



# // SECURE BY DEFAULT? PRAGMATICALLY IMPROVE APP SECURITY USING K8S BUILT-INS

JOHANNES SCHNATTERER

*CLOUDOGU GMBH*

VERSION: 202010151525-C9B8839



cloudogu

# Outline

**How to improve application security using  
Kubernetes security built-ins *pragmatically***

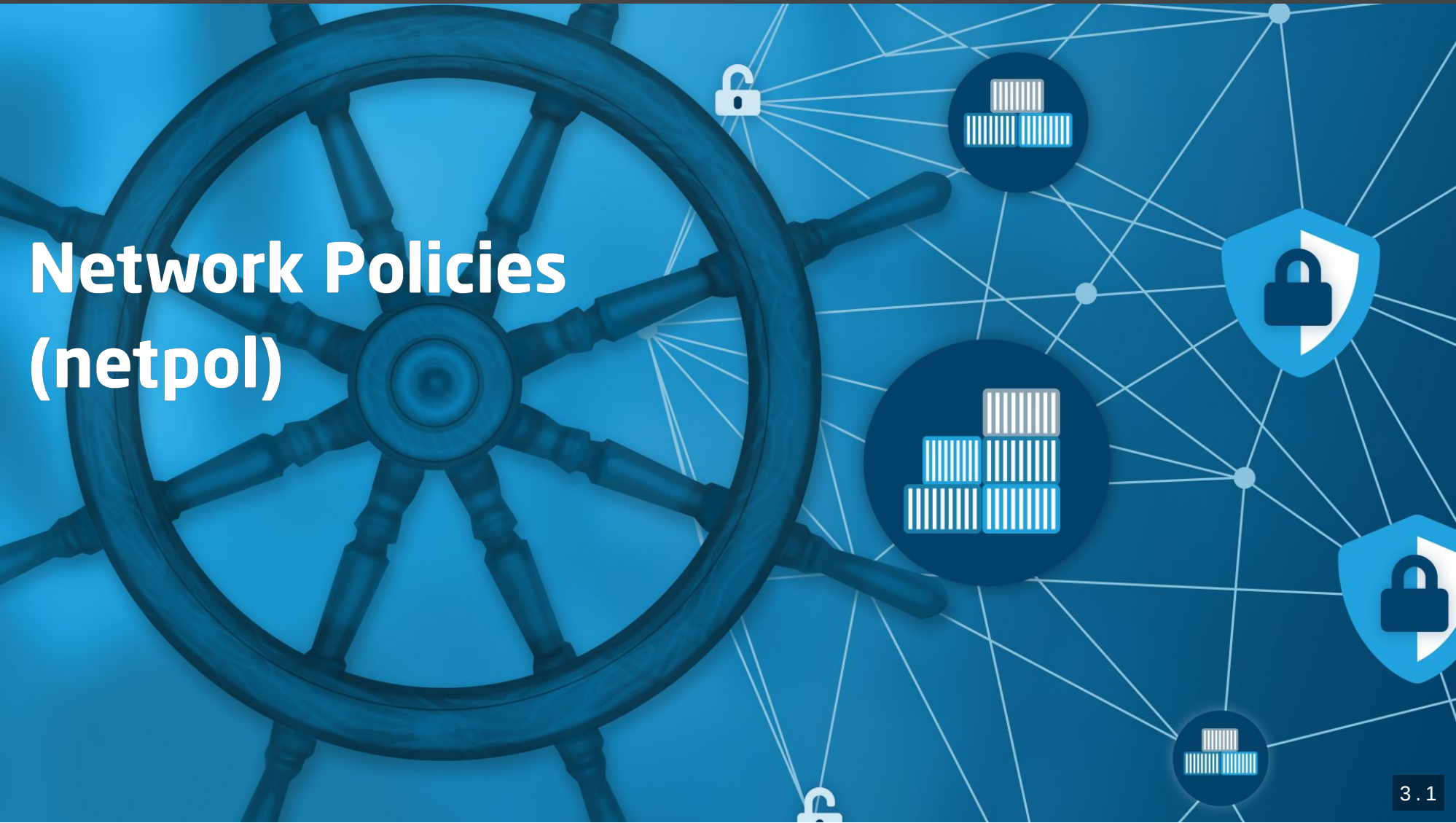
# K8s built-in security mechanisms

- Network Policies
- Security Context
- Pod Security Policies


# Plenty of Options

- Secure by default?
- How to improve pragmatically?

