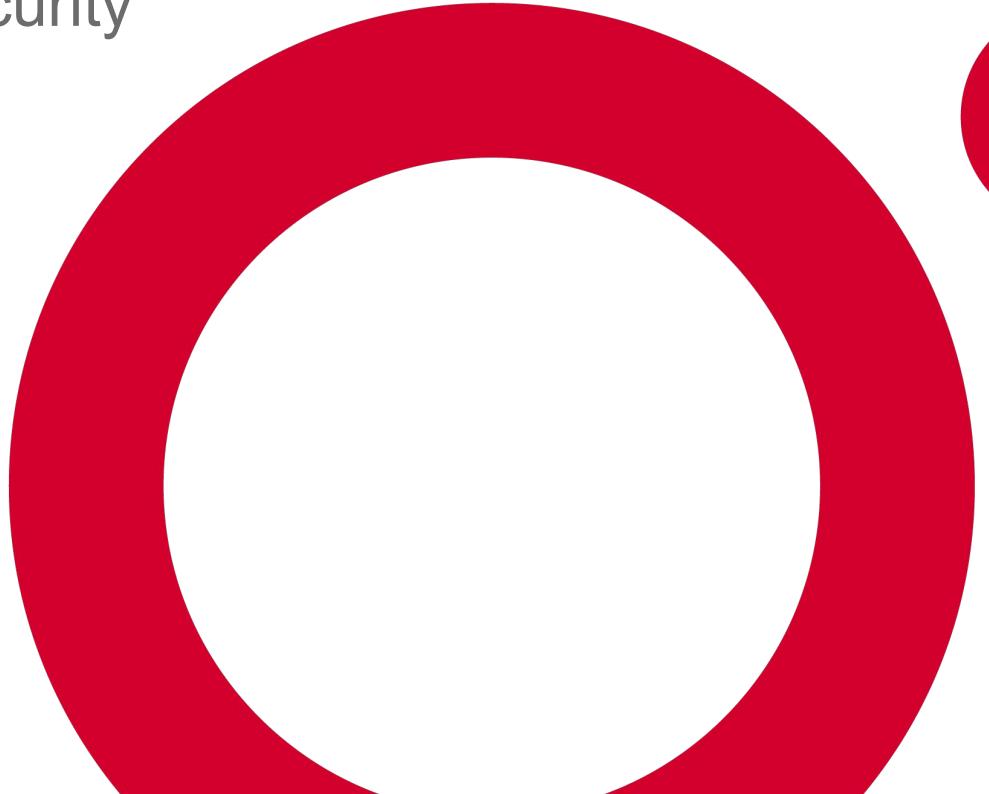




# Certified Kubernetes Security Specialist (CKS) Crash Course

*Kubernetes 1.25 Edition*



# About the trainer



**bmuschko**



**bmuschko**



**bmuschko.com**

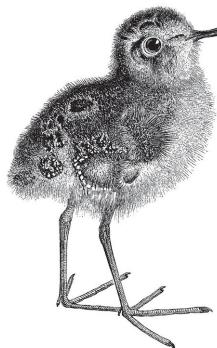


 **AUTOMATED  
ASCENT**  
[automatedascent.com](http://automatedascent.com)

O'REILLY®

# Certified Kubernetes Security Specialist (CKS) Study Guide

In-Depth Guidance and Practice



Early  
Release  
RAW &  
UNEDITED

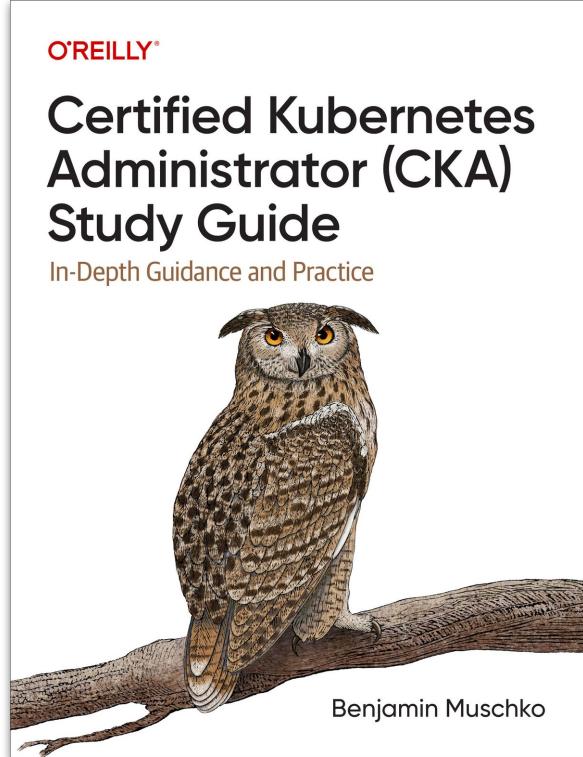
Benjamin Muschko

*Companion study guide with  
practice questions*

**Release mid 2023**

Online access on O'Reilly  
learning platform:

[https://learning.oreilly.com/library/view/  
certified-kubernetes-security/978109  
8132965](https://learning.oreilly.com/library/view/certified-kubernetes-security/9781098132965)



*Companion study guide with  
practice questions*

**Released in June 2022**

Online access on O'Reilly  
learning platform:

[https://learning.oreilly.com/library/view/  
certified-kubernetes-administrator/97  
81098107215/](https://learning.oreilly.com/library/view/certified-kubernetes-administrator/9781098107215/)

# *Interactive environment*

OREILLY®

## 2-1. CKAD Pods: Creating and Interacting with a Pod

◀ Step 2 of 4 ▶

### Creating a Pod

Create a new Pod named `nginx` running the image `nginx:1.17.10`.

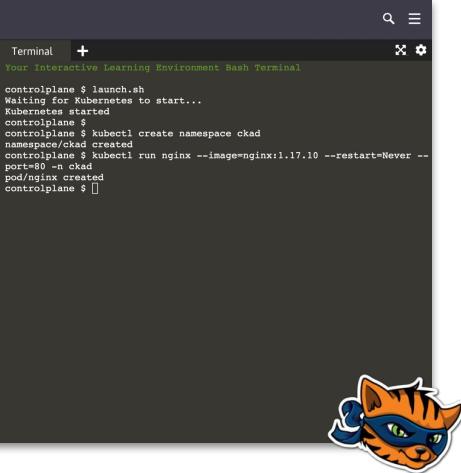
Expose container port 80.

The Pod should live in the namespace `ckad`.

Wait until the Pod transitions into the "Running" status.

[Solution](#)

[Continue](#)



## Kubernetes sandbox

Online access on O'Reilly learning platform:

<https://learning.oreilly.com/scenarios/kubernetes-sandbox/9781492062820/>

# Exam Details and Resources

Objectives, Environment, Time Management

# Exam Objectives

*“Demonstrate competence with securing container-based applications and Kubernetes platforms.”*



**The certification program allows users to demonstrate their competence in a hands-on, command-line environment.**

<https://www.cncf.io/certification/cks/>



# Exam Prerequisites

*Requires CKA certification*

**You need to be certified at the time of signing up for the CKS exam.**



<https://www.cncf.io/certification/cka/>



# Exam Domains & Weights

Domain	Weight
Cluster Setup	10%
Cluster Hardening	15%
System Hardening	15%
Minimize Microservice Vulnerabilities	20%
Supply Chain Security	20%
Monitoring, Logging, and Runtime Security	20%



# The Curriculum

## 10% - Cluster Setup

- Use Network security policies to restrict cluster level access
- Use CIS benchmark to review the security configuration of Kubernetes components (etcd, kubelet, kubedns, kubeapi)
- Properly set up Ingress objects with security control
- Protect node metadata and endpoints
- Minimize use of, and access to, GUI elements
- Verify platform binaries before deploying

## 15% - Cluster Hardening

- Restrict access to Kubernetes API
- Use Role Based Access Controls to minimize exposure
- Exercise caution in using service accounts e.g. disable defaults, minimize permissions on newly created ones
- Update Kubernetes frequently

## 15% - System Hardening

- Minimize host OS footprint (reduce attack surface)
- Minimize IAM roles
- Minimize external access to the network
- Appropriately use kernel hardening tools such as AppArmor, seccomp

## 20% - Minimize Microservice Vulnerabilities

- Setup appropriate OS level security domains e.g. using PSP, OPA, security contexts
- Manage kubernetes secrets
- Use container runtime sandboxes in multi-tenant environments (e.g. gvisor, kata containers)
- Implement pod to pod encryption by use of mTLS

## 20% - Supply Chain Security

- Minimize base image footprint
- Secure your supply chain: whitelist allowed image registries, sign and validate images
- Use static analysis of user workloads (e.g. kubernetes resources, docker files)
- Scan images for known vulnerabilities

## 20% - Monitoring, Logging and Runtime Security

- Perform behavioral analytics of syscall process and file activities at the host and container level to detect malicious activities
- Detect threats within physical infrastructure, apps, networks, data, users and workloads
- Detect all phases of attack regardless where it occurs and how it spreads
- Perform deep analytical investigation and identification of bad actors within environment
- Ensure immutability of containers at runtime
- Use Audit Logs to monitor access



# Candidate Skills



**kubernetes**

Architecture & Concepts



`kubectl`

Running Commands



container runtime

Underlying Concepts



---

# Exam Environment

*Online and proctored exam*

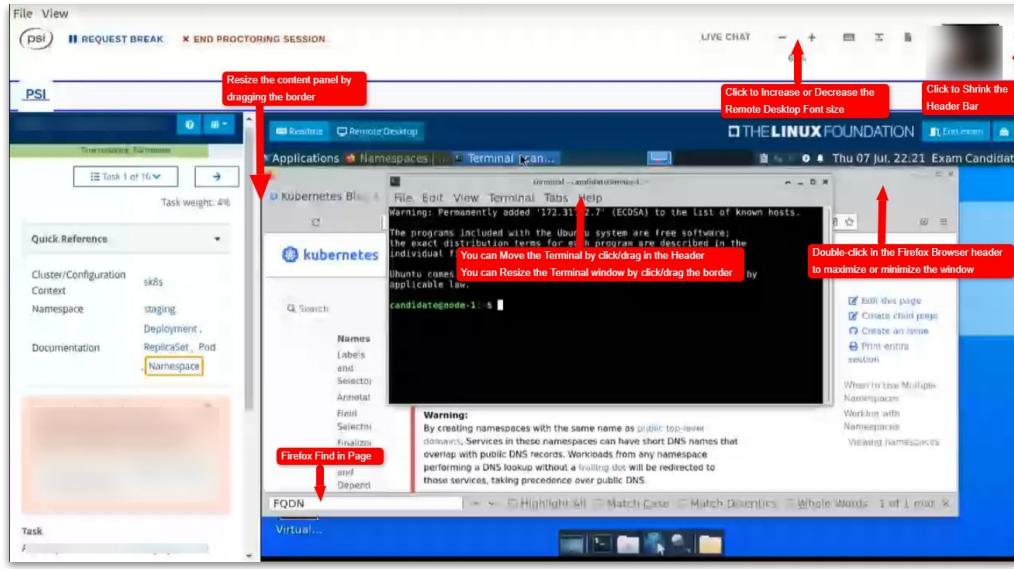


*The trinity of tooling you need to be familiar with*



# New PSI Exam Environment

*Single monitor, no more bookmarks (announcement)*



# Using Kubernetes Documentation

*Kubernetes docs and subdomains (see [FAQ](#))*

- Docs: <https://kubernetes.io/docs>
- GitHub: <https://github.com/kubernetes>
- Blog: <https://kubernetes.io/blog>



---

# Using Third-Party Documentation

*Third-party tools are part of the exam (see [FAQ](#))*

- Trivy: <https://github.com/aquasecurity/trivy>
- Falco: <https://falco.org/docs>
- AppArmor:  
<https://gitlab.com/apparmor/apparmor/-/wikis/Documentation>



# Getting Help on a Command

*Render subcommands and options with --help*

```
$ kubectl create --help
```

Create a resource from a file or from stdin.

JSON and YAML formats are accepted.

...

Available Commands:

...

configmap	Create a configmap from a local file, directory or literal value
-----------	--

deployment	Create a deployment with the specified name.
------------	--

...

Options:

...



