Automated Disaster Recovery for Multi-Region GenAI applications using vector databases on Kubernetes

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Agenda

1. Intro - “AI is magic”
2. Problem space
    a. pgvector on Kubernetes 101
    b. Multi-region deployments
    c. Disaster Recovery (DR) problems
3. Automating DR
4. Demo
5. Q&A

AI is Magic

Creativity and imagination

Pretty kitten working behind the laptop

Unicorn plays hockey

Dad became a monster, cause we broke his Lego

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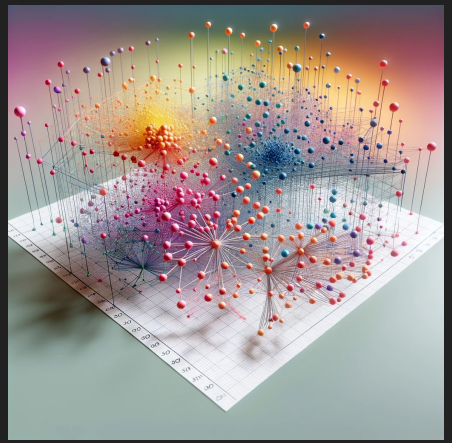
AI is magic, but for Muggles

Various technologies power AI:

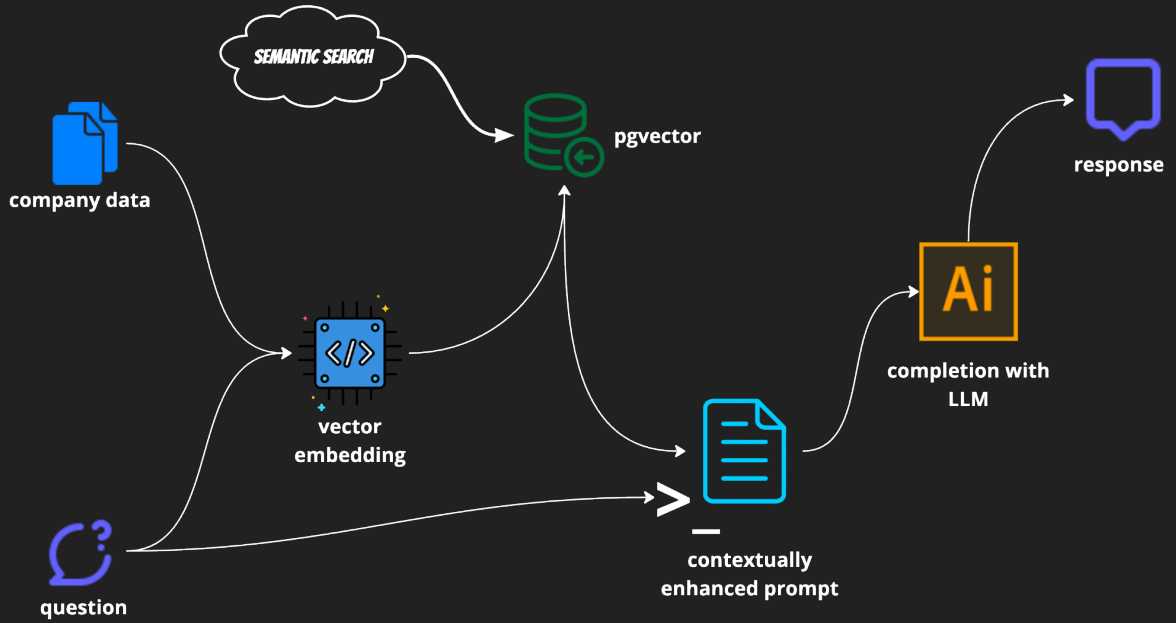
- Large Language Models - heart of modern Generative AI
  - Powered by Transformers (Attention is All You Need)
- GPUs for training
- Vector databases for semantic search, visual or multimodal search
  - Through vector embeddings

Everything is a vector



This is how DALL-E sees vector embedding

Example of RAG - Retrieval Augmented Generation



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Vector databases

Various options

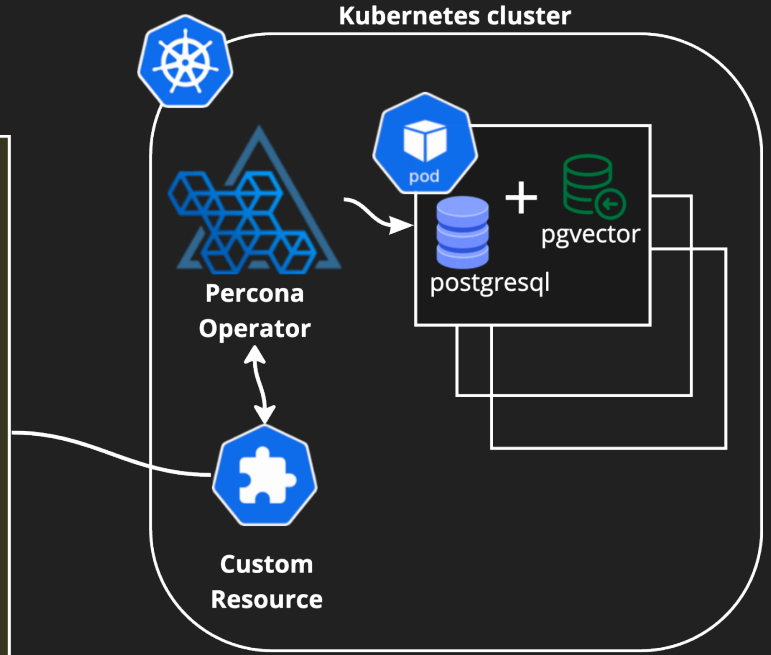
- Pinecone
- Milvus
- Chroma
- FAISS
- pgvector (extension for PostgreSQL)

Problem space

pgvector on Kubernetes

YAML manifest

```
apiVersion:
pgv2.percona.com/v2
kind: PerconaPGCluster
metadata:
  name: my-pg
spec:
  instances:
    - name: pgvector1
      replicas: 3
...
extensions:
  custom:
  - name: pgvector
    version: 0.5.1
```



