TWO SIGMA

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# Towards Trading on Kubernetes: Operating Multi-Tenant and Secure Clusters

- Javier Diaz-Montes and Andrzej (Andrew) Kochut

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# Two Sigma at a Glance

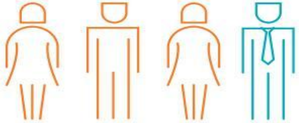
- Systematic investment manager  founded by a computer scientist and a mathematician

- Now 17 years old, 1200+ people

2/3

employees in research and development

72%



non-financial background

- Our mission: discover value in the world’s data

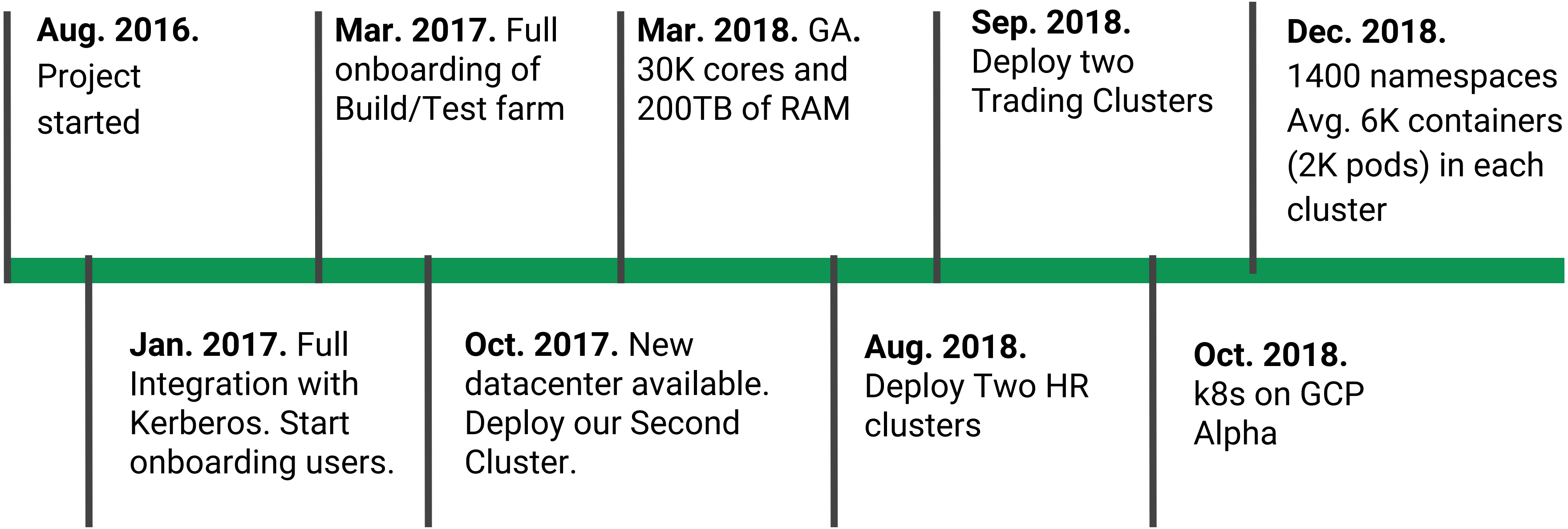
# Introduction

- Two Sigma, as a financial sector company, faces stringent security, resiliency, and isolation requirements
- Concerns such as data exfil by bad actors, as well as that we operate in highly regulated industry, are often a higher priority than for many other industries
- At the same time, we must support a diverse set of applications to perform large-scale data processing and complex mathematical modeling

# Why Kubernetes? Challenges of Private Cloud

- Few cloud-native applications
  - Lack of automation, test automation, and planning for failure
  - Hard to scale horizontally
- VM sprawl
  - Better than bare-metal, but still inefficient utilization
  - High management overhead
- Inconsistent environments
  - Hand-crafted, one-off machines (snowflaky)
  - Dev vs. QA vs. Prod

