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Securing Containers on the High Seas

Jack Mannino & Abdullah Munawar

Who Are We?

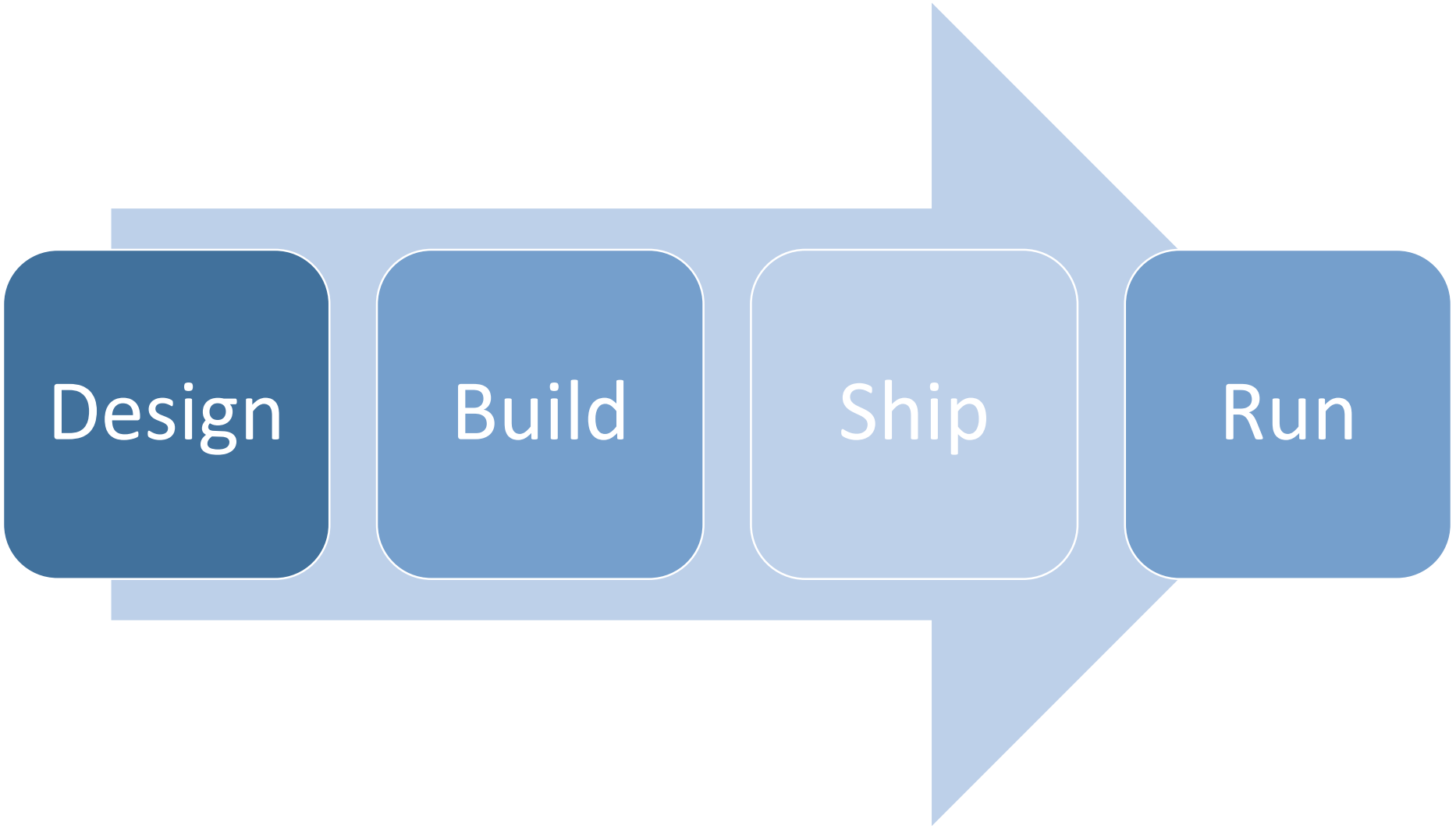
Abdullah Munawar

- Director of Professional Services at nVisium
- Helps clients build application security programs

