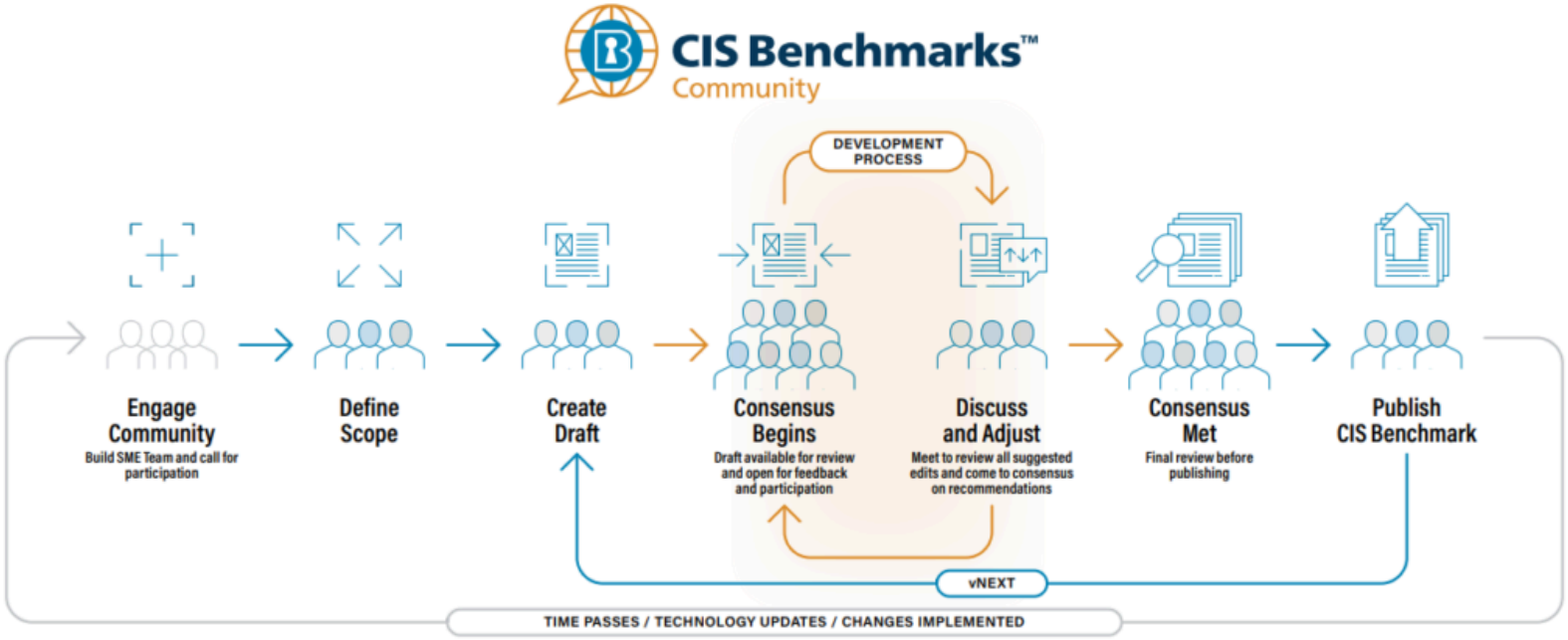
Certified Kubernetes Security Specialist (CKS)

Cluster setup

CIS Benchmarks & K8s Hardening

- **Standardization**: Industry-wide best practices for secure K8s configuration.
- **Scope**: Covers API Server, ETCD, Kubelet, and Controller Manager.
- **Scoring**: Provides a clear "Pass/Fail" security posture.
- **CKS Focus**: Understanding which flags (e.g., `--anonymous-auth=false`) satisfy the benchmark.



Kube-bench & Automation

- **Tooling**: Aqua Security's open-source tool to run CIS checks.
- **Remediation**: Output includes specific commands to fix vulnerabilities.
- **Continuous Compliance**: Monitoring drift in node security settings.

```
[INFO] 1 Master Node Security Configuration
[INFO] 1.1 API Server
[FAIL] 1.1.1 Ensure that the --allow-privileged argument is set to false (Scored)
[FAIL] 1.1.2 Ensure that the --anonymous-auth argument is set to false (Scored)
[PASS] 1.1.3 Ensure that the --basic-auth-file argument is not set (Scored)
[PASS] 1.1.4 Ensure that the --insecure-allow-any-token argument is not set (Scored)
[FAIL] 1.1.5 Ensure that the --kubelet-https argument is set to true (Scored)
[PASS] 1.1.6 Ensure that the --insecure-bind-address argument is not set (Scored)
[PASS] 1.1.7 Ensure that the --insecure-port argument is set to 0 (Scored)
[PASS] 1.1.8 Ensure that the --secure-port argument is not set to 0 (Scored)
[FAIL] 1.1.9 Ensure that the --profiling argument is set to false (Scored)
[FAIL] 1.1.10 Ensure that the --repair-malformed-updates argument is set to false (Scored)
[PASS] 1.1.11 Ensure that the admission control policy is not set to AlwaysAdmit (Scored)
[FAIL] 1.1.12 Ensure that the admission control policy is set to AlwaysPullImages (Scored)
[FAIL] 1.1.13 Ensure that the admission control policy is set to DenyEscalatingExec (Scored)
[FAIL] 1.1.14 Ensure that the admission control policy is set to SecurityContextDeny (Scored)
[PASS] 1.1.15 Ensure that the admission control policy is set to NamespaceLifecycle (Scored)
[FAIL] 1.1.16 Ensure that the --audit-log-path argument is set as appropriate (Scored)
[FAIL] 1.1.17 Ensure that the --audit-log-maxage argument is set to 30 or as appropriate (Scored)
[FAIL] 1.1.18 Ensure that the --audit-log-maxbackup argument is set to 10 or as appropriate (Scored)
[FAIL] 1.1.19 Ensure that the --audit-log-maxsize argument is set to 100 or as appropriate (Scored)
[PASS] 1.1.20 Ensure that the --authorization-mode argument is not set to AlwaysAllow (Scored)
[PASS] 1.1.21 Ensure that the --token-auth-file parameter is not set (Scored)
[FAIL] 1.1.22 Ensure that the --kubelet-certificate-authority argument is set as appropriate (Scored)
```

