Public
Cloud
Group

Image Signing and Supply Chain Security.

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Agenda.

01. —— **Introduction**

02. —— **CNCF Projects**

03. —— **Kubernetes Security**

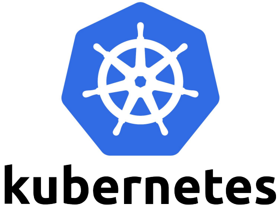
04. —— **Supply Chain Security Frameworks**

05. —— **Supply Chain Stages**

06. —— **Tools**

07. —— **Sign and Verify Container images**

CNCF Projects

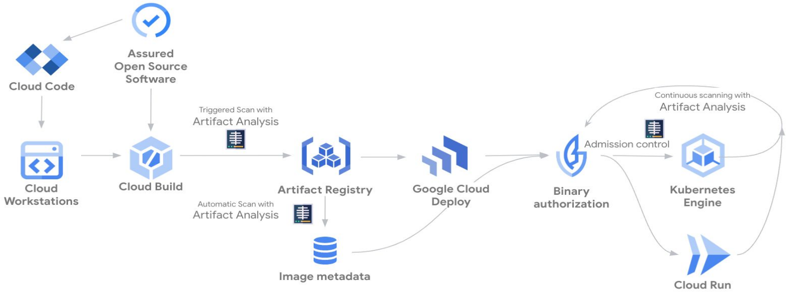


Kubernetes Security

- **Supply Chain Security**
  - SBOM / providence artifact generation
  - Vulnerability and compliance scanning (Grype)
  - Image signing (Notary & Ratify)
- **Cluster Security**
  - Secure API endpoint (authorized IP-ranges, mTLS)
  - Use robust RBAC for access control (OIDC)
  - Use cluster auto-upgrade (if possible)
  - Don’t install the dashboard (or if you do, do is the right way)
- **Node Security**
  - Automatically update node images
  - Disable SSH access
  - For potentially hostile workloads use compute isolation capabilities
    - Use confidential compute nodes (based on Intel SGX)
    - Confidential Containers - based on Kata Containers (using AMD SEV-SNP)
    - Pod Sandboxing
- **Network Security**
  - Deploy a network policy engine to secure pod network communications (Calico, Cilium, NPM)
  - Deploy WAF for ingress
- **Application Security**
  - Continuous scanning of running pods
  - Use a credential vault for storing secrets (CSI integration)

Container Secure Supply Chain Frameworks (Examples)

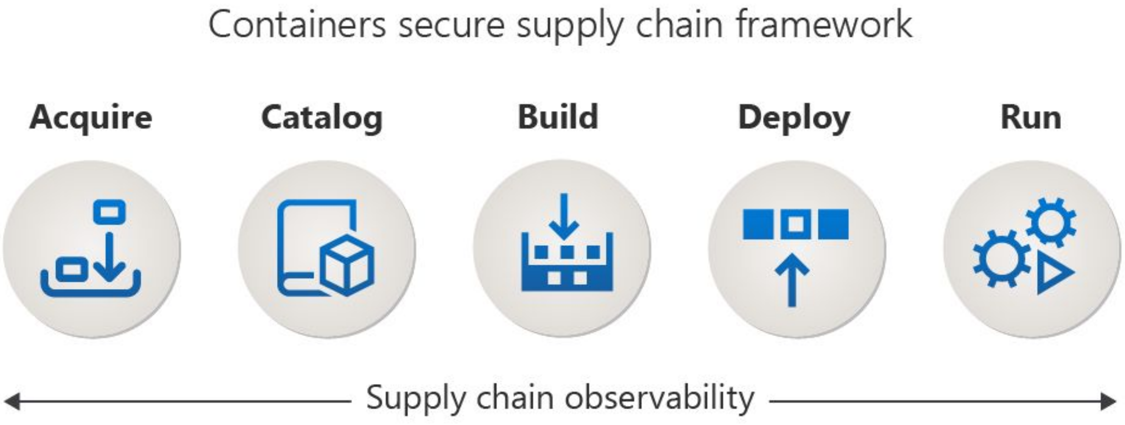
- **CNCF Software Supply Chain Best Practices**
  - Good overview of the topic
  - Unfortunately (very) outdated
  - Basis for many other frameworks
- **GCP Software supply chain security**
  - Comprehensive
  - Good documentation
  - Uses Google tools
- **Supply-chain Levels for Software Artifacts (SLSA)**
  - Part of the Open Source Security Foundation (OpenSSF)
  - Vendor neutral
  - Uses levels (get as much security as you need or can afford)
  - Has guidance for developers, organizations and infrastructure providers