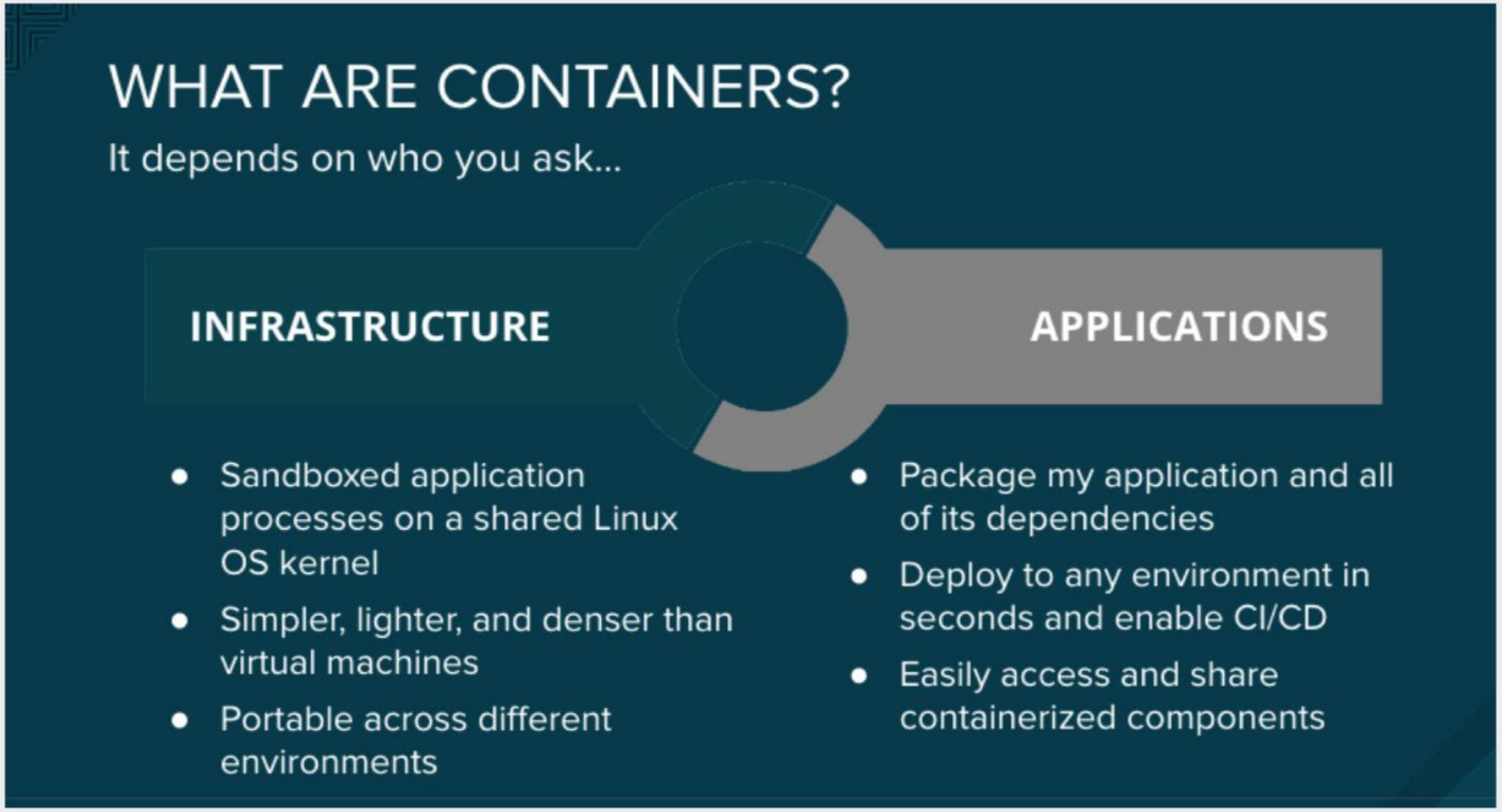
Jack Mannino

- CEO at nVisium, since 2009
- Helps make software security scale
- Hobbies: Scala, Go and Kubernetes