# Zeroing in on Command Details

*Drill into object details with the `explain` command*

```
$ kubectl explain pods.spec
KIND:     Pod
VERSION:  v1
```

```
RESOURCE: spec <Object>
```

```
DESCRIPTION:
```

```
...
```

```
FIELDS:
```

```
...
```

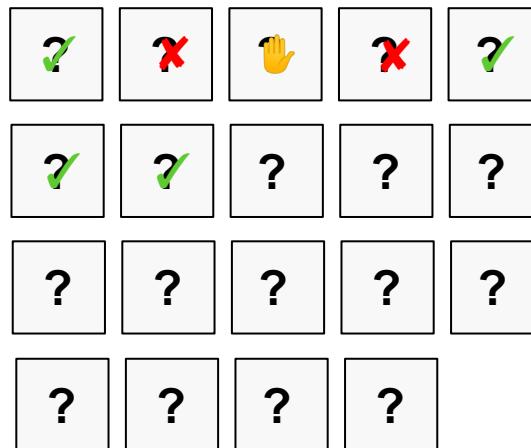
Most relevant information



---

# Time Management

*# of problems in 2 hours, use your time wisely!*



# Configuring Auto-Completion

*Allowed during exam, configurable on-demand*

```
$ kubectl cre<tab>
```

```
$ kubectl create
```



<https://kubernetes.io/docs/tasks/tools/included/optional-kubectl-configs-bash-linux/>



---

# Using an Alias for kubectl

*Preconfigured in the exam*

```
$ alias k=kubectl  
  
$ k version  
...
```



# Setting Namespace for a Context

*Questions will ask you to run a command on a specific cluster - Make sure to execute it!*

```
$ kubectl config set-context <context-of-question>--  
  --namespace=<namespace-of-question>  
$ kubectl config use-context <context-of-question>
```



# Internalize Resource Short Names

*Some API resources provide a shortcut*

```
$ kubectl get ns
```

Usage of `ns` instead  
of namespaces

```
$ kubectl describe pvc claim
```

Usage of `pvc` instead of  
`persistentvolumeclaim`

```
$ kubectl api-resources
```

Lists all API resources including  
their short names



---

# Deleting Kubernetes Objects

*Don't wait for a graceful deletion of objects...*

```
$ kubectl delete pod nginx --force
```



# Understand and Practice bash

*Practice relevant syntax and language constructs*

```
$ if [ ! -d ~/tmp ]; then mkdir -p ~/tmp; fi; while true; do echo $(date) >> ~/tmp/date.txt; sleep 5; done;
```



# Finding Object Information

*Filter configuration with context from a set of objects*

```
$ kubectl describe pods | grep -C 10 "author=John Doe"  
$ kubectl get pods -o yaml | grep -C 5 labels:
```

grep is your friend!



---

# How to Prepare

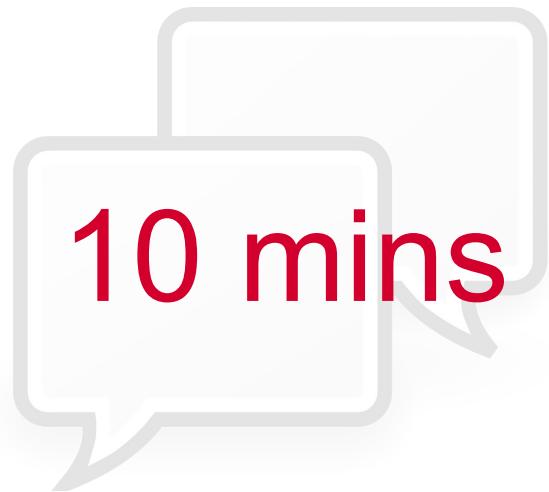
*Practice, practice, practice!*

**The key to cracking the exam**



---

# Q & A



---

# BREAK

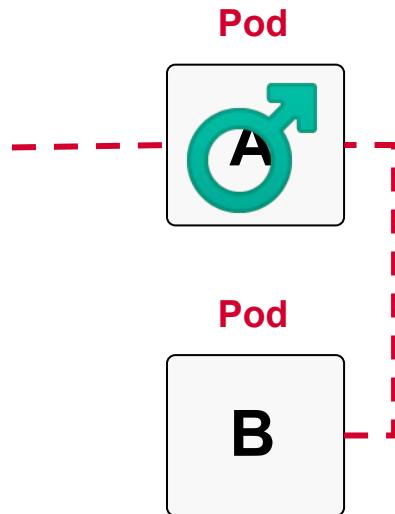


# Cluster Setup

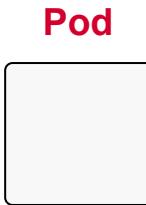
Network Security Policies, CIS Benchmark,  
Protecting nodes and GUI, Ingress, Verifying  
Binaries

# Scenario: Gaining Access to Pod

*Once a Pod can be compromised, it can easily access other Pods*

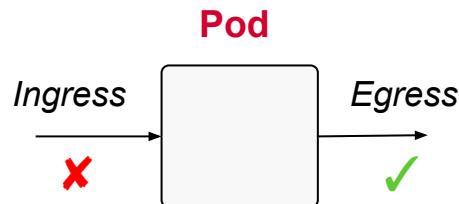


# Network Policy Rules



tier: frontend

*Which Pod does the rule apply to?* ✓



*Which direction of traffic?  
Who is allowed?*



# Creating a Network Policy

```
apiVersion: networking.k8s.io/v1
kind: NetworkPolicy
metadata:
  name: my-network-policy
spec:
  podSelector:
    matchLabels:
      tier: frontend
  policyTypes:
    - Ingress
    - Egress
  ingress:
    - from:
        ...
  egress:
    - to:
        ...
```



*Label selection for Pods*

*Inbound/outbound traffic*

*Who can connect to Pod?  
Where can Pod connect to?*



# General Rule of Thumb

*Start by denying all access and allowing access as needed*

```
apiVersion: networking.k8s.io/v1
kind: NetworkPolicy
metadata:
  name: default-deny
spec:
  podSelector: {} ← Applies to all Pods
  policyTypes:
    - Ingress ← Inbound/outbound
    - Egress   traffic is blocked
```

<https://kubernetes.io/docs/concepts/services-networking/network-policies/#default-deny-all-ingress-and-all-egress-traffic>



# Behavior of from/to Selectors

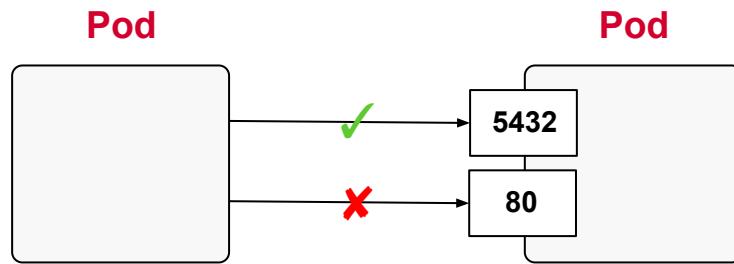
*Select by Namespace, Pod and IP address*

```
...
ingress:
- from:
  - namespaceSelector:
    matchLabels:
      app: awesome
  - podSelector:
    matchLabels:
      tier: backend
...
...
```

*Allow incoming traffic from  
Pod that matches the  
label `tier=backend` in  
the namespace `awesome`*



# Restricting Access to Ports



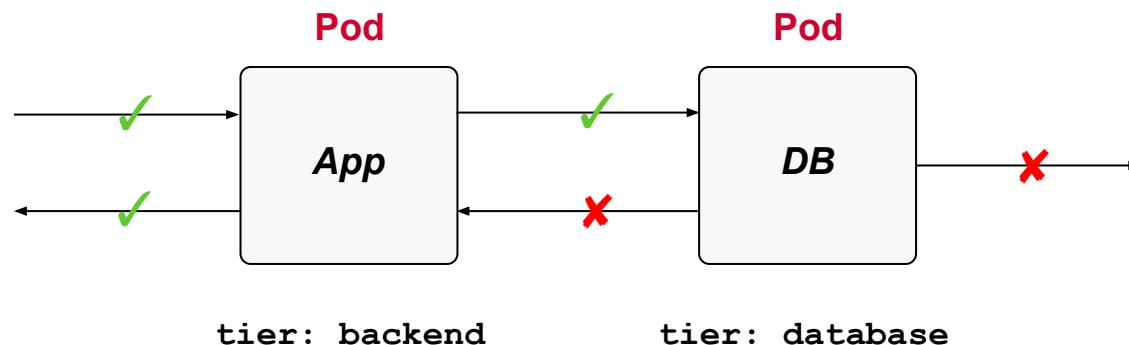
*By default all ports are open*

```
...  
ingress:  
- from:  
  - podSelector:  
    matchLabels:  
      tier: backend  
  ports:  
    - protocol: TCP  
    port: 5432  
...
```



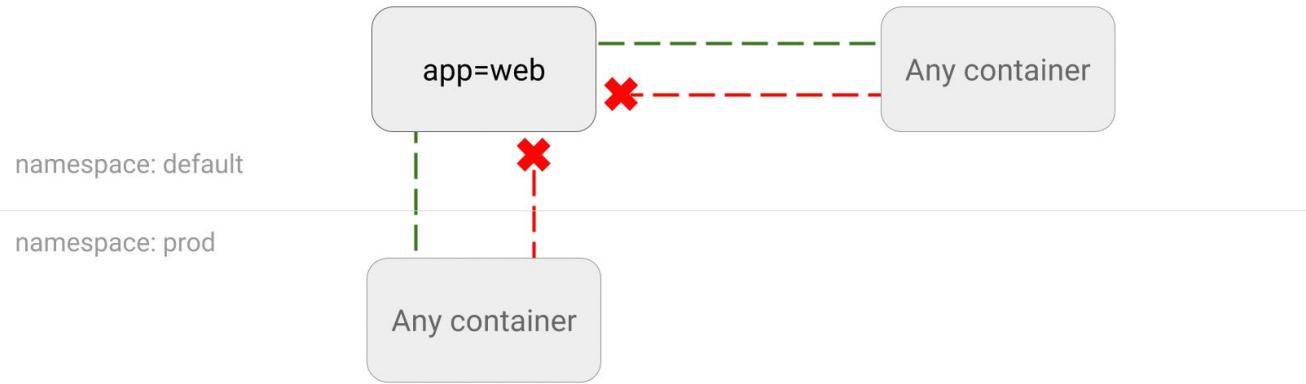
# Representative Use Case

*“Application makes request to database but database cannot make any outgoing requests.”*



# Additional Learning Resource

*Network Policies explained by use case and visualization*



<https://github.com/ahmetb/kubernetes-network-policy-recipes>



---

# EXERCISE

Restricting  
Communication  
Between Pods



# CIS Benchmarks

*Guidelines and benchmark tests for best practices in securing code*

- Published by non-profit [Center of Internet Security \(CIS\)](#)
- [CIS Kubernetes Benchmark](#) provides tests for Kubernetes environments



# Using kube-bench

Tool by Aqua for identifying and reporting issues (based on CIS)

```
$ kubectl apply -f  
https://raw.githubusercontent.com/aquasecurity/kube-benc  
h/main/job.yaml  
job.batch/kube-bench created  
  
$ kubectl get pods  
NAME             READY   STATUS    RESTARTS   AGE  
kube-bench-8f6qh   0/1     Completed   0          45s  
  
$ kubectl logs kube-bench-8f6qh  
...
```



# Results produced by kube-bench

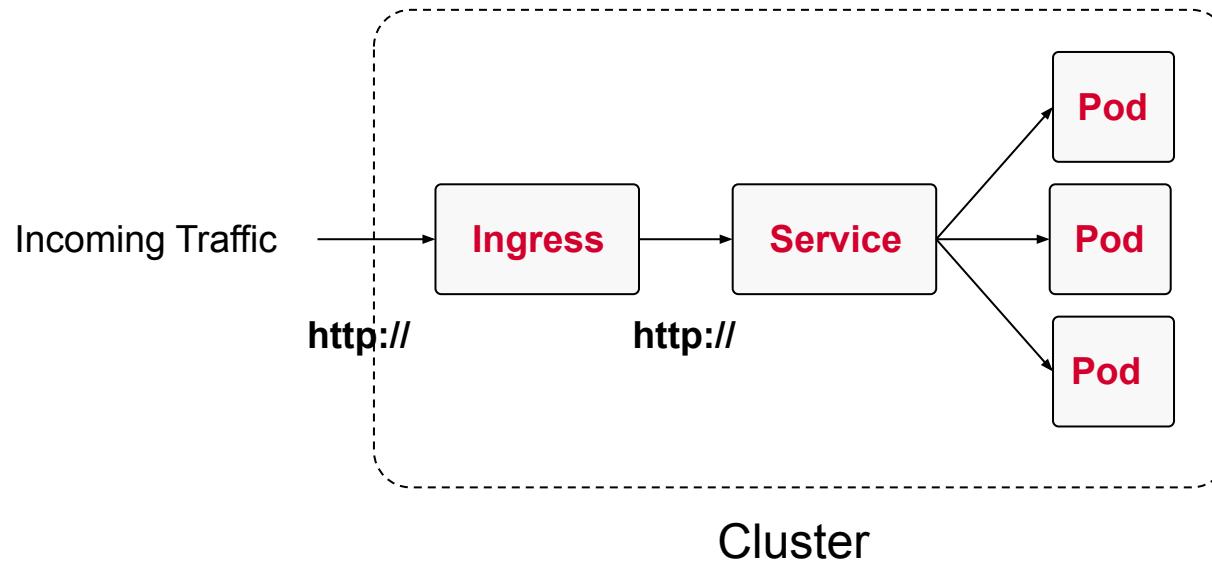
*Tests for different types of nodes and Pods running on them*

```
[INFO] 1 Master Node Security Configuration
[INFO] 1.1 Master Node Configuration Files
[PASS] 1.1.1 Ensure that the API server pod specification file permissions are
set to 644 or more restrictive (Automated)
[INFO] 1.2 API Server
[FAIL] 1.2.5 Ensure that the --kubelet-certificate-authority argument is set as
appropriate (Automated)
...
== Summary total ==
61 checks PASS
14 checks FAIL
48 checks WARN
0 checks INFO
```