Containers Secure Supply Chain Framework (CSSC)

- **The CSSC framework is built using the following steps:**
  - Identify the supply chain stages for containerized applications
  - Outline the risks and the required security controls in each stage
  - Describe the security objectives and goals in each stage
  - Identify security tools, processes, and best practices in each stage
  - Maintain security posture with metadata, logging, and reporting in each stage

- **Defines the following stages in supply chains:**


Containers secure supply chain framework
Acquire
Catalog
Build
Deploy
Run
Supply chain observability

Supply Chain Stages

- **Acquire**
  - Acquire container images from external sources or third-party vendors, e.g. os images, service proxies or logging and metric images.
- **Catalog**
  - Offer approved container images for internal consumption including builds and deployments.
- **Build**
  - Produce compliant service and application images and deployment artifacts.
- **Deploy**
  - Securely deploy containerized services and applications to the hosting environments.
- **Run**
  - Run containers created from compliant, latest, and secure container images executing the business logic for an application.

Types of Supply Chain Compromise

- **Dev Tooling**
  - Attack on development machine, SDK, tool chains, or build kit, Often results in backdoor access.
  - Mitigation: Use trusted binary repos and verify signatures and checksums.
- **Negligence**
  - Lack of adherence to best practices, e.g. missing dependency name checks etc.
- **Publishing Infrastructure**
  - The integrity or availability of shipment, publishing, or distribution mechanisms are compromised.
  - Mitigation: Code Signing
- **Source Code**
  - Source code repository (public or private) is manipulated maliciously.
- **Trust and Signing**
  - A signing key used is compromised.
- **Malicious Maintainer**
  - A maintainer, or an entity posing as a maintainer, deliberately injects a vulnerability
- **Technique: Attack Chaining**
  - Multiple attack vectors are chained together.

Acquire Stage

Possible workflow for the acquisition of external images:

- Import container images and cloud-native artifacts into an internal registry.
- Quarantine the images in the internal registry.
- Validate any signatures associated with the image.
- Validate any other metadata associated with the image including SBOMs and provenance.
- Scan the images for known vulnerabilities and malware.
- Attach the vulnerability and malware reports as image attestations.
- If not available, generate SBOM and provenance for the image and attach them .
- Sign the image and relevant metadata with enterprise keys to ensure integrity.
- If the image meets the internal policies, publish the image to the golden registry for internal use.

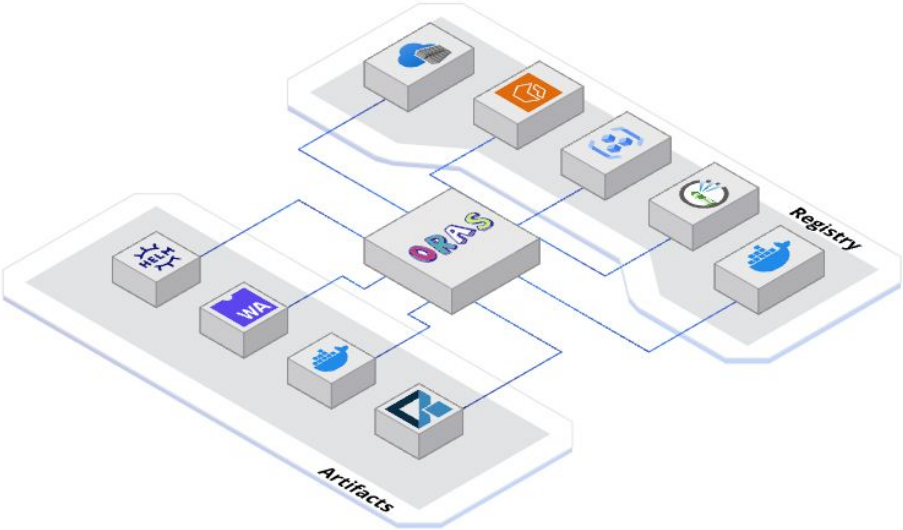
Tools used:

- An OCI-compliant container registry (Docker Hub, GitHub Container Registry (GHCR), Azure Container Registry (ACR), Google Container Registry (GCR), Amazon ECR, …)
- OCI Registry As Storage or ORAS (metadata enrichment for images)
- Notary & Notation (image signing)
- SBOM Tool (Creation of SBOMs)
- Alternative SBOM tools: CyclineDX, Sfyt (open-source), Fossa, Finite State, …

OCI Registry As Storage (ORAS)

The ORAS project provides a means to enable various client libraries with a way to push OCI Artifacts to OCI-conformant registries:

- Provides the ORAS CLI
- Github action is available for install
- Works with all OCI-compliant registries, see here.



SBOM Tool

The SBOM tool is a to create SPDX compatible SBOMs for any variety of artifacts:

- Supported on Windows, Linux and macOS
- Open-source (MIT) license
- Can create SBOMs in SPDX 2.2 or 3.0 formats
- Uses Component Detection for component detection and ClearlyDefined for license information.

```
- name: Generate SBOM
   run: |
    curl -Lo $RUNNER_TEMP/sbom-tool
https://github.com/microsoft/sbom-tool/releases/latest/download/sbom-tool-linux-x64
    chmod +x $RUNNER_TEMP/sbom-tool
    $RUNNER_TEMP/sbom-tool generate -b ./buildOutput -bc . -pn Test -pv 1.0.0 -ps MyCompany -nsb

https://sbom.mycompany.com -V Verbose
```

Catalog Stage

Possible workflow for cataloging images:

- Hosts the container images that pass quality checks in an internal staging registry.
- Catalog container images to enable internal teams to easily discover images.
- Schedule vulnerability and malware scans on a regular cadence
- Signs the reports with enterprise keys to ensure integrity and provide a trusted stamp of approval for internal use.
- Monitor the lifecycle of container images in the catalog and retire the images that are out of support.

Tools used:

- An OCI-compliant container registry (Docker Hub, GitHub Container Registry (GHCR), Azure Container Registry (ACR), Google Container Registry (GCR), Amazon ECR, …)
- Vulnerability scanning tool (Trivy, Grype, Defender for Cloud, ..)
- Notary & Notation (image signing)

Build Stage

Possible workflow for building & using images:

- Pull base images from the internal catalog only.
- Verify base images before using it to ensure it is trustworthy and compliant.
- Add additional frameworks, application code, and/or configurations from trusted sources on top of base images for build.
- Generate SBOM during the build process.
- Scan the resulting container image for known vulnerabilities.
- Patch the resulting container image to address known vulnerabilities and malware.
- Attach the vulnerability and malware reports as image attestations.
- Attach SBOM as image attestations to use in subsequent stages of the supply chain.
- Sign the resulting image and relevant metadata with enterprise keys to ensure integrity.

Tools used:

- Dependabot (automated dependency updates)
- Copacetic & copa (container patching)
- SBOM Tool
- Vulnerability scanning tool (Trivy, Grype, Defender for Cloud, …)
- Notary & Notation (image signing)

Deploy Stage

Possible workflow for deploying images:

- Implement Image integrity policy to verify image signatures before deployment.Implement Vulnerability scanning policy to scan container images for vulnerabilities.
- Implement Image lifecycle policy to ensure deployed images are within support and valid.
- Generate and sign vulnerability and malware reports for each image.
- Attach the signed reports to container images for visibility and compliance validation.
- Verify container image metadata.
- Implement admission control mechanisms to enforce deployment policies.
- Automate deployment processes with CI/CD pipelines, integrating image validation and verification checks.
- Continuously monitor deployed images and enforce compliance.
- Log deployment activities and conduct regular audits.
- Implement automated or manual remediation procedures to address security incidents.