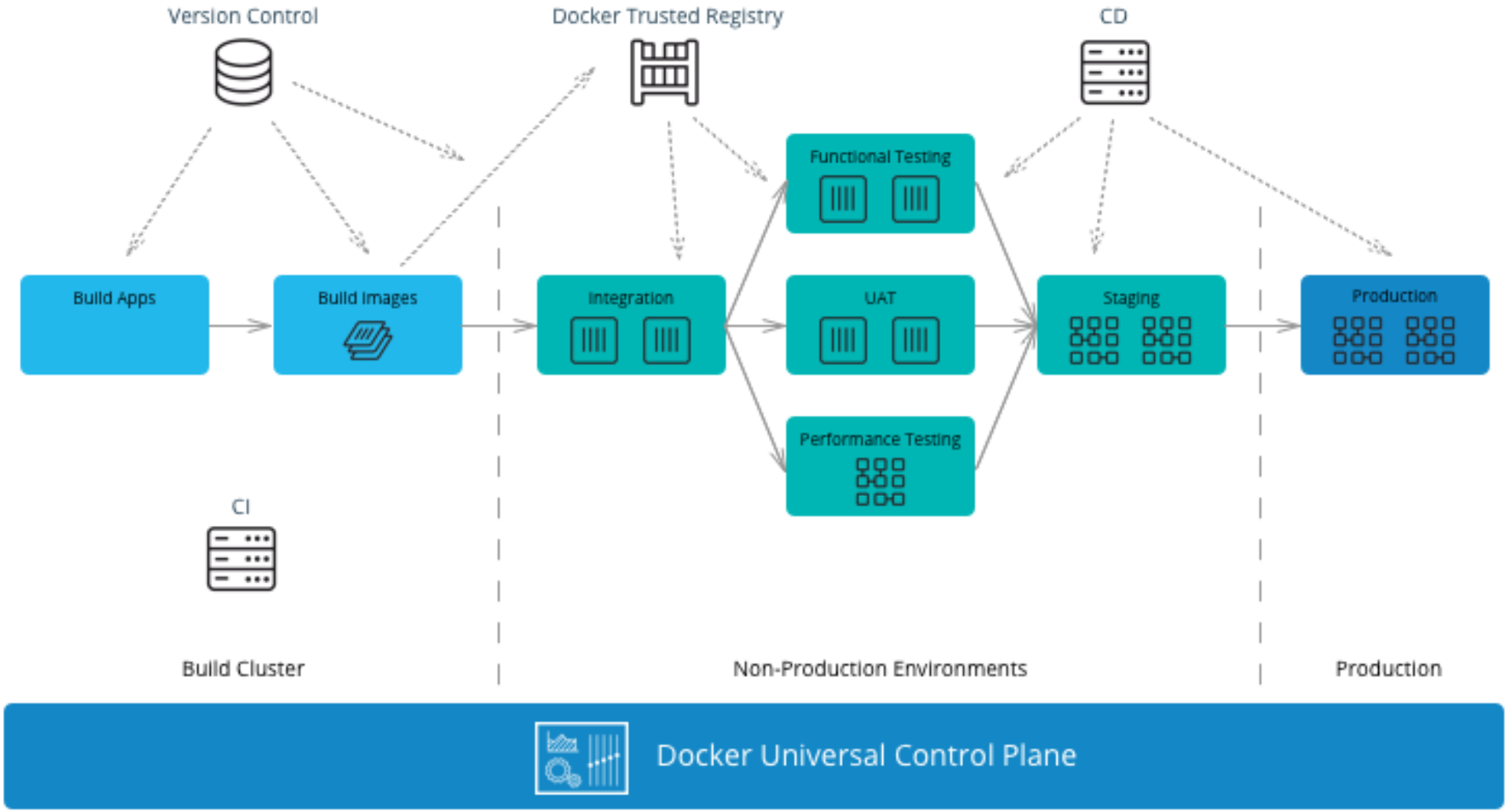
Container Security



Containers are ___



Containerized



Security Opportunities &

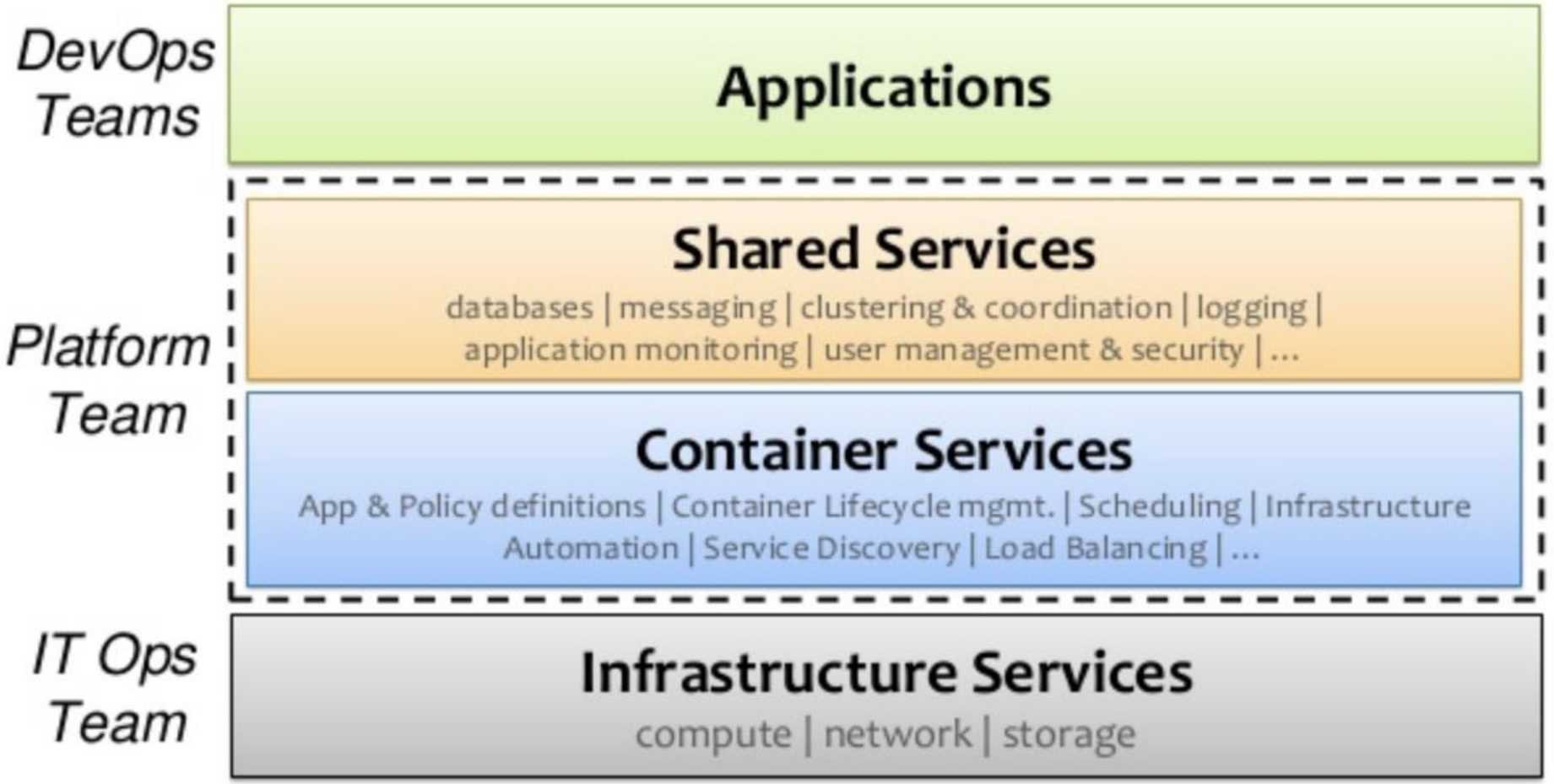
Reduced Attack Surface

Immutable Infrastructure

Isolation by Design

Automation and Repeatability

Who Does What Now?



Design

Design

Model your containerized architecture and identify where security control should be present.

Understand how the system will be used and abused

Beware of Bounded Contexts or tightly-coupled components!

Secure Architecture

- ✓ Orchestration & Management - Control Plane
- ✓ Network Segmentation & Isolation
- ✓ Encrypted communications
- ✓ Authentication (container & cluster-level)
- ✓ Identity Management & Access Control
- ✓ Secrets Management
- ✓ Logging & Monitoring