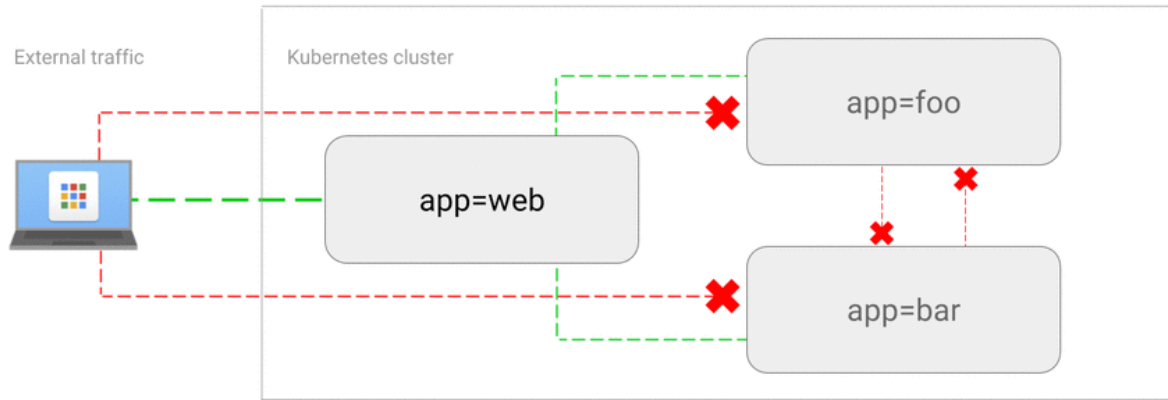
# Network Policies (netpol)





A “firewall” for communication between pods.

- Applied to pods
  - within namespace
  - via labels
- Ingress / egress
  - to/from pods (in namespaces) or CIDRs (egress only)
  - for specific ports (optional)
- Enforced by the CNI Plugin (e.g. Calico)
-  No Network Policies: All traffic allowed

# 📌 Helpful to get started



-  <https://github.com/ahmetb/kubernetes-network-policy-recipes>
- Securing Cluster Networking with Network Policies - Ahmet Balkan  
 <https://www.youtube.com/watch?v=3gGpMmYeE08>
- Interactively describes what a netpol does:

```
kubectl describe netpol <name>
```

## **Recommendation: Whitelist ingress traffic**

In every namespace except kube-system:

- Deny ingress between pods,
- then whitelist all allowed routes.



## Advanced: ingress to kube-system

⚠ Might stop the apps in your cluster from working

Don't forget to:

- Allow external access to ingress controller
- Allow access to kube-dns/core-dns to every namespace

# Advanced: egress

- Verbose solution:
  - Deny egress between pods,
  - then whitelist all allowed routes,
  - repeating all ingress rules. 🙄
- More pragmatic solution:
  - Allow only egress within the cluster,
  - then whitelist pods that need access to internet.

## Net pol pitfalls

- Whitelisting monitoring tools (e.g. Prometheus)
- Restart might be necessary (e.g. Prometheus)
- No labels on namespaces by default
- egress more recent than ingress rules and less sophisticated
- Policies might not be supported by CNI Plugin.

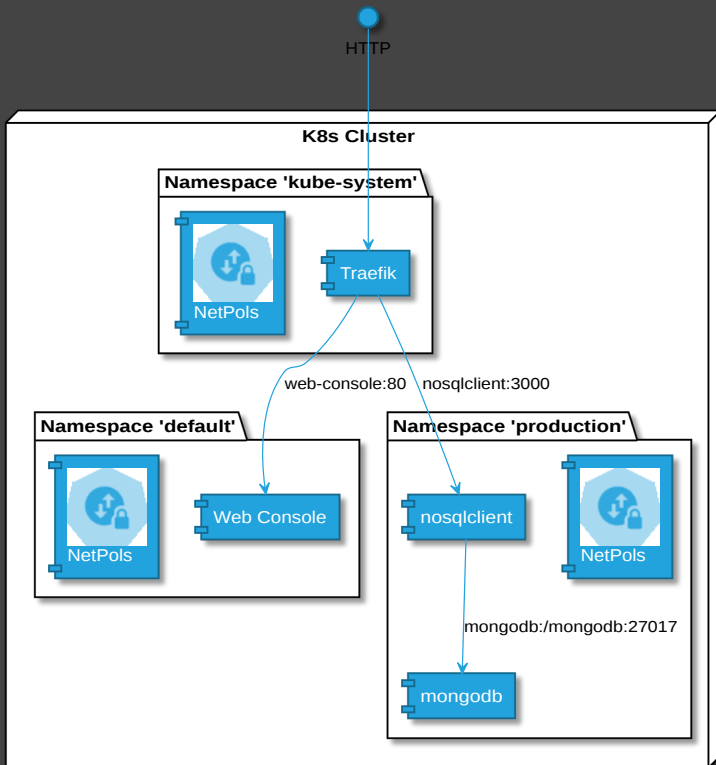
Testing!

