JETSTACK

# Taming Distributed Pets with Kubernetes

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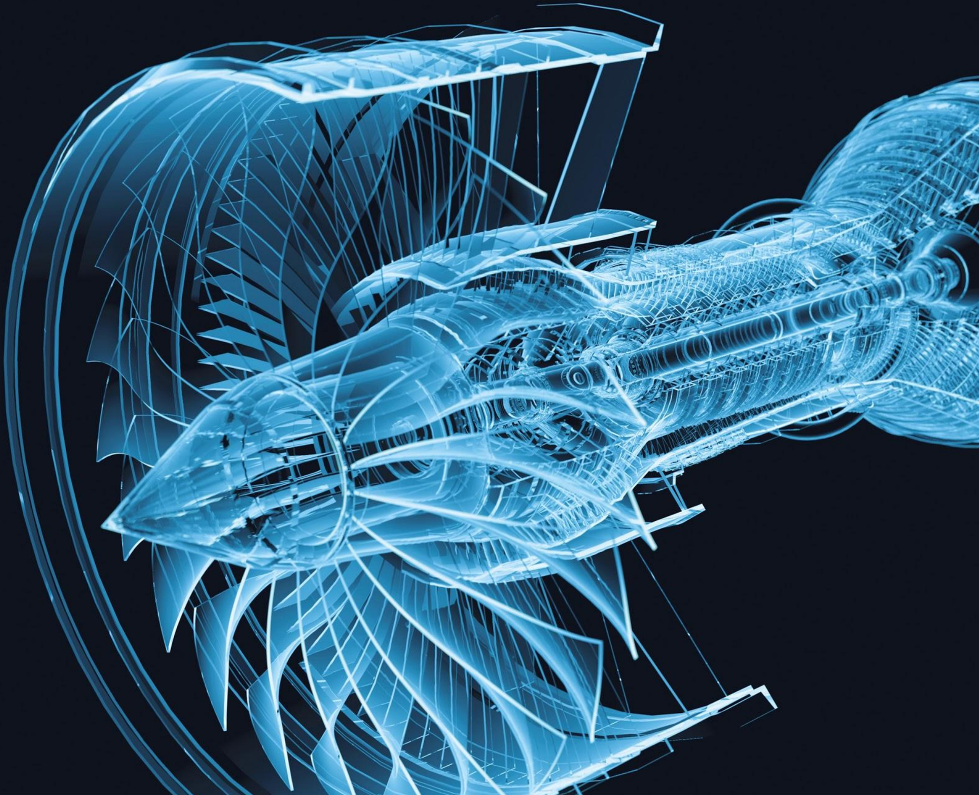
QCon London 2018

jetstack.io



## Who are Jetstack?

We are a UK-based company that help enterprises in their path to modern cloud-native infrastructure. We develop tooling and integrations for Kubernetes to improve the user experience for customers and end-users alike.

## Who are we?

@mattbates

@mattbates25

@munnerz

@JamesMunnelly

# INTRODUCTION

## Containers and distributed state

- Containers are here and here to stay and many of us are now using them for production services at scale
- Containers are ephemeral and can come and go - this is just for stateless applications, right?
- But a container is a.. **process**
- Why should we treat stateful systems differently?
- Large-scale container management systems exist - why not use these systems to manage all workloads?

# KUBERNETES

## Anyone heard of it?

- Kubernetes handles server ‘Cattle’ to pick and choose resources
- Can be installed on many different types of infrastructure
- Abstracts away the servers so developers can concentrate on code
- Pro-actively monitors, scales, auto-heals and updates

# BORG

## Clusters to manage all types of workload at Google

*Borg cells run a heterogeneous workload…*
*…long-running services that should "never" go*
*down, and handle short-lived latency-sensitive requests (a*
*few µs to a few hundred ms). Such services are used for*
*end-user-facing products such as Gmail, Google Docs, and*
*web search, and for* ***internal infrastructure services*** *(e.g.,*
*BigTable)…The workload mix varies across cells…*
*. Our distributed storage systems such as GFS [34] and its successor CFS,*
*Bigtable [19], and Megastore [8] all run on Borg*

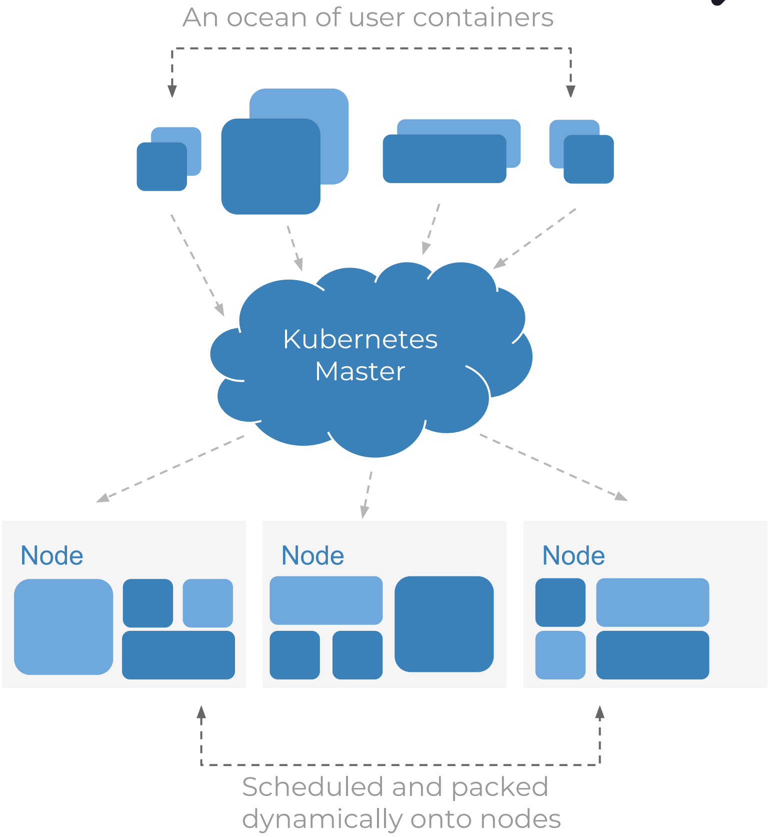
https://research.google.com/pubs/pub43438.html

# KUBERNETES

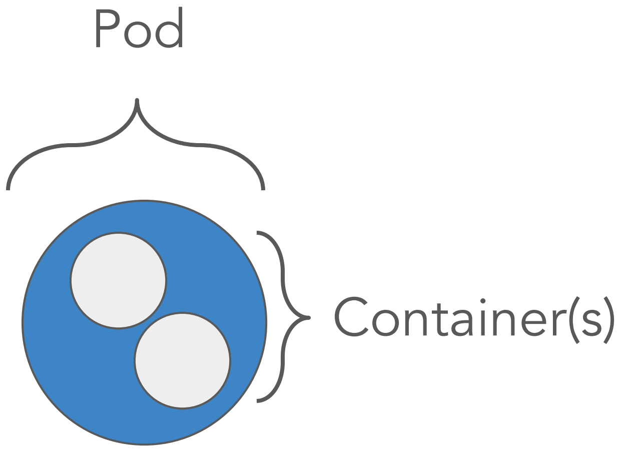
## Declarative systems management

- Declarative system description using application abstractions
  - Pods
  - Replica Sets
  - Deployments
  - Services
  - Persistent Volumes
  - Ingress
  - Secrets

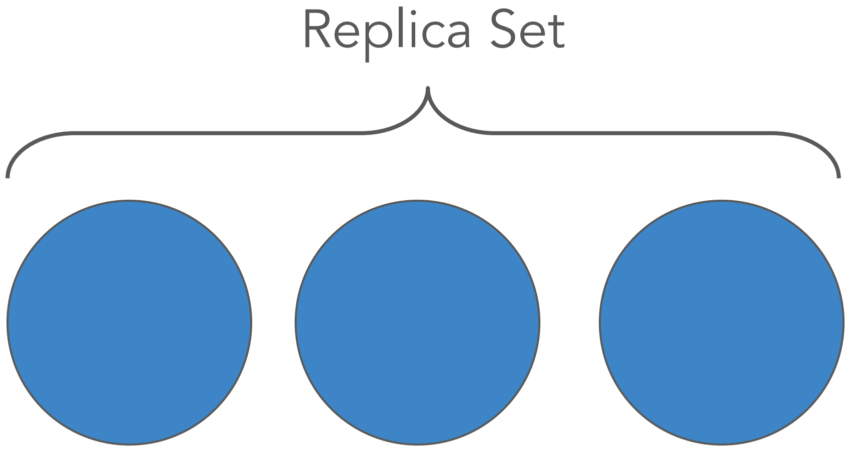
  .. and many more!


An ocean of user containers
Kubernetes Master
Node
Node
Node
Scheduled and packed dynamically onto nodes

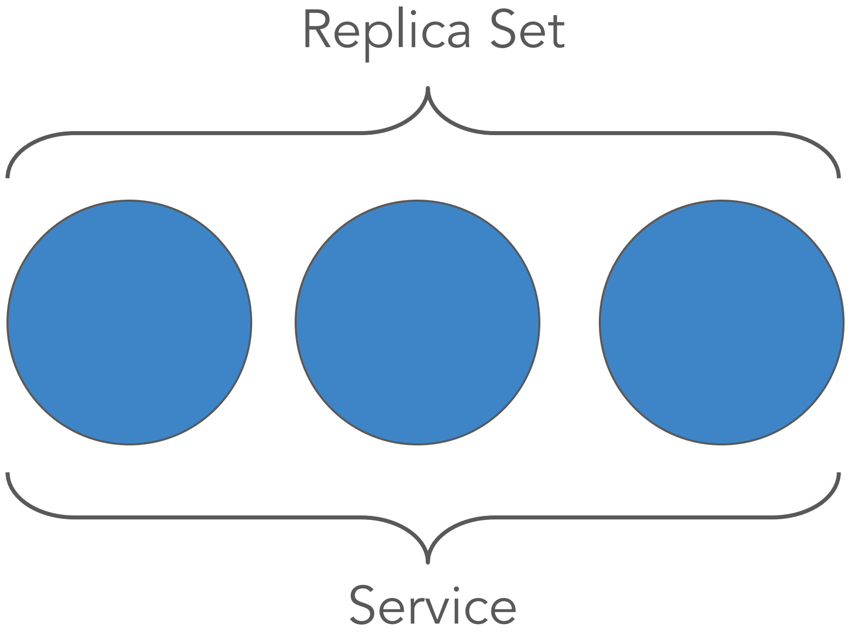
# WORKLOADS ON KUBERNETES: PODS AND CONTAINERS