# Our Kubernetes Journey



**Aug. 2016.** Project started

**Jan. 2017.** Full Integration with Kerberos. Start onboarding users.

**Mar. 2017.** Full onboarding of Build/Test farm

**Oct. 2017.** New datacenter available. Deploy our Second Cluster.

**Mar. 2018.** GA. 30K cores and 200TB of RAM

**Aug. 2018.** Deploy Two HR clusters

**Sep. 2018.** Deploy two Trading Clusters

**Oct. 2018.** k8s on GCP Alpha

**Dec. 2018.** 1400 namespaces Avg. 6K containers (2K pods) in each cluster

# Fitting in Two Sigma Environment

- Stringent security constraints
  - No general access to *root* -- even in containers
  - Users can only use specific role accounts

**Entity**

| | |
|---|---|
| Entity Type: | unix_role_account |
| Unix_login: | tsfoo |
| Unix_uid: | 1234 |
| Unix_gid: | 1111 |

**Relationships**

| | |
|---|---|
| • Can be logged into by: | andrew |
| • Can be logged into by: | javier |
| • Member of group: | tsbar |
| • Member of group: | tsbaz |

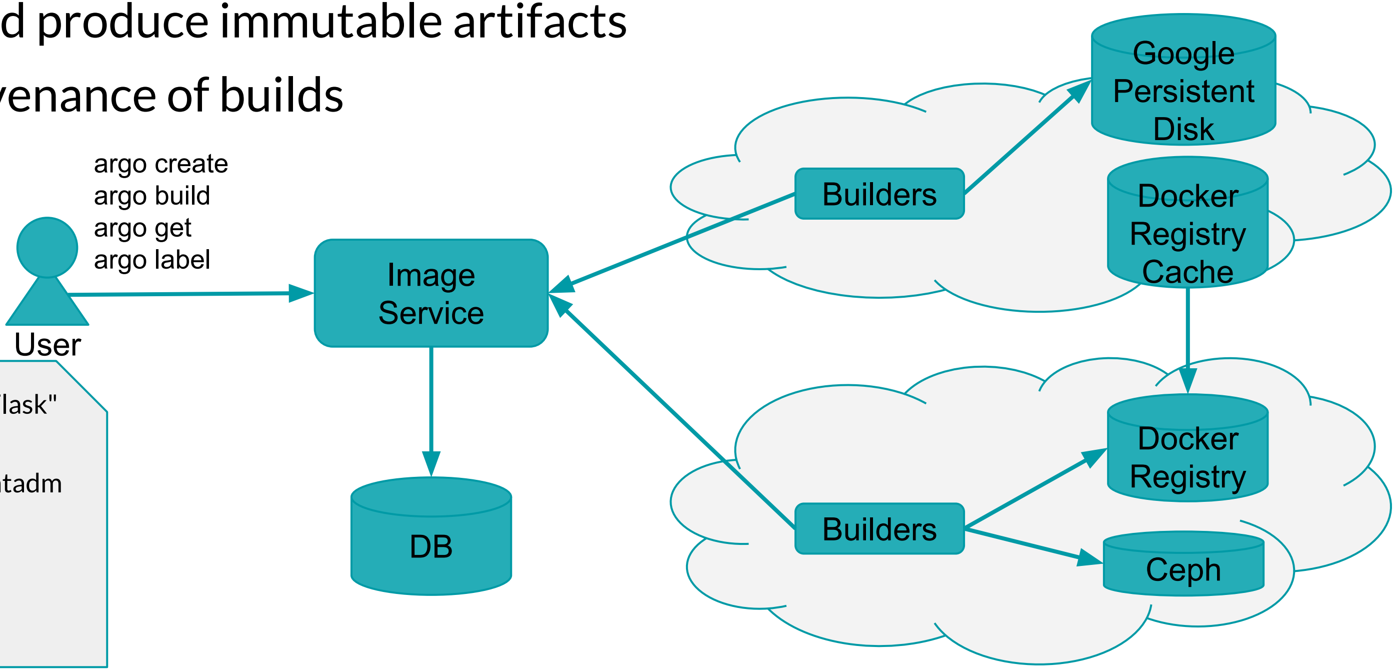
- Large number of heterogeneous applications of limited size

- Multi-tenant cluster integrated with Two Sigma’s entitlements

- Large size of build artifacts not compatible with docker

# Kubernetes at Two Sigma: Building Containers

- Define container image specification (OS, packages, and software artifacts)
- Build it and produce immutable artifacts
- Keep provenance of builds