Picking the Right Container Runtime

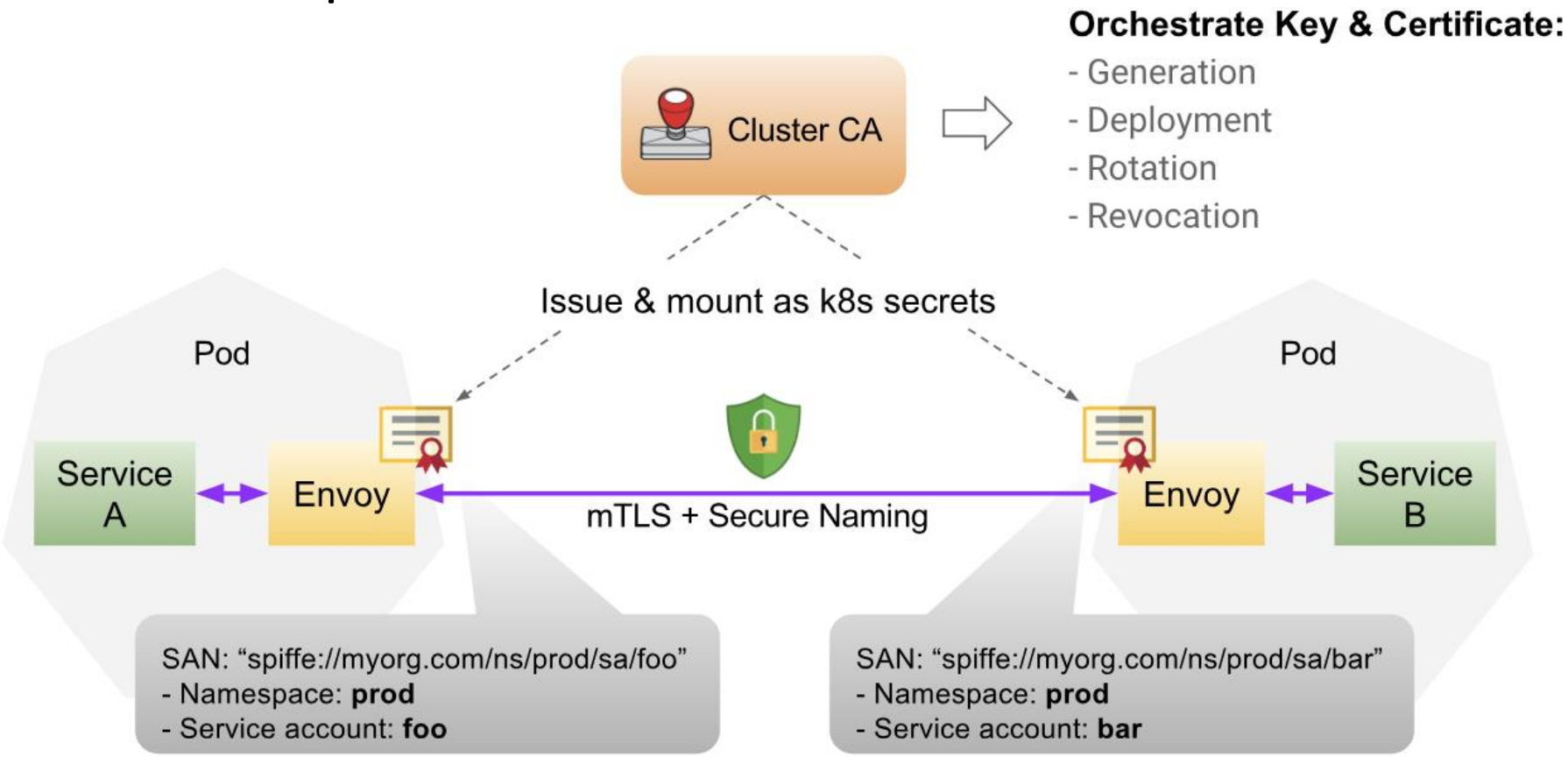
- Open Container Initiative (OCI) spec promotes a broader set of container tech (life beyond Docker)
- Isolate containerized resources differently
- Goal is to prevent escaping from the container
- Isolation via Namespaces & Control Groups
- Isolation via Hypervisor

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

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

Leveraging Design Patterns for Security

We can solve security issues through patterns that lift security out of the container itself. Example – Service Mesh.



Build

Securing the Build Process

- Build steps focus on code repositories and container registries
- Run Tests -> Package Apps -> Build Image
- Build first level of security controls into containers
- Orchestration & management systems can override these controls and mutate containers through an extra layer of abstraction

Base Image Management

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

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

Limiting Privileges

- More often than not, your container does not need root
- Often, we only need a subset of capabilities
- Limit access to underlying host resources (network, storage, or IPC)

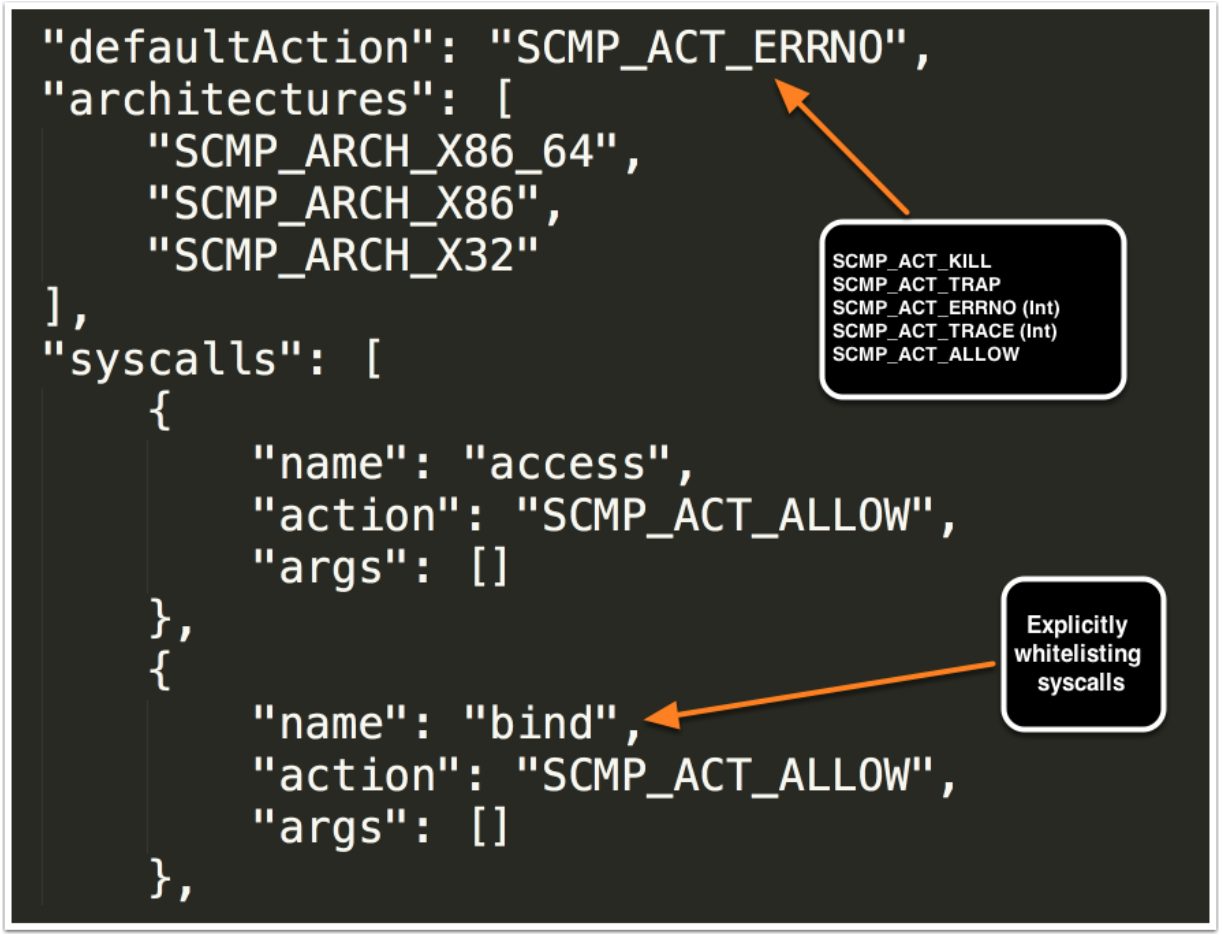
Example – Ping command requires CAP_NET_RAW