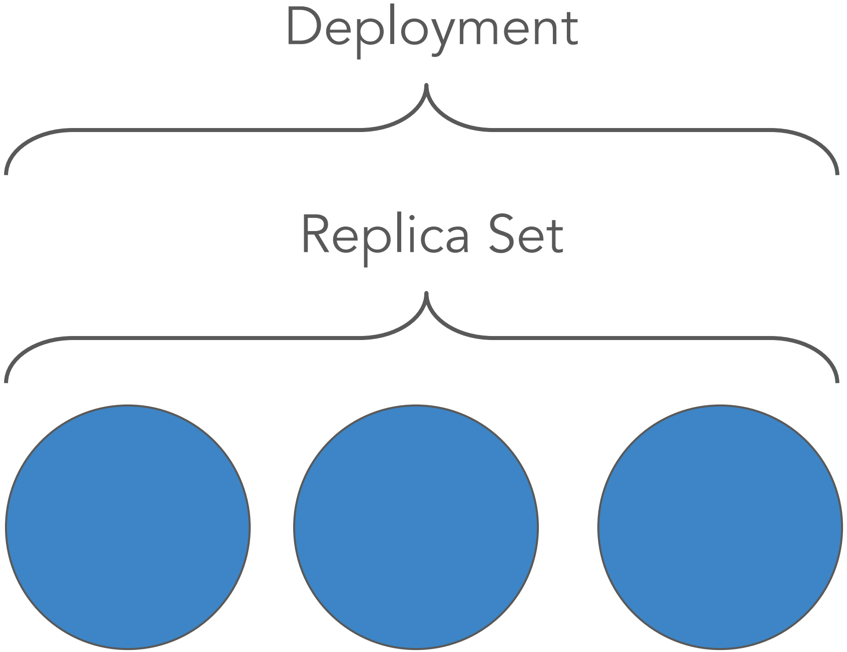
# WORKLOADS ON KUBERNETES: REPLICA SET



# WORKLOADS ON KUBERNETES: SERVICES

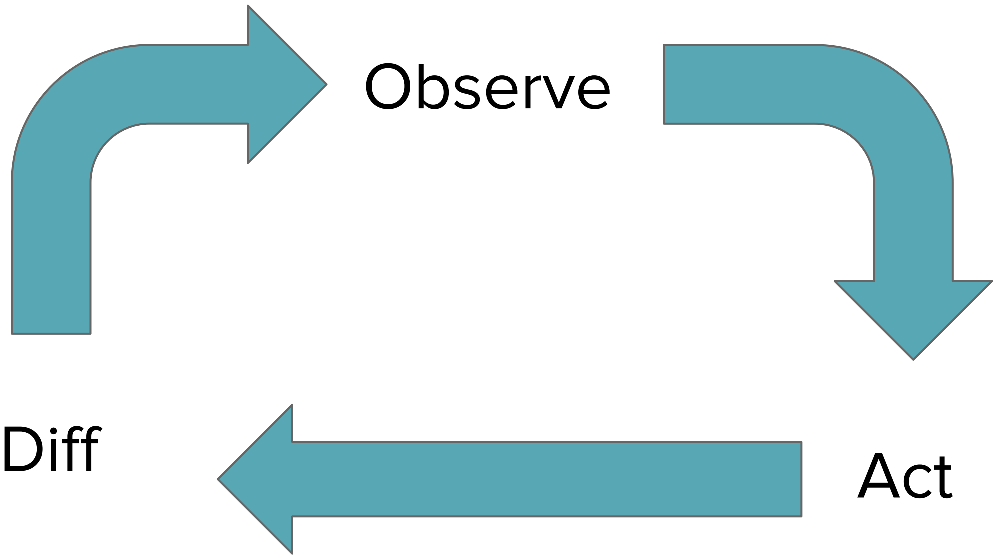


# WORKLOADS ON KUBERNETES: DEPLOYMENT



# RESOURCE LIFECYCLE

Reconciliation of desired state



# STATEFUL SERVICES

## Why Kubernetes?

**Consistent deployment between environments**

- Systems often built for the environment they run in
    - e.g. cloud VMs, provisioned via Terraform/CloudFormation or manually

# STATEFUL SERVICES

## Why Kubernetes?

**Visibility into management operations**

- Upgrades
- Scale up/down
- Disaster recovery

Due to the way these applications are deployed, it can be difficult and inconsistent to record and manage cluster actions

# STATEFUL SERVICES

## Why Kubernetes?

**Self-service distributed applications**

- Who can perform upgrades? (authZ)
- How do we scale?
- These events must be coordinated with operations teams

Putting a dependence on central operations teams to coordinate maintenance events = time = money

# STATEFUL SERVICES

## Why Kubernetes?

**Automated cluster actions**

- HorizontalPodAutoscaler allows us to automatically scale up and down
- Teams can manage their own autoscaling policies

# STATEFUL SERVICES

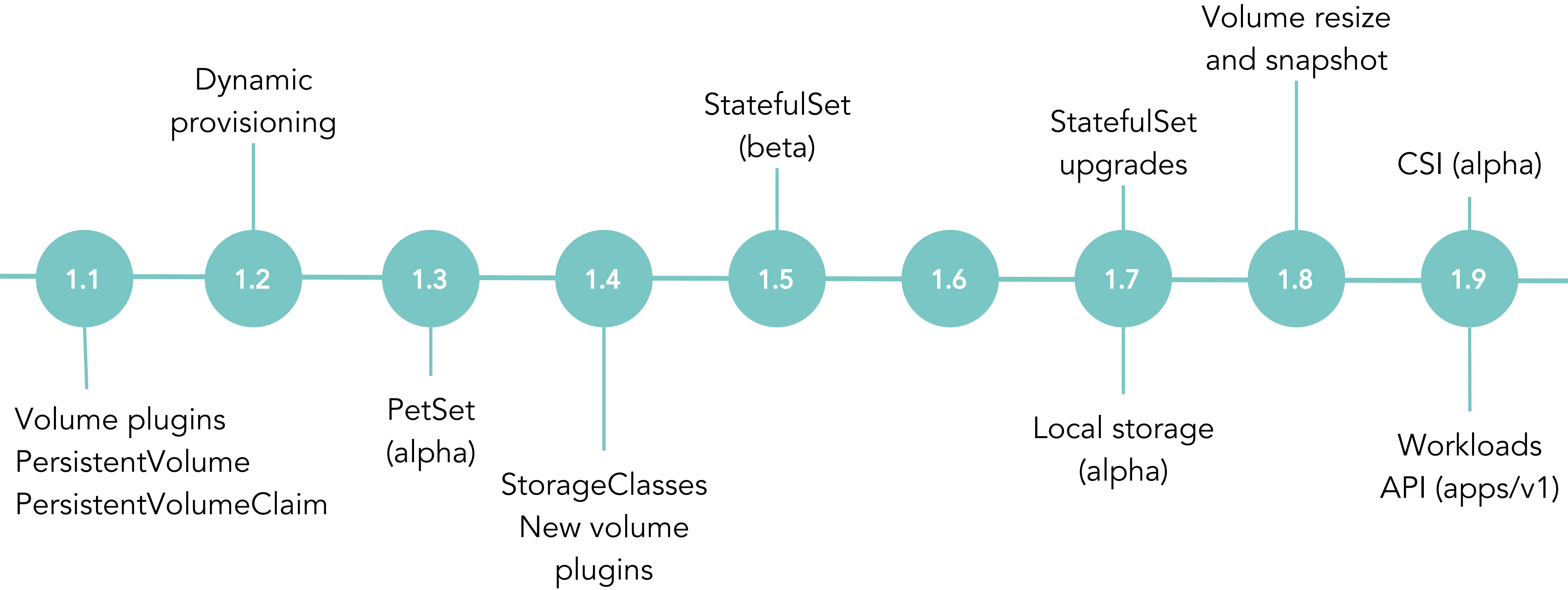
## Why Kubernetes?

**Centralised monitoring, logging and discovery**

- Kubernetes provides these services already that we can reuse these for all kinds of applications
  - Prometheus
  - Labelling
  - Instrumentation

# LAYING THE GROUNDWORK

Features developed by the project in previous releases



1.1
Volume plugins
PersistentVolume
PersistentVolumeClaim

1.2
Dynamic provisioning

1.3
PetSet (alpha)

1.4
StorageClasses
New volume plugins

1.5
StatefulSet (beta)

1.6

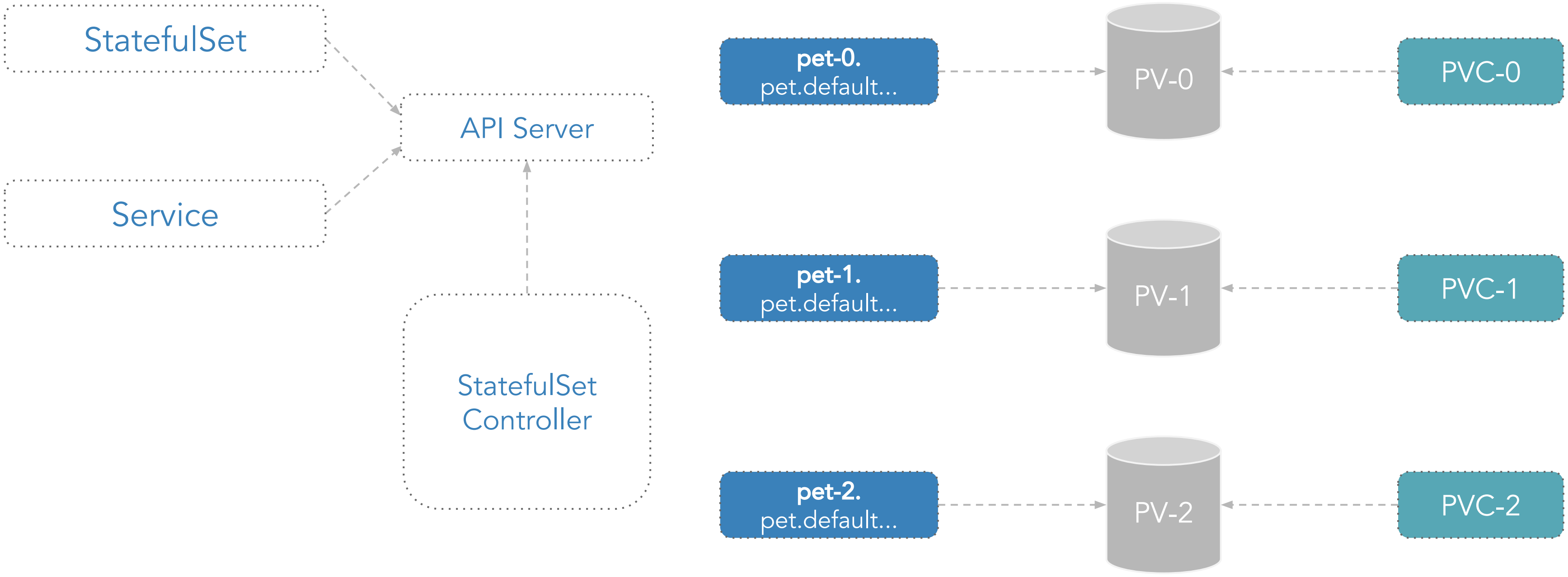
1.7
StatefulSet upgrades
Local storage (alpha)