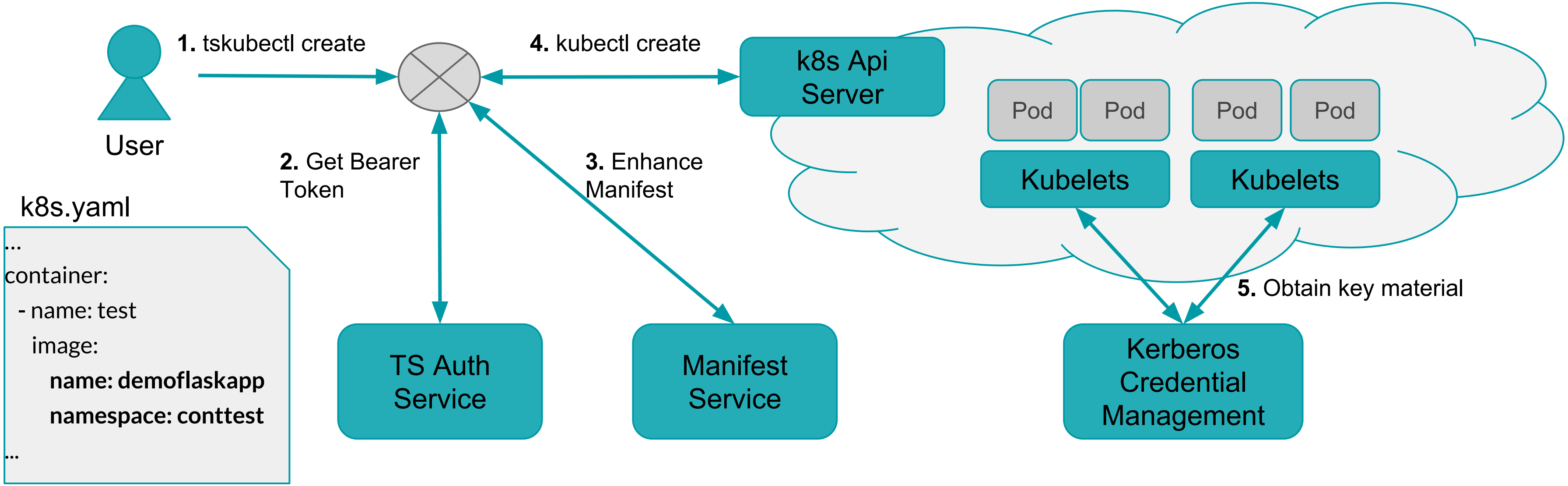
```
argo create
argo build
argo get
argo label
```

spec.yaml

```
description: "HelloWorld Flask"
base_spec_name: stretch
base_spec_namespace: contadm
deployments:
 - k8s-quickstart
name: demoflaskapp
namespace: conttest
```

# Kubernetes at Two Sigma: Running Containers

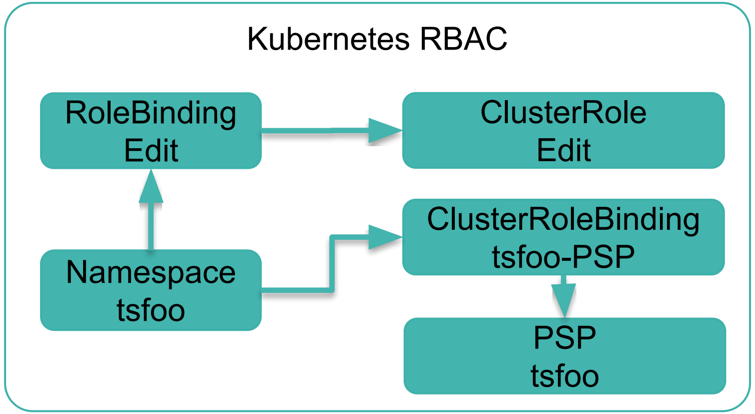
- Service to enhance Kubernetes users' manifests
- Enterprise integrations



```
...
container:
  - name: test
    image:
      name: demoflaskapp
      namespace: conttest
...
```

# Enforcing User Identities in Kubernetes

- Leverage RBAC rules to control user's identities in Kubernetes
  - Associate each user (UID) with a namespace
  - PSP to enforce each namespace can only use its assigned UID and specific supplemental groups
  - Admission controller to enforce runAsUser field in Security Context
- Automatically Synchronize Kubernetes state with our Corporate Identity System