LAB: Cluster Setup & Hardening

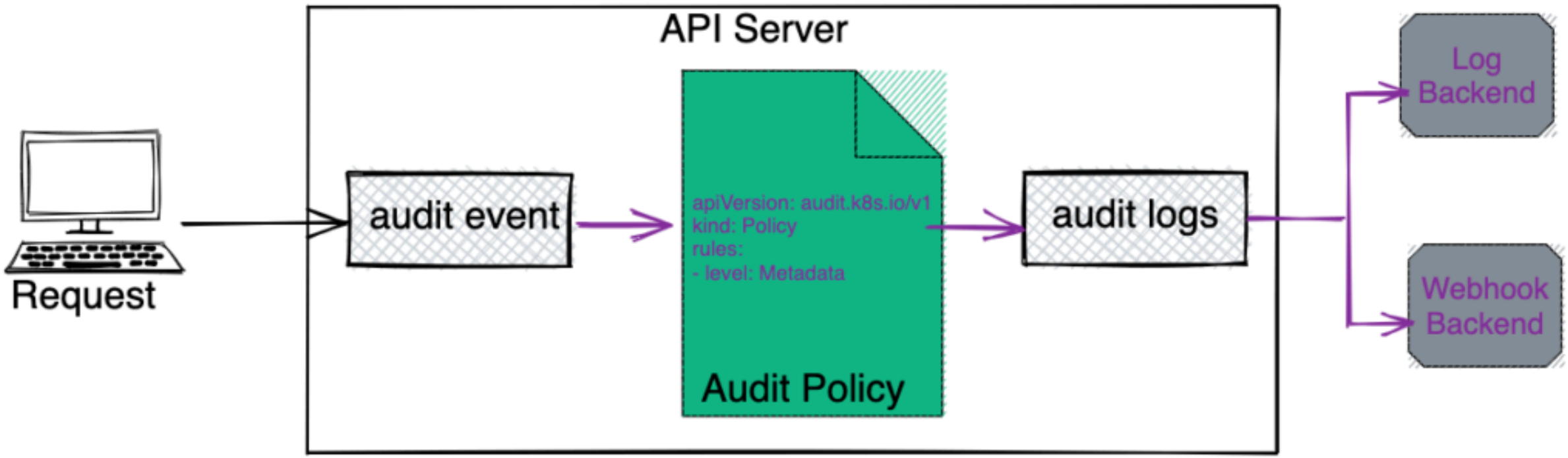
- **Exercise 1**: Running Kube-bench as a Job
- **Exercise 2**: Manual Remediation of Control Plane
- **Exercise 3**: Automation and Continuous Compliance

Auditing, Monitoring, Logging

API Server Audit Logging

- **Configuration**: Set via `--audit-policy-file` and `--audit-log-path` in `api-server` Pod.
- ⚠️ **Exam Tip**: You MUST know how to mount the policy file and log directory using `hostPath` volumes and `volumeMounts` within the API Server static pod manifest.

API Server Audit Workflow



Simple Audit Policy Example

```
apiVersion: audit.k8s.io/v1
kind: Policy
omitStages:
- "RequestReceived"
rules:
- level: Metadata
  resources:
  - group: ""
    resources: ["secrets"]
- level: RequestResponse
  resources:
  - group: ""
    resources: ["pods"]
  namespaces: ["production"]
```

[Official Documentation Examples]

Understanding Audit Stages

Each request can be recorded with an associated stage:

- **RequestReceived**: The stage for events generated as soon as the audit handler receives the request, and before it is delegated down the handler chain.
- **ResponseStarted**: Once the response headers are sent, but before the response body is sent. This stage is only generated for long-running requests (e.g. watch).
- **ResponseComplete**: The response body has been completed and no more bytes will be sent.
- **Panic**: Events generated when a panic occurred.

⚠️ **Exam Tip**: If no stages are defined in the policy, ALL stages are logged by default, which can explode the log file size.

Think of stages as a timeline of a request. For the CKS exam, you will likely use "ResponseComplete" to ensure you capture whether the request was actually authorized and successful.