# Understanding Ingress

*Manages external access to the services in a cluster via HTTP(S)*



---

# Detailed Coverage

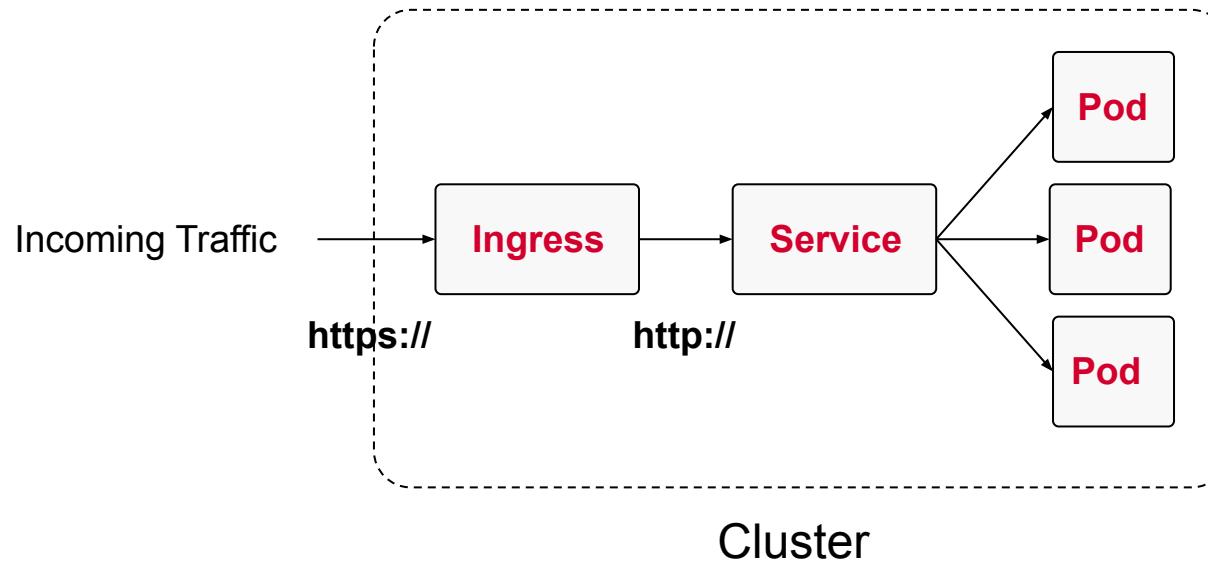
*The CKA exam lays the foundation for Ingress*

- [Certified Kubernetes Administrator \(CKA\) Study Guide](#)
- Exercise: [Creating an Ingress](#)



# Ingress with TLS termination

*Use HTTPS for Ingress, route to Service with HTTP*



# Creating the Secret

*Requires the type kubernetes.io/tls*

## Create TLS certificate and key

```
$ openssl req -nodes -new -x509 -keyout tls-ingress.key -out  
tls-ingress.crt -subj "/CN=ingress.tls"
```

## Create the Secret

```
$ kubectl create secret tls tls-ingress-secret  
--cert=tls-ingress.crt --key=tls-ingress.key
```



# Creating the Ingress

*Assign Secret upon creation*

```
apiVersion: networking.k8s.io/v1
kind: Ingress
metadata:
  name: tls-ingress
spec:
  tls:
  - hosts:
    - bar.foo.com
    secretName: tls-ingress-secret
  rules:
  - host: bar.foo.com
  ...
```

```
$ kubectl create ingress tls-ingress
--rule="bar.foo.com/=web-app-service
:8080,tls=tls-ingress-secret"
```



---

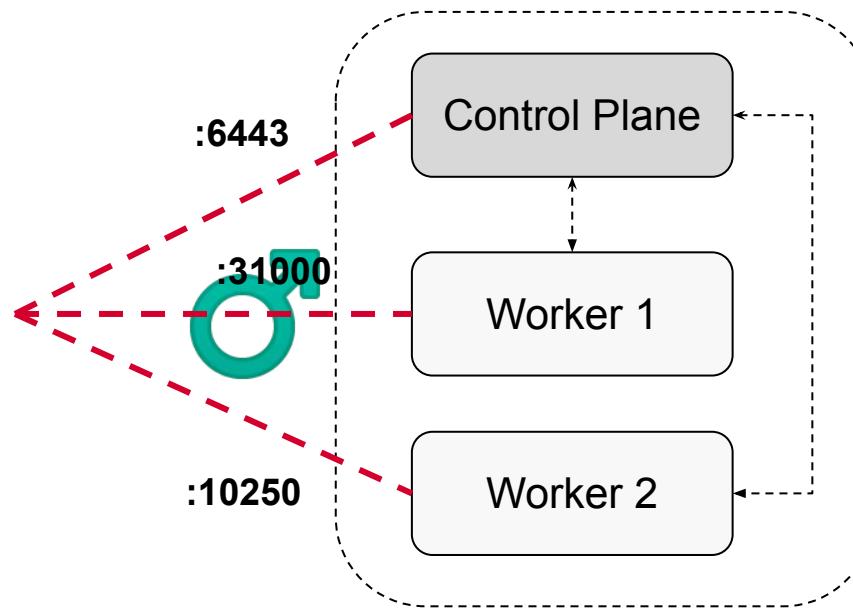
# EXERCISE

Creating an Ingress  
with TLS  
termination



# Scenario: Node Port Scans

*Nodes need to expose ports for communication*



# Default Incoming Node Ports

## Control Plane Node

Port Range	Purpose
6643	Kubernetes API server
2379–2380	etcd server client API
10250	Kubelet API
10259	kube-scheduler
10257	kube-controller-manager

## Worker Node(s)

Port Range	Purpose
10250	Kubelet API
30000–32767	NodePort Services



---

# Securing Node Endpoints

*Only expose ports you need*

- Minimize attack surface area
- Limit exposure of ports
- Instantiate firewall rules to protect against access of endpoints



---

# Securing Node Metadata

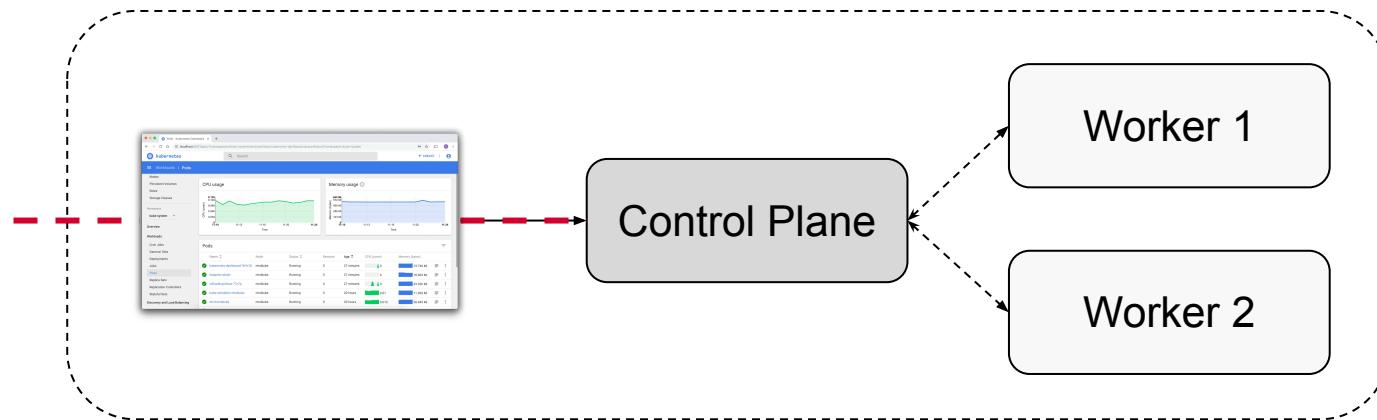
*Retrieving cluster metadata via API endpoint*

- Cloud provider Kubernetes environments can expose metadata via an API endpoint (including cloud credentials)
- Those endpoints are accessible by Pods running on the same node
- Limit permissions given to instance credentials and stand up network policies to restrict Pod access



# Scenario: Attack on GUI

*Dashboards grant access the control plane node*



---

# Securing GUI Elements

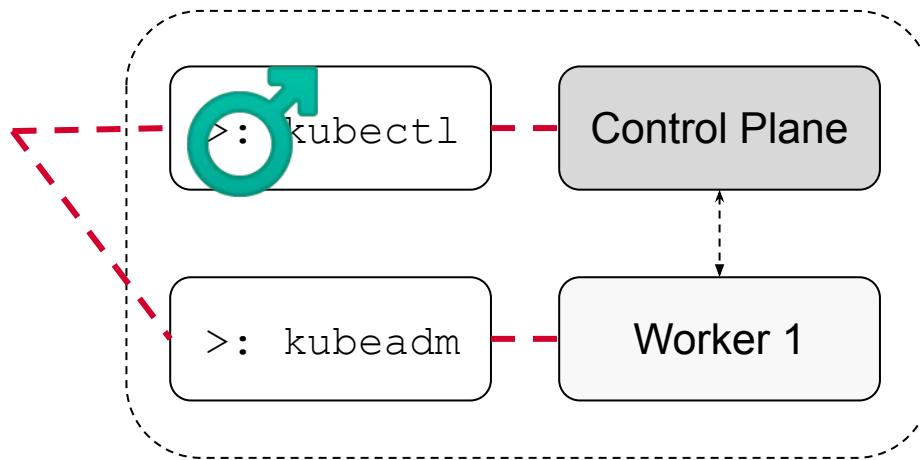
*Convenient management of Kubernetes objects*

- Exposing GUIs for Kubernetes provide attackers with a way to control the cluster
- Limit access to those GUIs (e.g. with firewall rules, RBAC permissions)
- Some organizations go as far as removing all GUI access to minimize attack surface



# Scenario: Malicious Code Inject.

*Gain control to cluster by modifying the byte code*



# Verifying Kubernetes Binaries

*Use checksum to ensure that binary hasn't been tampered with*

- Typical Kubernetes binaries are `kubectl`, `kubeadm`, and `kubelet`
- SHA256 checksum file should match the generated checksum of binary
- If both values don't match, then the file has been modified e.g. malicious code has been injected



# Retrieving the Checksum File

*Determine version, then use download link*

**Determine version of binary**

```
$ kubectl version --client --short # DO NOT RUN THIS!
Client Version: v1.23.5
```

**Download corresponding checksum file**

```
$ curl -LO
"https://dl.k8s.io/v1.23.5/bin/linux/amd64/kubectl.sha256"
```



# List of Download URLs

*Replace version, OS, and architecture to reflect your platform*

- kubectl: <https://dl.k8s.io/v1.23.5/bin/linux/amd64/kubectl.sha256>
- kubeadm: <https://dl.k8s.io/v1.23.5/bin/linux/amd64/kubeadm.sha256>
- kubelet: <https://dl.k8s.io/v1.23.5/bin/linux/amd64/kubelet.sha256>
- kube apiserver:  
<https://dl.k8s.io/v1.23.5/bin/linux/amd64/kube-apiserver.sha256>



# Verifying the Binary

*Use sha256 tool to compare binary checksum ([docs](#))*

## Linux

```
$ echo "$(cat kubectl.sha256)  kubectl" | sha256sum --check
```

## MacOSX

```
$ echo "$(cat kubectl.sha256)  kubectl" | shasum -a 256 --check
```



---

# EXERCISE

Verifying Existing  
Kubernetes  
Binaries



# Cluster Hardening

Restricting API Access, RBAC for Minimizing  
Exposure, Service Accounts, Keeping Kubernetes  
Updated

# RBAC High-Level Overview

*Three key elements for understanding concept*

## Subject

Groups  
Users  
Service-  
Accounts

## API Resources

ConfigMap  
Pod  
Deployment  
Node  
...