Tools used:

- Ratify (verify image metadata according to admission policy)
- Gatekeeper (admission controller)
- Open Policy Agent (state admission policies)
- Vulnerability scanning tool (Trivy, Grype, Defender for Cloud, …)
- Notary & Notation (image signing)

Run Stage

Possible workflow for building & using images:

- Continuously scan for vulnerabilities and malware in containerized workloads.
- Regularly update containers and worker nodes.
- Check the image lifecycle metadata to identify outdated images.
- Regularly clean up stale images from the cache on the node.
- Configure strong authentication and authorization mechanisms on hosting environments and containers, as well as running containers.
- Reduce attack surface by restricting container and node ports, restricting network access of containers, enabling mutual TLS, and enforcing resource constraints to containers..

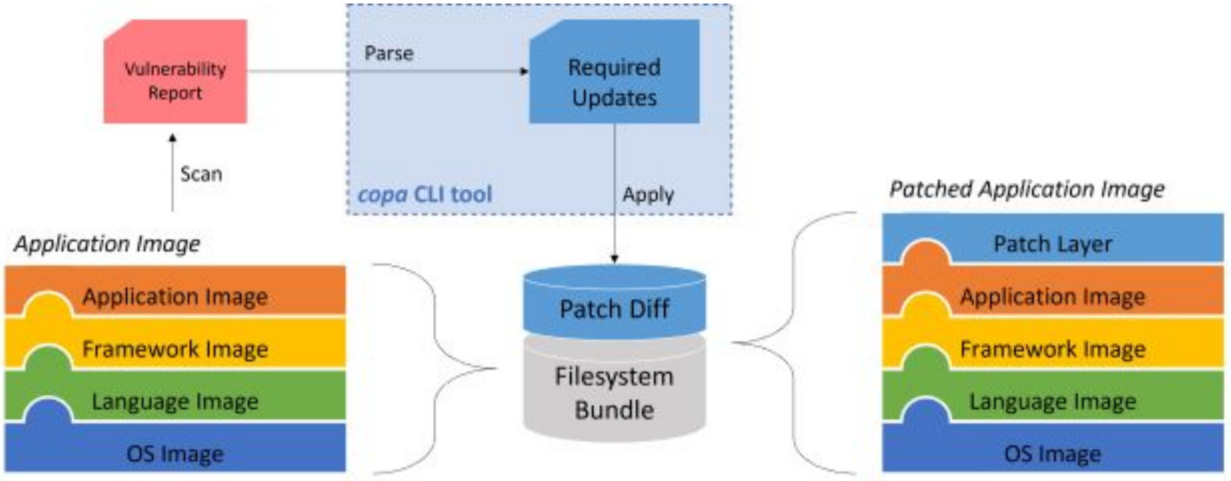
Tools used:

- Dependabot (automated dependency updates)
- Copacetic & copa (container patching)
- SBOM Tool
- Vulnerability scanning tool (Trivy, Grype, Defender for Cloud, ..)
- Notary & Notation (image signing)
- Eraser (image cleaning)

Copacetic (copa)

copa is a CLI tool written in Go and based on buildkit that can be used to directly patch container images given the vulnerability scanning results from popular tools like Trivy.

