure that a pod can access a PodSecurityPolicy, it must be granted RBAC access.

```yaml
kind: ClusterRole
apiVersion: rbac.authorization.k8s.io/v1
metadata:
  name: authenticated-users-psp
rules:
- apiGroups: ['policy']
  resources: ['podsecuritypolicies']
  verbs:     ['use']
  resourceNames:
  - psp-1
  - psp-2
```

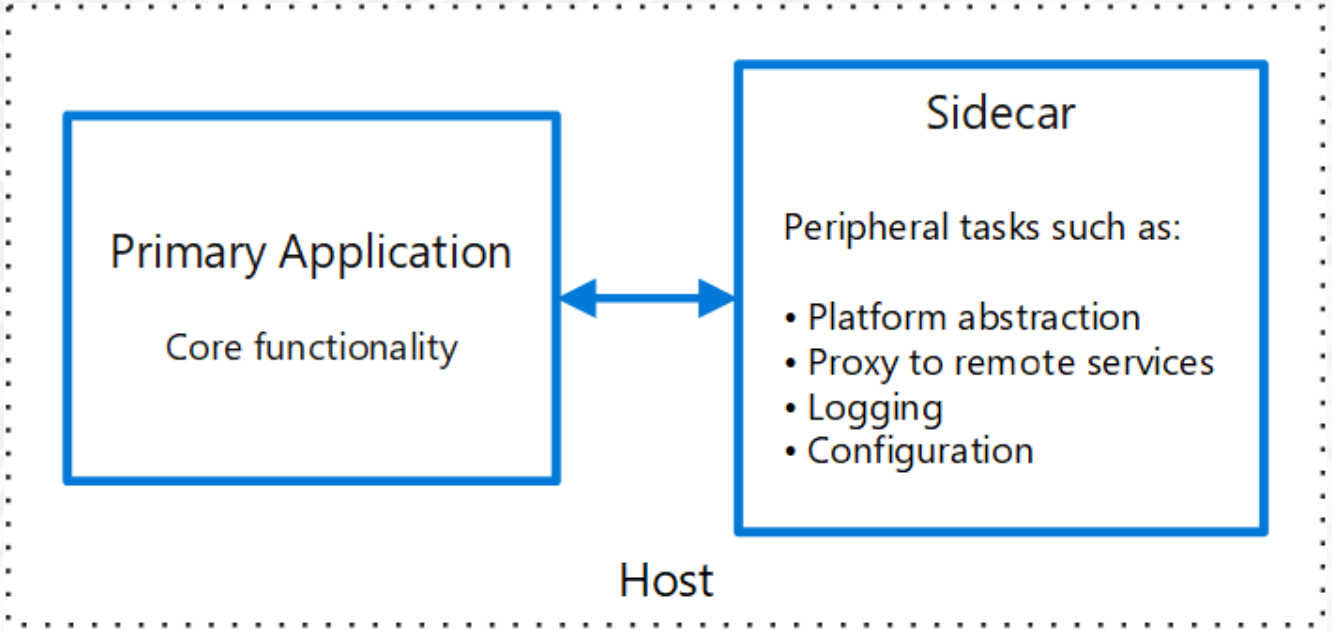
Sidecar Pattern

Decomposition pattern

Extends a container's capabilities & security boundaries

Introduces complexity & tighter coupling

Generally requires centralized

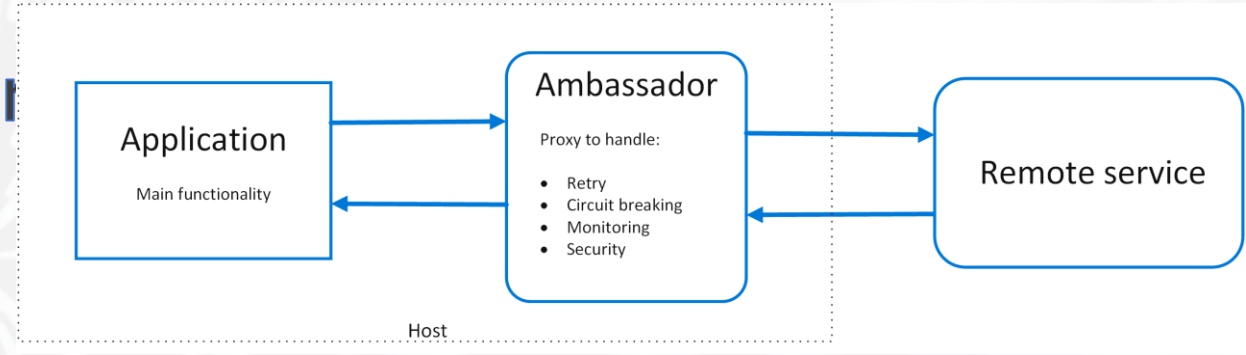


https://docs.microsoft.com/en-us/azure/architecture/patterns/_images/sidecar.png

Ambassador Pattern

Out-of-process proxy

Deployed as a sidecar or daemon



https://docs.microsoft.com/en-us/azure/architecture/patterns/_images/ambassador.png

Update legacy apps without changes

Avoid when features can't be generalized & require deeper integration with the client application.