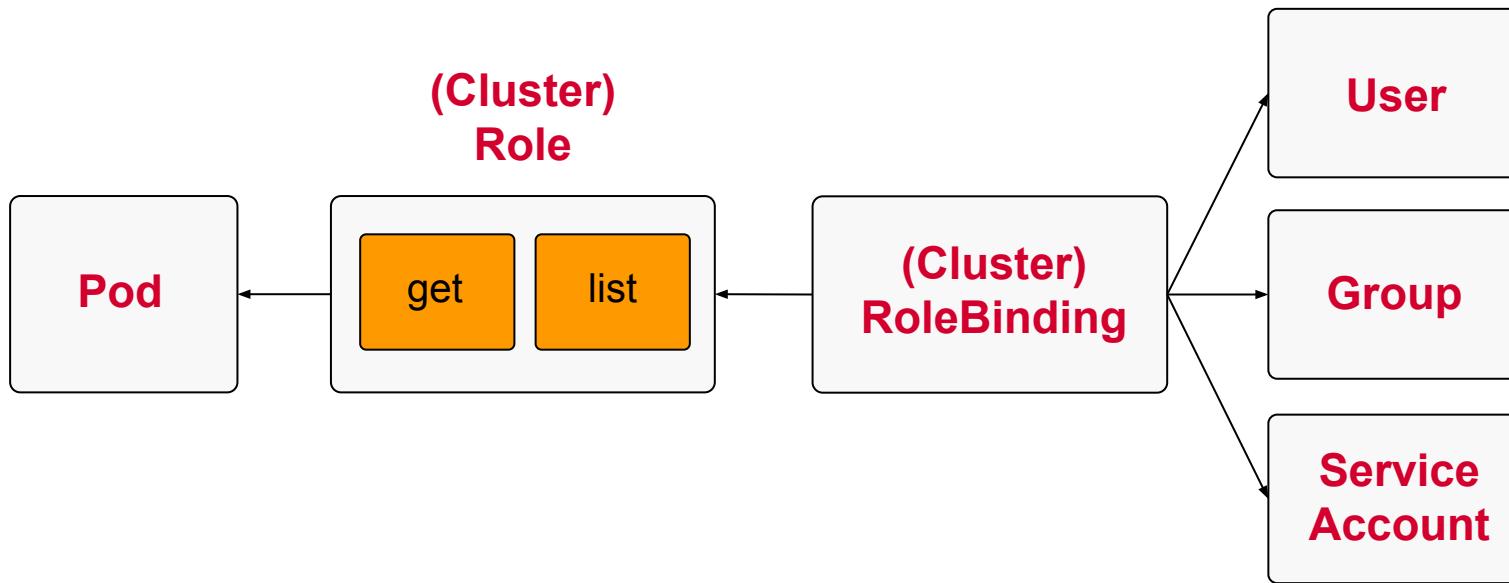
## Operations (Verbs)

create  
list  
watch  
delete  
...



# Involved RBAC Primitives

*Restrict access to API resources based on user roles*



---

# Detailed Coverage

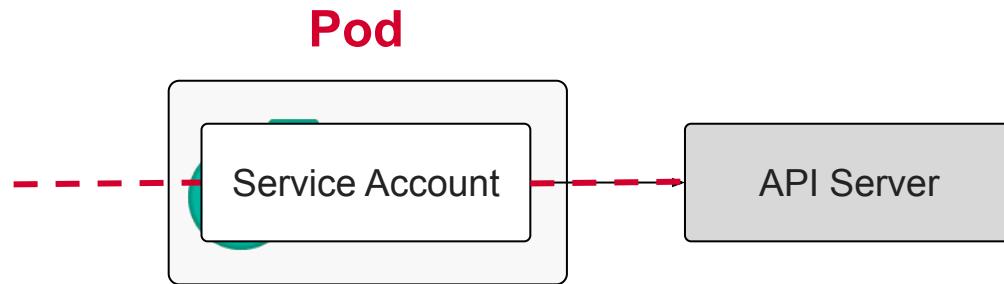
*The CKA exam lays the foundation for RBAC*

- [Certified Kubernetes Administrator \(CKA\) Study Guide](#)
- Exercise: [RBAC for a User](#)



# Scenario: Pod + Service Account

*A Service Account with too many permissions that can be misused*



# Service Account Permissions

*Restrict as much as possible*

- Service Account should only allow be allowed the permissions needed for the process running in Pod
- Restricting those permissions is implemented via (Cluster)Role and (Cluster)RoleBinding (combination of verbs + API resources)
- An attacker of a compromised Pod using the Service Account gains access to operations executed against the API server (e.g. delete Pods)



---

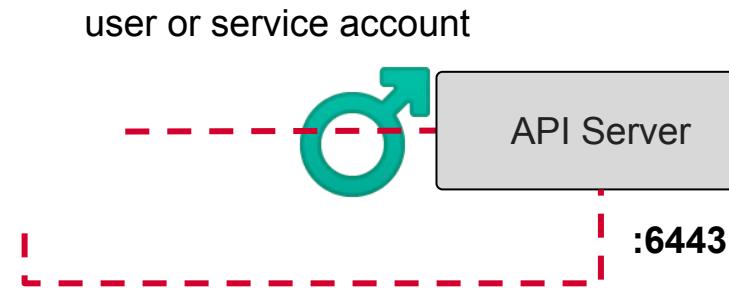
# EXERCISE

Minimizing Service  
Account Permissions  
and Usage



# Scenario: Attack on API server

*Used compromised user/service account or by port 6443*



---

# Securing API Endpoints

*Restrict as much as possible*

- Limit outside network access by defining firewall rules
- Only expose API endpoints via intranet
- User permissions should be limited and on point in case they get compromised



# Scenario: Exploiting Vulnerability

*Older Kubernetes versions can expose critical issues*



1.7

[https://www.cvedetails.com/vulnerability-list/vendor\\_id-15867/product\\_id-34016/Kubernetes-Kubernetes.html](https://www.cvedetails.com/vulnerability-list/vendor_id-15867/product_id-34016/Kubernetes-Kubernetes.html)



---

# Updating Kubernetes Frequently

*Upgrade early and often!*

- Versioning schema follows semantic versioning e.g. 1.23.5
- Check discovered vulnerabilities and upgrade to latest patch and minor version
- Make concerted effort to upgrade to next major version (they may contain breaking changes)



---

# Detailed Coverage

*The CKA exam lays the foundation for cluster management*

- [Certified Kubernetes Administrator \(CKA\) Study Guide](#)
- Exercise: [Upgrading a cluster version](#)



# System Hardening

Minimizing OS Footprint, IAM Roles, and External Network Access, Kernel Hardening Tools

# Container Namespaces

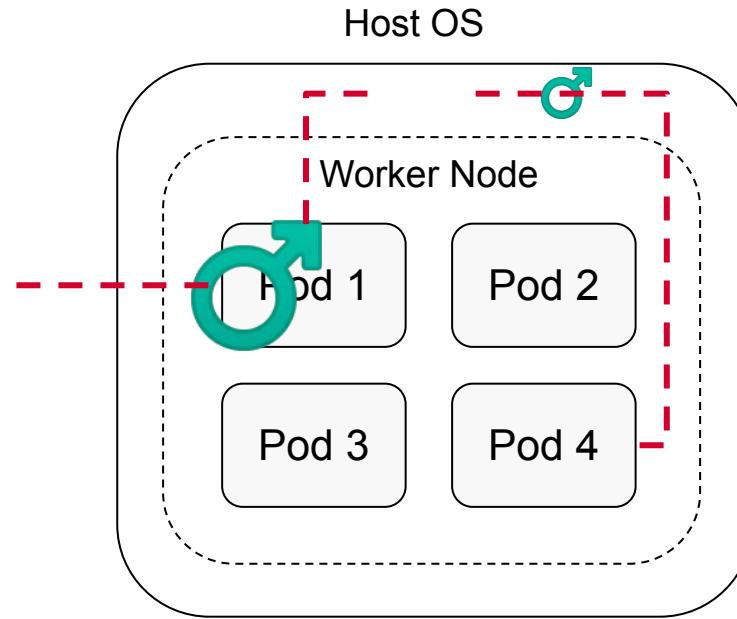
*Containers only have limited access to OS namespace*

- Regular processes run in OS namespace
- Containers run in container namespace isolated from OS namespace
- This leaves less room for attackers to gain access to host
- **Warning:** Containers can be configured to use OS namespace



# Scenario: Pod to Host OS Attack

*Compromised Pod gains access to other Pods via host OS*



# Enabling Host Namespace Usage

The Pod spec defined a handful of attributes for configuration

YAML Element	Purpose
spec.hostIPC	The host's inter-process communication namespace
spec.hostNetwork	The host's network namespace
spec.hostPID	The host's process ID namespace

```
apiVersion: v1
kind: Pod
metadata:
  name: alpine
spec:
  hostIPC: true
  hostNetwork: true
  hostPID: true
  containers:
  - name: alpine
    image: alpine/curl:3.14
```



# Enabling Privileged Mode

*Access to host-level resources can be granted via security context*

```
apiVersion: v1
kind: Pod
metadata:
  name: alpine
spec:
  containers:
    - name: alpine
      image: alpine/curl:3.14
      securityContext:
        privileged: true
```

Equivalent to granting root access on host. Avoid if not absolutely necessary!



---

# Granting Host Access to Pods

*Only grant those permissions if needed*

- By default, host access and privileged mode are disabled
- Enabling any of those settings opens an attack vector to the host
- Host access and privileged mode should only be enabled if really required



# IAM Roles on

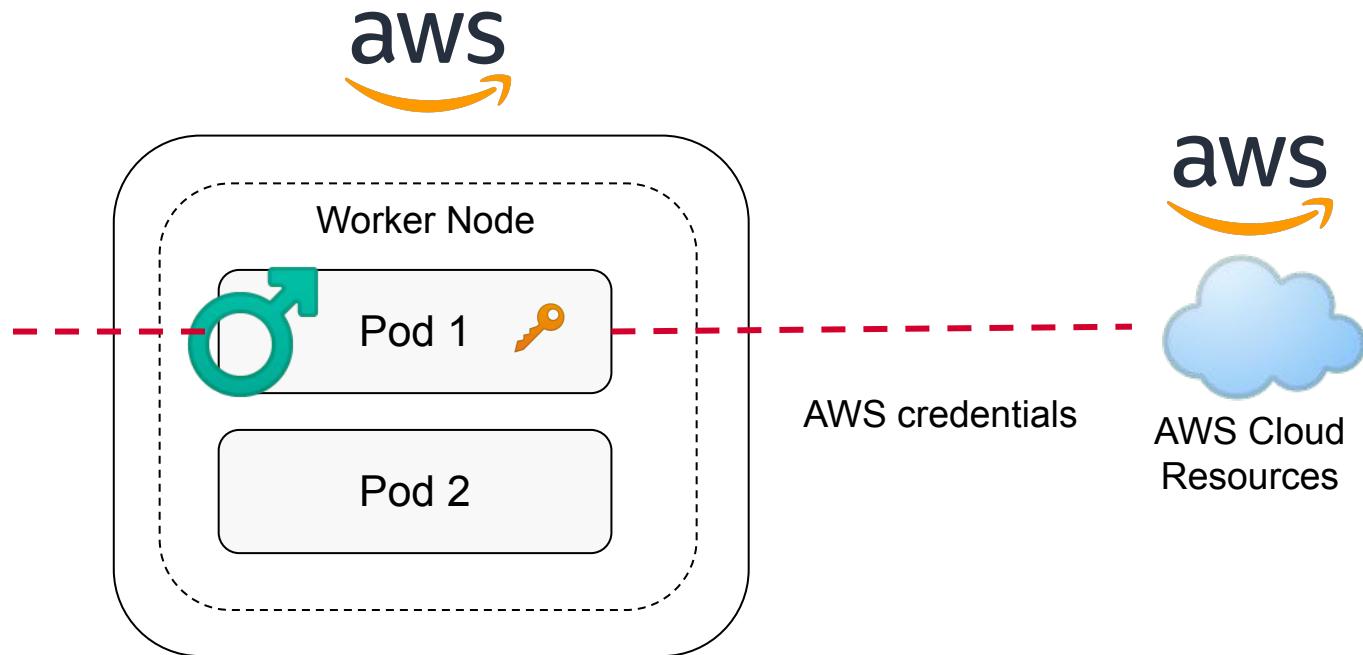
*Obtain permissions/credentials to access AWS resources*

- Only relevant if Kubernetes runs on AWS
- Containers can retrieve credentials if run on AWS and gain access to other resources



# Scenario: Misusing AWS creds.

*Compromised Pod can gain access to other AWS resources*



# Handling IAM Roles

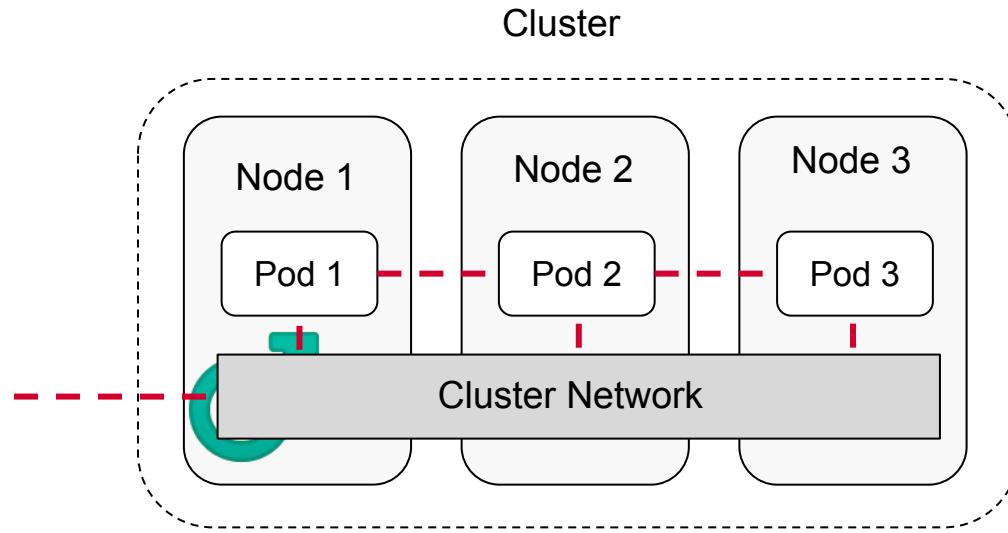
*Follow those guidelines if you are running Kubernetes on AWS*

- Only grant the minimal set of IAM roles required to do the job
- Block access from containers that don't need IAM roles (e.g. via firewall, Network Policies...)