Kubernetes RBAC

RoleBinding Edit

ClusterRole Edit

Namespace tsfoo

ClusterRoleBinding tsfoo-PSP

PSP tsfoo

**Entity**

| | |
|---|---|
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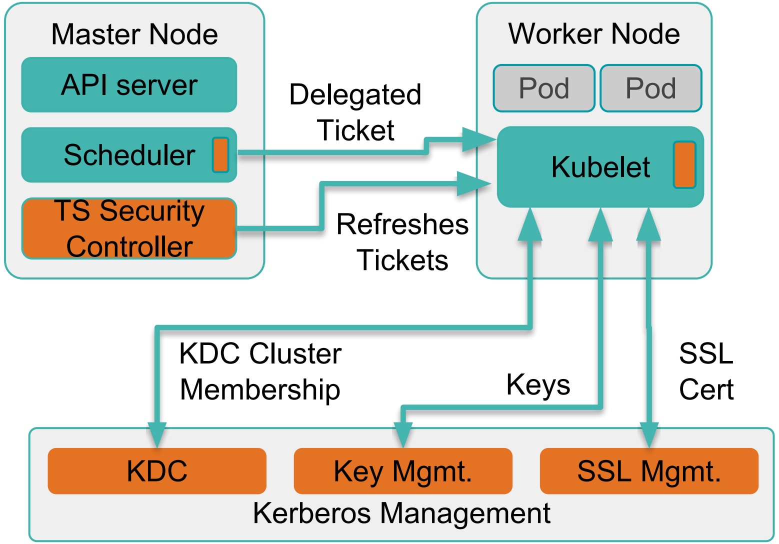
**Relationships**

| | |
|---|---|
| • Can be logged into by: | Andrew |
| • Can be logged into by: | Javier |
| • Member of group: | tsbar |
| • Member of group: | tsbaz |

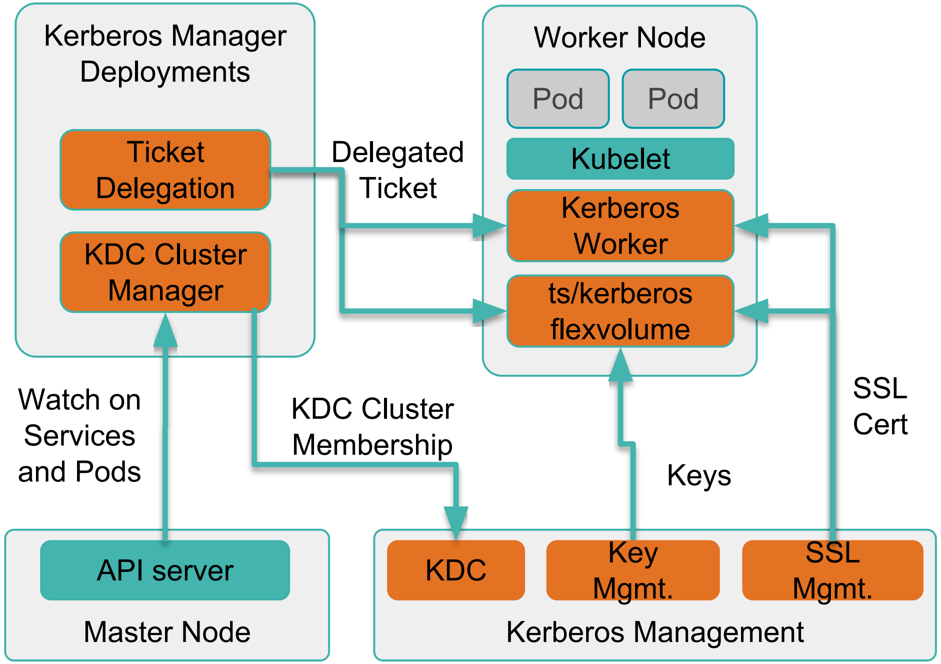
# Kerberos Credential Management - 1st attempt

- User request key material via custom annotations
  - ts/services, ts/prestashtxt, ts/certs
- Challenges:
  - Fork encumbers upgrading Kubernetes
  - Security of  workers managing KDC
  - Negotiating keys when worker nodes go down without deregistering themselves
  - Kerberos infrastructure struggles to keep up with request rate



# Kerberos Credential Management - 2nd attempt

- Create central controller outside of Kubernetes code
- Externalized using flexvolume
- Centralized key distribution mechanisms
- Considering Open Source Kerberos - Kubernetes integration framework