Understanding Audit Levels

The defined audit levels are:

- **None**: don't log events that match this rule.
- **Metadata**: log events with metadata (requesting user, timestamp, resource, verb, etc.) but not request or response body.
- **Request**: log events with request metadata and body but not response body. This does not apply for non-resource requests.
- **RequestResponse**: log events with request metadata, request body and response body. This does not apply for non-resource requests.

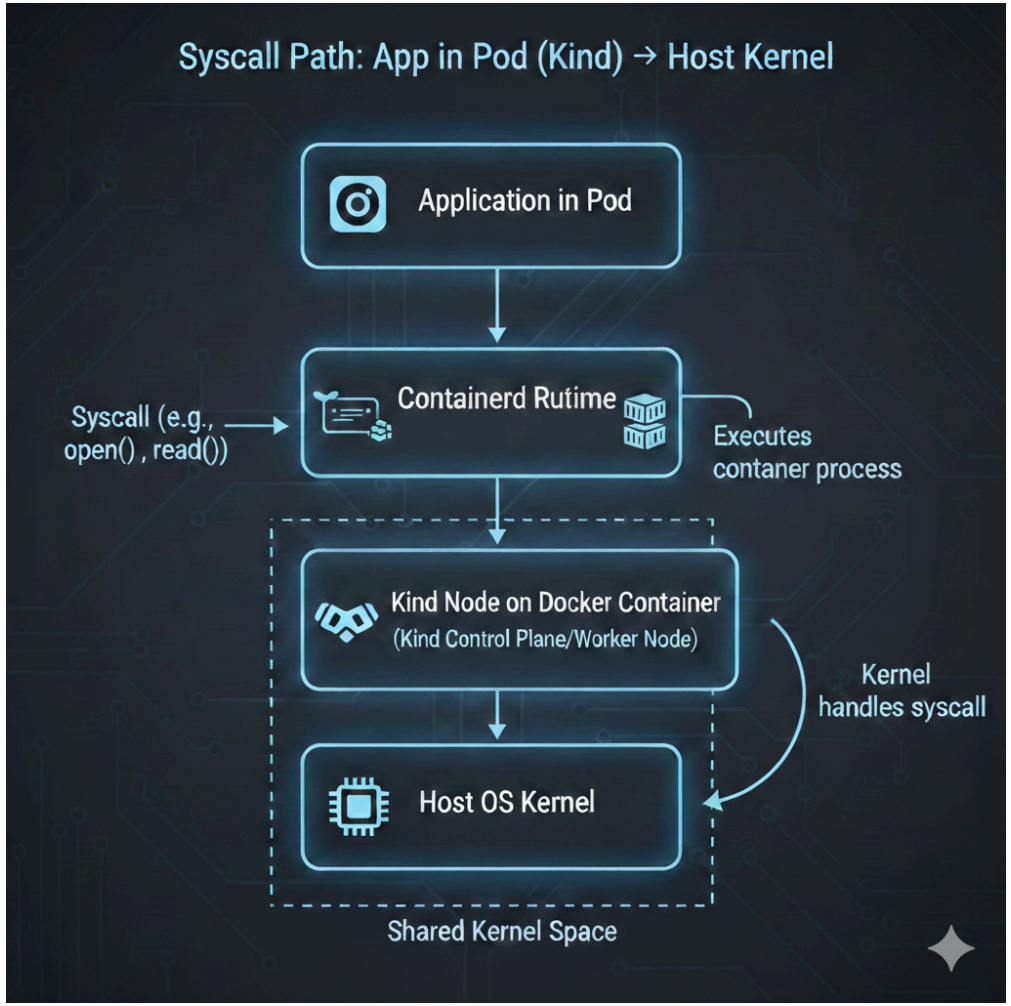
⚠️ **Exam Tip**: the "RequestResponse" level is very resource-intensive for CPU and Storage. In production, we usually prefer "Metadata" for sensitive resources like Secrets to maintain performance.*

Deep Dive: Kernel & Isolation

- **Container Architecture**: Containers share the host's OS kernel through System Calls (syscalls)
- **Process Isolation**: Containers use namespaces/cgroups, but lack the hardware isolation of VMs.
- **Security Boundary**: Explains the need for syscall filtering (Seccomp).

⚠️ Kind (Kubernetes in Docker)

Syscalls from a "kind" node impact the physical host kernel directly.