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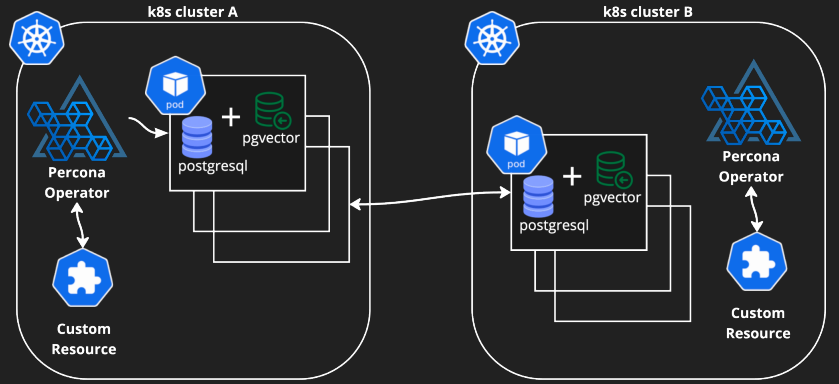
Why multi-region

- Not only multi-region:
  - multi-cloud
  - hybrid-cloud
- Main reasons
  - Disaster recovery
  - Migration
  - No-vendor lock-in / cloud-ready



Disaster recovery

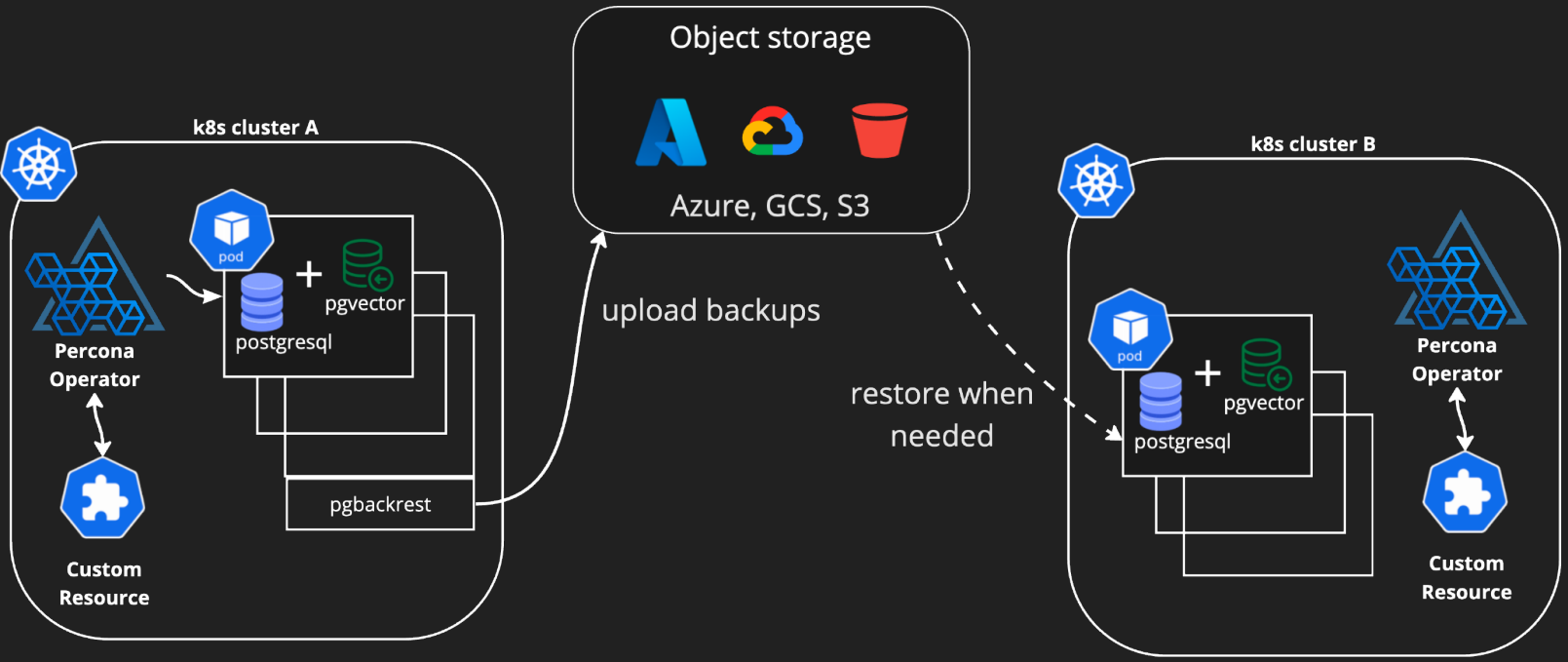
Recovery Time Objective (RTO)

- How fast do you recover from failure?

Recovery Point Objective (RPO)

- What is your last transaction?

DR through Backups - high RTO



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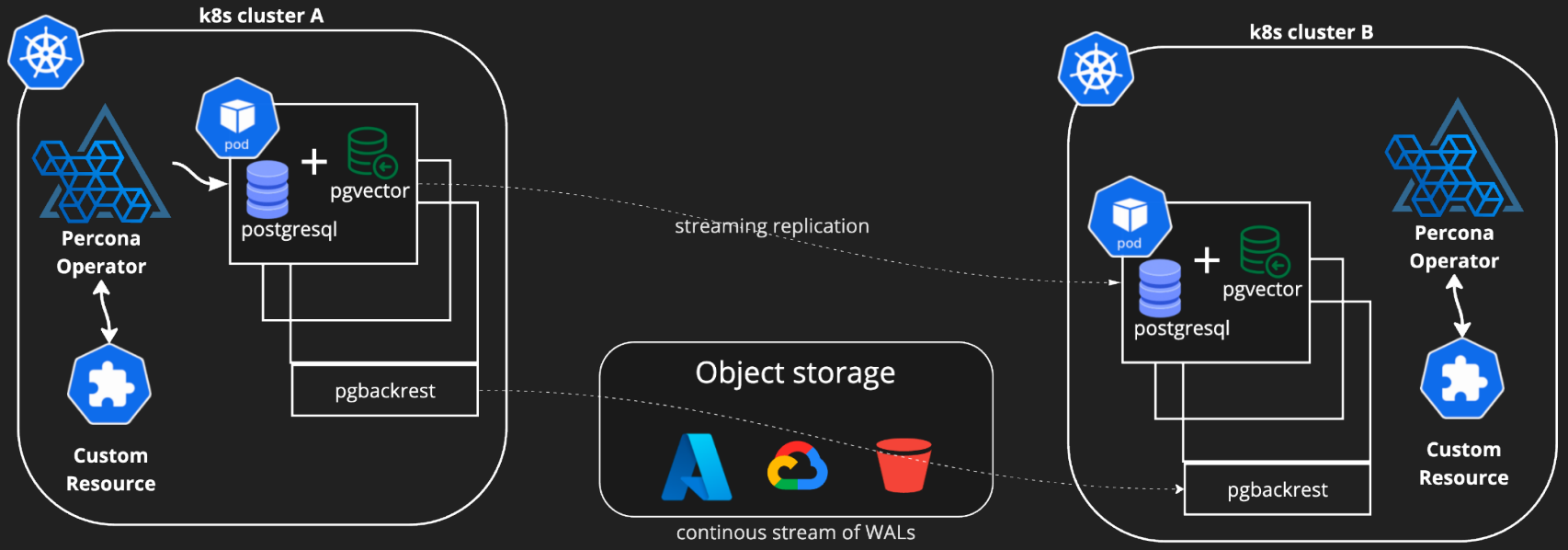
DR through Replication - low RTO