1.8
Volume resize and snapshot

1.9
CSI (alpha)
Workloads API (apps/v1)

# STATEFULSET

## Unique and ordered pods



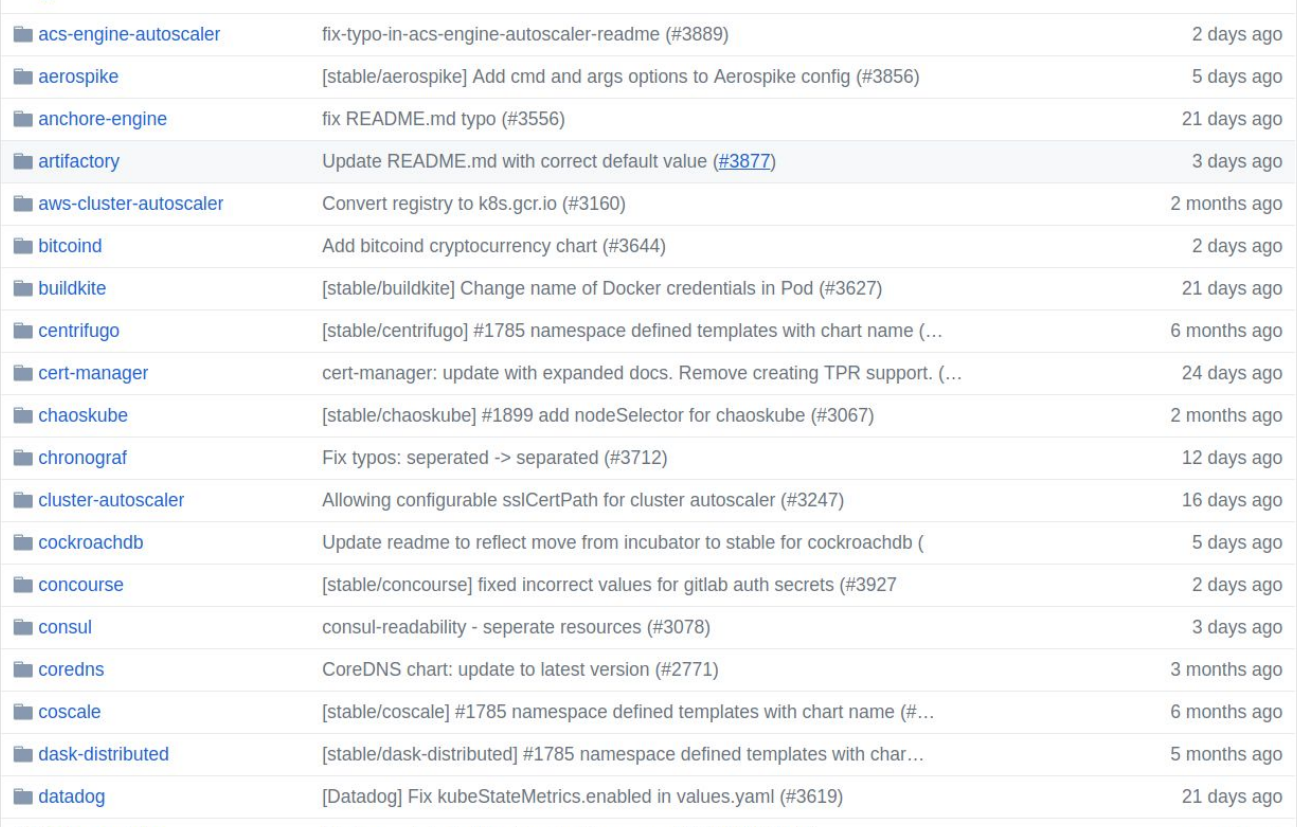
# HELM CHARTS

*“Helm is a tool for managing Kubernetes charts. Charts are packages of pre-configured Kubernetes resources.”*

github.com/kubernetes/helm

# HELM CHARTS

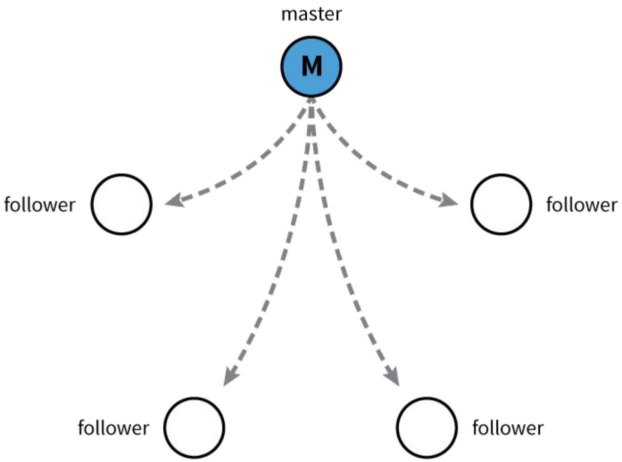
## Many integrations exist - e.g. see the Helm charts repo...



| | | |
|---|---|---|
| acs-engine-autoscaler | fix-typo-in-acs-engine-autoscaler-readme (#3889) | 2 days ago |
| aerospike | [stable/aerospike] Add cmd and args options to Aerospike config (#3856) | 5 days ago |
| anchore-engine | fix README.md typo (#3556) | 21 days ago |
| artifactory | Update README.md with correct default value (#3877) | 3 days ago |
| aws-cluster-autoscaler | Convert registry to k8s.gcr.io (#3160) | 2 months ago |
| bitcoind | Add bitcoind cryptocurrency chart (#3644) | 2 days ago |
| buildkite | [stable/buildkite] Change name of Docker credentials in Pod (#3627) | 21 days ago |
| centrifugo | [stable/centrifugo] #1785 namespace defined templates with chart name (… | 6 months ago |
| cert-manager | cert-manager: update with expanded docs. Remove creating TPR support. (… | 24 days ago |
| chaoskube | [stable/chaoskube] #1899 add nodeSelector for chaoskube (#3067) | 2 months ago |
| chronograf | Fix typos: seperated -> separated (#3712) | 12 days ago |
| cluster-autoscaler | Allowing configurable sslCertPath for cluster autoscaler (#3247) | 16 days ago |
| cockroachdb | Update readme to reflect move from incubator to stable for cockroachdb ( | 5 days ago |
| concourse | [stable/concourse] fixed incorrect values for gitlab auth secrets (#3927 | 2 days ago |
| consul | consul-readability - seperate resources (#3078) | 3 days ago |
| coredns | CoreDNS chart: update to latest version (#2771) | 3 months ago |
| coscale | [stable/coscale] #1785 namespace defined templates with chart name (#… | 6 months ago |
| dask-distributed | [stable/dask-distributed] #1785 namespace defined templates with char… | 5 months ago |
| datadog | [Datadog] Fix kubeStateMetrics.enabled in values.yaml (#3619) | 21 days ago |

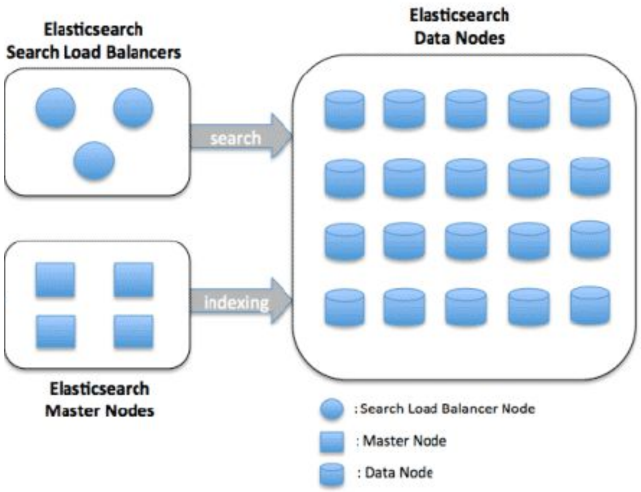
# STATEFUL SERVICES

## All distributed systems are not equal



Leader elected quorum

(e.g. etcd, ZK, MongoDB)



Active-active / multi-master

(e.g. MySQL Galera, Elasticsearch)

etc..