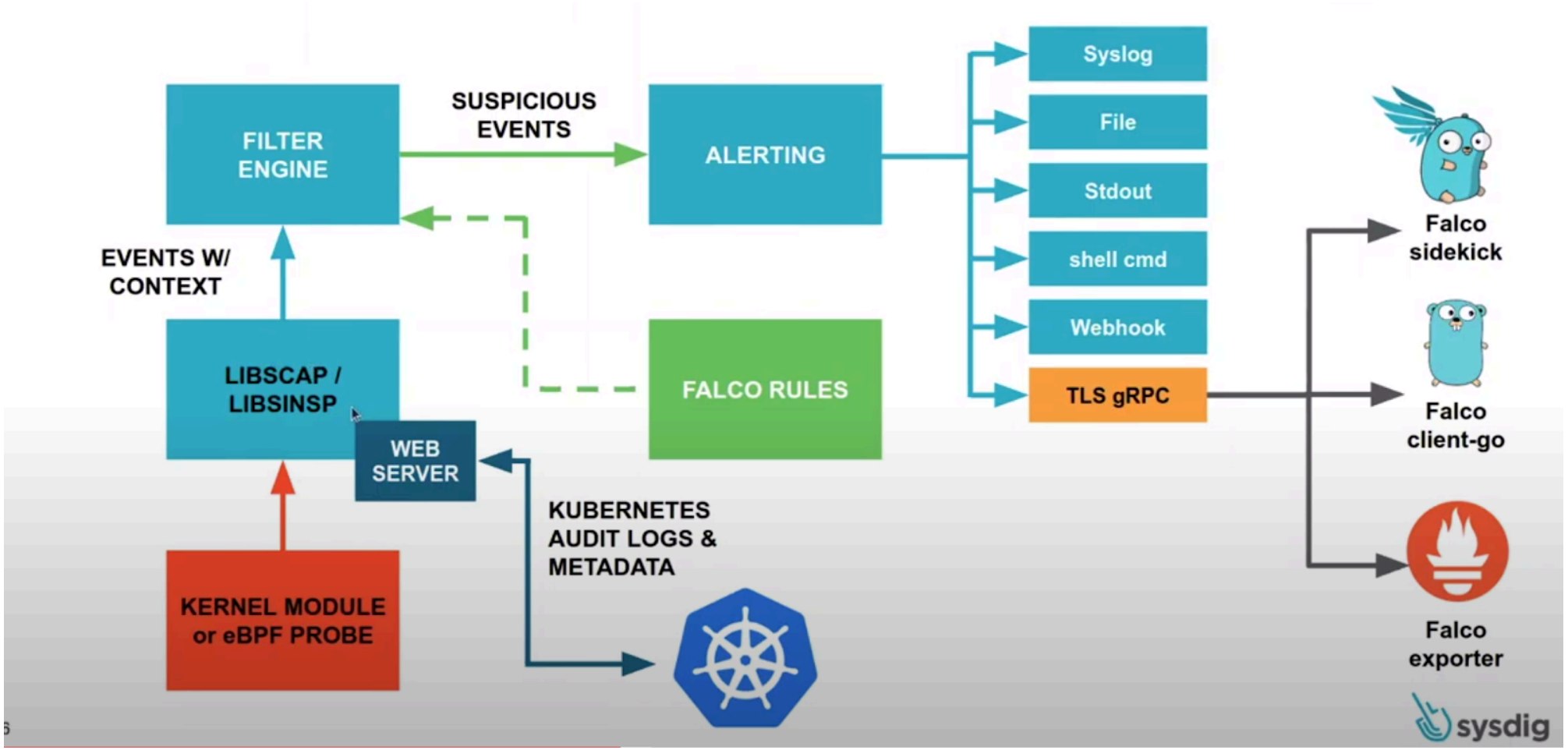
Falco: Runtime Security

- **Detection Engine**: Real-time alerting based on kernel system calls.
- **Rule Syntax**: Simple YAML format (Conditions, Outputs, Priorities).
- **Use Cases**: Detecting shell execution in pods, unauthorized file access, or outbound network changes.
- **Output**: Logs to stdout, file, gRPC, or Slack/Webhooks.

Falco is the "security monitor" of your cluster. It detects threats in real-time but does not block anything (unlike an Admission Controller)

For the CKS exam, focus on learning how to modify local rule.

Falco: Runtime Security



Falco: Rule Configuration Example

To pass the CKS, most tasks involve modifying local rule files (usually `/etc/falco/falco_rules.local.yaml`) to trigger alerts or filter false positives.

Structure of a Simple Rule

Below is a standard rule designed to detect when a shell is spawned inside a container:

```
- rule: Shell spawned in container
  desc: A shell was used inside a container
  condition: container.id != host and proc.name = bash
  output: "bash in container (user=%user.name container_id=%container.id)"
  priority: WARNING
```

Key Components for the Exam

- **Condition**: The logic used to trigger the alert. Uses field names like `fd.name` (files), `proc.name` (processes), and `container.id`.
- **Output**: The message sent to your logs. Use `%` to inject dynamic data from the event.
- **Macros & Lists**: In a real environment, you often use macros (e.g., `spawned_process`) to keep conditions readable.

Official Resources

- **Documentation**: Falco Rules Reference
- **Default Rule Examples**: Falco GitHub Ruleset

  CKS Tip: If the exam asks you to "silence" an alert for a specific tool, look for the corresponding **Macro** in the configuration and add your exception there rather than deleting the whole rule.

LAB: Audit & Monitoring

- **Exercise 1**: Configuring Audit Policies
- **Exercise 2**: Falco Runtime Alerts