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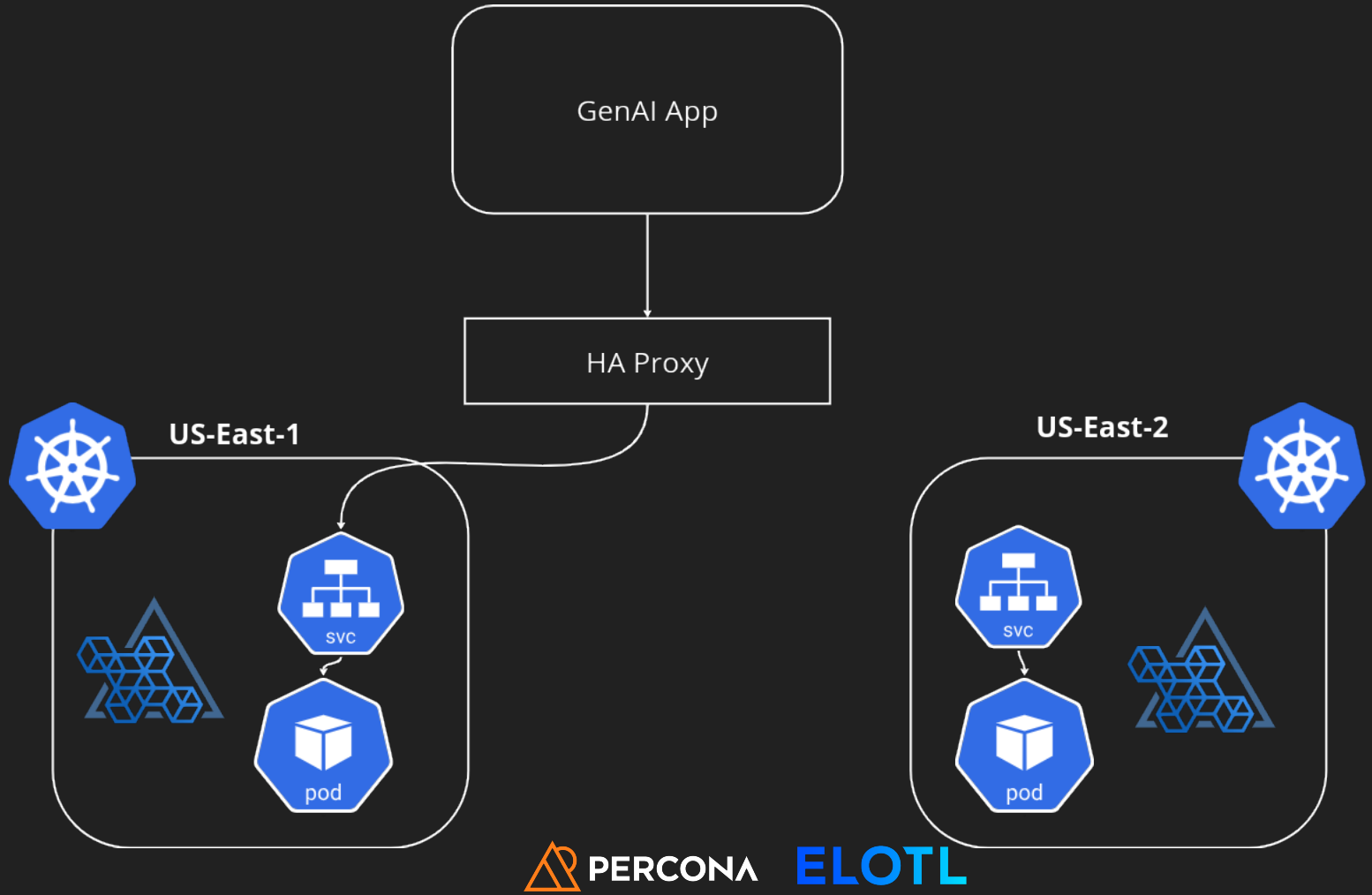
Looks like problem solved?

1. Recover fast from failure
2. Recovery Point Objective is solved on DB level
    a. For streaming replication it can be down to almost 0

What about the app and failover?

1. Failover is not automated
    - Operators can detect failure, but 3rd agent needed (quorum)
2. Point application to correct database
    - Which endpoint should the app use when failover happens?
    - Who is reconfiguring it and how?
3. Failback
    - What should happen when main site goes back up?