# HELM CHARTS

## Problems encountered

### Point-in-time management

- Resources are only modified when an administrator updates them
- This is a non-starter for self-service applications

We're back to waking up at 3am to our pagers

# HELM CHARTS

Problems encountered

## Failure handling

- This requires an administrator to intervene
- Prone to errors, and requires specialist knowledge

We’re back to waking up at 3am to our pagers

# HELM CHARTS

## Problems encountered

### No native provisions for understanding the applications state

- There’s no way to quickly see the status of a deployment in a meaningful way

# HELM CHARTS

## Problems encountered

### Difficult to understand why and what is happening

- Opaque ‘preStop’ hook allows us to run a script before the main process is terminated

```
lifecycle:
  preStop:
    exec:
      command: ["/bin/bash","/pre-stop-hook.sh"]
```

# OPERATOR PATTERN

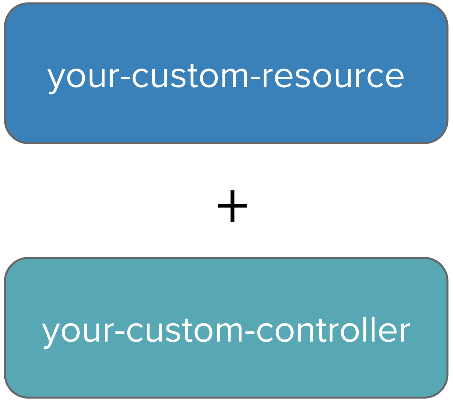
Application-specific controllers that extend the Kubernetes API

*“An Operator represents human operational knowledge in software to reliably manage an application.”* (CoreOS)

# OPERATOR PATTERN

## Application-specific controllers that extend the Kubernetes API

- Follows the same declarative principles as the rest of Kubernetes
- Express desired state as part of your resource specification
- Controller ‘converges’ the desired and actual state of the world



your-custom-resource

+

your-custom-controller

# OPERATOR PATTERN

Application-specific controllers that extend the Kubernetes API

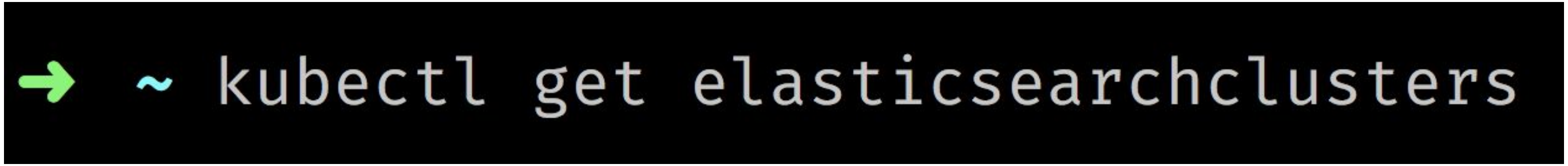
Examples include:

- etcd-operator (https://github.com/coreos/etcd-operator)
- service-catalog (https://github.com/kubernetes-incubator/service-catalog)
- metrics (https://github.com/kubernetes-incubator/custom-metrics-apiserver)
- cert-manager (https://github.com/jetstack/cert-manager)
- navigator (https://github.com/jetstack/navigator)

# CUSTOM RESOURCES

## Standing on the shoulders of Kubernetes

- API “as a service”
- Kubernetes API primitives for ‘custom’ types
  - CRUD operations
  - Watch for changes
  - Native authentication & authorisation



```
➜  ~ kubectl get elasticsearchclusters
```

# CUSTOM RESOURCES

## Standing on the shoulders of Kubernetes

CustomResourceDefinition (CRD)

- Quick and easy. No extra apiserver code
- Great for simple extensions
- No versioning, admission control or defaulting

https://kccncna17.sched.com/event/CU6r/extending-the-kubernetes-api-what-the-docs-dont-tell-you-i-james-munnelly-jetstack

# CUSTOM RESOURCES

## Standing on the shoulders of Kubernetes

Custom API server (aggregated)

- Full power and flexibility of Kubernetes
  Similar to how many existing APIs are created
- Versioning, admission control,
  validation, defaulting
- Requires etcd to store data

https://kccncna17.sched.com/event/CU6r/extending-the-kubernetes-api-what-the-docs-dont-tell-you-i-james-munnelly-jetstack

# Cassandra on Kubernetes

Let’s see it in action

# WHAT'S GOING ON

## Cassandra on Kubernetes

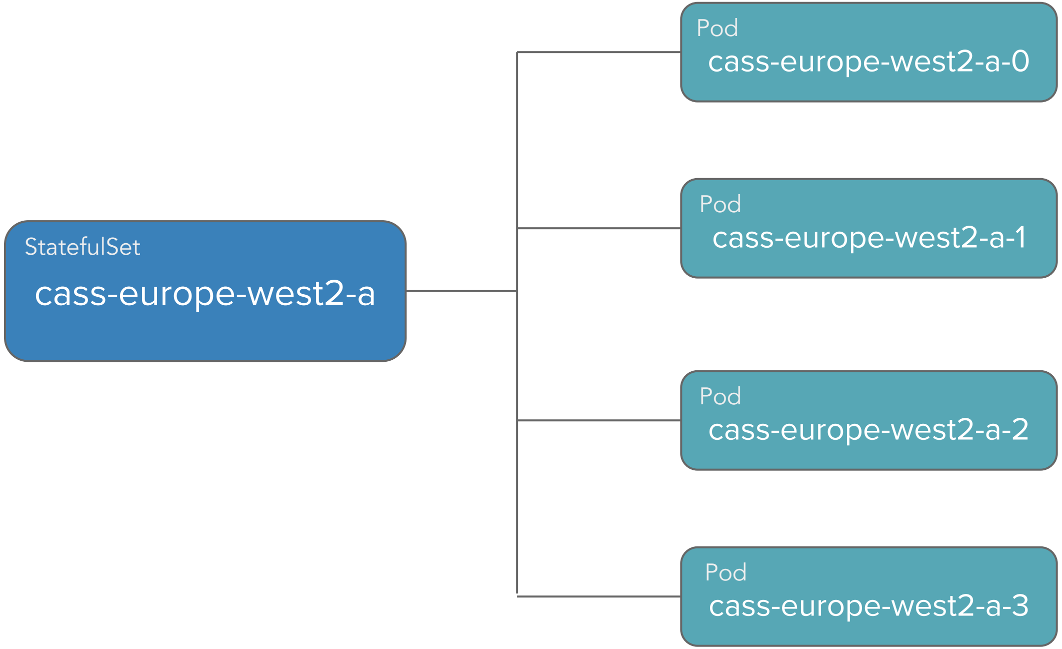
Native Kubernetes resources are created

| StatefulSets | Load Balancers/Services | Persistent Disks | Workload identities |
|---|---|---|---|
| cass-europe-west2-a | client-service | cass-europe-west2-a-0<br>cass-europe-west2-a-1<br>cass-europe-west2-a-2 | cass-europe-west2-a |
| cass-europe-west2-b | discovery-service | cass-europe-west2-b-0<br>cass-europe-west2-b-1<br>cass-europe-west2-b-2 | cass-europe-west2-b |

# WHAT'S GOING ON

## Cassandra on Kubernetes

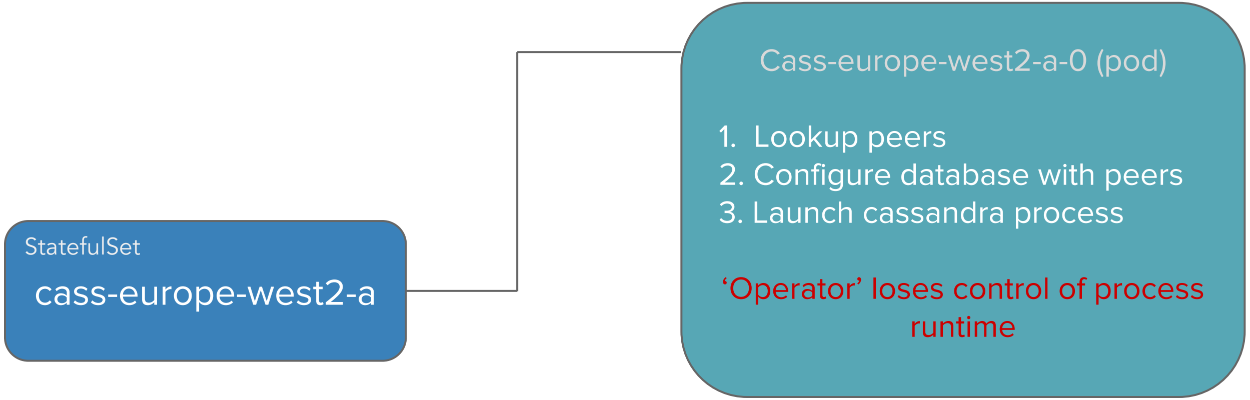
Custom 'entrypoint' code runs before Cassandra starts



# WHAT'S GOING ON

## Cassandra on Kubernetes

Custom 'entrypoint' code runs before Cassandra starts



StatefulSet

cass-europe-west2-a

Cass-europe-west2-a-0 (pod)

1. Lookup peers
2. Configure database with peers
3. Launch cassandra process

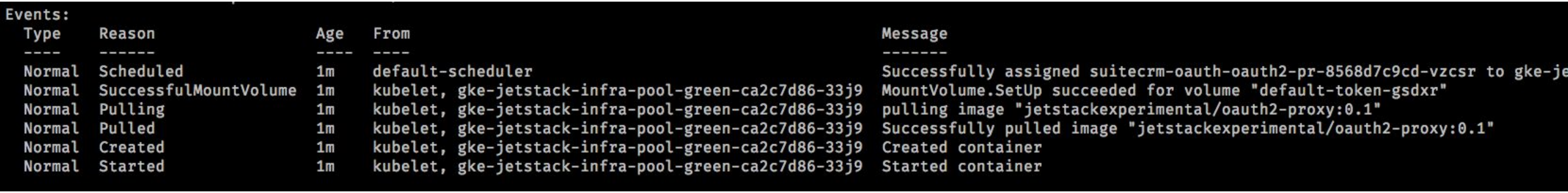
'Operator' loses control of process runtime

# OPERATOR PATTERN

## Problems encountered

### Application state information collection is varied

- Kubernetes usually provides the ability to inspect with kubectl describe



```
Events:
  Type    Reason                 Age   From                                         Message
  ----    ------                 ----  ----                                         -------
  Normal  Scheduled              1m    default-scheduler                            Successfully assigned suitecrm-oauth-oauth2-pr-8568d7c9cd-vzcsr to gke-je
  Normal  SuccessfulMountVolume  1m    kubelet, gke-jetstack-infra-pool-green-ca2c7d86-33j9  MountVolume.SetUp succeeded for volume "default-token-gsdxr"
  Normal  Pulling                1m    kubelet, gke-jetstack-infra-pool-green-ca2c7d86-33j9  pulling image "jetstackexperimental/oauth2-proxy:0.1"
  Normal  Pulled                 1m    kubelet, gke-jetstack-infra-pool-green-ca2c7d86-33j9  Successfully pulled image "jetstackexperimental/oauth2-proxy:0.1"
  Normal  Created                1m    kubelet, gke-jetstack-infra-pool-green-ca2c7d86-33j9  Created container
  Normal  Started                1m    kubelet, gke-jetstack-infra-pool-green-ca2c7d86-33j9  Started container
```