# State of the World

- Total Capacity: ~30k cores, 200TB memory
- Examples:

**Critical Infrastructure**

- Build and test farm
- Integration Testing
- Distributed Memory Cache

**Trading Related Services**

- Post trade data transformation processes
- Event System services

**Burstable Modelling Workloads**

- Interactive Spark Driver
- Modelling workflow
- News translation service

**Cloud Native Microservices**

- People Data Platform
- QA services for Back Office and trading

# Use Case - Build and Test Farm

Runs in containers on K8s for every build and pre-push test in the company

**Metrics:**

- 250k+ builds per day
- 3 million average, 9 million peak tests per day
- 11 TB of artifacts served per day

**Benefits:**

- Machine maintenance was a pain, no longer
- Used to run multiple threads, now use isolation to run one thread / container
- Able to easily run different architectures (Debian Wheezy and Stretch)
- No concerns about scaling during peak times

# Use Case: Continuous Integration with Jenkins

A large central Jenkins for general integration tests of our monorepo, with per team dedicated instances for custom pipelines

***Metrics:***

- Around 5K pipelines and an average of 30K tests per day

**Benefits:**

- Easy to deploy and manage

**Challenges**

- Jenkins-Kubernetes driver generally works, but tries to DoS API Server
- Jenkins manages state using tiny files in disk, does not work well on NFS
- Persistence maintained in Ceph images, provisioned using Kubernetes PVC
    - Mounting persistent volumes using RBD driver is unreliable and has timeouts

# Use Case - news translation

The news team uses Kubernetes to translate foreign language news and documents into English, to be sourced for research