💡 Automating DR


GenAI App
HA Proxy
US-East-1
svc
pod
US-East-2
svc
pod
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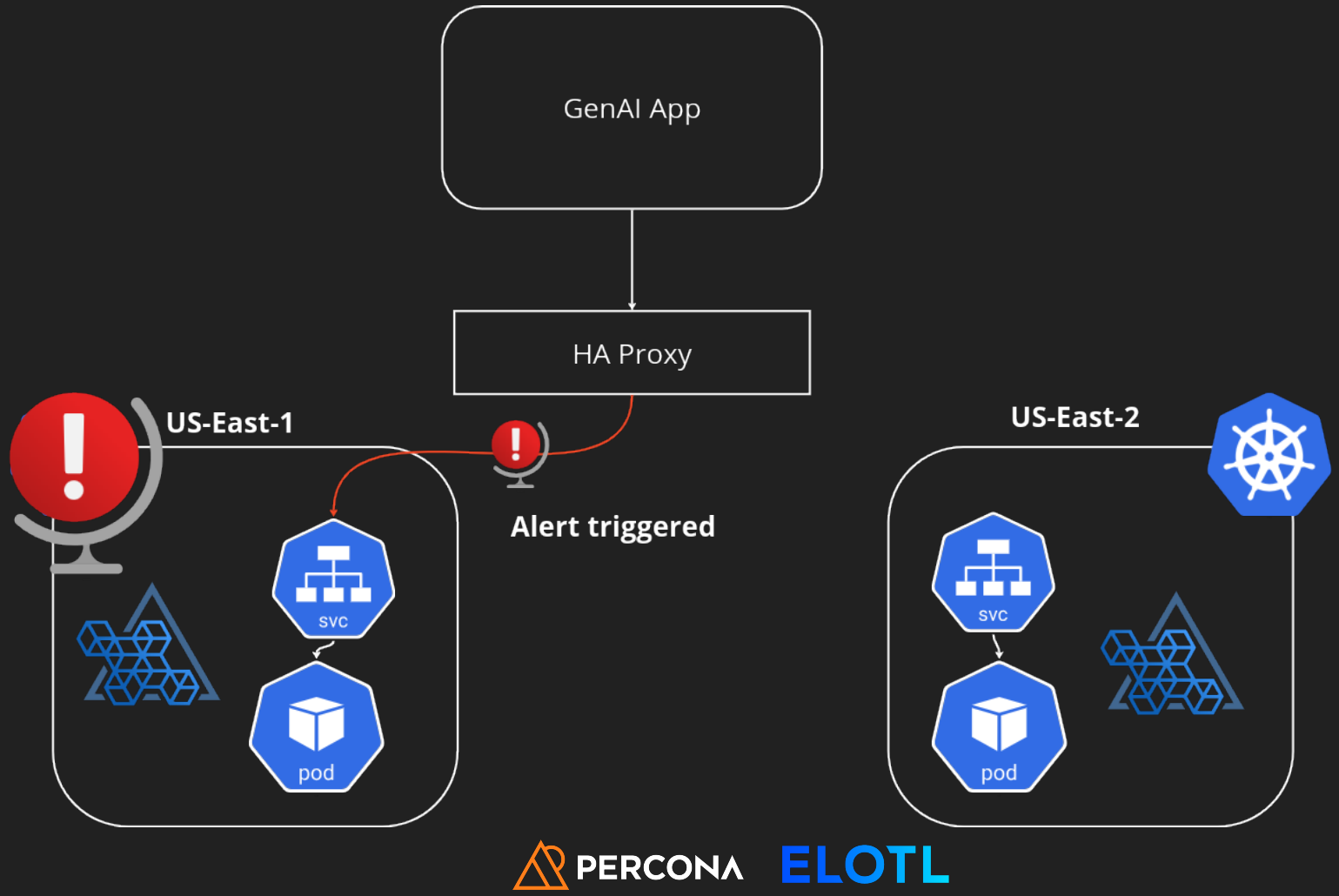
GenAI App
HA Proxy
US-East-1
Alert triggered
US-East-2
svc
pod
svc
pod
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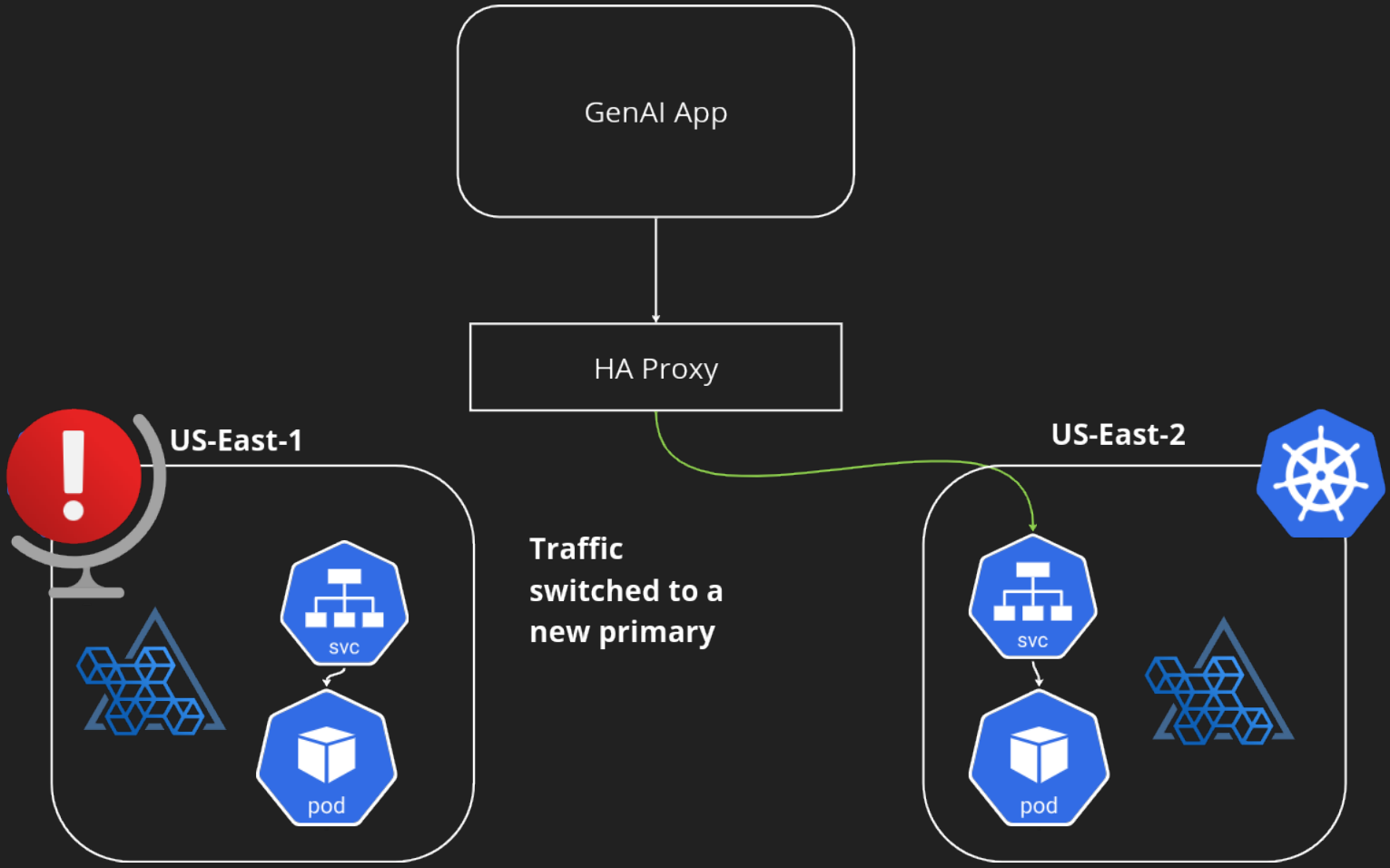