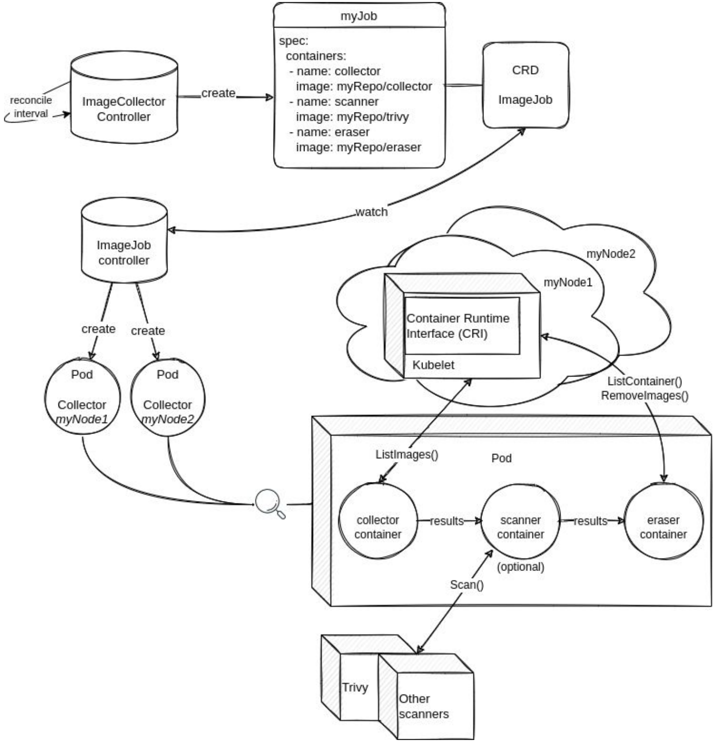
- CNCF sandbox project
- Supports patching existing container images
- Supports containers **without** package managers including distroless containers
- Works with the **existing** vulnerability scanning and mitigation ecosystems, e.g. Trivy, Grype
- GitHub Action and Docker Desktop extensions available



Eraser

Eraser aims to provide a simple way to determine the state of an image, and delete it if it meets the specified criteria.

- CNCF sandbox project
- Simple
- Installed via manifest file or Helm chart
- Configuration via configmap eraser-manager-config
- Two modes of operation: manual or automated
- Targets no-running images only
- Exclusions can be registries or specific images
- Supports Trivy or custom scanners



myJob

```
spec:
  containers:
   - name: collector
     image: myRepo/collector
   - name: scanner
     image: myRepo/trivy
   - name: eraser
     image: myRepo/eraser
```

Signing and verifying OCI artifacts

Types of OCI artifacts

- Container Images
- Software bills of materials (SBOMs)
- Helm charts
- Configuration bundles
- Ai models

Signing and verification ensures:

- **Integrity:** The artifact that you use is exactly the same as the one that was published.
- **Authenticity**: The artifact truly came from the expected publisher.

Processes used are

- **Signing:** Produces cryptographic signatures that bind a publisher's identity to an artifact descriptor, including the digest.
- **Verification:** Checks that a signature is valid, the publisher's identity is trusted, and the artifact isn't altered.

Tools:

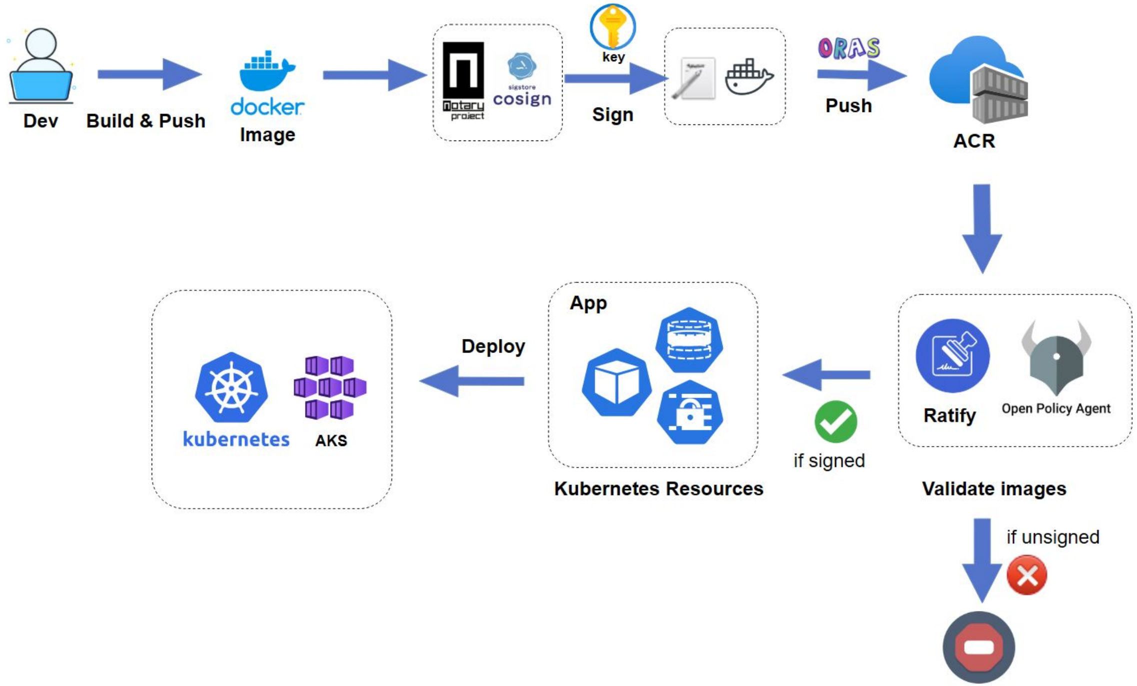
- **Cosign**
- **Docker Content Trust (DCT)**
- **Notation (Notary v2)**