# Scenario: Infiltr. Cluster Network

*The cluster network spans across all nodes*



---

# Minimizing Ext. Network Access

*By default, a Pod can talk to any other Pod in the cluster*

- The cluster network spans across all nodes and enables Pods to communicate with each other
- Access to the cluster networks grants access to all Pods running on all nodes
- Limit network access from the outside



# Linux Security Kernel Modules

*Application that controls what programs can run on host OS*

- AppArmor: Protects the OS from external or internal threats, even zero-day attacks, by enforcing good behavior and preventing flaws from being exploited
- seccomp: Restricts the system calls of an application to the kernel





# AppArmor Installation Check

*Usually exists on Linux system independent of Kubernetes*

```
$ aa-status
apparmor module is loaded.
33 profiles are loaded.
33 profiles are in enforce mode.
...
...
```

Minikube does not support an AppArmor add-on at this time





# AppArmor Profiles

A set of rules that define what a program is allowed/denied to do

```
#include <tunables/global>

profile k8s-deny-write flags=(attach_disconnected)
{
    #include <abstractions/base>

    file,
    # Deny all file writes.
    deny /** w,
}
```





# Enforcing AppArmor Profile

*Store the profile in a file and use apparmor\_parser command*

```
$ sudo apparmor_parser /etc/apparmor.d/k8s-deny-write  
  
$ aa-status  
apparmor module is loaded.  
32 profiles are loaded.  
32 profiles are in enforce mode.  
k8s-deny-write  
...
```

The command uses enforce mode by default. Use -C option for complain mode. **Needs to be enabled on node that runs the Pod.**





# AppArmor Profile in Pod

*Assign annotation, profile needs to be activated on node*

```
apiVersion: v1
kind: Pod
metadata:
  name: hello-apparmor
  annotations:
    container.apparmor.security.beta.kubernetes.io/hello:
      localhost/k8s-deny-write
spec:
  containers:
    - name: hello
      image: busybox:1.28
      command: ["sh", "-c", "echo 'Hello AppArmor!' && sleep 1h"]
```



---

# EXERCISE

Preventing Network  
Calls From a Pod  
With AppArmor

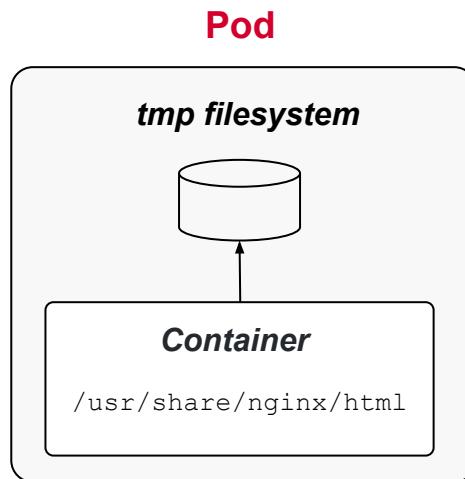


# Minimizing Microservice Vulnerabilities

OS-Level Security Domain, Secrets, Container  
Runtime Sandboxes, mTLS Encryption

# Understanding Security Contexts

*Privilege and access control settings for a Pod or container*



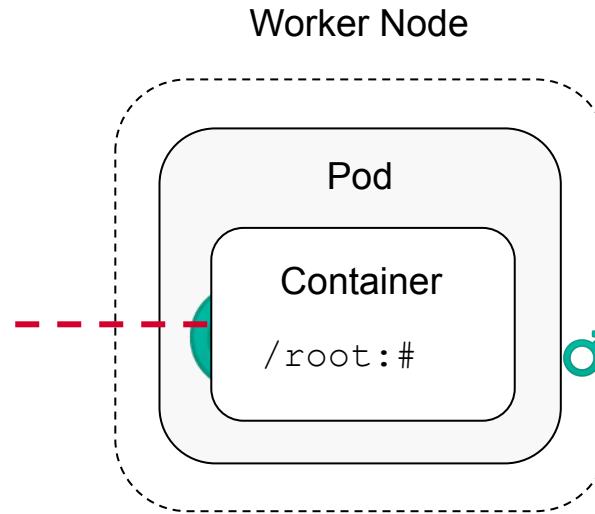
“Create files with a specific Unix group ID”

“Run this container with a specific Unix user ID”



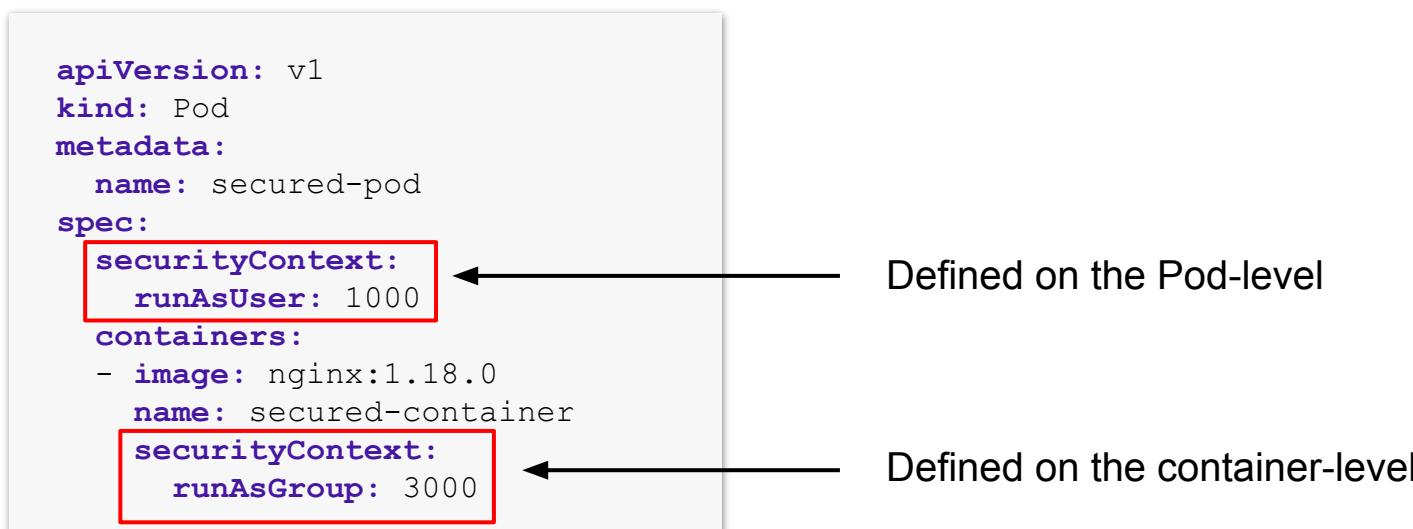
# Scenario: Using root Credentials

*By default, containers run with root privileges*



# Defining a Security Context

*Pod- vs. container-level definition*



# Security Context API

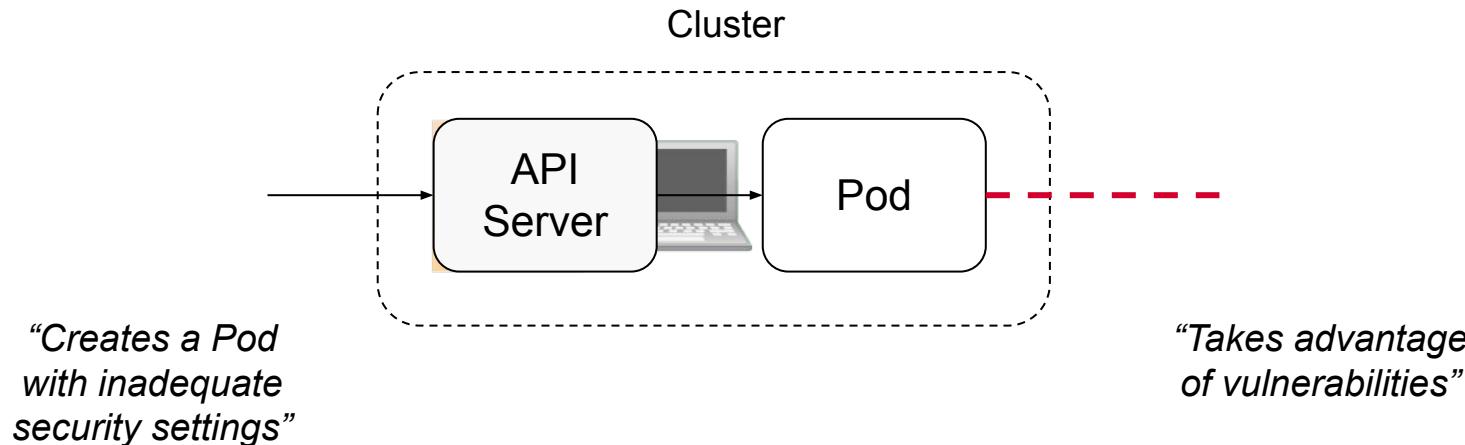
*Only partial overlap for Pod- and container attributes*

API	Description
<a href="#"><u>PodSecurityContext</u></a>	Defines Pod-level security attributes.
<a href="#"><u>SecurityContext</u></a>	Defines container-level security attributes.



# Scenario: Governing Pod Security

*Developers may be less familiar with Pod security best practices*



# Core Kubernetes Feature

*PSPs have been removed with Kubernetes 1.25*

## Pod Security Policies

**FEATURE STATE:** Kubernetes v1.21 [deprecated]

**Caution:** PodSecurityPolicy is deprecated as of Kubernetes v1.21, and **will be removed in v1.25**. We recommend migrating to [Pod Security Admission](#), or a 3rd party admission plugin. For a migration guide, see [Migrate from PodSecurityPolicy to the Built-In PodSecurity Admission Controller](#). For more information on the deprecation, see [PodSecurityPolicy Deprecation: Past, Present, and Future](#).



---

# Pod Security Admission Overview

*Administration-level security feature for Pods (see [docs](#))*

- Controls which security settings should be used for Pods
- Can reject, audit, or log Pods that don't follow the desired security settings
- Examples: Prevent running a container privileged mode or as root user



# Defining a PSA for a Namespace

*No imperative command available, extensive configuration*

```
apiVersion: v1
kind: Namespace
metadata:
  name: psa
  labels:
    pod-security.kubernetes.io/enforce: restricted
```

Hard-coded prefix

Mode

Level



# PSA Modes

*Rejection or logging the violation*

Mode	Behavior
enforce	Violations will cause the Pod to be rejected.
audit	Pod creation will be allowed. Violations will be appended to the audit log.
warn	Pod creation will be allowed. Violations will be rendered on the console.



# PSA Levels

*What level of Pod Security Standard do you want to apply?*

Level	Behavior
privileged	Fully unrestricted policy.
baseline	Minimally restrictive policy that cover crucial standards.
restricted	Heavily restricted policy following best practices for hardening Pods from a security perspective.