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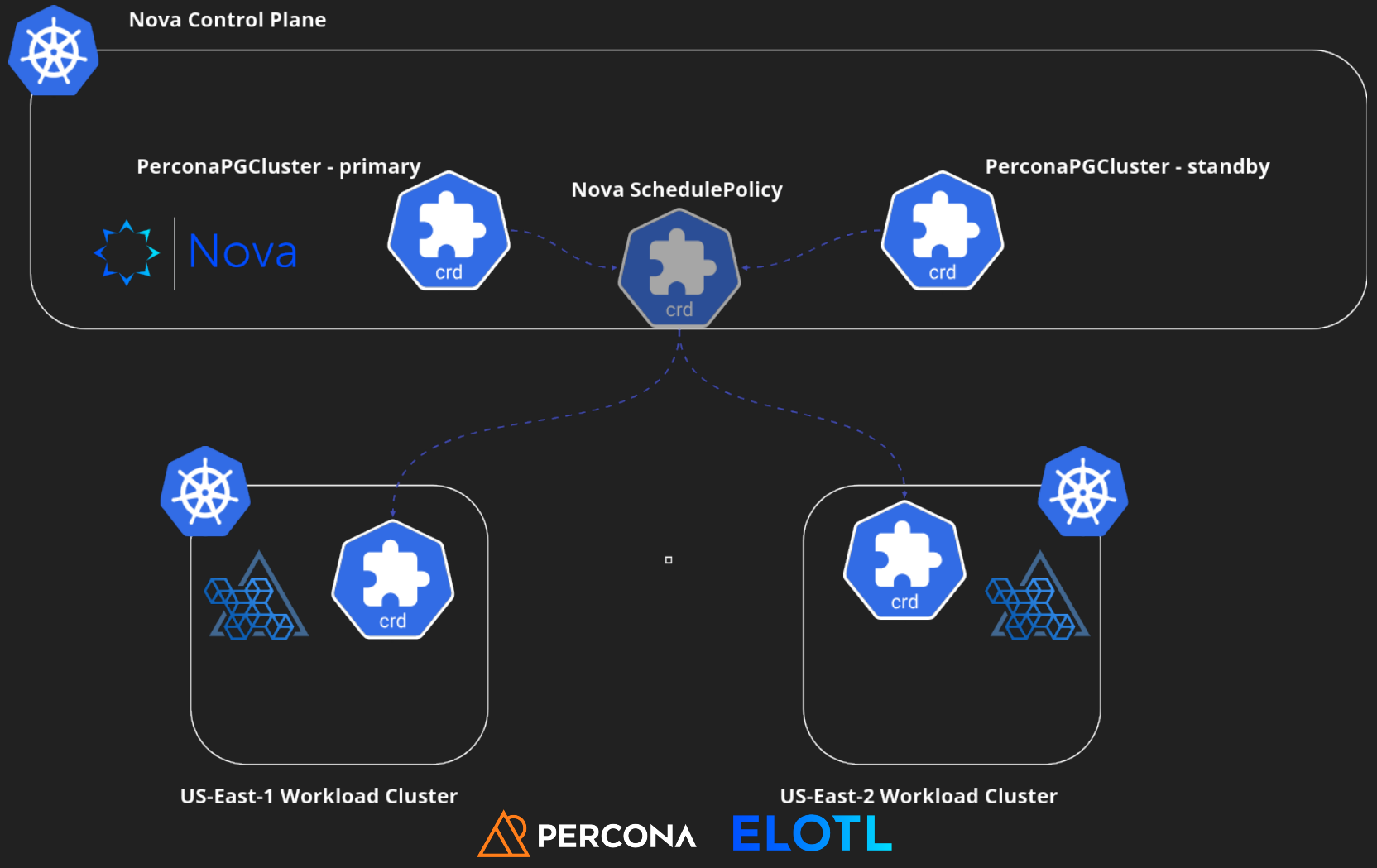
Nova Control Plane
PerconaPGCluster - primary
Nova
crd
Nova SchedulePolicy
crd
PerconaPGCluster - standby
crd
crd
crd
US-East-1 Workload Cluster
US-East-2 Workload Cluster
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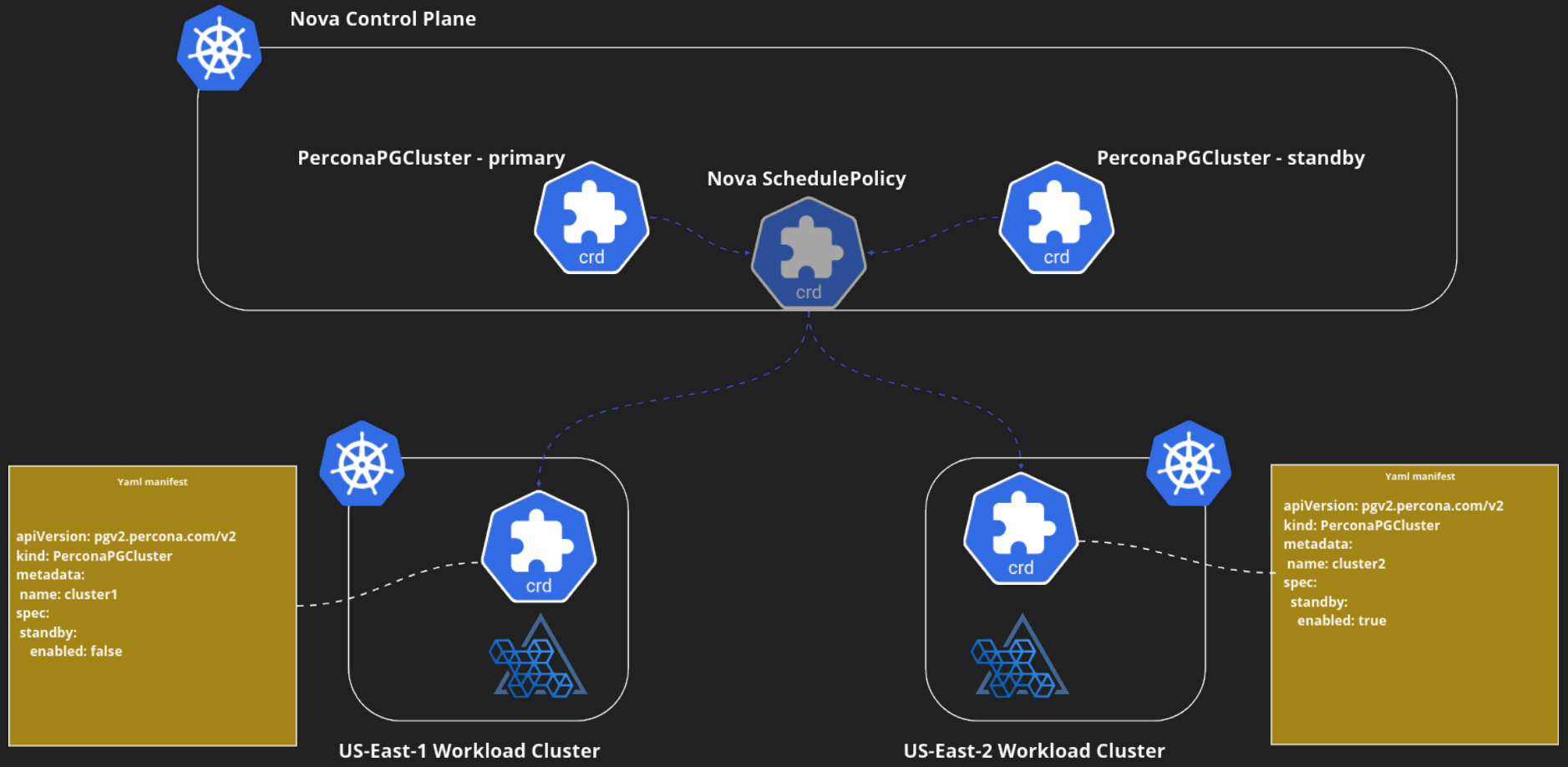