Key Boundary

Consider whether to use a single shared instance or an instance for each client.

Service Mesh Pattern

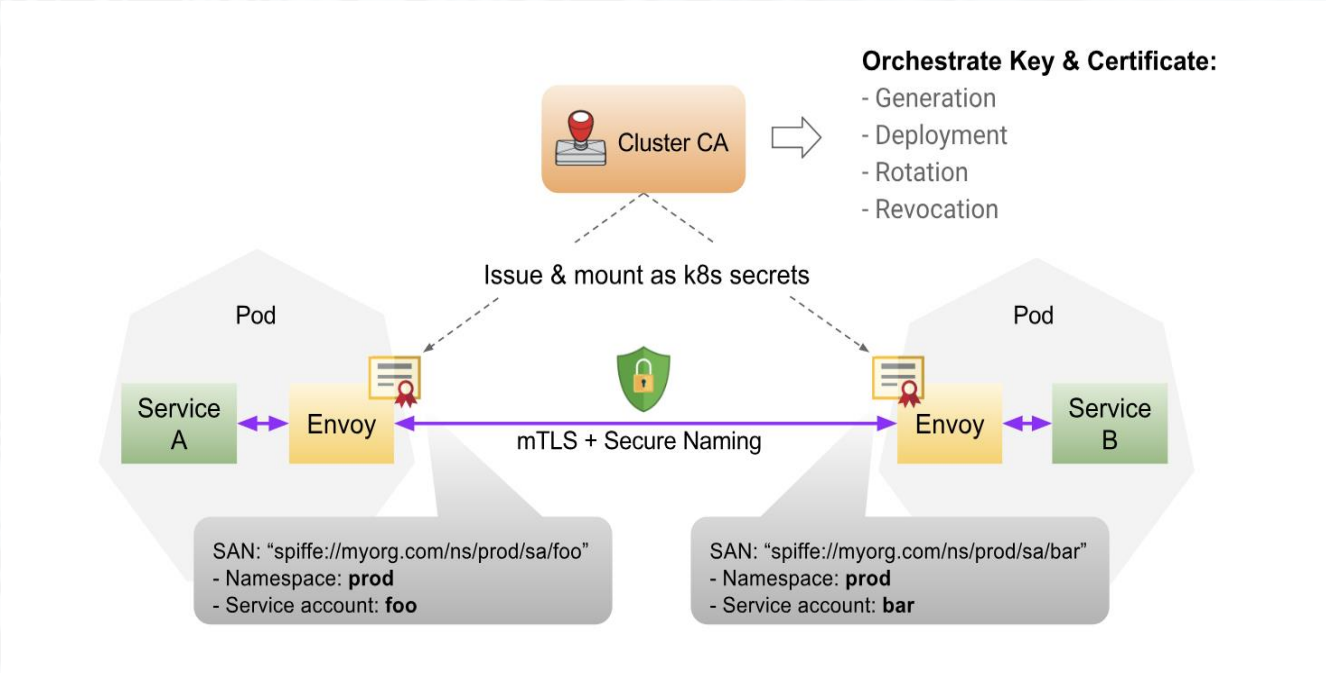
Mesh of sidecars with centralized management