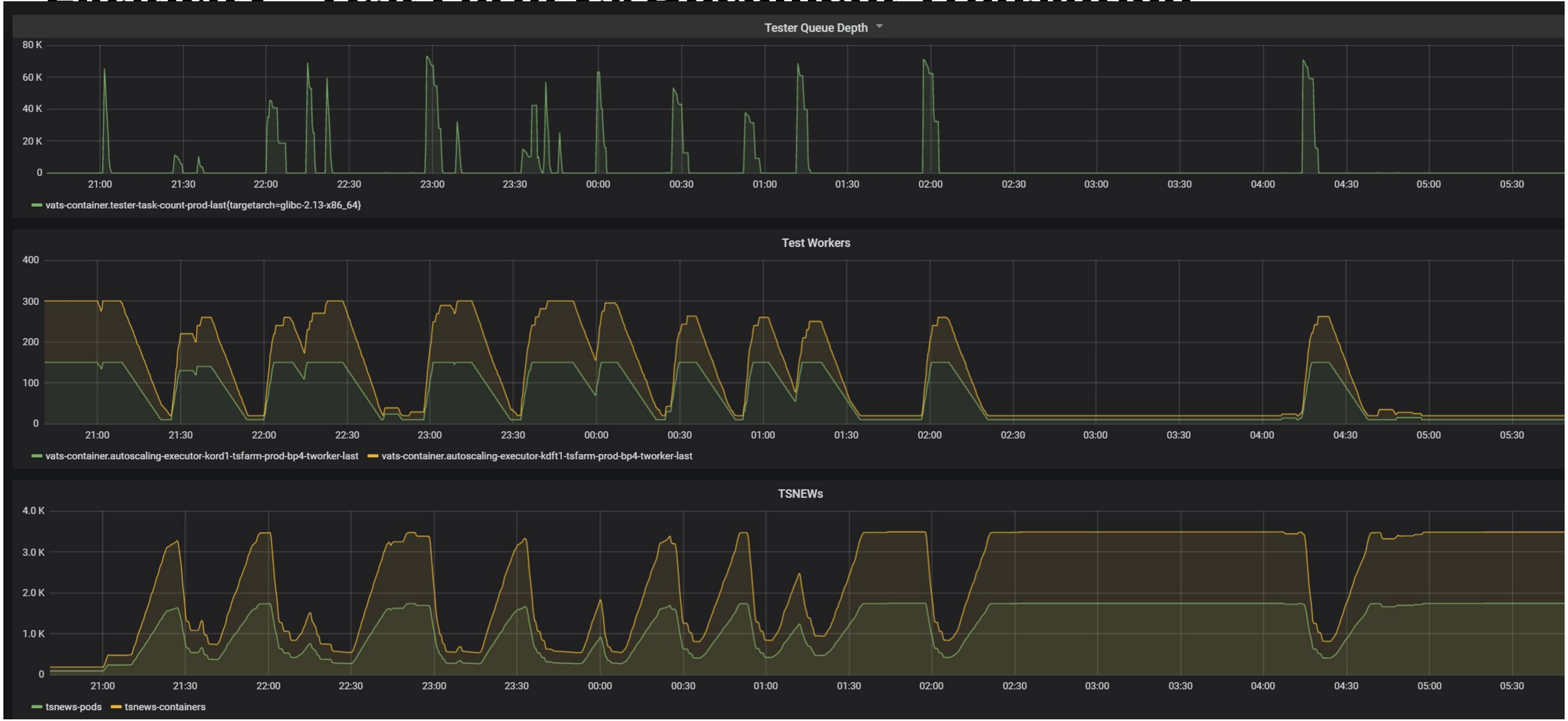
**Metrics:**

- 15 years of data
- 300M documents in 5 different languages

**Benefits:**

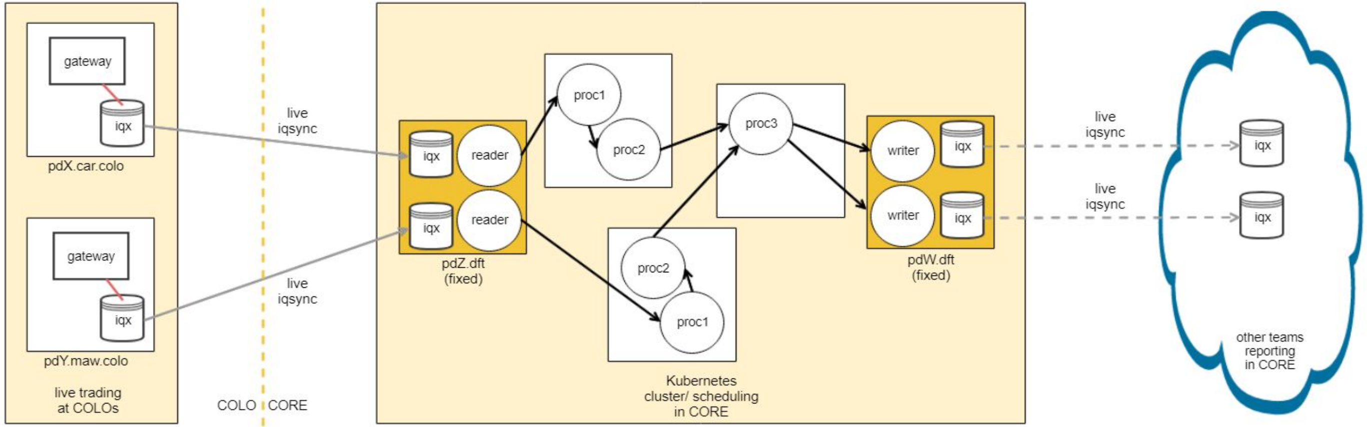
- Running in a container with vendor image by the translation service
- Leverages elasticity of the Kubernetes platform

# Elasticity - Test Farm vs. Document Translation



# Use Case: Trading

- Process post trading data using custom workflow stream engine
- Kubernetes allows easy resource management
- Performance comparable to baremetal
  - Jobs with latency of 100ms from event landed to all relevant reports completed
  - Throughput of 300k x 1kb msgs/s



# Cultural Change: Towards Cloud Native

- Introduced Chaos engineering by default in our general purpose clusters

- Introduced process to triage non-cloud native applications

- Very successful initiative with very few exceptions (e.g., jenkins, Postgres)

# Lessons Learned: Operations

- Building “well-behaved” applications using Kubernetes is not trivial
- Kubernetes has proven to be very resilient and scalable with little effort
- Runtime issues: Enterprise integrations, Docker, OS level
- Kubernetes Scheduler is deterministic and a bad worker can cause issues
- Monitoring for early warning
- Active probing
- Upgrading Kubernetes in place

# Ongoing Work

- Self-healing infrastructure
- Moving towards Kubernetes on Public Cloud -- exploring GCP and  GKE
- Extending scheduler to improve quota management and fairness
- Expanding use cases and adopting more mission critical applications

Questions?