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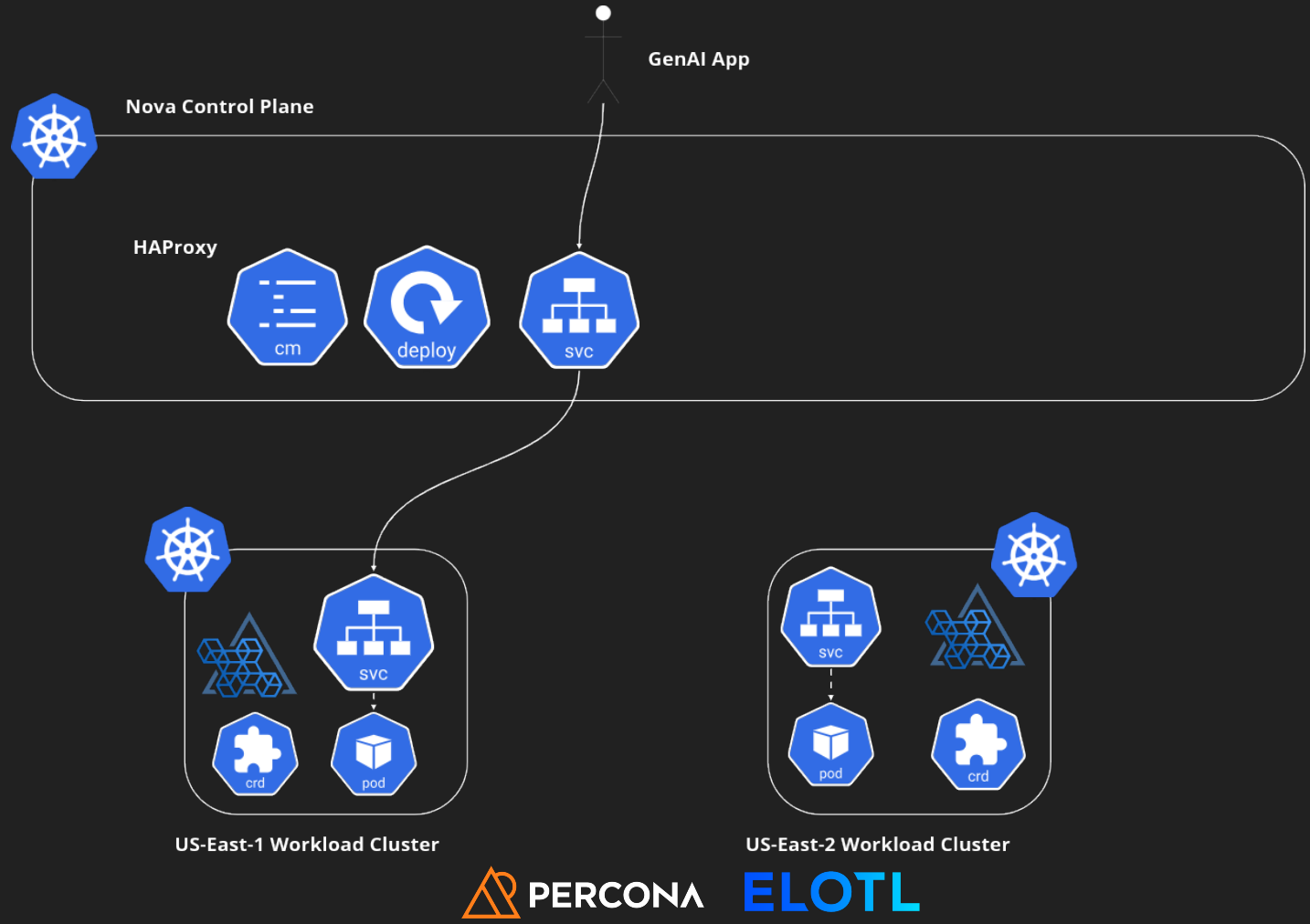