We can drop everything else.

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

Kernel Hardening

- Restrict the actions a container can perform
- Seccomp is a linux kernel feature that allows you to filter dangerous syscalls
- Docker has a great default profile to get started



Mandatory Access Control (MAC)

- SELinux and AppArmor allow you to set granular controls on files and network access.
- Limits what a process can access or do
- Logging to identify violations (during testing and production)
- Docker leads the way with its default AppArmor profile

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

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

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

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

Deny Network Traffic

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

Container Package Management

- Vulnerabilities can possibly exist in:
  - Container configurations
  - Container packages
  - Application Libraries
- Solutions:
  - Clair
  - Dependency Check
  - Brigade
  - Commercial tools

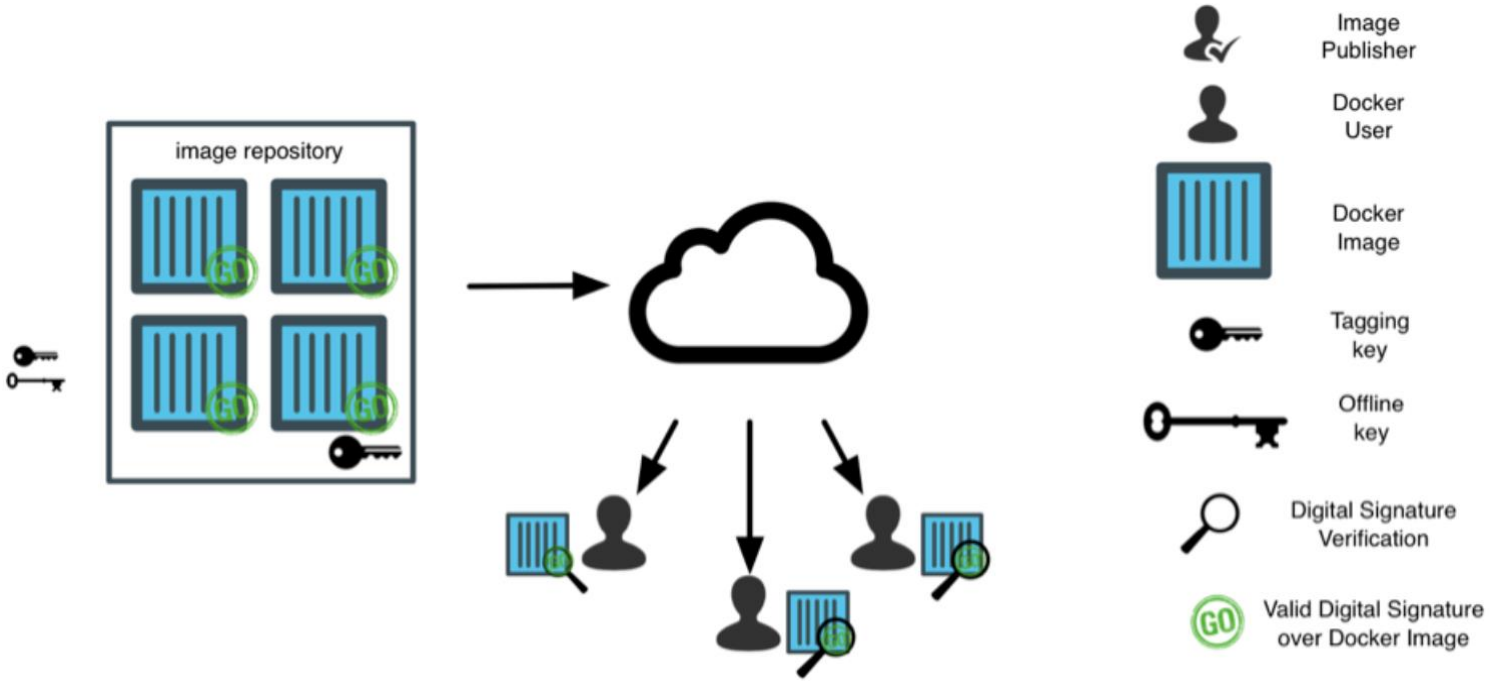
Ship

Ship

- Securely move the container from registry -> runtime environment
- Controlled container promotion and deployment
- Validate the integrity of the container
- Validate security pre-conditions

Validating Integrity & Signing

- Ensures the integrity of the images and trusted publisher.
- Sign to validate pipeline phases
- Example – Docker Content Trust & Notary
- Consume only trusted content for tagged Docker builds