 <https://www.inovex.de/blog/test-kubernetes-network-policies/>

## More Features?

- Proprietary extensions of CNI Plugin (e.g. cilium or calico)
- Service Meshes: similar features, also work with multiple clusters
  - ➔ different strengths, support each other
  - 🌐 <https://istio.io/blog/2017/0.1-using-network-policy/>

# Demo



- nosqlclient
- web-console

## **Wrap-Up: Network Policies**

My recommendations:

- Ingress whitelisting in non-kube-system namespaces
- Use with care
  - whitelisting in kube-system
  - egress whitelisting for cluster-external traffic

# Security Context



- Security Context: Defines security parameters *per pod/container*
  - ➡ container runtime
- 📌 Secure Pods - Tim Allclair
  - 🎥 <https://www.youtube.com/watch?v=GLwmJh-j3rs>
- ↔ Cluster-wide security parameters: See Pod Security Policies



# Recommendations per Container

```
apiVersion: v1
kind: Pod
metadata:
  annotations:
    seccomp.security.alpha.kubernetes.io/pod: runtime/default
spec:
  containers:
    - name: restricted
      securityContext:
        runAsNonRoot: true
        runAsUser: 100000
        runAsGroup: 100000
        readOnlyRootFilesystem: true
        allowPrivilegeEscalation: false
        capabilities:
          drop:
            - ALL
      enableServiceLinks: false
      automountServiceAccountToken: false # When not communicating with API Server
```

# **Recommendation per Container in Detail**


## Enable seccomp

- Enables e.g. docker's seccomp default profile that block 44/~300 Syscalls
- 🔥 Has mitigated Kernel vulns in past and might in future 🧪  
🌐 <https://docs.docker.com/engine/security/non-events/>
- See also k8s security audit:  
🌐 <https://www.cncf.io/blog/2019/08/06/open-sourcing-the-kubernetes-security-audit/>

## Run as unprivileged user

- `runAsNonRoot: true`

Container is not started when the user is root

- `runAsUser` and `runAsGroup > 10000`
  - 🔥 Reduces risk to run as user existing on host
  - 🔥 In case of container escape UID/GID does not have privileges on host
- 🔥 E.g. mitigates vuln in runc (used by Docker among others)  
 <https://kubernetes.io/blog/2019/02/11/runc-and-cve-2019-5736/>

## No Privilege escalation

- Container can't increase privileges
- 🔥 E.g. sudo, setuid, Kernel vulnerabilities

## Read-only root file system

- Starts container without read-write layer
- Writing only allowed in volumes
- 🔥 Config or code within the container cannot be manipulated

## Drop Capabilities

- Drops even the default caps:



<https://github.com/moby/moby/blob/3152f94/oci/caps/defaults.go>

- 🔥 E.g. Mitigates CapNetRaw attack - DNS Spoofing on Kubernetes Clusters

 <https://blog.aquasec.com/dns-spoofing-kubernetes-clusters>

## Bonus: No Services in Environment

- By default: Each K8s service written to each container's env vars
  - ➔ Docker Link legacy, no longer needed
- 🔥 But convenient info for attacker where to go next



## Bonus: Disable access to K8s API

- SA Token in every pod for api-server authn

```
curl --cacert /var/run/secrets/kubernetes.io/serviceaccount/ca.crt \  
-H "Authorization: Bearer $(cat /var/run/secrets/kubernetes.io/serviceaccount/token)" \  
https://${KUBERNETES_SERVICE_HOST}/api/v1/
```

- If not needed, disable!
- No authentication possible
- 🔥 Lesser risk of security misconfig or vulns in authz

# Security context pitfalls

## Read-only root file system

Application might need temp folder to write to

- Run image locally using docker, access app
  - 📌 Run automated e2e/integration tests
- Review container's read-write layer via

```
docker diff <containerName>
```