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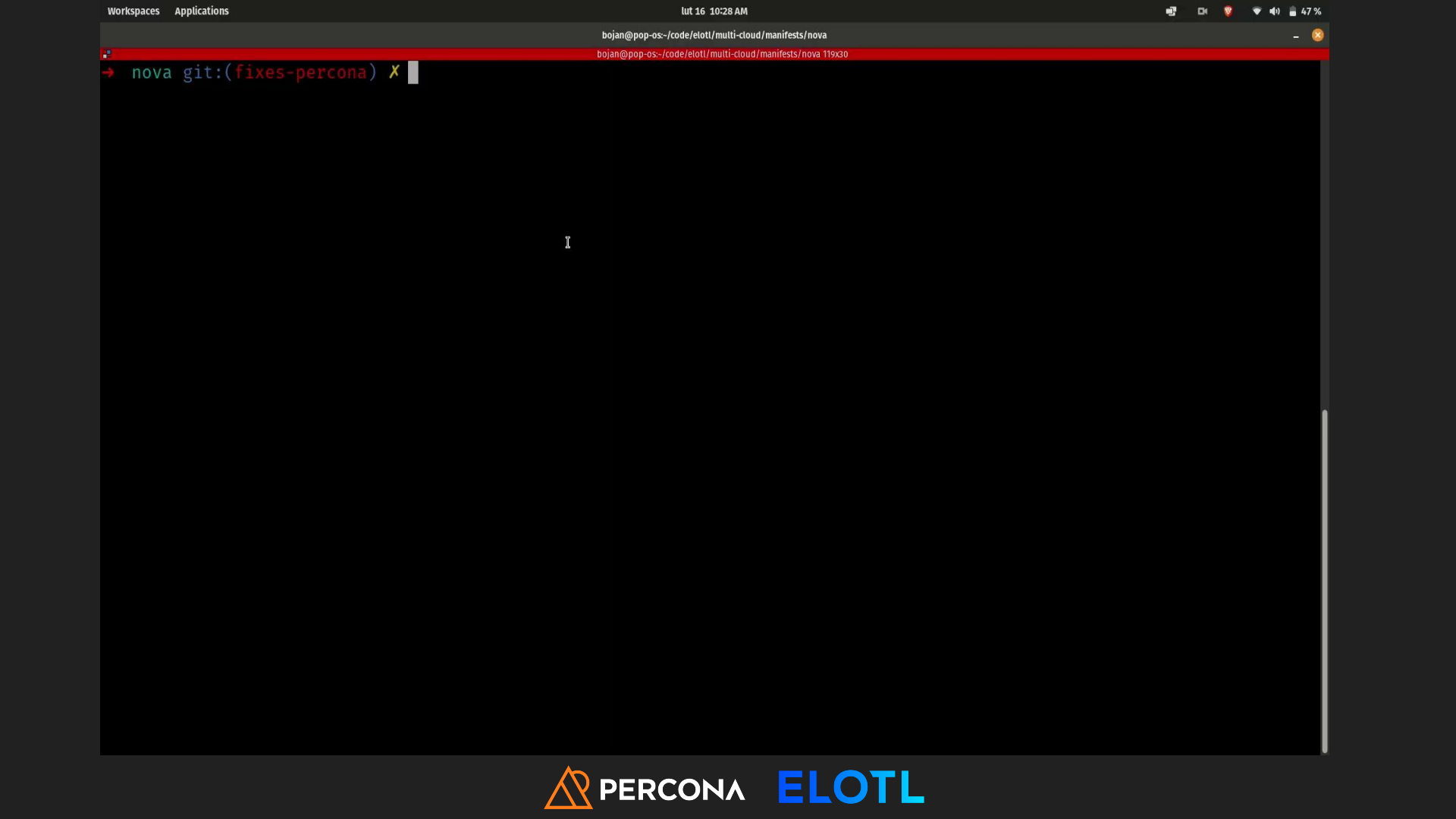
Workspaces
Applications
lut 16 10:28 AM
47 %
bojan@pop-os:~/code/elotl/multi-cloud/manifests/nova
bojan@pop-os:~/code/elotl/multi-cloud/manifests/nova 119x30
nova git:(fixes-percona) ✗
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```yaml
apiVersion: recovery.elotl.co/v1alpha1
kind: RecoveryPlan
metadata:
 name: psql-primary-failover-plan
spec:
 alertLabels:
  app: example-app
 steps:

  - type: patch
    patch:
      apiVersion: "pgv2.percona.com/v2"
      resource: "perconapgclusters"
      namespace: "psql-operator"
      name: "cluster1"
      override:
        fieldPath: "spec.standby.enabled"
        value:
          raw: false
      patchType: "application/merge-patch+json"

  - type: patch
    patch:
      apiVersion: "pgv2.percona.com/v2"
      resource: "perconapgclusters"
      namespace: "psql-operator"
      name: "cluster2"
      override:
        fieldPath: "spec.standby.enabled"
        value:
          raw: true
      patchType: "application/merge-patch+json"
```

Matches metadata of incoming alert (e.g. from prometheus)

```yaml
groups:
- name: example
  rules:
  - alert: HighRequestLatency
    expr: percona_pg_cluster_failure_total{cluster="cluster-1"} > 0
    for: 10m
    labels:
      app: example-app
```

https://prometheus.io/docs/alerting/latest/configuration/#webhook_config

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```
apiVersion: recovery.elotl.co/v1alpha1
kind: RecoveryPlan
metadata:
 name: psql-primary-failover-plan
spec:
 alertLabels:
   app: example-app
 steps:

 - type: patch
   patch:
     apiVersion: "pgv2.percona.com/v2"
     resource: "perconapgclusters"
     namespace: "psql-operator"
     name: "cluster1"
     override:
       fieldPath: "spec.standby.enabled"
       value:
         raw: true
     patchType: "application/merge-patch+json"

 - type: patch
   patch:
     apiVersion: "pgv2.percona.com/v2"
     resource: "perconapgclusters"
     namespace: "psql-operator"
     name: "cluster2"
     override:
       fieldPath: "spec.standby.enabled"
       value:
         raw: false
     patchType: "application/merge-patch+json"

 - type: readField
```

Puts PerconaPGCluster primary into standby

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```yaml
apiVersion: recovery.elotl.co/v1alpha1
kind: RecoveryPlan
metadata:
 name: psql-primary-failover-plan
spec:
  alertLabels:
    app: example-app
  steps:

    - type: patch
      patch:
        apiVersion: "pgv2.percona.com/v2"
        resource: "perconapgclusters"
        namespace: "psql-operator"
        name: "cluster1"
        override:
          fieldPath: "spec.standby.enabled"
          value:
            raw: true
        patchType: "application/merge-patch+json"

    - type: patch
      patch:
        apiVersion: "pgv2.percona.com/v2"
        resource: "perconapgclusters"
        namespace: "psql-operator"
        name: "cluster2"
        override:
          fieldPath: "spec.standby.enabled"
          value:
            raw: false
        patchType: "application/merge-patch+json"

    - type: readField
```

Turns PerconaPGCluster standby into primary

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```
- type: patch
  patch:
    apiVersion: "pgv2.percona.com/v2"
    resource: "perconapgclusters"
    namespace: "psql-operator"
    name: "cluster1"
    override:
      fieldPath: "spec.standby.enabled"
      value:
        raw: true
    patchType: "application/merge-patch+json"

- type: patch
  patch:
    apiVersion: "pgv2.percona.com/v2"
    resource: "perconapgclusters"
    namespace: "psql-operator"
    name: "cluster2"
    override:
      fieldPath: "spec.standby.enabled"
      value:
        raw: false
    patchType: "application/merge-patch+json"

- type: readField
  readField:
    apiVersion: "pgv2.percona.com/v2"
    resource: "perconapgclusters"
    namespace: "psql-operator"
    name: "cluster2"
    fieldPath: "status.host"
    outputKey: "Cluster2IP"

- patch:
    apiVersion: "v1"
    resource: "configmaps"
    namespace: "default"
```

Reads address of a new primary

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```
- type: patch
  patch:
    apiVersion: "pgv2.percona.com/v2"
    resource: "perconapgclusters"
    namespace: "psql-operator"
    name: "cluster2"
    override:
      fieldPath: "spec.standby.enabled"
      value:
        raw: false
    patchType: "application/merge-patch+json"