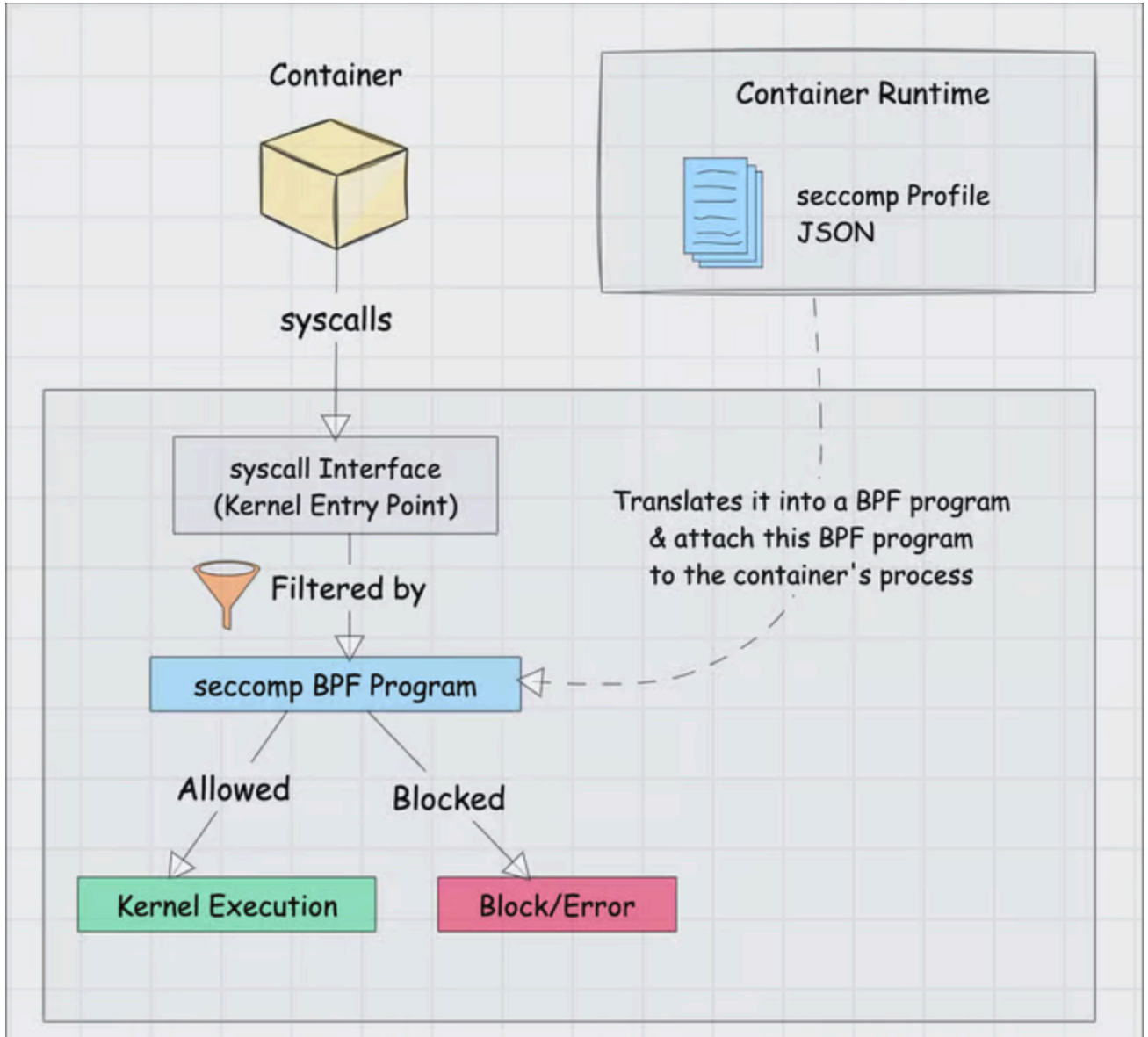
System Hardening

Seccomp (Secure Computing)

- **Syscall Filtering**: Limits what operations a process can request from the kernel, preventing potentially dangerous or unauthorized kernel operations.
- **Default Profiles**: `RuntimeDefault` (provided by Docker/Containerd). It blocks dangerous syscalls while allowing common operations.
- **Custom Profiles**: JSON-based filters for fine-grained syscall control, must stored on **all** Nodes in `/var/lib/kubelet/seccomp/`.

Seccomp reduces the kernel's "attack surface." If a zero-day vulnerability exists in a rarely-used syscall, Seccomp can protect the cluster by simply blocking that syscall.

Seccomp Workflow



Seccomp: Pod Application

- Use `securityContext.seccompProfile` to enforce profiles.

Example Pod with Seccomp:

```
apiVersion: v1
kind: Pod
metadata:
    name: secure-pod
spec:
    securityContext:
        seccompProfile:
            type: RuntimeDefault
    containers:
    - name: app
        image: nginx:latest
```

Seccomp profiles

- **Unconfined**: The workload runs without any seccomp restrictions.
- **RuntimeDefault**: The default Seccomp profile provided by the container runtime (Docker/Containerd).
- **Localhost**: The availability of the seccomp profile on the Node is verified by the container runtime on container creation.

Official documentation

Here is the updated content in English, integrating your specific `rsync` profile example and using the modern `securityContext` syntax.

AppArmor & SELinux

AppArmor and SELinux are Kernel-level modules that enforce Mandatory Access Control (MAC).

- restrict process capabilities—even for root
- prevent compromised containers from accessing sensitive files, unauthorized binaries, or restricted network protocols
- based on **strict security profiles**.
- **SELinux**: Label-based security. Uses contexts and policies for fine-grained system access control.
- **AppArmor**: Path-based security. Uses profiles applied to specific programs to restrict capabilities and file access.