Validating Security Pre-Conditions

- Allow or deny a container's cluster admission
- Centralized interfaces and validation
- Mutate a container's security before admission
- Example – Kubernetes calls this a *PodSecurityPolicy*

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

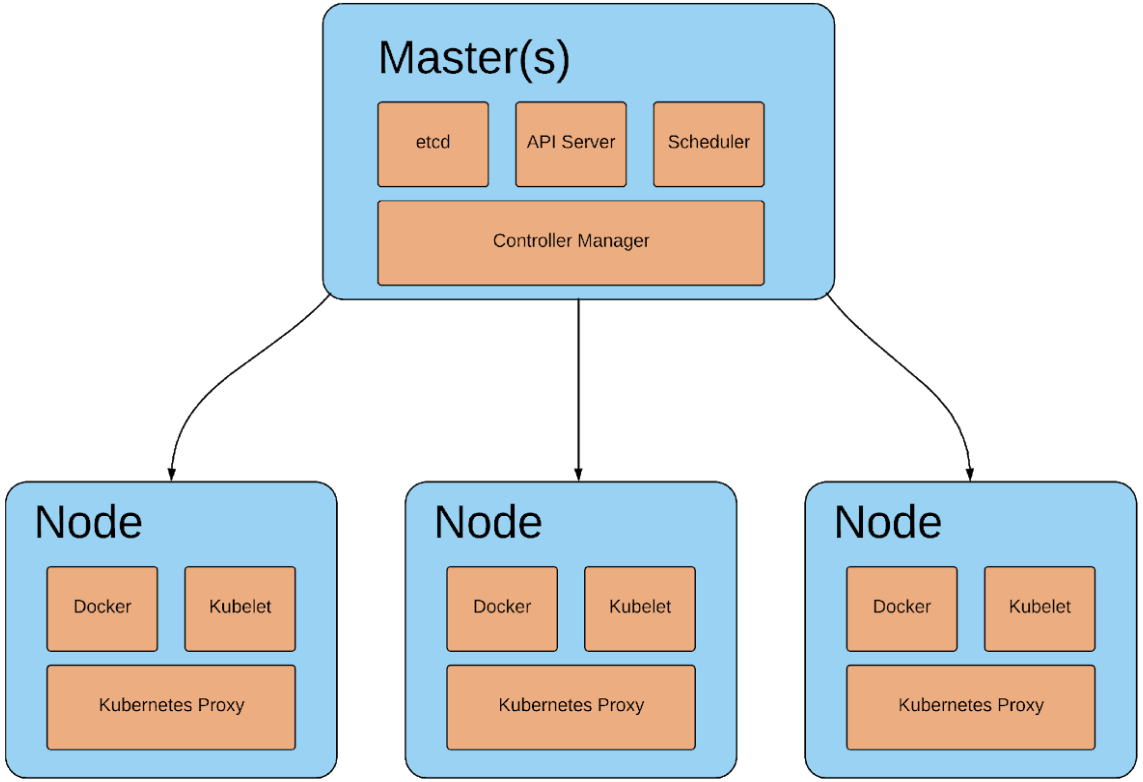
Run

Run

Typically, containers are managed, scheduled, and scaled through orchestration systems.

Kubernetes, Mesos, Docker Swarm, AWS ECS, etc.

- Cluster/Service authentication
- Identity Management & Access Control
- Policy & Constraint Enforcement
- Propagation of secrets
- Logging & Monitoring



Example – Kubernetes Control Plane

Control Plane Hardening

- Control plane manages & schedules containers
- Critical infrastructure; keys to the kingdom
- Restrict network access to control plane components
- Isolate components and containerized workloads

Management APIs

- Deploy, modify, and kill services
- Run commands inside of containers
- Kubernetes, Marathon, and Swarm API work similarly
- *Frequently deployed without authentication or access control*

Authentication

- Authenticate subjects (users and service accounts) to the cluster
- Authentication occurs at several layers
  - Authenticating API subjects
  - Authenticating nodes to the cluster
  - Authenticating services to each other

Avoid sharing service accounts across multiple services!

```go
// computeDetachedSig takes content and token details and computes a detached
// JWS signature.  This is described in Appendix F of RFC 7515.  Basically, this
// is a regular JWS with the content part of the signature elided.
func computeDetachedSig(content, tokenID, tokenSecret string) (string, error) {
    jwk := &jose.JSONWebKey{
        Key:   []byte(tokenSecret),
        KeyID: tokenID,
    }

    opts := &jose.SignerOptions{
        // Since this is a symmetric key, go-jose doesn't automatically include
        // the KeyID as part of the protected header. We have to pass it here
        // explicitly.
        ExtraHeaders: map[jose.HeaderKey]interface{}{
            "kid": tokenID,
        },
    }

    signer, err := jose.NewSigner(jose.SigningKey{Algorithm: jose.HS256, Key: jwk}, opts)
    if err != nil {
        return "", fmt.Errorf("can't make a HS256 signer from the given token: %v", err)
    }

    jws, err := signer.Sign([]byte(content))
    if err != nil {
        return "", fmt.Errorf("can't HS256-sign the given token: %v", err)
    }

    fullSig, err := jws.CompactSerialize()
    if err != nil {
        return "", fmt.Errorf("can't serialize the given token: %v", err)
    }
    return stripContent(fullSig)
}
```

Example – K8s JWT Generator

Authorization & Access Control

- Subjects should only have access to the resources they need
- Limit what a single hostile user or container can achieve)
- Multiple vantage points - to the API, between containers, between control plane components

K8s - Create a Role

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

K8s - Bind a Subject to the Role

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

Logging and

- Container lifecycle is short and unpredictable
- Visibility through telemetry and logs
- Tag and label assets for context and de-duplication
- Focus on visibility at these levels
  - Application
  - Operating System
  - Container
  - Orchestration & Management
  - Infrastructure