Notary (notation)

The Notary Project is designed to secure software supply chains by enabling digital signatures and verification for container images and other OCI (Open Container Initiative) artifacts.

- Open-source
- CNCF incubating project
- Supports any software artifacts, not only images
- Supports COSE (CBOR Object Signing and Encryption) and JWS signature formats
- Supports OCI-compliant registries
- Github Actions for installation and signing available
- Used by Ratify to verify signatures

Notary Workflow



Sign container images with notation and AKV

Workflow:

- **Certificate requirements for root and intermediate certificates:**
  - The basicConstraints extension must be present and marked as critical. The CA field must be set to true.
  - The keyUsage extension must be present and marked as critical. Bit positions for keyCertSign must be set.
- **Certificate requirements for leaf (signing) certs:**
  - Subject must contain common name (CN), country/region (C), state or province (ST), and organization (O).
  - X.509 key usage flag must be DigitalSignature only.
  - Extended Key Usages (EKUs) must be empty or 1.3.6.1.5.5.7.3.3 (for code signing).
  - Key must NOT be exportable
  - Use supported key type and size:Algorithm Selection
- **Import certificate in Key Vault**
- **Authorize access to Key Vault (use RBAC)**
- **Use notation GitHub actions in image build pipeline to sign artifacts**

Ratify

Ratify is a verification engine as a binary executable and on Kubernetes which enables verification of artifact security metadata and admits for deployment only those that comply with policies you create..

- Open-source
- CNCF sandbox project
- Can verify signatures, validate checksums, and ensure that artifacts are up-to-date
- Flexible verification policies
- (Relatively) easy installation
- Consists of the following parts:
  - Executor
  - Referrer Store
  - Reference verifier
  - Policy Providers

Validate container image signatures in AKS with Ratify

Workflow:

- **Set up identity and access controls for Container Registry:** Configure the identity that Ratify uses to access Container Registry with the necessary roles.
- **Set up identity and access controls for Key Vault:**
  - Configure the identity that Ratify uses to access Key Vault with the necessary roles.
- **Set up Ratify on your AKS cluster:** Set up Ratify by using a Helm charts
- **Set up a custom Azure policy:** Create and assign a custom Azure policy with the desired policy effect: Deny or Audit.

Prerequisites:

- **Install latest Azure CLI, Helm and kubectl**
- **Enable OIDC issuer an AKS cluster**
- **Connect Azure Container Registry to AKS cluster**
- **Enable Azure Policy add-on (enables Gatekeeper and OPA Agents)**

Link Collection

- Software supply chain security | Google Cloud
- Supply-chain Levels for Software Artifacts
- US DoD Securing the Software Supply Chain
- NIST SP 800-204D
- OWASP Supply Chain Security
- Notary
- Ratify
- Copacetic
- Eraser
- Sbom-tool
- ORAS

Questions?

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Let's work together.

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