- Mount folders as `emptyDir` volumes in pod

# Drop Capabilities



Some images require capabilities

- Find out needed Caps locally:

```
docker run --rm --cap-drop ALL <image>  
# Check error  
docker run --rm --cap-drop ALL --cap-add CAP_CHOWN <image>  
# Keep adding caps until no more error
```

- Add necessary caps to k8s resource
- Alternative: Find image with same app that does not require caps, e.g. `nginxinc/nginx-unprivileged`



# Run as unprivileged user

- Some official images run as root by default.
  - Find a **trusted** image that does not run as root  
e.g. for mongo or postgres:  
 <https://hub.docker.com/r/bitnami/>
  - Create your own non-root image  
(potentially basing on original image)  
e.g. nginx:  <https://github.com/schnatterer/nginx-unpriv>
- Non-root verification only supports numeric user. 🙄
  - `runAsUser: 1000000` in `securityContext` of pod or
  - `USER 1000000` in `Dockerfile` of image.

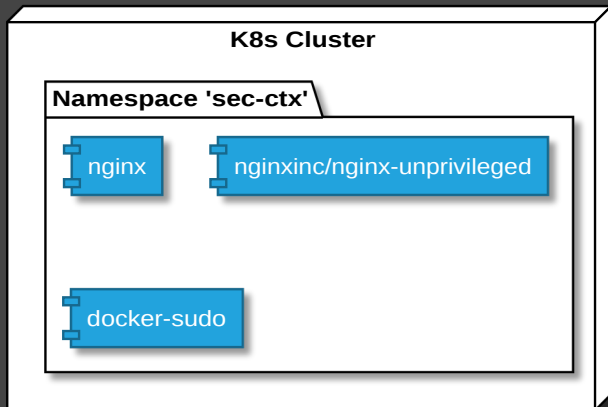
- UID 100000 might not have permissions. Solutions:
    - Init Container sets permissions for PVCs
    - Permissions in image ➡ `chmod/chown` in `Dockerfile`
    - Run in root Group - GID 0
- 🌐 [https://docs.openshift.com/container-platform/4.3/openshift\\_images/create-images.html#images-create-guide-openshift\\_create-images](https://docs.openshift.com/container-platform/4.3/openshift_images/create-images.html#images-create-guide-openshift_create-images)

# Tools

Find out if your cluster adheres to these and other good security practices:

-  [controlplaneio/kubesec](#) - manageable amount of checks
  -  [Shopify/kubeaudit](#)
    - a whole lot of checks,
    - even deny all ingress and egress NetPols and AppArmor Annotations
- 
- ➔ Be prepared for a lot of findings
  - ➔ Create your own good practices

# Demo





## **Wrap-Up: Security Context**

My recommendations:

- Start with least privilege
- Only differ if there's absolutely no other way

# Pod Security Policies (PSP)



- enforces security context cluster-wide
- additional options enforcing secure defaults
- more effort than security context and different syntax 🙄

➡ Still highly recommended!

# Recommendations

- Same as Security Context
- Plus: Enforce secure defaults.

Block pods from

- entering node's Linux namespaces, e.g. net, PID (includes binding ports to nodes directly),
- mounting arbitrary host paths (from node) (includes docker socket),
- starting privileged containers,
- changing apparmor profile

# Security Context Recommendations PSP

```
apiVersion: policy/v1beta1
kind: PodSecurityPolicy
metadata:
  annotations:
    seccomp.security.alpha.kubernetes.io/defaultProfileName: runtime/default
    seccomp.security.alpha.kubernetes.io/allowedProfileNames: runtime/default
spec:
  requiredDropCapabilities:
    - ALL
  allowedCapabilities: []
  defaultAllowPrivilegeEscalation: false
  allowPrivilegeEscalation: false
  readOnlyRootFilesystem: true
  runAsUser: # Same for runAsGroup, supplementalGroups, fsGroup
    rule: MustRunAs
  ranges:
    - min: 100000
      max: 999999
```


# Additional Recommendations

```
apiVersion: policy/v1beta1
kind: PodSecurityPolicy
metadata:
  annotations:
    apparmor.security.beta.kubernetes.io/defaultProfileName: runtime/default
    apparmor.security.beta.kubernetes.io/allowedProfileNames: runtime/default
spec:
  hostIPC: false
  hostPID: false
  hostNetwork: false
  hostPorts: []
  privileged: false
  allowedHostPaths: []
  volumes:
    - configMap
    - emptyDir
    - projected
    - secret
    - downwardAPI
    - persistentVolumeClaim
```