Popular implementations

- Envoy
- Istio
- Consul

Lift security controls out of containers

Automated Injection



Secrets Management

Docker

~~docker run –it –e “DBUSER=dbuser” –e “DBPASSWD=dbpasswd” mydbimage~~

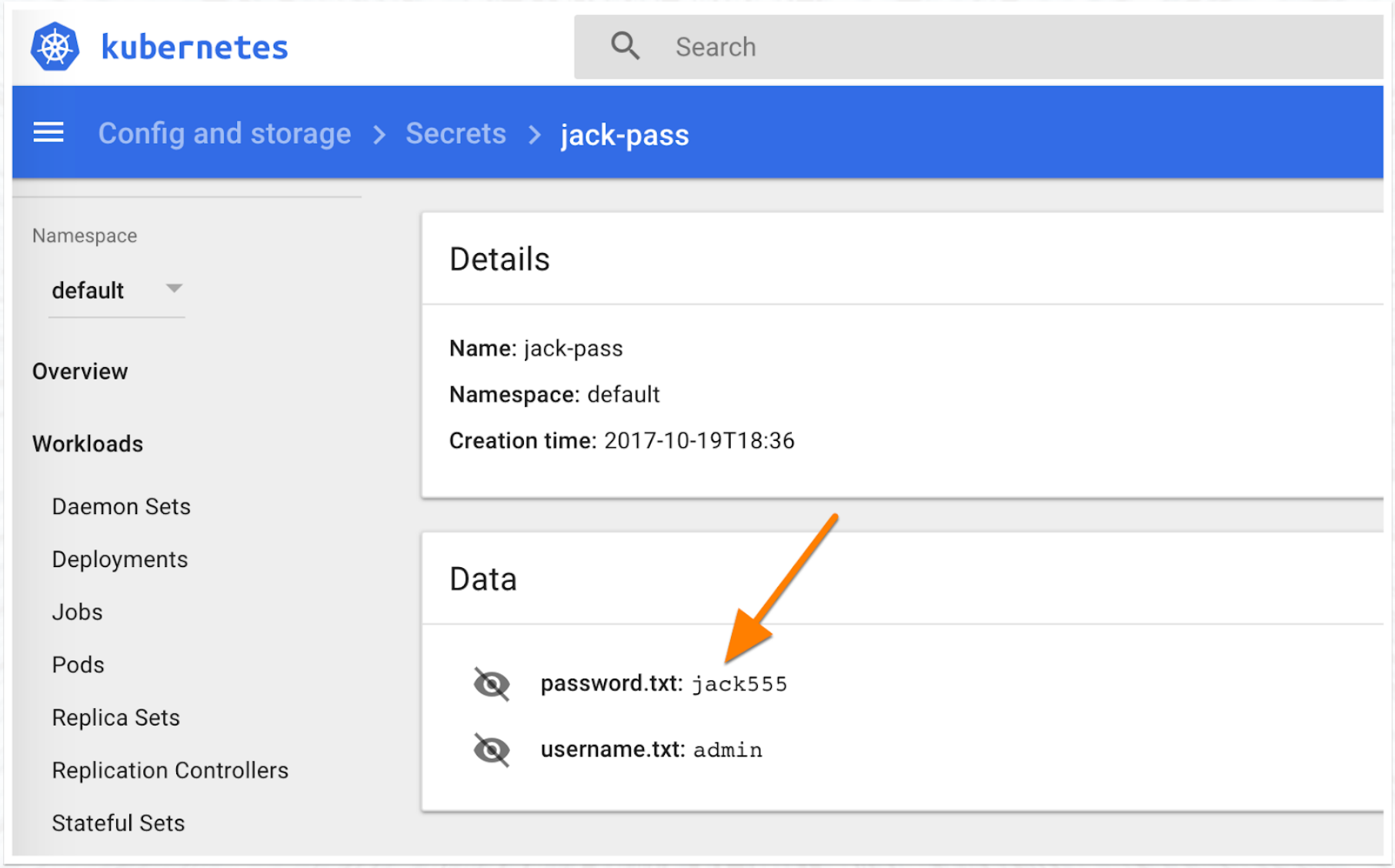
echo <secret> | docker secret create some-secret

Kubernetes

kubectl create secret generic db-user-pw --from-file=./username.txt --from-file=./password.txt