# OPERATOR PATTERN

## Problems encountered

### Reimplementing large parts of Kubernetes

- Limitations in StatefulSet result in the entire controller being reimplemented
- We should be building on these primitives, not recreating them

# OPERATOR PATTERN

Problems encountered

## Integrating with synchronous APIs reliably

- No easy way to see if ‘nodetool decommission’ succeeded
- Makes assuredly executing cluster infrastructure changes difficult

This is on account of the operator losing control after the process has started

# Navigator

Co-located application intelligence

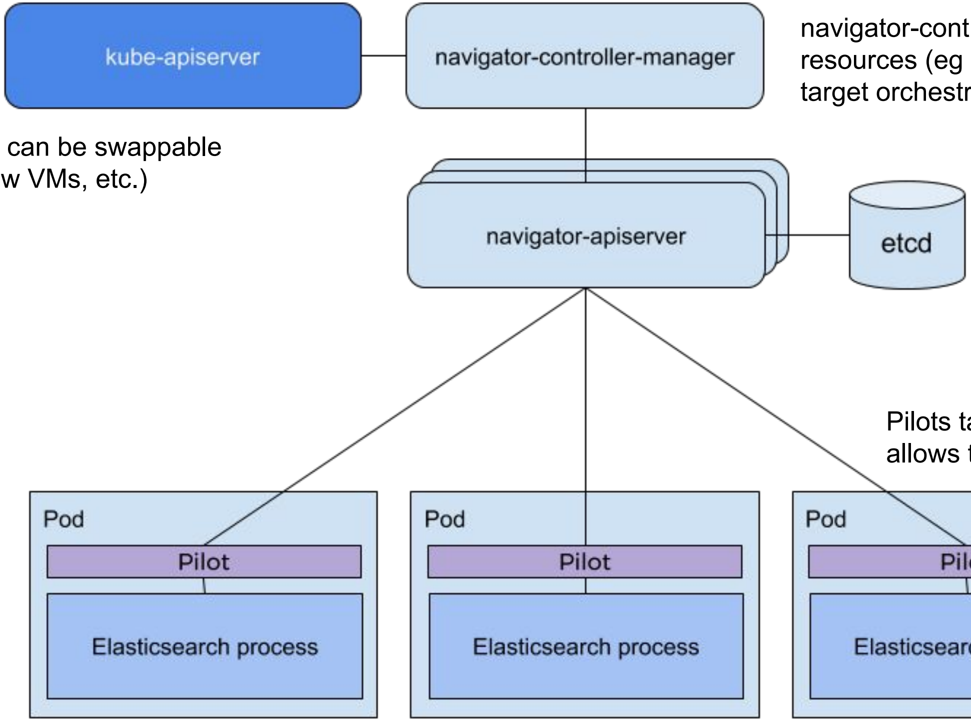
# NAVIGATOR

## Motivations

- Pro-actively monitor and heal applications
- Reduce the operational burden on teams by making management of complex applications as easy as any other Kubernetes resource
- Make it easy to understand the state of the system
- Re-use existing Kubernetes primitives - don’t reinvent the wheel
- Providing a reliable and flexible building block for integrating with the varied and sometimes difficult database APIs/management tools

# NAVIGATOR

## Navigator and Pilot Architecture



navigator-controller-manager creates resources (eg deployments, secrets) in target orchestrator

Underlying orchestrator can be swappable (e.g. OpenShift, K8s, raw VMs, etc.)

navigator-apiserver  follows Kubernetes API conventions, so can be aggregated

Pilots talk only to ‘navigator-apiserver’ - this allows to easily embed in other envs

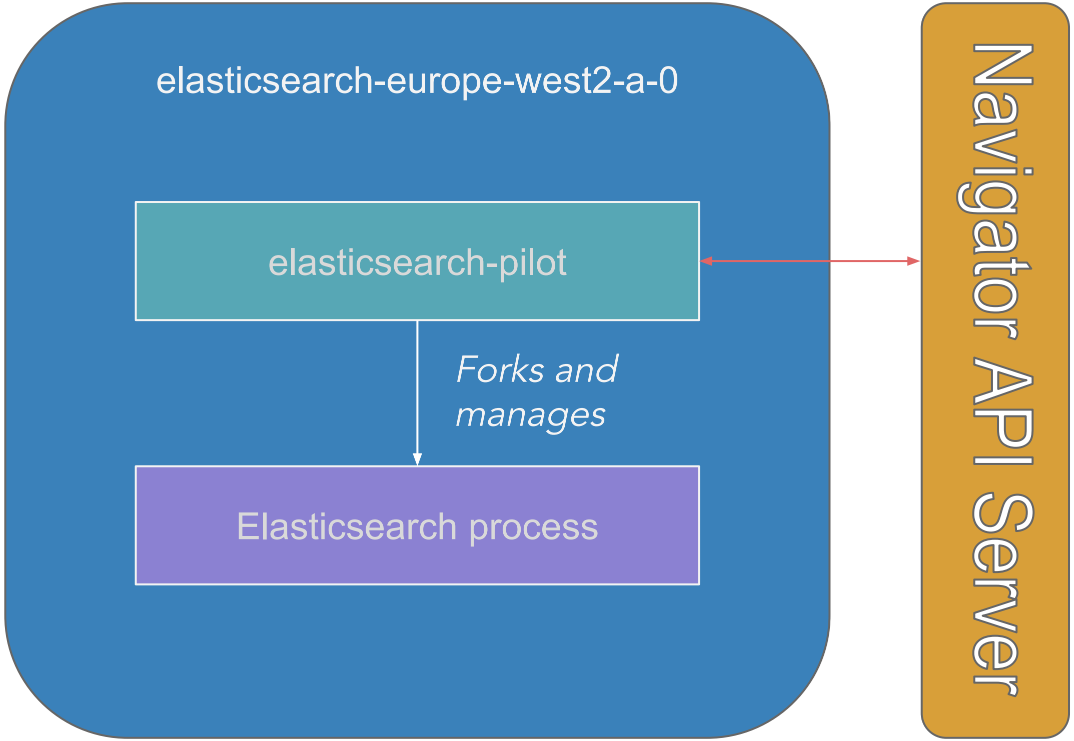
# NAVIGATOR

## Features

- Follows the ‘operator pattern’
- Abstracts configuration of complex topologies (i.e. automated rack awareness, sharding)
- Manages the lifecycle of applications over time
- Provides a common and familiar interface for modifying applications
- Validates configurations and helpfully rejects invalid requests

# PILOTS - COLOCATED INTELLIGENCE

## Pilots alongside our processes



- Pilot 'wraps' the Elasticsearch process
- Performs operation on the underlying database node
- Updates the Navigator API with information about the state of the node
- 'GenericPilot' to make it easy to extend
- Similar to kubelet

# PILOTS - COLOCATED INTELLIGENCE

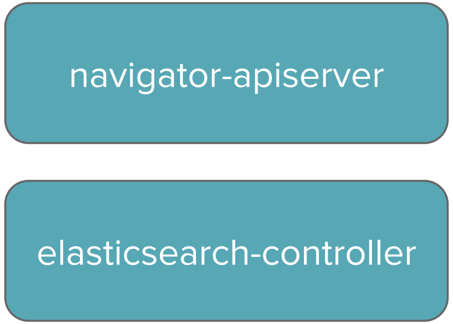
## Pilots alongside our processes

- Examples of information reported to Pilots:
  - Node’s reported version
  - Amount of data on node
  - Node health
- Leader elected Pilots also report overall cluster status
- This information influences which ‘Action’ is taken

# NAVIGATOR

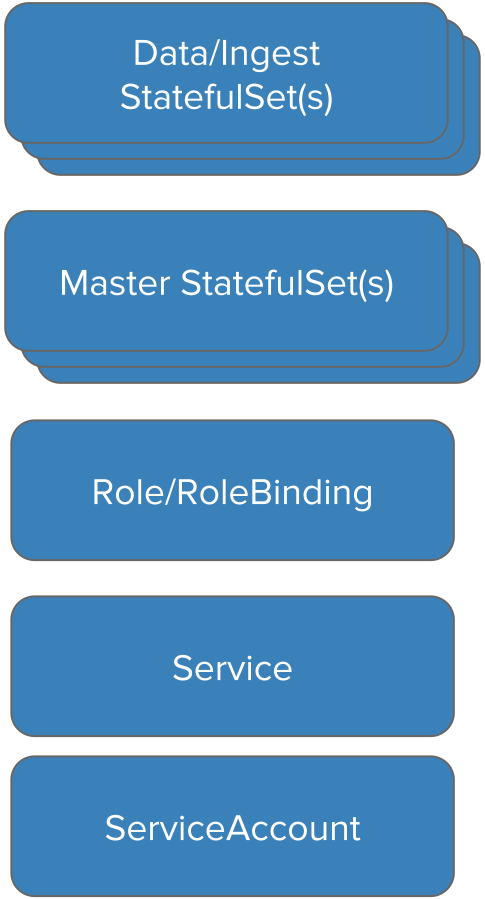
## From YAML to Elasticsearch cluster

```
$ kubectl create -f elasticsearch-cluster.yaml
```



navigator-apiserver

elasticsearch-controller



Data/Ingest StatefulSet(s)

Master StatefulSet(s)