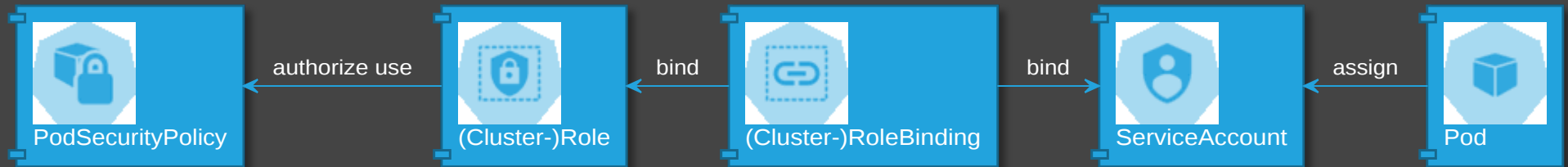
# Usage

- 1 Activate Admission controller via API-Server  
(also necessary for most managed k8s)
- 2 Define PSP (YAML)
- 3 Activate via RBAC

Example:


 <https://github.com/cloudogu/k8s-security-demos/blob/master/4-pod-security-policies/demo/01-psp-restrictive.yaml>

# Activation via RBAC







## PSP pitfalls

- Loose coupling in RBAC ➡ fail late with typos
-  *AdmissionController*
  - only evaluates Pods before starting
  - if not active ➡ PSP are ignored
  - if active but no PSP defined ➡ *no* pod can be started
- Different PSP API group in (Cluster)Role
  - < 1.16: apiGroups [ extensions ]
  - ≥ 1.16: apiGroups [ policy ]

## 📌 PSP Debugging Hints

```
# Query active PSP
kubectl get pod <POD> -o jsonpath='{.metadata.annotations.kubernetes\.io/psp}'
# Check authorization
kubectl auth can-i use psp/privileged --as=system:serviceaccount:<NS>:<SA>
# Show which SA's are authorized (kubectl plugin)
kubectl who-can use psp/<PSP>
# Show roles of a SA (kubectl plugin)
kubectl rbac-lookup <SA> # e.g. subject = sa name
```

# PSP Limitations


- Unavailable options in PSPs
  - `enableServiceLinks: false`
  - `automountServiceAccountToken: false`
- Future of PSPs uncertain
  -  <https://github.com/kubernetes/enhancements/issues/5>
  -  Still easiest way for cluster-wide least privilege

# What if pod requires more privileges?

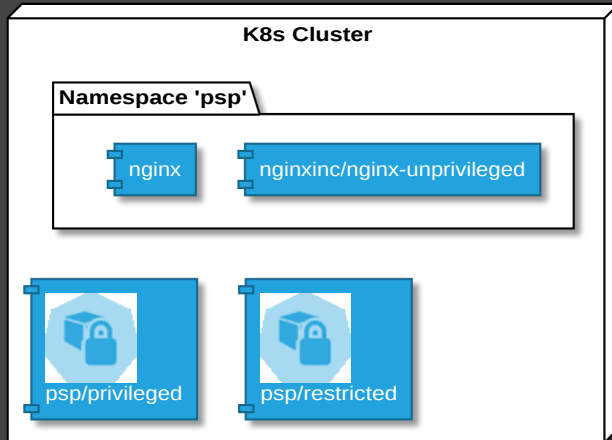
"Whitelisting" via RBAC.



- 1 Duplicate least privilege PSP
- 2 Grant required privilege in new PSP
- 3 Allow PSP via a Role (namespaced)
- 4 Create ServiceAccount
- 5 Create RoleBinding
- 6 Assign ServiceAccount to Pod

 <https://github.com/cloudogu/k8s-security-demos/blob/master/4-pod-security-policies/demo/02a-psp-whitelist.yaml>

# Demo



# Summary

- Don't allow arbitrary connections between pods, e.g. via NetPols
- Start with least privilege for your containers
  - using either Security Context or
  - PSP

# Johannes Schnatterer

Cludogu GmbH

 [cloudogu.com/schulungen](https://cloudogu.com/schulungen)

K8s AppOps security series on JavaSPEKTRUM 05/2019+

See also  [cloudogu.com/blog/tag/k8s-security](https://cloudogu.com/blog/tag/k8s-security)

 [@cloudogu](https://twitter.com/cloudogu)

 [@jschnatterer](https://twitter.com/jschnatterer)

Demo Source:  [github.com/cloudogu/k8s-security-demos](https://github.com/cloudogu/k8s-security-demos)