kubectl create –f ./secret.yaml

Nothing is Perfect



Beware of Plain Text Storage

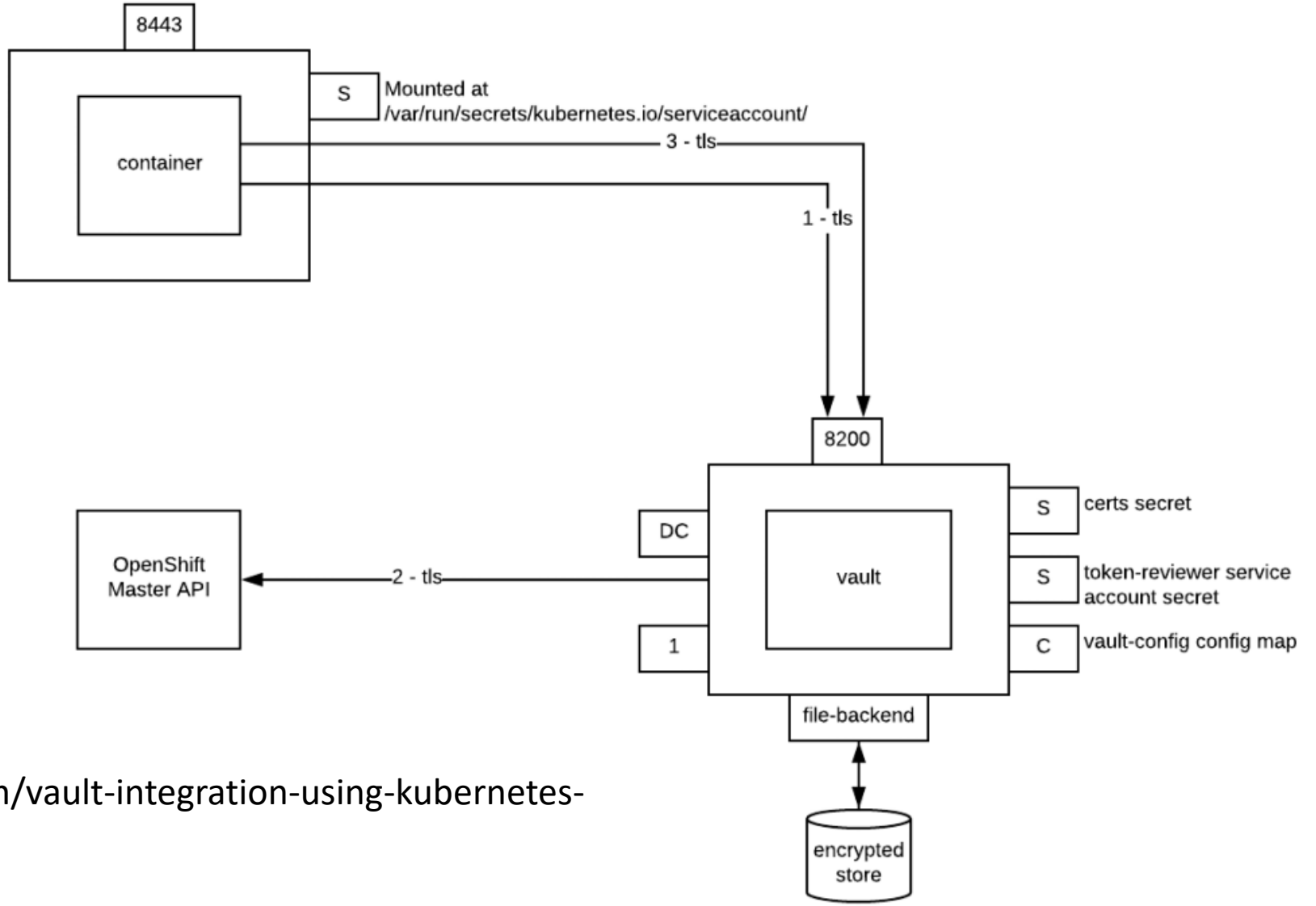
Prior to 1.7, secrets were stored in plain text at-rest

As of v1.7+, k8s can encrypt your secrets in **etcd**

Not perfect at all, either.

```
kind: EncryptionConfig
apiVersion: v1
resources:
  - resources:
      - secrets
    providers:
    - aescbc:
        keys:
        - name: key1
          secret: YOURKEYHERE
    - identity: {}
```

Dynamic Secrets



https://blog.openshift.com/vault-integration-using-kubernetes-authentication-method/

Example – Retrieve & Mount a Secret

```
command:
  - "sh"
  - "-c"
  - >
    X_VAULT_TOKEN=$(cat /etc/vault/token);
    VAULT_LEASE_ID=$(cat /etc/app/creds.json | jq -j '.lease_id');
    while true; do
      curl --request PUT --header "X-Vault-Token: $X_VAULT_TOKEN" --data '{"lease_id": "'"$VAULT_LEASE_ID"'",
      "increment": 3600}' http://errant-mandrill-vault:8200/v1/sys/leases/renew;
      sleep 3600;
    done
lifecycle:
  preStop:
    exec:
      command:
        - "sh"
        - "-c"
        - >
          X_VAULT_TOKEN=$(cat /etc/vault/token);
          VAULT_LEASE_ID=$(cat /etc/app/creds.json | jq -j '.lease_id');
          curl --request PUT --header "X-Vault-Token: $X_VAULT_TOKEN" --data '{"lease_id":
          "'"$VAULT_LEASE_ID"'"}' http://errant-mandrill-vault:8200/v1/sys/leases/revoke;
volumeMounts:
  - name: app-creds
    mountPath: /etc/app
  - name: vault-token
    mountPath: /etc/vault
```

Conclusion

Think about security early and anticipate future growth

Focus on logical and organizational structure and codify it into your environment

Enable your engineers to move fast, but protect them from themselves

Apply security controls at the layers that make the most sense

Keep in Touch

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