Example: Custom AppArmor Profile (`rsync`)

This profile restricts the `rsync` binary to specific capabilities and file paths.

```
# File: /etc/apparmor.d/usr.bin.rsync
#include <tunables/global>

profile rsync-custom /usr/bin/rsync {
   #include <abstractions/base>
   capability net bind_service,
   network inet tcp,

   # Binaries
   /usr/bin/rsync mr,
   # Configuration files (Read-only)
   /etc/rsyncd.conf r,
   # Logs (Read/Write)
   /var/log/rsyncd.log rw,
}
```

Kubernetes Pod Implementation

Since Kubernetes **v1.30**, use `securityContext.appArmorProfile` to apply these profiles.

```
apiVersion: v1
kind: Pod
metadata:
  name: rsync-backup
spec:
  securityContext:
    appArmorProfile:
      type: Localhost
      # The profile "rsync-custom" must be loaded on the Node
      localhostProfile: rsync-custom
  containers:
  - name: rsync-container
    image: my-rsync-image:latest
```

Important CKS Reminders

- **Check Status**: Use `aa-status` on the node to verify the profile is in **enforce mode**.
- **Loading**: Load a new profile using: `apparmor_parser -r /etc/apparmor.d/usr.bin.rsync`
- **Localhost Type**: When using `type: Localhost`, the `localhostProfile` name must match the profile name defined in the AppArmor file exactly.
- **Deployment**: Profiles must be loaded on **all** worker nodes via `apparmor_parser` before the Pod is scheduled.

AppArmor: Key Learning Points

- Creating and loading AppArmor profiles on nodes
- Applying profiles to Kubernetes pods using `securityContext`

LAB: Kernel-Level Security

- **Exercise**: Custom Seccomp Profiles

Apparmor lab will be skipped because it is very similar to the secomp one

- **Exercise**: AppArmor Security Profiles
- **Official Tutorial**: Kubernetes AppArmor Documentation

Container Isolation Alternatives: Sandboxed Runtimes

- **Traditional Containers**: Share host kernel directly (Docker, containerd with runc)
- **Sandboxed Runtimes**: Add extra isolation layers

⚠️ **CKS Context**: Understanding these alternatives helps explain why syscall filtering (Seccomp) and MAC (AppArmor/SELinux) are important for traditional container security.

gVisor

- **User-space Kernel**: Intercepts syscalls before they reach the host kernel
- **Language**: Written in Go, provides a "fake" kernel interface
- **Use Case**: High security workloads that need strong isolation
- **Trade-off**: Performance overhead vs security

Security Benefit: Malicious syscalls are handled by gVisor's user-space kernel, not the host kernel.

Kata Containers

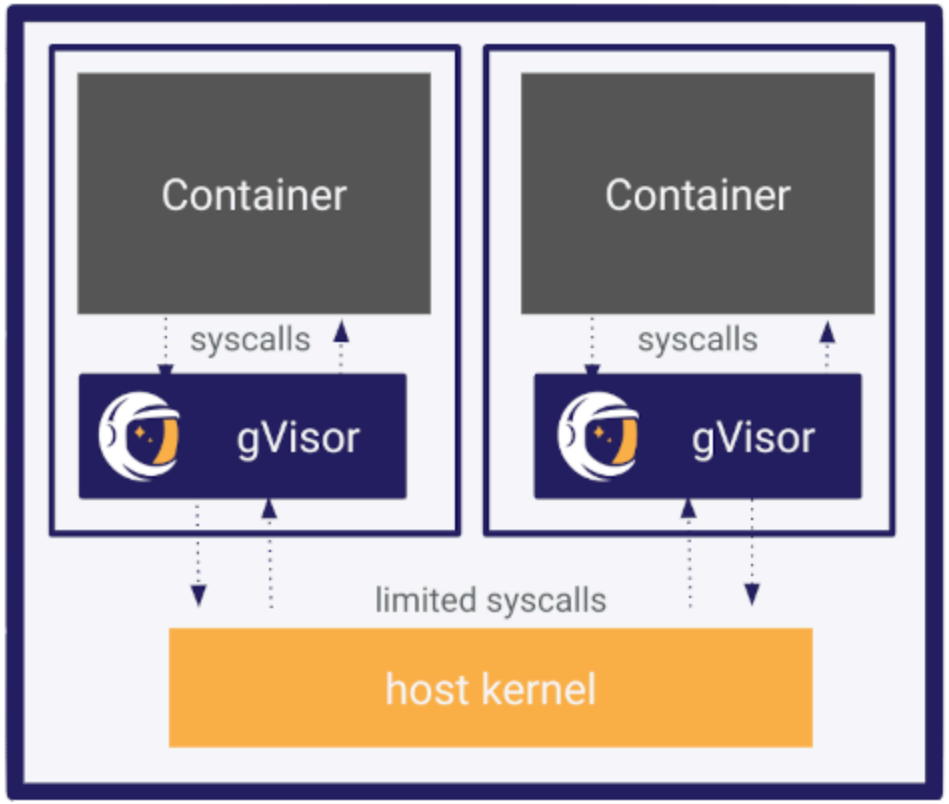
- **VM-based**: Each container runs in its own lightweight VM
- **Hardware Isolation**: True kernel isolation using hypervisor
- **Compatibility**: OCI-compliant, works with existing container tools
- **Trade-off**: Resource overhead vs maximum security

Security Benefit: Complete kernel isolation - container breaches cannot affect the host kernel directly.

gVisor in Practice

User-space Kernel Implementation

gVisor provides a **user-space kernel** written in Go that intercepts syscalls before they reach the host kernel.