# Defining a Pod in Namespace

*All you need to do is to create Pod in governed namespace*

```
apiVersion: v1
kind: Pod
metadata:
  name: busybox
  namespace: psa
spec:
  containers:
  - image: busybox:1.35.0
    name: busybox
    command: ["sh", "-c", "sleep 1h"]
```



# Rendered Violation on Console

*Pod wasn't created as mode is set to enforce*

```
$ kubectl apply -f PSA-violating-pod.yaml
Error from server (Forbidden): error when creating "PSA-pod.yaml": pods
"busybox" is forbidden: violates PodSecurity "restricted:latest":
allowPrivilegeEscalation != false (container "busybox" must set
securityContext.allowPrivilegeEscalation=false), unrestricted capabilities
(container "busybox" must set securityContext.capabilities.drop=["ALL"]),
runAsNonRoot != true (pod or container "busybox" must set
securityContext.runAsNonRoot=true), seccompProfile (pod or container "busybox"
must set securityContext.seccompProfile.type to "RuntimeDefault" or
"localhost")
```

```
$ kubectl get pod -n PSA
No resources found in PSA namespace.
```



---

# EXERCISE

Enforcing a Pod  
Security Standard  
Upon Pod Creation





# OPA Gatekeeper

*Customization for Kubernetes objects at creation time*

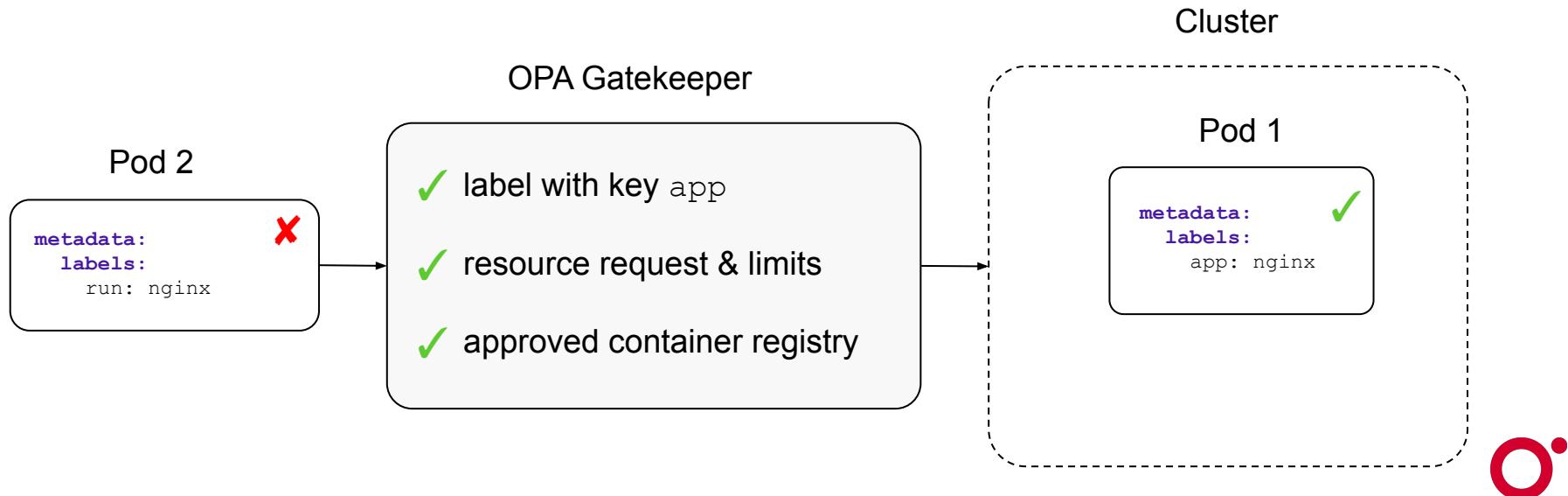
- Framework for defining constraints for any kind of objects, not just Pods
- Highly-flexible policy definition
- Examples: Ensure that certain labels are defined, which image registry are allowed to be used for pulling images





# OPA Enforcement

*Require the definition of a specific label key*





# OPA Key Elements

*Three key elements important to understanding concept*

- Constraint template: Defines the schema for the constraint with the help of Rego logic
- Constraint: Assigns the template to a set of primitives
- Gatekeeper: Components installed in the cluster that enforce the constraints.





# OPA Constraint Template

*No imperative command available, extensive configuration*

```
apiVersion: templates.gatekeeper.sh/v1beta1
kind: ConstraintTemplate
metadata:
  name: k8srequiredlabels
spec:
  crd:
    spec:
      names:
        kind: K8sRequiredLabels
      validation:
        # Schema for the `parameters` field
        openAPIV3Schema:
          properties:
            labels:
              type: array
              items: string
targets:
- target: admission.k8s.gatekeeper.sh
  rego: |
    package k8srequiredlabels

    deny[{"msg": msg, "details": {"missing_labels": missing}}] {
      provided := {label | input.review.object.metadata.labels[label]}
      required := {label | label := input.parameters.labels[_]}
      missing := required - provided
      count(missing) > 0
      msg := sprintf("you must provide labels: %v", [missing])
    }
```

Required parameters and their data types to be passed in

Constraint logic defined with the declarative language Rego





# OPA Constraint

*Maps constraint logic to specific primitives & defines params*

```
apiVersion: constraints.gatekeeper.sh/v1beta1
kind: K8sRequiredLabels
metadata:
  name: ns-must-have-hr
spec:
  match:
    kinds:
      - apiGroups: [""]
        kinds: ["Namespace"]
parameters:
  labels: ["hr"]
```

Name of constraint template

Primitives the constraint applies to

Values for parameters





# OPA Gatekeeper Installation

*Deployable with a single command*

**Deploying a release using prebuilt image**

```
$ kubectl apply -f  
https://raw.githubusercontent.com/open-policy-agent/gatekeeper  
/release-3.7/deploy/gatekeeper.yaml
```

**Ensure that Gatekeeper Pods are running**

```
$ kubectl get pods -n gatekeeper-system
```





# OPA Gatekeeper Validation

*Enforcement during object creation*

```
$ kubectl create ns hello
Error from server ([ns-must-have-hr] you must provide labels:
{"gatekeeper"}): admission webhook "validation.gatekeeper.sh"
denied the request: [ns-must-have-hr] you must provide labels:
{"hr"}
```



---

# EXERCISE

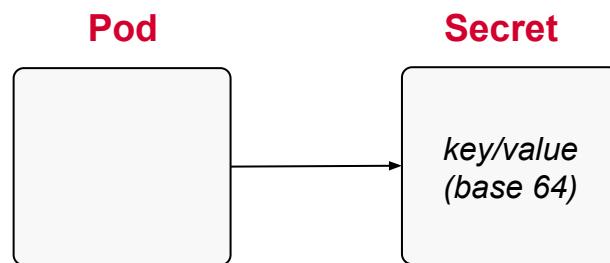
OPA Gatekeeping for  
Pods



---

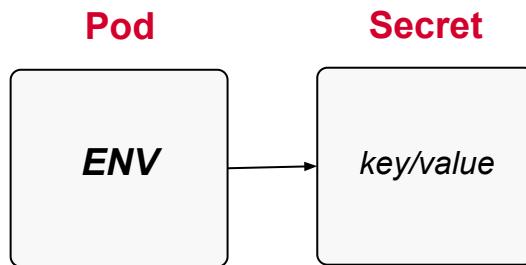
# Centralized Configuration Data

*Stores sensitive data, consumed by Pod*

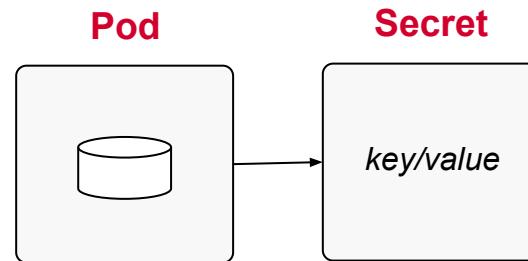


# Mounting a Secret

*Two options for consuming data*



**Injected as environment variables**



**Mounted as volume**



# Secret Options

*Imperative command:* `kubectl create secret`

Option	Description
<code>generic</code>	Creates a secret from a file, directory, or literal value.
<code>docker-registry</code>	Creates a secret for use with a Docker registry.
<code>tls</code>	Creates a TLS secret.



# Creating Secrets (imperative)

*Similar usage to creation of ConfigMap*

```
# Literal values
$ kubectl create secret generic db-creds ←
  --from-literal=pwd=s3cre!

# File containing environment variables
$ kubectl create secret generic db-creds ←
  --from-env-file=secret.env

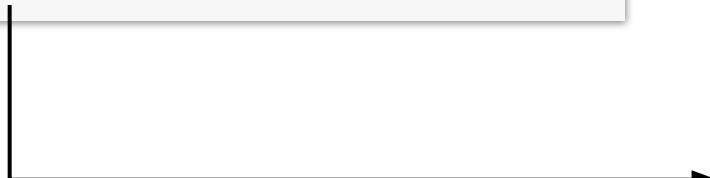
# SSH key file
$ kubectl create secret generic db-creds ←
  --from-file=ssh-privatekey=~/ssh/id_rsa
```



# Creating Secrets (declarative)

*Value has to be base64-encoded manually*

```
$ echo -n 's3cre!' | base64  
czNjcmUh
```



```
apiVersion: v1  
kind: Secret  
metadata:  
  name: mysecret  
type: Opaque  
data:  
  pwd: czNjcmUh
```



# Secret in Pod as Volume

*Inside of the container, values are base64-decoded*

```
apiVersion: v1
kind: Pod
metadata:
  name: backend
spec:
  containers:
    - name: backend
      image: nginx
      volumeMounts:
        - name: secret-volume
          mountPath: /etc/secret
  volumes:
    - name: secret-volume
      secret:
        secretName: mysecret
```

```
$ kubectl exec -it backend -- /bin/sh
# ls /etc/secret
pwd
# cat /etc/secret/pwd
s3cre!
```



# Specialized Secret Types

*The table only lists some, more in [docs](#)*

Type	Description
kubernetes.io/basic-auth	Credentials for basic authentication
kubernetes.io/ssh-auth	Credentials for SSH authentication
kubernetes.io/service-account-token	ServiceAccount token



# Plain-Text Secret Values

*The `stringData` attribute allows for plain-text values*

```
apiVersion: v1
kind: Secret
metadata:
  name: secret-basic-auth
type: kubernetes.io/basic-auth
stringData:
  username: admin
  password: t0p-Secret
```



---

# Detailed Coverage

*The CKAD exam lays the foundation for ConfigMaps/Secrets*

- Certified Kubernetes Application Developer (CKAD) Study Guide
- Exercise: Creating and using a Secret



---

# EXERCISE

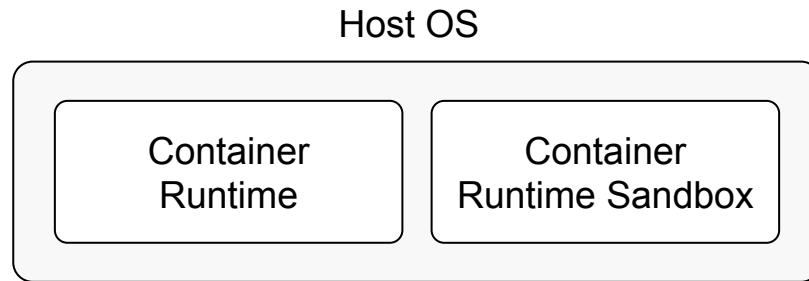
Creating and  
Consuming a Secret



# Container Runtime Sandboxes

*Provides extra layers of process isolation & security*

- Does not execute in standard container runtime (for regular workload)
- The container runtime sandbox exists alongside the container runtime in isolation (for workload we are concerned about)



---

# Container Runtime Sandboxes

*Why would you want to use them?*

- You don't trust the workload as it could execute malicious operations
- Applications that don't need host access
- Provide an extra level of security for workloads executed in a multi-tenant environment (e.g. different customers)



# Implementation Options

*Two solutions are relevant to the exam*



gVisor/runsc: Linux application kernel by Google. Runs within host OS system with a less-lightweight solution than Virtual Machines. This blog post explains the motivation and some implementation details.



Kata containers: Containers run in lightweight Virtual Machines.



---

# Using a gVisor Sandbox

*Three-step process*

- Install the container runtime sandbox implementation e.g. `runsc`
- Configure the container runtime (e.g. Docker Engine, containerd) to interact with the sandbox implementation (see [docs for Docker Engine](#))
- Define a `RuntimeClass` object and reference its name in a Pod



# Runtime Class Definition & Usage

*Defines the container runtime sandbox implementation*

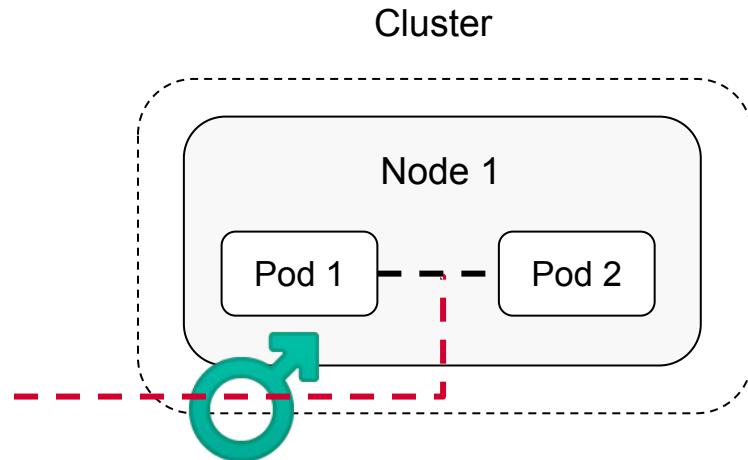
```
apiVersion: node.k8s.io/v1
kind: RuntimeClass
metadata:
  name: gvisor
handler: runsc
```

```
apiVersion: v1
kind: Pod
metadata:
  name: alpine
spec:
  runtimeClassName: gvisor
  containers:
    - name: alpine
      image: alpine/curl:3.14
```



# Scenario: Pod-to-Pod Communic.

*Attacker can infiltrate unencrypted Pod to Pod messaging*



---

# Encryption with mTLS

*Like HTTPS but both parties authenticate*

- In the case of Pod-to-Pod communication each Pod has a certificate
- Makes it much harder to impersonate client- or server-side of communication
- Kubernetes API is able to programmatically retrieve a certificate from a Certificate Authority (CA)



# Certificate Process

*More information in [documentation](#)*

- Create a `CertificateSigningRequest` object to request certificate
- Approve or deny the certificate request via `kubectl certificate`
- The attribute `status.certificate` of the `CertificateSigningRequest` object will contain the approved certificate