Role/RoleBinding

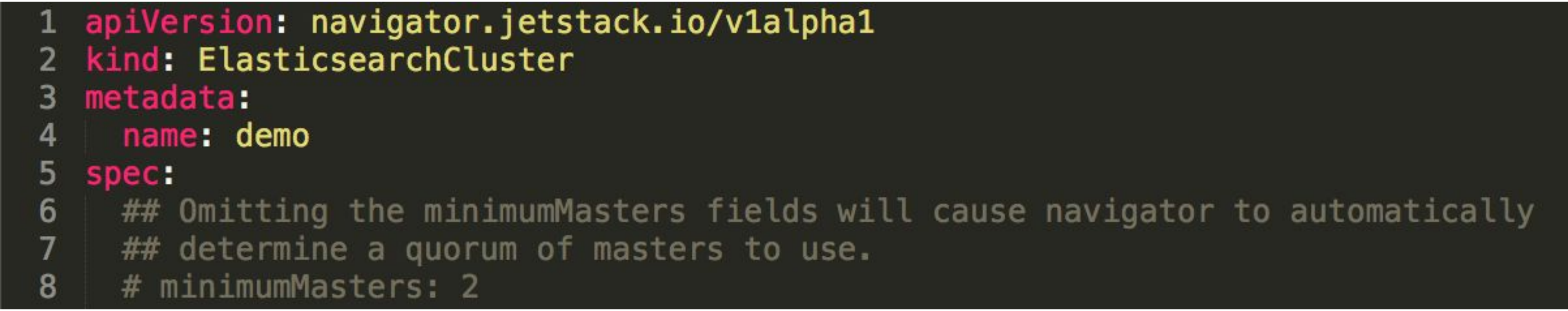
Service

ServiceAccount

# NAVIGATOR

## From YAML to Elasticsearch cluster

- Providing sensible and safe defaults makes it easier for developers to consume complex applications ‘as a service’



```yaml
apiVersion: navigator.jetstack.io/v1alpha1
kind: ElasticsearchCluster
metadata:
  name: demo
spec:
  ## Omitting the minimumMasters fields will cause navigator to automatically
  ## determine a quorum of masters to use.
  # minimumMasters: 2
```

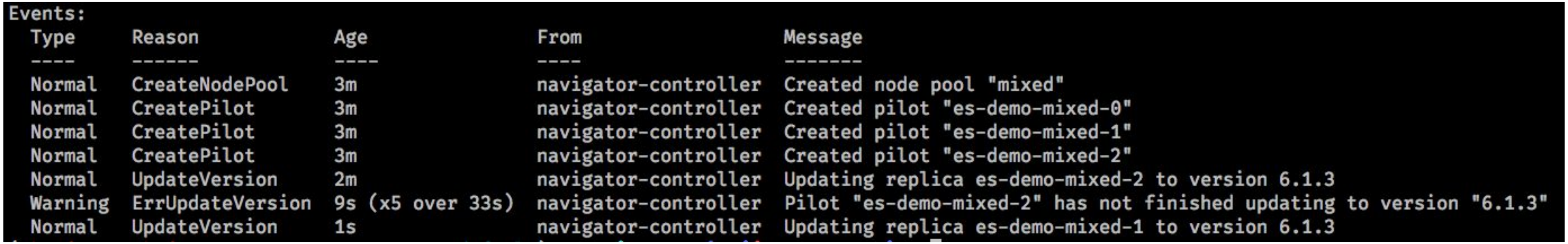
# Elasticsearch scale-up and upgrade

Actions in action

# ACTIONS

## Transitioning cluster state with Actions

- A small unit of work to perform
- Can be reasoned about and debugged by users through ‘kubectl describe’



```
Events:
  Type     Reason             Age                From                  Message
  ----     ------             ----               ----                  -------
  Normal   CreateNodePool     3m                 navigator-controller  Created node pool "mixed"
  Normal   CreatePilot        3m                 navigator-controller  Created pilot "es-demo-mixed-0"
  Normal   CreatePilot        3m                 navigator-controller  Created pilot "es-demo-mixed-1"
  Normal   CreatePilot        3m                 navigator-controller  Created pilot "es-demo-mixed-2"
  Normal   UpdateVersion      2m                 navigator-controller  Updating replica es-demo-mixed-2 to version 6.1.3
  Warning  ErrUpdateVersion   9s (x5 over 33s)   navigator-controller  Pilot "es-demo-mixed-2" has not finished updating to version "6.1.3"
  Normal   UpdateVersion      1s                 navigator-controller  Updating replica es-demo-mixed-1 to version 6.1.3
```

# ACTIONS

## Transitioning cluster state with Actions

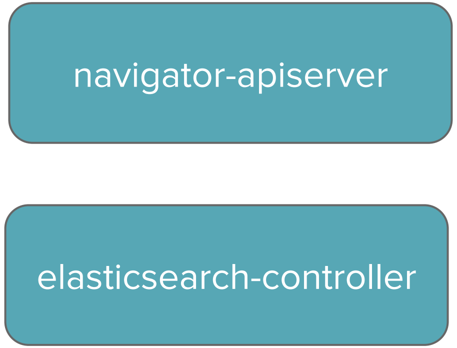
What constitutes an Action?

- Upgrade
- Scale
- Backup
- Apply new configuration
- Create or delete a node pool
- Adjust resources assigned to a node pool
- Resize persistent disk

# ACTIONS

## Transitioning cluster state with Actions

```
$ kubectl patch esc demo -p '{"spec":{"version":"6.1.3"}}'
```



navigator-apiserver

elasticsearch-controller

Elasticsearch upgrade action

https://github.com/jetstack/navigator/tree/master/pkg/controllers/elasticsearch/actions

# ACTIONS

## Transitioning cluster state with Actions

```
$ kubectl patch esc demo -p '{"spec":{"version":"6.1.3"}}'
```

1. Observes change

elasticsearch-controller

Elasticsearch upgrade action

https://github.com/jetstack/navigator/tree/master/pkg/controllers/elasticsearch/actions

# ACTIONS

## Transitioning cluster state with Actions

```
$ kubectl patch esc demo -p '{"spec":{"version":"6.1.3"}}'
```

1. Observes change
2. Evaluates each ‘Pilot’ resource one at a time

elasticsearch-controller

Elasticsearch upgrade action

https://github.com/jetstack/navigator/tree/master/pkg/controllers/elasticsearch/actions

# ACTIONS

## Transitioning cluster state with Actions

```
$ kubectl patch esc demo -p '{"spec":{"version":"6.1.3"}}'
```

elasticsearch-controller

1. Observes change
2. Evaluates each ‘Pilot’ resource one at a time
   a. Is the node healthy?
   b. Is the node already at the desired version?
   c. Is the cluster healthy?

Elasticsearch upgrade action

https://github.com/jetstack/navigator/tree/master/pkg/controllers/elasticsearch/actions

# ACTIONS

## Transitioning cluster state with Actions

```
$ kubectl patch esc demo -p '{"spec":{"version":"6.1.3"}}'
```

elasticsearch-controller

1. Observes change
2. Evaluates each ‘Pilot’ resource one at a time
   a. Is the node healthy?
   b. Is the node already at the desired version?
   c. Is the cluster healthy?
3. Inform the relevant Pilot it is to be upgrade

Elasticsearch upgrade action

https://github.com/jetstack/navigator/tree/master/pkg/controllers/elasticsearch/actions

# ACTIONS

## Transitioning cluster state with Actions

```
$ kubectl patch esc demo -p '{"spec":{"version":"6.1.3"}}'
```

elasticsearch-controller

1. Observes change
2. Evaluates each ‘Pilot’ resource one at a time
   a. Is the node healthy?
   b. Is the node already at the desired version?
   c. Is the cluster healthy?
3. Inform the relevant Pilot it is to be upgrade
4. Upgrade the node that needs to be upgraded

Elasticsearch upgrade action

https://github.com/jetstack/navigator/tree/master/pkg/controllers/elasticsearch/actions

# ACTIONS

## Transitioning cluster state with Actions

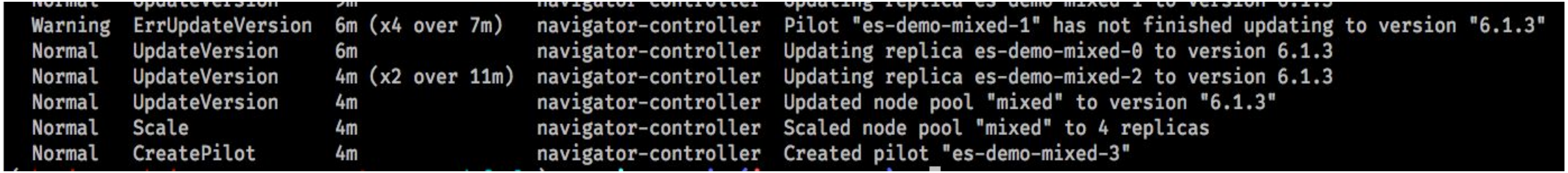
Why do it this way?

- Controller can evaluate *all* actions to perform, and sequence them appropriately
- This allows one central ‘brain’ when making infrastructure changes
- Clearly defined and contained as a unit of work in code
- It can wait for ‘pre-conditions’ to be met e.g.
  - waiting for shards to be drained from an Elasticsearch node
  - waiting for a node to be decommissioned

# ACTIONS

## Transitioning cluster state with Actions

- Controller can evaluate all actions that need to be performed and sequence them safely
- Prevents accidental mistakes by administrators



```
  Normal    UpdateVersion      5m                   navigator-controller  Updating replica es-demo-mixed-1 to version 6.1.3
  Warning   ErrUpdateVersion   6m (x4 over 7m)      navigator-controller  Pilot "es-demo-mixed-1" has not finished updating to version "6.1.3"
  Normal    UpdateVersion      6m                   navigator-controller  Updating replica es-demo-mixed-0 to version 6.1.3
  Normal    UpdateVersion      4m (x2 over 11m)     navigator-controller  Updating replica es-demo-mixed-2 to version 6.1.3
  Normal    UpdateVersion      4m                   navigator-controller  Updated node pool "mixed" to version "6.1.3"
  Normal    Scale              4m                   navigator-controller  Scaled node pool "mixed" to 4 replicas
  Normal    CreatePilot        4m                   navigator-controller  Created pilot "es-demo-mixed-3"
```

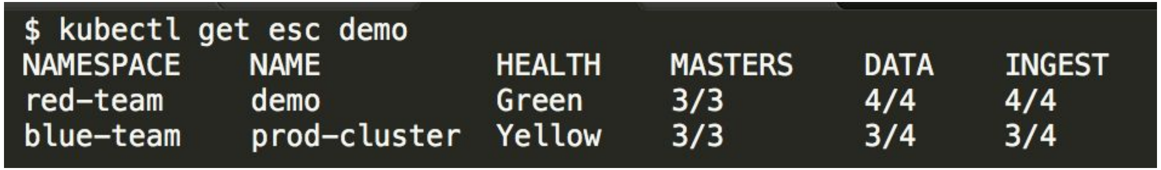
- Upgrade, and scale once the cluster is in a healthy state.