Secrets Management

- Safely inject secrets into containers at runtime
- Reduced footprint for leaking secrets
- Dynamic key generation and rotation is ideal
- Anti-patterns:
  - Hardcoded
  - Environment variables
- Limit the scope of subjects that can retrieve secrets

```
# Has known vulnerabilities: you shouldn't use this in production, if you like
yourself.
FROM golang:1.10.2
MAINTAINER Jack Mannino <jack@nvisium.com>

#yes, this is intentional.
USER root

# Don't
ENV ROOT-PW s3curitah1

RUN apt-get update && apt-get install -y apt-transport-https
# Install vulnerable bash version for ShellShock.
RUN apt-get install -y build-essential wget
RUN wget https://ftp.gnu.org/gnu/bash/bash-4.3.tar.gz && \
    tar zxvf bash-4.3.tar.gz && \
    cd bash-4.3 && \
    ./configure && \
    make && \
    make install

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

Secrets Management

Docker

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

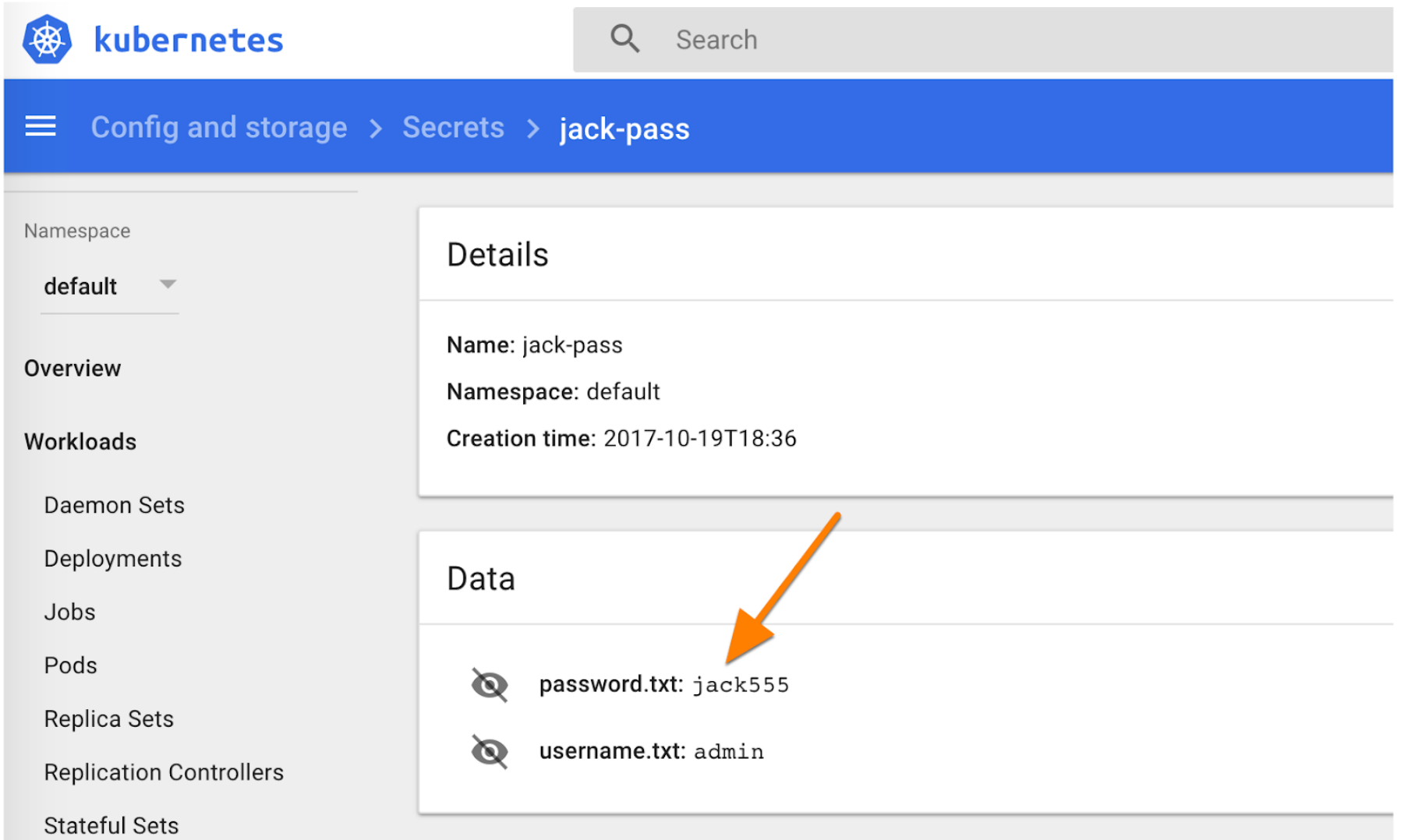
echo <secret> | docker secret create some-secret

Kubernetes

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

kubectl create –f ./secret.yaml

Nothing is Perfect



Beware of Plain Text Storage

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

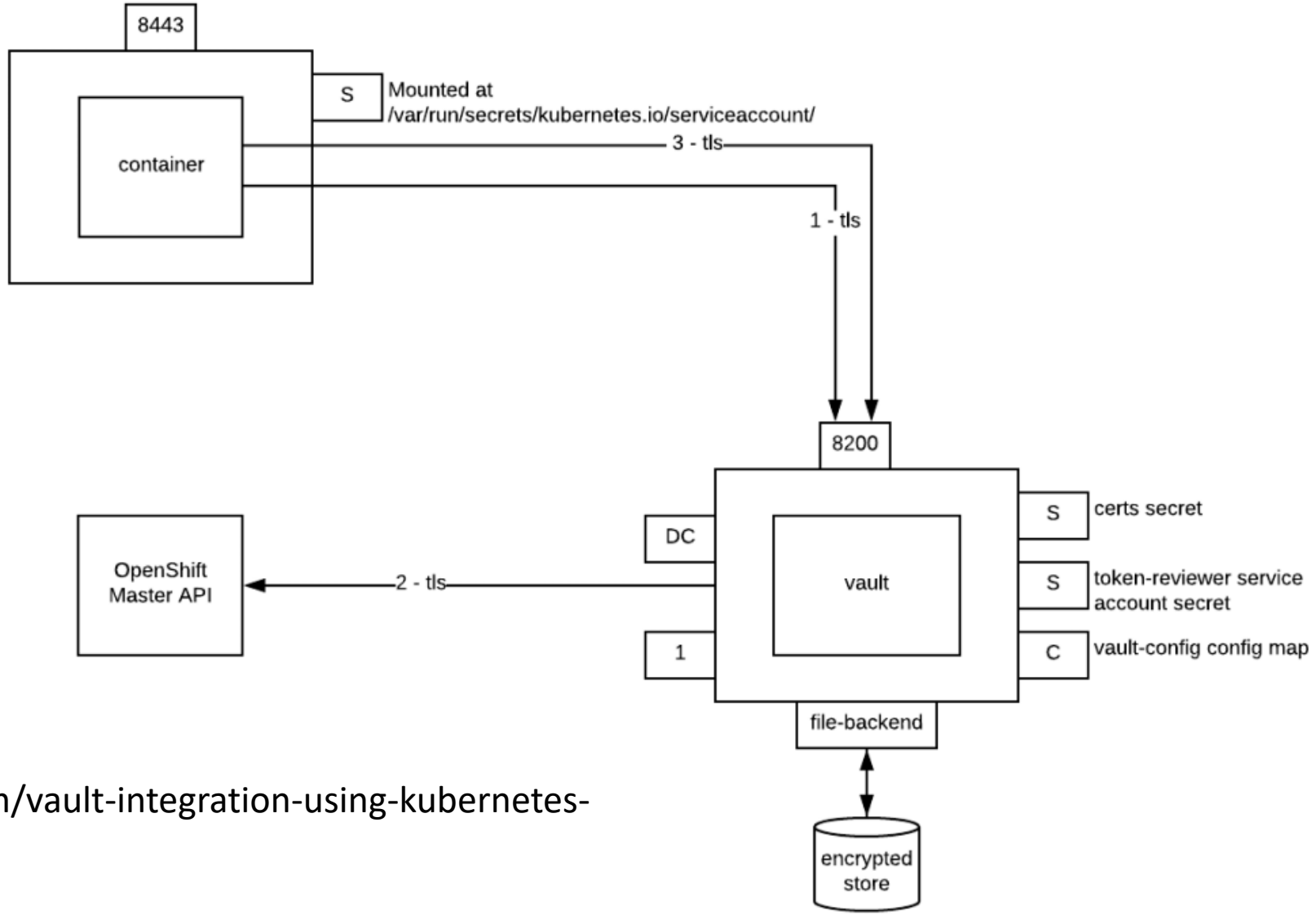
```
$ ls /etc/foo/
username
password