- type: readField
  readField:
    apiVersion: "pgv2.percona.com/v2"
    resource: "perconapgclusters"
    namespace: "psql-operator"
    name: "cluster2"
    fieldPath: "status.host"
    outputKey: "Cluster2IP"
```

Updates HAProxy configuration with an address of a new primary

```
- patch:
    apiVersion: "v1"
    resource: "configmaps"
    namespace: "default"
    name: "haproxy-config"
    override:
      fieldPath: "data"
      value:
        raw: {"haproxy.cfg": "defaults\n    mode tcp\n    timeout connect 5000ms\n    timeout client 50000ms\n    timeout server
50000ms\n\nfrontend fe_main\n    bind *:5432\n    default_backend be_db_2\n\nbackend be_db_2\n    server db2 {{ .Values.Cluster2IP
}}:5432 check"}

    patchType: "application/merge-patch+json"
  type: patch
```

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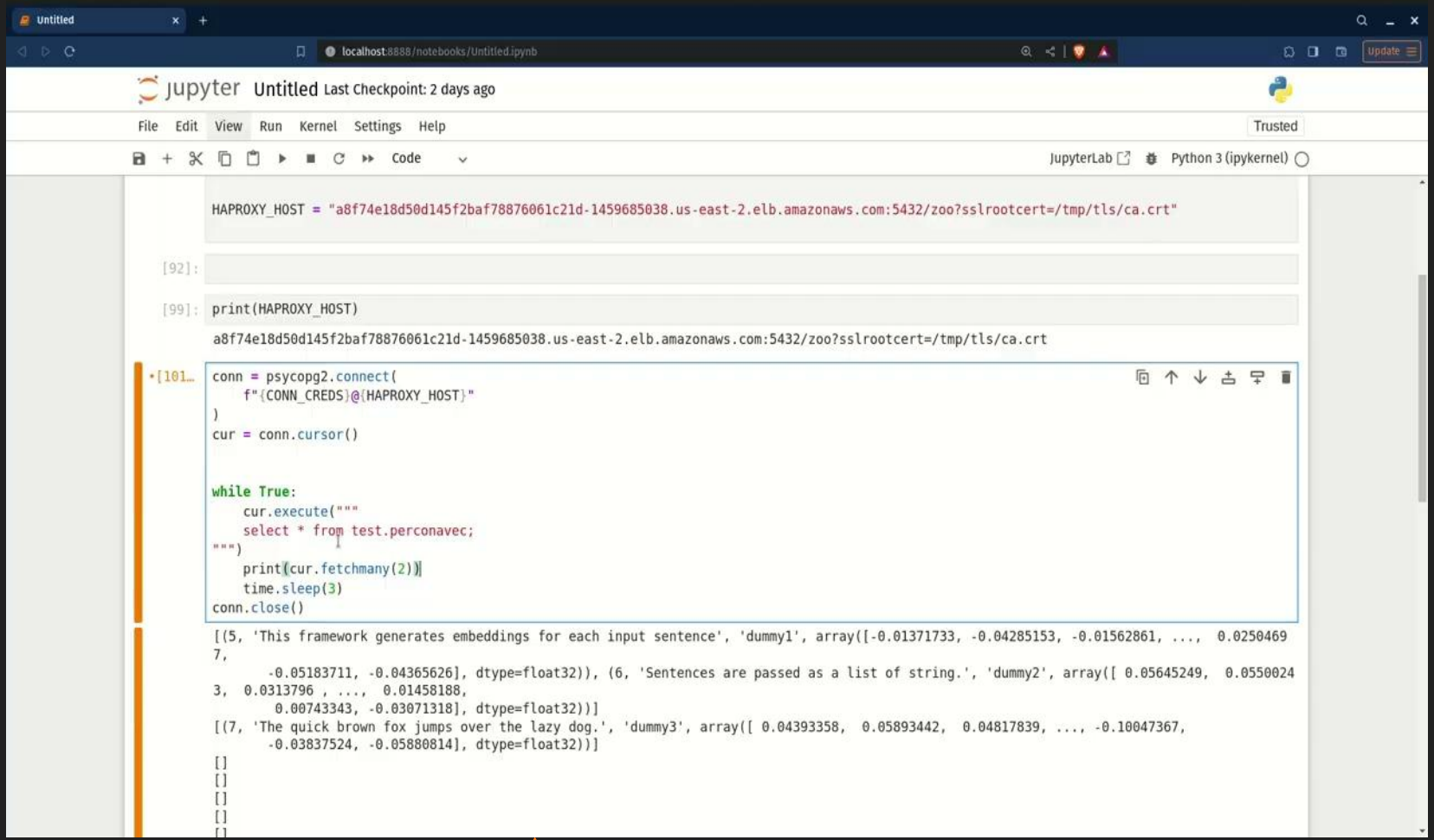
Demo



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Nova’s secret sauce: Schedule Policies


```
apiVersion: pgv2.percona.com/v2
kind: PerconaPGCluster
metadata:
 name: cluster1
 namespace: psql-operator
 labels:
   psql-cluster: cluster-1
spec:
  ...
```

```
apiVersion: policy.elotl.co/v1alpha1
kind: SchedulePolicy
metadata:
 name: psql-cluster-1
spec:
 namespaceSelector:
  matchLabels:
   kubernetes.io/metadata.name: psql-operator
 clusterSelector:
  matchLabels:
    kubernetes.io/metadata.name: us-east-1-wlc
 resourceSelectors:
  labelSelectors:
   - matchLabels:
      psql-cluster: cluster-1
```

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```
kind: CustomResourceDefinition
metadata:
 labels:
   psql-cluster: all
names:
  kind: PerconaPGBackup
  ...
---
apiVersion: apiextensions.k8s.io/v1
kind: CustomResourceDefinition
metadata:
  labels:
    psql-cluster: all
names:
  kind: PerconaPGCluster
  ...
---
apiVersion: apps/v1
kind: Deployment
metadata:
  labels:
    psql-cluster: all
    ...
```

```
apiVersion: policy.elotl.co/v1alpha1
kind: SchedulePolicy
metadata:
 name: psql-all-clusters
spec:
  namespaceSelector:
    matchLabels:
      kubernetes.io/metadata.name: psql-operator
  groupBy:
    labelKey: psql-cluster
  clusterSelector:
    matchExpressions:
      - key: kubernetes.io/metadata.name
        operator: In
        values:
          - us-east-1-wlc
          - us-east-2-wlc
  spreadConstraints:
    spreadMode: Duplicate
    topologyKey: kubernetes.io/metadata.name
  resourceSelectors:
    labelSelectors:
      - matchLabels:
          psql-cluster: all
```

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Thank you!

Learn more:

Percona Operators

Elotl Nova

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