# THE FUTURE

## What’s next for Navigator?

- Cutting a maintainable API - this will allow users to begin using Navigator for real
- Improving existing controller intelligence
- Supporting more database specific features (e.g. x-pack, rack awareness)
- Support ad-hoc administrator initiated Actions
- Automated OS and application patching through ‘managed versions’

- Custom ‘kubectl get’ output (from Kubernetes 1.10 onwards)
  - Makes custom resources ‘feel native’ in the system



```
$ kubectl get esc demo
NAMESPACE    NAME          HEALTH    MASTERS    DATA    INGEST
red-team     demo          Green     3/3        4/4     4/4
blue-team    prod-cluster  Yellow    3/3        3/4     3/4
```

# SUMMARY

- Kubernetes provides us the building blocks to orchestrate and manage stateful systems
- Consistent deployment of stateless + stateful workloads across multiple environments means more efficiency and ability to deploy quicker without the complexities and overhead of centralised management
- Kubernetes is highly extensible: we can build on top of the API with custom resources and codify stateful operational logic into controllers

# CREDITS

To our other team members working on Navigator

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@wallrj

Louis Taylor

@kragniz

JETSTACK

# Thanks!

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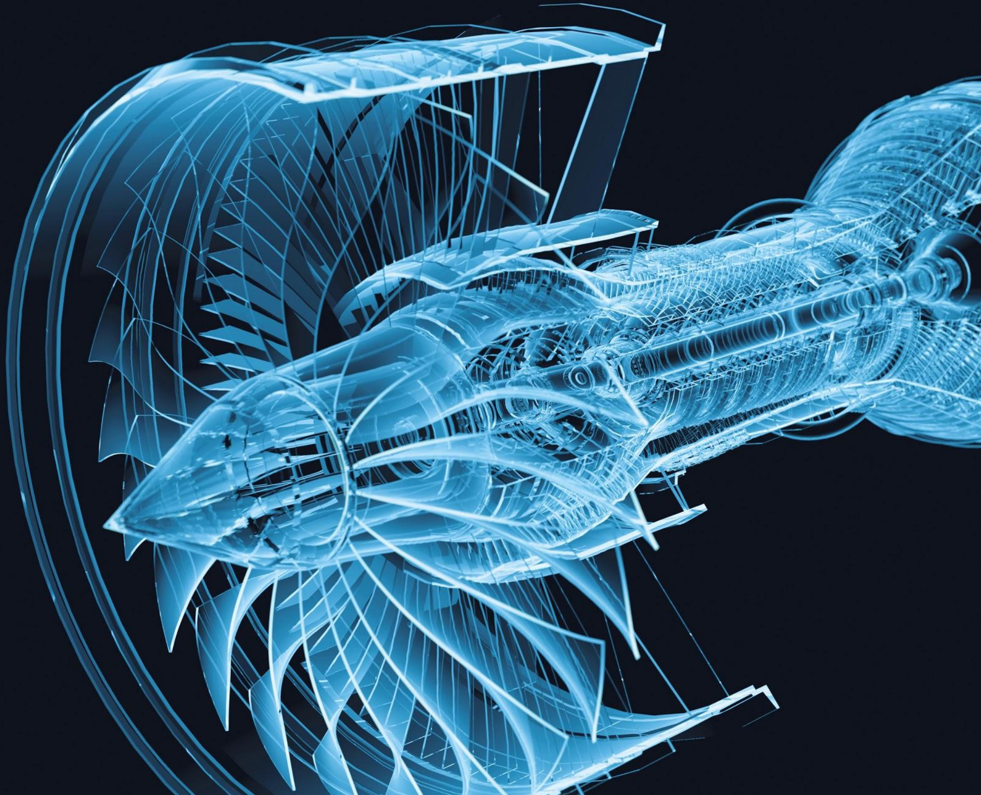
@JetstackHQ