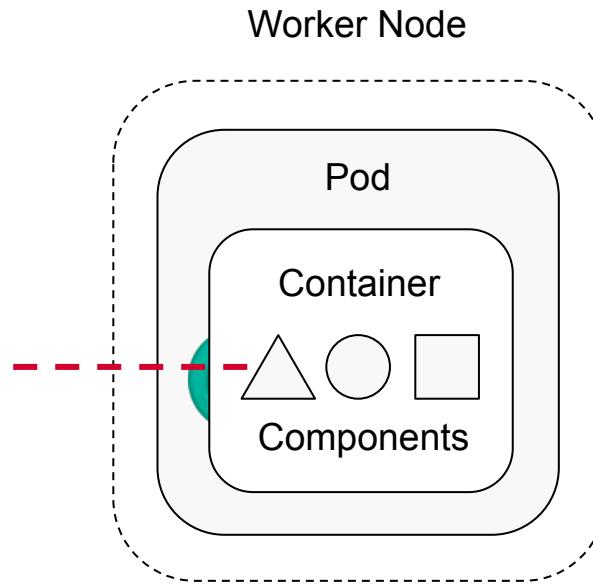


# Supply Chain Security

Base Image Footprint, Image Signing, Validation,  
and Registries, Static Analysis of Workloads,  
Scanning for Vulnerabilities

# Scenario: Exploit Vulnerabilities

*A base image can contain components with known issues*



---

# Minimizing Base Image Footprint

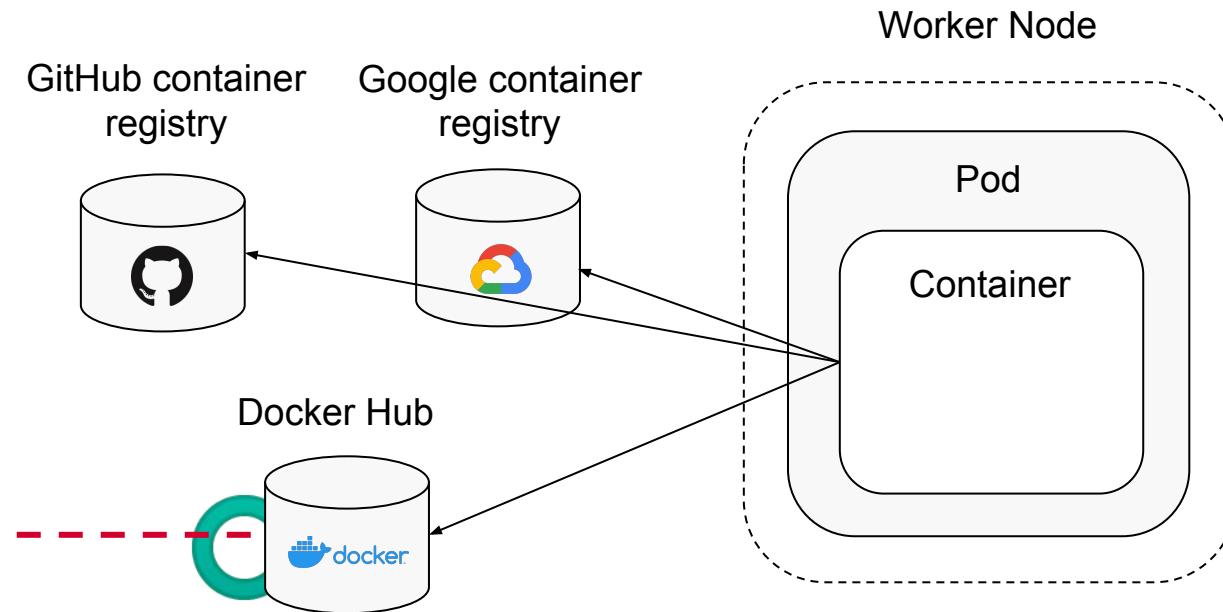
You can find helpful tips in this [blog post](#)

- Choose base images small in size (e.g. alpine uses a minimal OS footprint, distroless don't have a shell)
- Keep your images up to date including their dependencies + configs
- Avoid unnecessary components to be installed (which increases potential security risks) e.g. by using multi-stage builds



# Scenario: Compromised Registry

*Attacker can upload images with malicious instructions*



# Whitelisting Registries

*Only trust an inhouse registry within the network*

- All requests for retrieving container images should be funneled through a trusted registry e.g. Artifactory
- Images can be scanned automatically or upon request
- Enforce the use of a whitelisted registry on Kubernetes e.g. with [OPA Gatekeeper policy](#)



# Validating Images

*Many images have a corresponding hash in registry*

- Hash (e.g. SHA256) can be used to validate the image against
- If validation fails then the image has been manipulated by an attacker
- Append @sha256:<hash> when declaring the image in a Pod



# Image with SHA256

*Definition with an appended hash for validation*

```
apiVersion: v1
kind: Pod
metadata:
  name: alpine
spec:
  containers:
  - name: alpine
    image: alpine:3.15.4@sha256:a777c9c66ba177ccfea2...
```



# Image Validation in Action

*Node fails validation and doesn't download the image*

```
$ kubectl get pods
NAME      READY      STATUS           RESTARTS      AGE
alpine    0/1       ErrImagePull      0            3m12s

$ kubectl describe pod alpine
Events:
  Type      Reason     Age      From          Message
  ----      ----      --      ----          -----
  Warning   Failed    5s       kubelet        Failed to pull image
"alpine:3.15.4@sha256:a877c9c66ba177ccfea23f2a216ff6721e78a662cd17019488c417135299
cd89": rpc error: code = Unknown desc = Error response from daemon: manifest for
alpine@sha256:a877c9c66ba177ccfea23f2a216ff6721e78a662cd17019488c417135299cd89 not
found: manifest unknown: manifest unknown
```



# Creating a Container Image



*Definition of instructions in a Dockerfile*

- Writing a Dockerfile is “easy” but can introduce issues with sizing, and potential attack vectors
- There are a lot of best practices to adhere to that are not checked automatically



---

# Some Best Practices



*Definition of instructions in a Dockerfile*

- The base image should use a concrete tag other than latest
- Avoid running the container with the `root` user
- Do not use sensitive data anywhere in the Dockerfile
- Use multi-stage builder to avoid having to ship with unnecessary tools



# Creating a Kubernetes Object



*Imperative or declarative approach*

- The declarative approach requires a JSON or YAML manifest file via the `kubectl apply` or `kubectl create` command
- The YAML manifest applies to specific Kubernetes primitive and is very configurable
- Some primitives allow for granting permissions that can be used against you by an attacker





# Some Best Practices

*Restrict permissions, declare resource needs*

- Avoid using privileged mode for Pods if you can avoid it
- Enforce running a container a non-root user via a security context
- Don't use the latest tags for images run in a container
- Define resource requests and limits for containers



---

# Scanning Images

*Detecting vulnerabilities in an automated fashion*

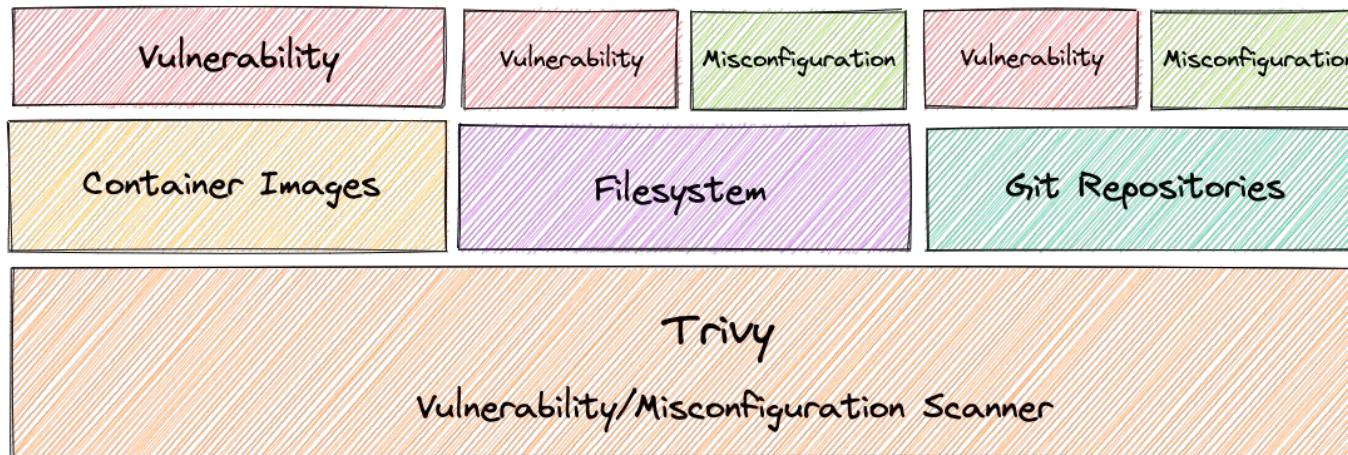
- Vulnerabilities are reported and stored in a central database
- The Common Vulnerability Scoring System (CVSS) assign the degree of severity
- Tools like [Trivy](#) can verify an image with the central database of vulnerabilities





# Using Trivy

*CLI tool for scanning images, Git repos, config files, FS*





# Installing & Using Trivy

*Easy to install and use with different modes*

- Installation: apt-get install, yum install **and** brew install
- Scanning an image: \$ trivy image nginx:1.18.0
- Scanning a config file: \$ trivy config pod.yaml
- Scanning a repo: \$ trivy repo  
<https://github.com/bmuschko/cks-crash-course>





# Trivy Vulnerability Report

*Lists vulnerabilities per library used in an image*

```
2022-04-20T11:24:24.060-0600      INFO      Table result includes only package filenames. Use '--format json' option to get the full path to the package file.

Node.js (node-pkg)
=====
Total: 35 (UNKNOWN: 0, LOW: 7, MEDIUM: 12, HIGH: 14, CRITICAL: 2)

+-----+-----+-----+-----+-----+
| LIBRARY | VULNERABILITY ID | SEVERITY | INSTALLED VERSION | FIXED VERSION | TITLE
+-----+-----+-----+-----+-----+
| ajv (package.json) | CVE-2020-15366 | MEDIUM | 5.5.2 | 6.12.3 | nodejs-ajv: prototype pollution
|                   |                   |          |          |          | via crafted JSON schema
|                   |                   |          |          |          | in ajv.validate function
|                   |                   |          |          |          | -->avd.aquasec.com/nvd/cve-2020-15366
+-----+-----+-----+-----+-----+
```



---

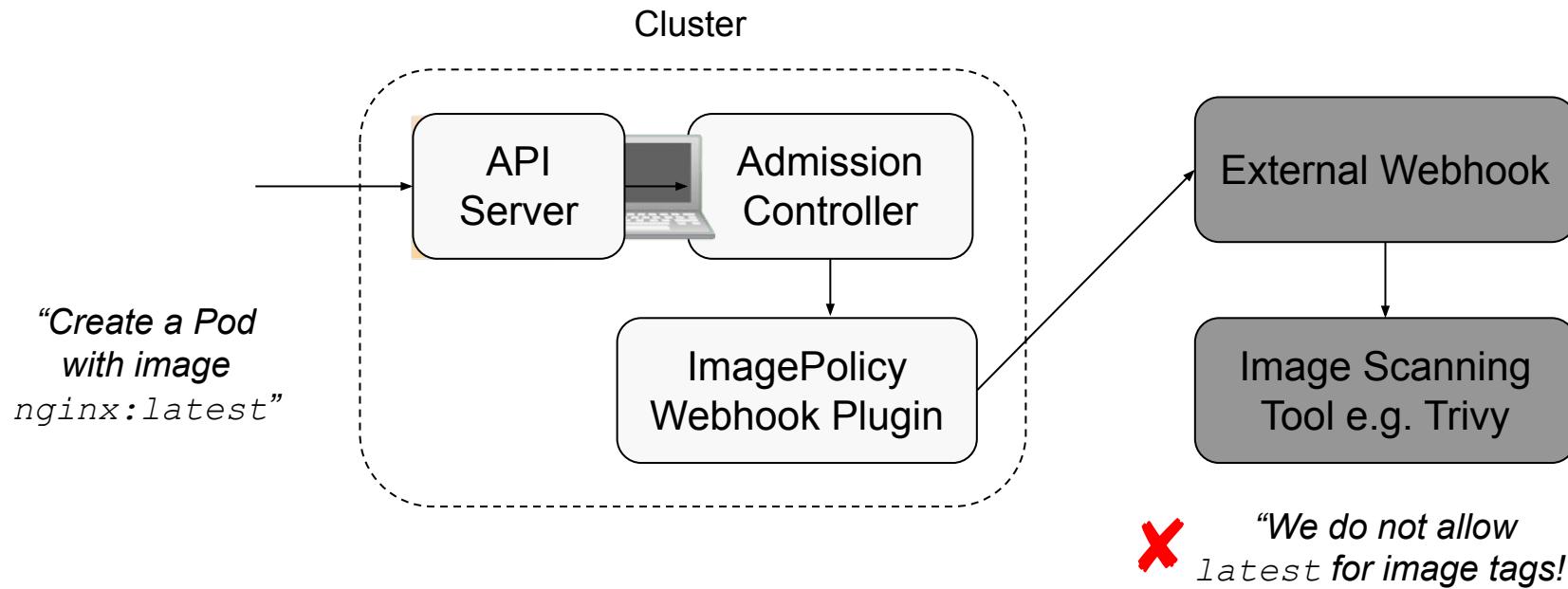
# EXERCISE

Image Scanning with  
Trivy



# Scenario: Intercepting API Calls

*Image approval via admission controller and image policy webhook*



# Admission Controllers

*Intercept calls via the Kubernetes API*

- Decides if a request should be approved/denied or mutated before any changes take place to enforce aspects like security, governance, or configuration management
- Evaluation is based on information sent e.g. image name
- Example: Disallow containers from running with a non-root user when creation of a Pod is requested