Create RuntimeClass for gVisor

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

Deploy Pod with gVisor

```
apiVersion: v1
kind: Pod
metadata:
  name: secure-app-gvisor
spec:
  runtimeClassName: gvisor  # Use gVisor runtime
  containers:
  - name: app
    image: nginx:alpine
```

Supply Chain security

Trivy: Comprehensive Vulnerability Scanner

Trivy is an open-source security scanner that helps identify vulnerabilities and misconfigurations across your entire software supply chain.

Core Capabilities

- **Multi-target Scanning**: Container images, filesystems, Git repositories, Kubernetes clusters, and IaC files
- **Vulnerability Detection**: CVEs from multiple databases (MIST/NVD, Red Hat, Debian, Ubuntu, Amazon Linux, etc.)
- **Misconfiguration Detection**: Dockerfile, Kubernetes manifests, Terraform
- **Secret Detection**: API keys, passwords, tokens embedded in code
- **SBOM Generation**: Software Bill of Materials in multiple formats (SPDX, CycloneDX)

Trivy: Key Features

- **Severity Filtering**: Focus on `CRITICAL` and `HIGH` vulnerabilities
- **CI/CD Integration**: Fail builds based on vulnerability thresholds
- **Kubernetes Integration**: Scan running workloads with the Trivy Operator

GitLab CI with Trivy

Trivy: Essential Commands

```
# Scan container image
trivy image nginx:latest

# Scan with severity filtering
trivy image --severity HIGH,CRITICAL alpine:latest

# Generate SBOM
trivy image --format spdx-json nginx:latest

# Scan Kubernetes cluster
trivy k8s --report summary
```

Cosign: Container Image Signing & Verification

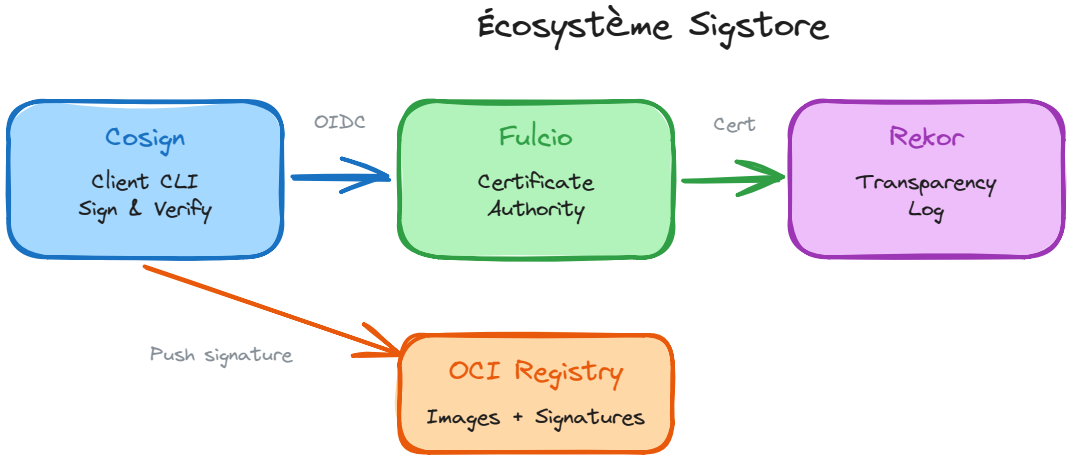
Cosign is a tool for signing and verifying container images and artifacts, ensuring software supply chain security through cryptographic signatures.

Core Capabilities

- **Image Signing**: Sign container images with private keys or keyless signing (OIDC)
- **Signature Verification**: Verify signatures before deploying images
- **Attestation Support**: Attach and verify SLSA provenance, SBOM, and custom attestations
- **Policy Enforcement**: Integration with admission controllers for automatic verification

Cosign: Key Features

- **Keyless Signing**: Use GitHub Actions, GitLab CI, or other OIDC providers
- **Hardware Security**: Support for HSM and hardware tokens
- **Transparency Logs**: Integration with Rekor for signature transparency
- **Kubernetes Integration**: Policy enforcement via admission webhooks



Cosign: Essential Commands

```
# Generate key pair
cosign generate-key-pair

# Sign an image
cosign sign --key cosign.key myregistry.io/myimage:v1.0.0

# Verify signature
cosign verify --key cosign.pub myregistry.io/myimage:v1.0.0

# Keyless signing with OIDC
cosign sign myregistry.io/myimage:v1.0.0

# Attach and verify SBOM
cosign attach sbom --sbom sbom.json myregistry.io/myimage:v1.0.0
cosign verify-attestation --type slsaprovenance --key cosign.pub myregistr
```

Cosign: Supply Chain Security Benefits

- **Authenticity**: Prove image origin and prevent tampering
- **Integrity**: Detect unauthorized modifications
- **Non-repudiation**: Cryptographic proof of who signed what
- **Compliance**: Meet regulatory requirements for software provenance

ImagePolicyWebhook: Admission Control for Images

The ImagePolicyWebhook admission controller enables external validation of container images before Pod creation, providing the ultimate level of supply chain security control.