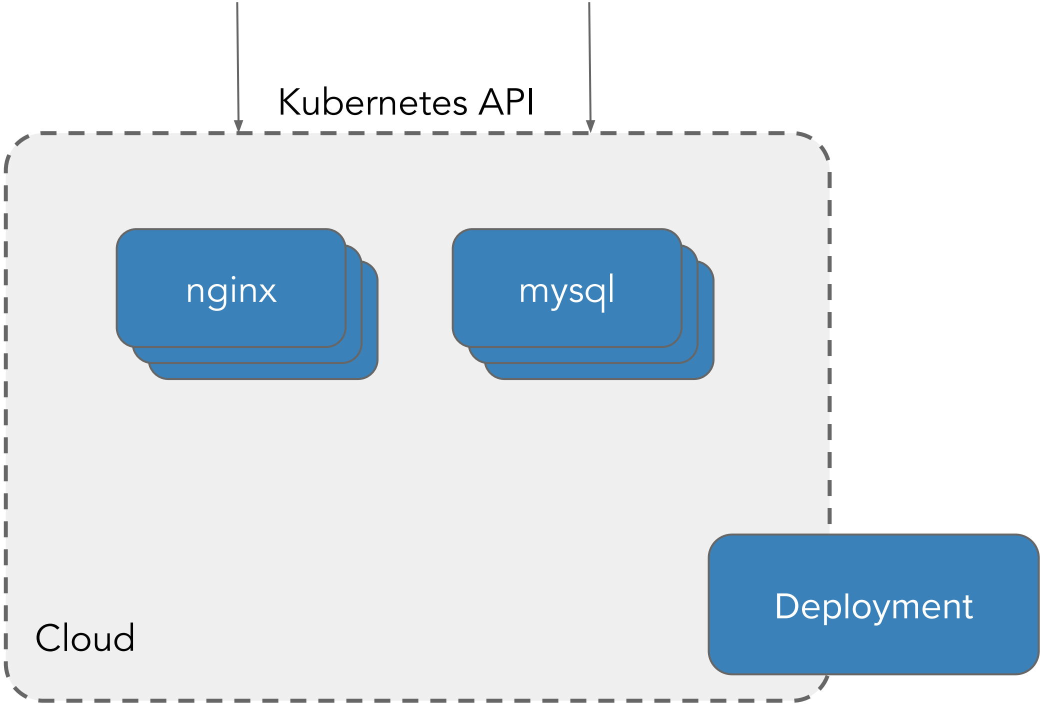
github.com/jetstack/navigator

jetstack.io



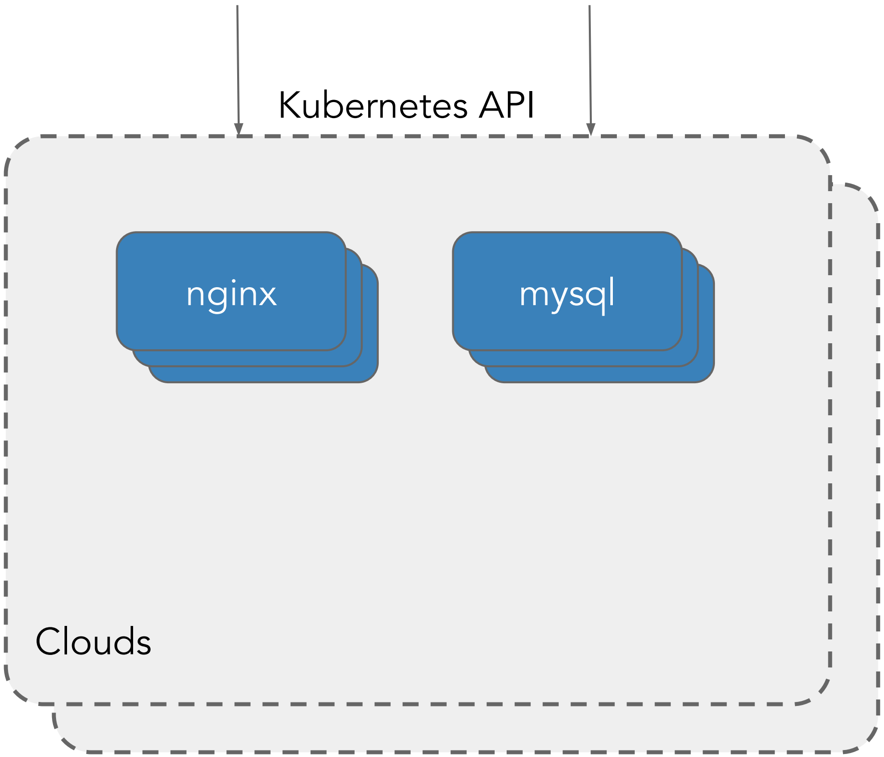
# KUBERNETES ALL THE THINGS

## Stateless and stateful workloads in cluster co-existence



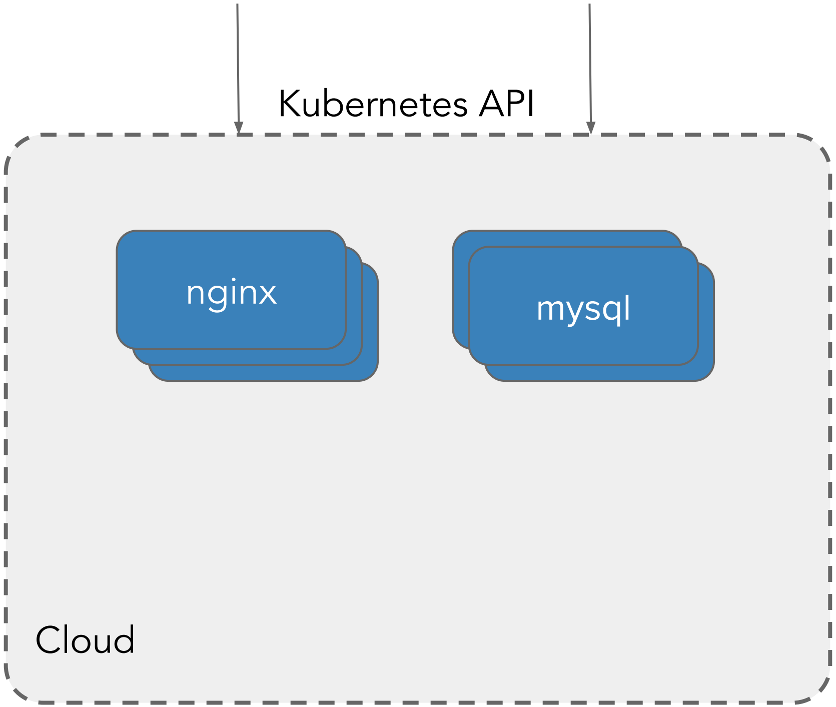
# KUBERNETES ALL THE THINGS

Stateless and stateful workloads in cluster co-existence



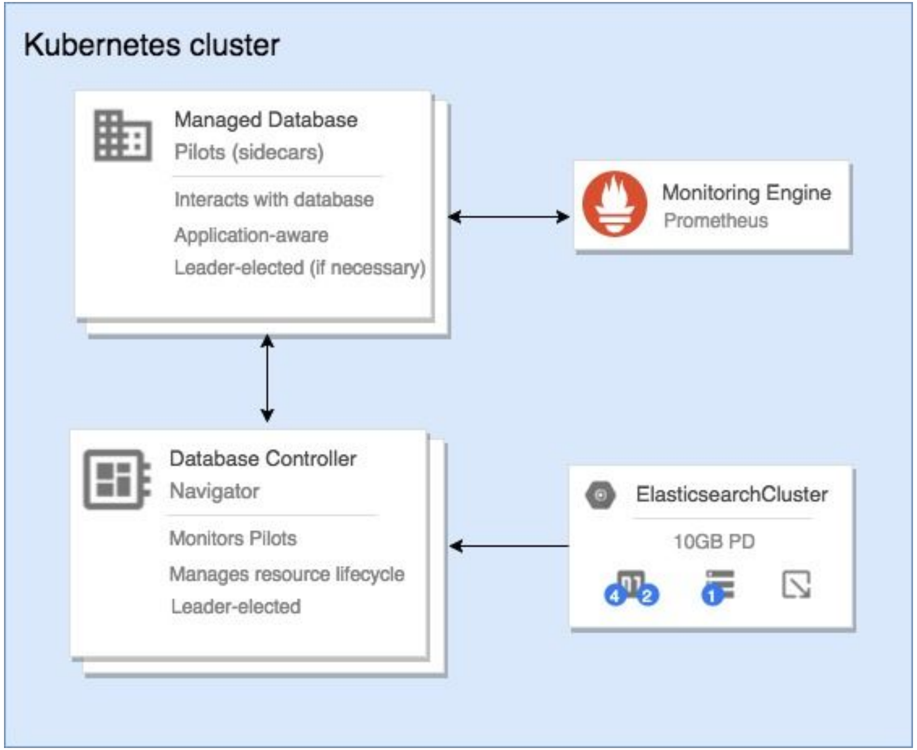
# KUBERNETES ALL THE THINGS

Stateless and stateful workloads in cluster co-existence - across cloud



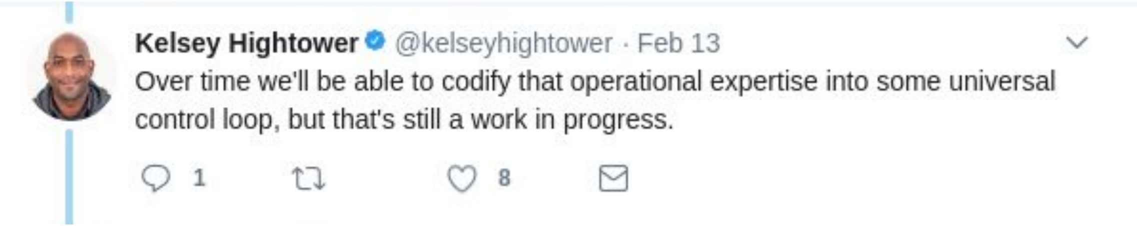
# NAVIGATOR

## Navigator and Pilot Architecture



# NAVIGATOR

## Navigator and Pilot Architecture

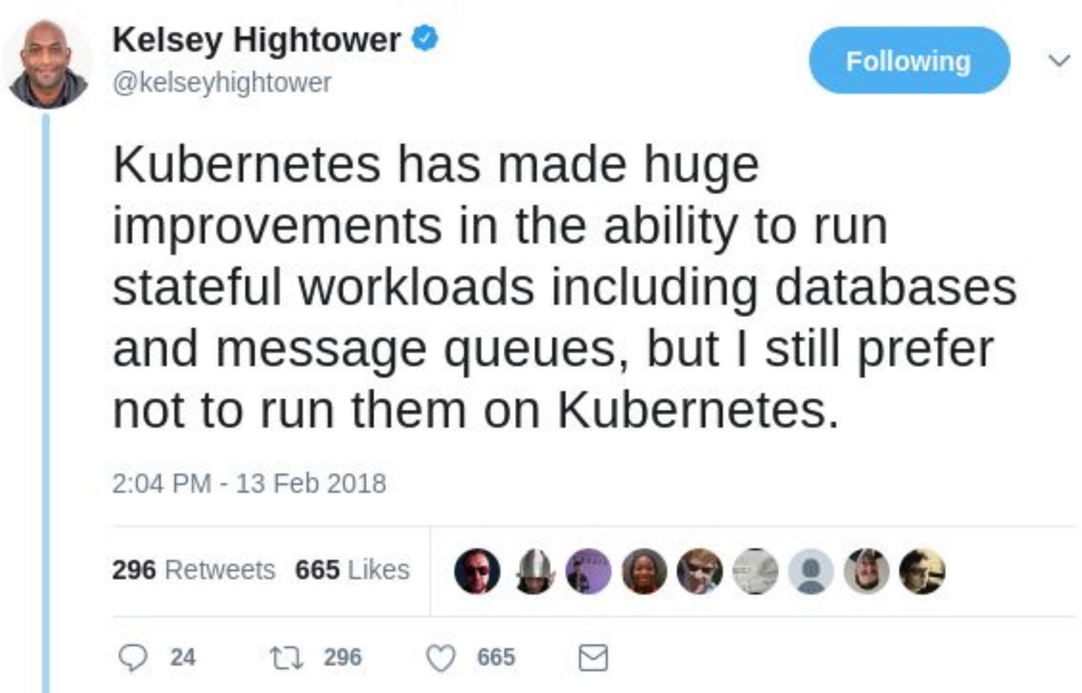


Kelsey Hightower @kelseyhightower · Feb 13

Over time we'll be able to codify that operational expertise into some universal control loop, but that's still a work in progress.

# STATEFUL SERVICES

But there's mixed option



Kelsey Hightower
@kelseyhightower

Kubernetes has made huge improvements in the ability to run stateful workloads including databases and message queues, but I still prefer not to run them on Kubernetes.

2:04 PM - 13 Feb 2018

**296** Retweets **665** Likes

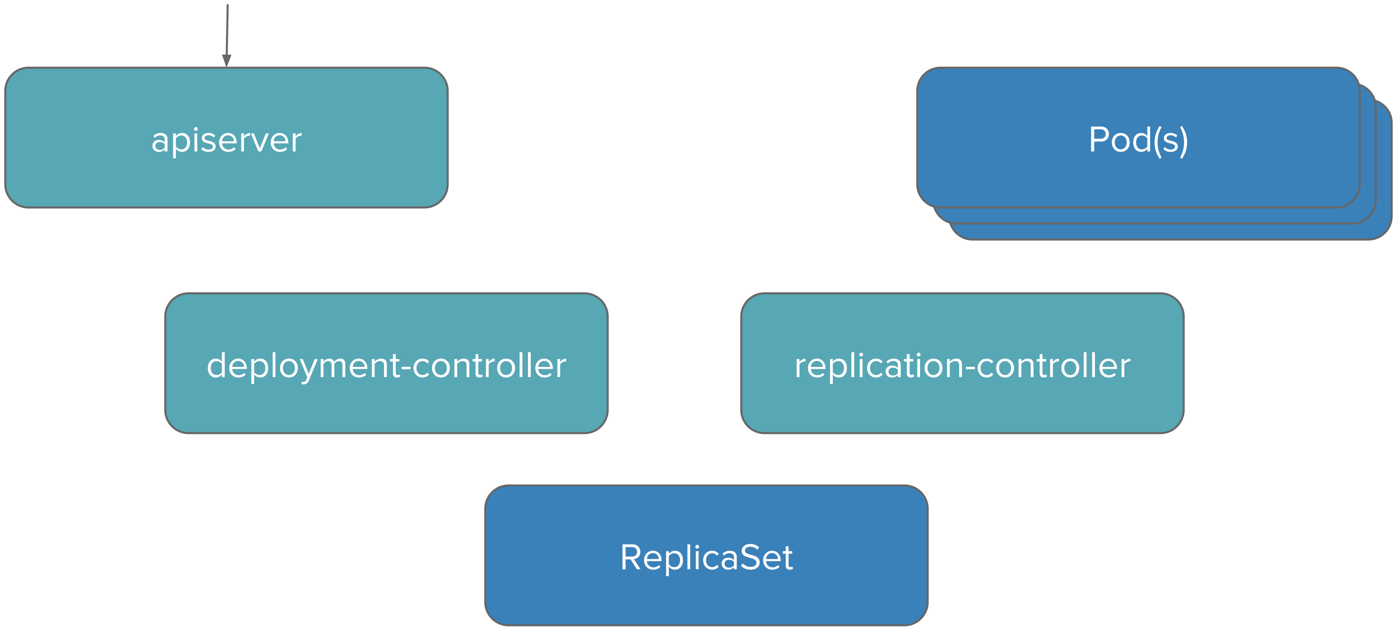
24 296 665

https://twitter.com/kelseyhightower/status/963413508300812295

# RESOURCE LIFECYCLE

## From YAML to pods

```
$ kubectl apply -f deployment.yaml
```


apiserver
Pod(s)
deployment-controller
replication-controller
ReplicaSet