$ cat /etc/foo/username

admin
$ cat /etc/foo/password
1f2d1e2e67df
```

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

Not perfect at all, either.

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

Dynamic Loading & Rotation



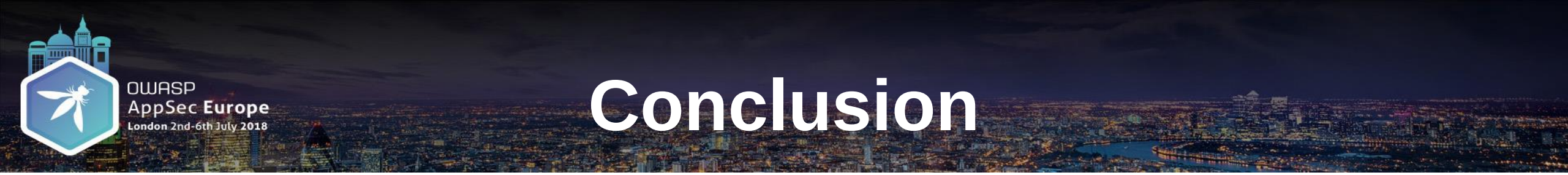
https://blog.openshift.com/vault-integration-using-kubernetes-authentication-method/

Policy & Constraint Enforcement

- Harden by applying a Security Context at the pod or container level
- Mutate the container's configuration as needed
  - i.e- overrides a Dockerfile

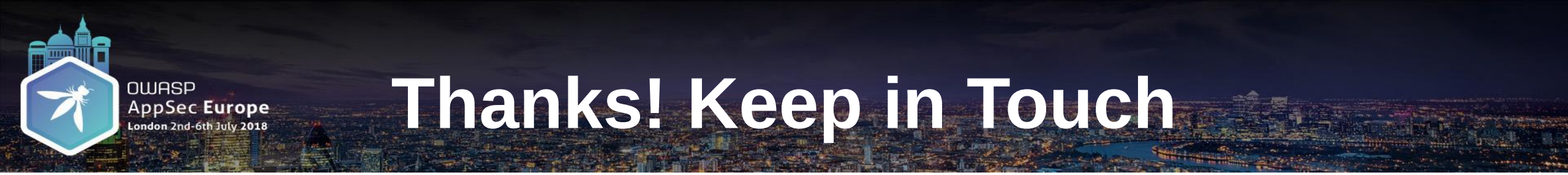
Setting	PodSecurityContext	SecurityContext
Allow Privilege Escalation		X
Capabilities		X
Privileged Read-Only Root Filesystem		X
Run as Non Root	X	X
Run as User	X	X
SELinux Options	X	
FS Group	X	
Supplemental Groups	X	

Example – K8s SecurityContext



Conclusion

- Secure your container ecosystem and supply chain, not just the runtime
- You probably don't need root – start with minimally privileged containers
- Focus on layered security and strong isolation
- Ensure visibility from a developer's laptop to running in production



Thanks! Keep in Touch

Abdullah Munawar
@amanofwar
Abullah@nvisium.com

Jack Mannino
@jack_mannino
Jack@nvisium.com