Core Mechanism

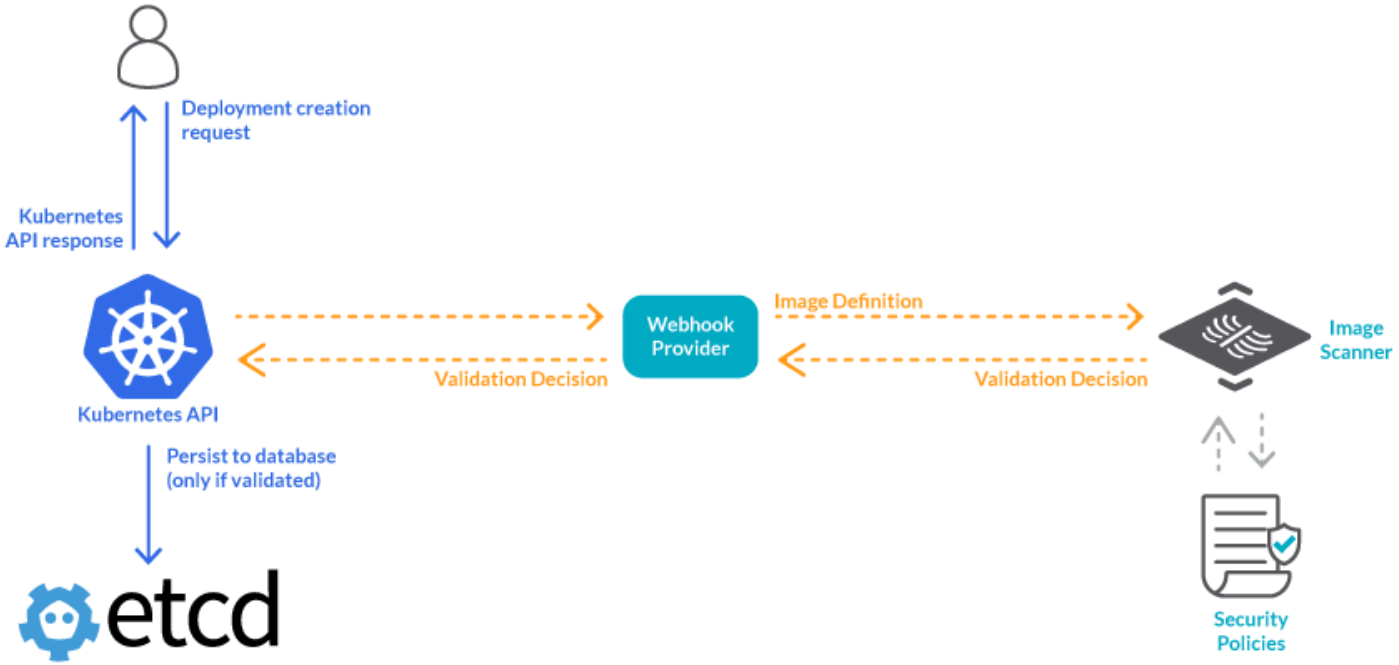
- **External Validation**: API Server queries an external webhook before admitting Pods
- **JSON Payload**: Sends `ImageReview` objects containing image details to the webhook
- **Policy Decision**: Webhook responds with `allowed: true/false` based on custom logic
- **Fail-Safe**: If webhook is unreachable, requests are denied by default

ImagePolicyWebhook: Key Features

- **Image Scanning Integration**: Block images with vulnerabilities above threshold
- **Signature Verification**: Ensure only signed images are deployed
- **Registry Allowlisting**: Restrict images to trusted registries
- **Tag Policies**: Prevent deployment of `:latest` or untagged images

ImagePolicyWebhook: Configuration Requirements

- **Admission Configuration**: Enable `ImagePolicyWebhook` in `--enable-admission-plugins`
- **Webhook Configuration**: Define webhook endpoint in admission configuration file
- **TLS Setup**: Secure communication between API Server and webhook
- **KubeConfig**: Authentication configuration for webhook communication



LAB: Supply Chain Security

- **Exercise**: Scanning with Trivy
- **Exercise**: Signing with Cosign

Summary 1/2

🔧 Cluster Setup & Hardening

- **CIS Benchmarks**: Industry standards for K8s security configuration
- **Kube-bench**: Automated CIS compliance checking and remediation
- **API Server Hardening**: Disable anonymous auth, enable audit logging, secure ETCD

🔍 Auditing, Monitoring & Logging

- **Audit Policies**: Track API requests with configurable levels (Metadata, Request, RequestResponse)
- **Falco**: Real-time runtime security monitoring using syscall analysis
- **Log Analysis**: Centralized security event correlation and alerting

Summary 2/2

🛡️ System Hardening

- **Seccomp**: Syscall filtering to reduce kernel attack surface (`RuntimeDefault`, custom profiles)
- **AppArmor/SELinux**: Mandatory Access Control (MAC) for process restrictions
- **Container Isolation**: gVisor (user-space kernel) and Kata Containers (VM-based)

🔒 Supply Chain Security

- **Trivy**: Multi-target vulnerability scanning (images, clusters, IaC, secrets)
- **Cosign**: Container image signing and verification with SLSA attestations
- **ImagePolicyWebhook**: Admission control for external image validation