---

# ImagePolicyWebhook Plugin

*Make admission decisions via backend*

- One of the [plugins](#) for an admission controller
- Approve/deny usage of image when creating workloads e.g. scan image
- Example: Deny an image that contains known critical vulnerabilities



# Admission Configuration

*Deny Pod creation via ImagePolicyWebhook plugin*

```
apiVersion: apiserver.config.k8s.io/v1
kind: AdmissionConfiguration
plugins:
- name: ImagePolicyWebhook
  configuration:
    imagePolicy:
      kubeConfigFile: /etc/kubernetes/admission/kubeconf
      allowTTL: 50
      denyTTL: 50
      retryBackoff: 500
      defaultAllow: false
```

Deny all Pods if  
backend is not  
available



# Enabling ImagePolicyWebhook

*Point to admission config file and enable plugin*



```
$ vim /etc/kubernetes/manifests/kube-apiserver.yaml
spec:
  containers:
    - command:
      - kube-apiserver
      - ...
      - --admission-control-config-file=/etc/kubernetes/admission/admission-config.yaml
      - --enable-admission-plugins=NodeRestriction,ImagePolicyWebhook
```



```
$ minikube start
--extra-config=apiserver.admission-control-config-file=...
--extra-config=apiserver.enable-admission-plugins=ImagePolicyWebhook
```



# The Kubeconfig File

*Sets up communication with backend via TLS*

```
clusters:  
- name: name-of-remote-imagepolicy-service  
  cluster:  
    certificate-authority: /path/to/ca.pem  
    server: https://images.example.com/policy  
  
users:  
- name: name-of-api-server  
  user:  
    client-certificate: /path/to/cert.pem  
    client-key: /path/to/key.pem
```

HTTPS URL of  
remote service to  
query

Cert and key for the  
webhook admission  
controller to use



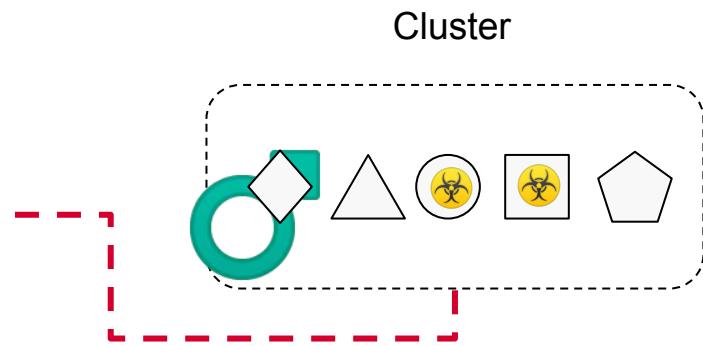
# Monitoring, Logging, and Runtime Security

Behavioral Analysis, Detecting Threats, Immutable Containers, Audit Logs

---

# Scenario: Infiltrating Components

*Detecting if and how cluster components are attacked*



---

# Behavioral Analytics

*Process of observing abnormal & malicious events*

- Answers questions like “Are we currently under attack?” or “Was something changed after an attack?”
- Can be performed in a manual and automated fashion
- Tools like [Falco](#) continuously detect unexpected behavior, configuration changes, intrusions, and data theft in real time





# Installing & Using Falco



*Only installable and executable on Linux systems*

- Modes of operation
  - CLI tool
  - Background process
  - Web server

```
$ falco -r custom-rules.yaml -M 60
```

Length of  
execution time



Custom rules file



# Falco Rules



*Define the conditions that trigger an alert*

```
- rule: shell_in_container
  desc: notice shell activity within a container
  condition: evt.type = execve and evt.dir=< and container.id != host and proc.name = bash
  output: shell in a container (user=%user.name
            container_id=%container.id
            container_name=%container.name
            shell=%proc.name parent=%proc.pname
            cmdline=%proc.cmdline)
  priority: WARNING
```

*“Alert whenever a user opens a shell to a container”*



# Falco 101 Video Course



*Free with online registration at [Sysdig webpage](#)*

A screenshot of a web browser displaying the 'Learn with Sysdig' website at learn.sysdig.com. The main header features the Sysdig logo and the text 'Learn with Sysdig'. On the right, there's a 'Sign In' button. The main content area is titled 'Falco 101' with the subtitle 'All you need to learn to get started with Falco'. It includes a 'Register Now' button, a 'Sign In' link for registered users, and social sharing links for Facebook and Twitter. Below this, there's a section for 'ALSO AVAILABLE AS PART OF:' with a small thumbnail image. The left sidebar contains a navigation menu with ten items: 01 Introduction to Course, 02 Introduction to Runtime Security, 03 What is Falco?, 04 Installation, 05 Configuration, 06 Rules Deep Dive, 07 Event Sources, 08 Alerts, 09 Rule Fine Tuning, and 10 Response Engine. A video player interface is shown on the right side of the sidebar. At the bottom of the page, there are three sections: 'About this course', 'Curriculum (5 hr 41 min)', and a footer note.

This course introduces Falco, including its rules syntax, alerting, configuration, and more.

*What is Runtime Security?*

*How can I use the default rule set for my particular use case?*

*Can I define custom rules for my production environment?*

If some of these questions resonate with you, this is your course. The first three lessons are composed of a short video introducing the course and main concepts. The rest of the content is hands-on oriented, so you'll have the opportunity to get some actual practice with the tool in real scenarios.

**Falco 101**

All you need to learn to get started with Falco

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ALSO AVAILABLE AS PART OF:

**About this course**

**Curriculum (5 hr 41 min)**

- 101.01 - Introduction (0 hr 1 min)
- 101.02 - Introduction to Runtime Security (0 hr 3 min)
- 101.03 - What is Falco? (0 hr 2 min)
- 101.04 - Falco Installation and basic settings (0 hr 30 min)
- 101.05 - Falco Event Sources (0 hr 0 min)
- 101.06 - Falco Rules Basics (1 hr 0 min)
- 101.07 - Falco Rules Deep Dive (0 hr 45 min)
- 101.08 - Fine Tuning Falco Rules (Exceptions) (0 hr 45 min)
- 101.09 - Falco Alerts (0 hr 35 min)
- 101.10 - Falco Response Engine (0 hr 30 min)

Check what you learned!



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# EXERCISE

Intrusion Detection  
with Falco



---

# Container Immutability

*Cannot be changed during its lifespan*

- Container's file system cannot be modified (no updates, no patches, no configuration changes)
- Updates can only be made via new container image
- Container configuration needs to be externalized e.g. environment variables, ConfigMaps, Secrets and can be used to control runtime behavior



# Avoid Privileged Containers

*No access to all the devices of the host machine*

- Running container with root access opens door for attackers to gain full access to server
- Control host access in the Pod's security context configuration
- Use PodSecurityPolicies to prevent privileged access



---

# Immutability Best Practices

*No access to all the devices of the host machine*

- Avoid running container with root user via `securityContext.runAsUser` with value `root` or `0`
- Avoid privileged mode via `securityContext.privileged` or `securityContext.allowPrivilegedEscalation` with value `true`
- Avoid access to host resources via `hostNetwork` with value `true`



# Ensuring Container Immutability

*Prevent writing to container file system*

```
apiVersion: v1
kind: Pod
metadata:
  name: immutable
spec:
  securityContext:
    readOnlyRootFilesystem: true
  containers:
    - ...
```

*Mount a Volume if you need to write data from the application*



---

# EXERCISE

Verifying Container  
Immutability



# Audit Logging

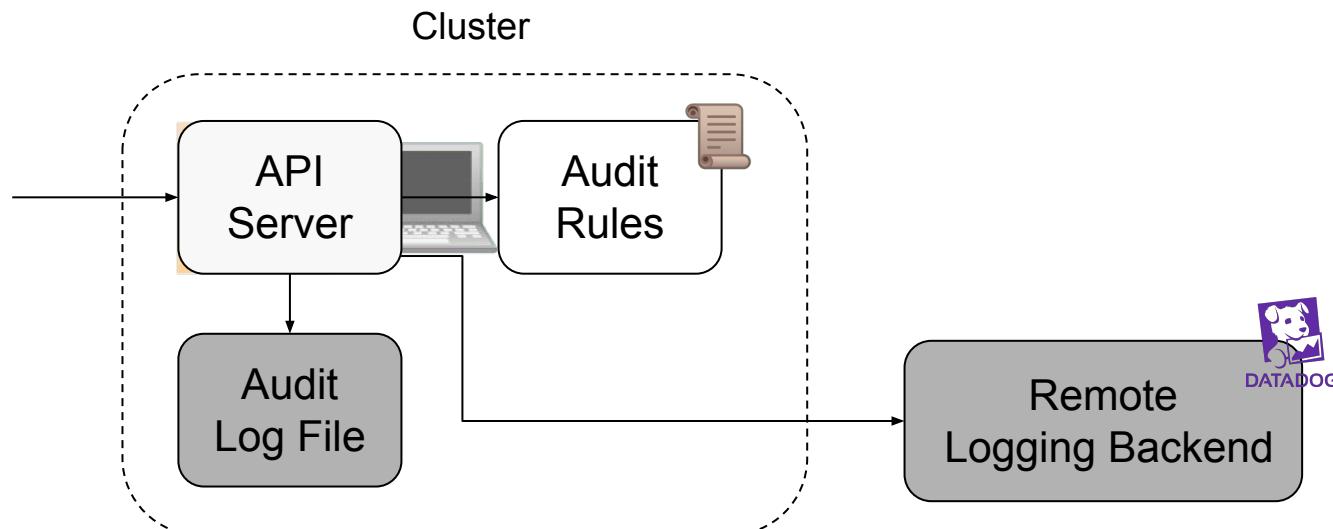
*Chronological records of actions in the cluster*

- Records requests to Kubernetes API for internal and external components (e.g. a user creates a Pod with `kubectl`, or a change to CoreDNS)
- Structured in JSON format
- Helpful for real-time view on cluster events (e.g. threat detection) or why or what happened in the past (e.g. for debugging issues)



# Audit Backends

*Write to file system or external HTTP API*



# Audit Policy Configuration File

*Rules about events and their data to be recorded*

```
apiVersion: audit.k8s.io/v1
kind: Policy
rules:
- level: RequestResponse
  resources:
  - group: ""
    resources: [ "pods" ]
```

Audit level, in this case event metadata,  
request and response bodies

Kubernetes resource types to match  
including a potential API group



# Audit Levels

Level	Runtime Behavior
None	Omit log events
Metadata	Log request metadata (requesting user, timestamp, resource, verb, etc.) but not request or response body
Request	Log event metadata and request body but not response body
RequestResponse	Log event metadata, request and response bodies



# File System Audit Logging

*Point to audit log config file and output log file*



```
$ vim /etc/kubernetes/manifests/kube-apiserver.yaml
spec:
  containers:
    - command:
      - kube-apiserver
      - ...
      - --audit-policy-file=/etc/kubernetes/audit-policy.yaml
      - --audit-log-path=/var/log/kubernetes/audit/audit.log
```



```
$ minikube start
--extra-config=apiserver.audit-policy-file=/etc/ssl/certs/audit-policy.yaml
--extra-config=apiserver.audit-log-path=
```

Workaround: Config  
dir/file needs to exist in  
~/.minikube/files/



# Persisting Audit Log Records

*Requires mounting the config file + produced audit log*

## Mount Volumes

```
volumeMounts:  
- mountPath: /etc/kubernetes/audit-policy.yaml  
  name: audit  
  readOnly: true  
- mountPath: /var/log/kubernetes/audit/  
  name: audit-log  
  readOnly: false
```

## Configure host paths

```
volumes:  
- name: audit  
  hostPath:  
    path: /etc/kubernetes/audit-policy.yaml  
    type: File  
- name: audit-log  
  hostPath:  
    path: /var/log/kubernetes/audit/  
    type: DirectoryOrCreate
```



---

# EXERCISE

Configuring and  
Using Audit Logging



# Summary & Wrap Up

Last words of advice...

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# Gaining confidence

- Run through practice exams as often as you can
- Read through online documentation start to end
- Know your tools (especially vim, bash, YAML)
- Pick time you are most comfortable, get enough sleep
- Take your first attempt easy but give it your best





Thank you

