epics-containers

A workshop to look at containerizing EPICS IOCs

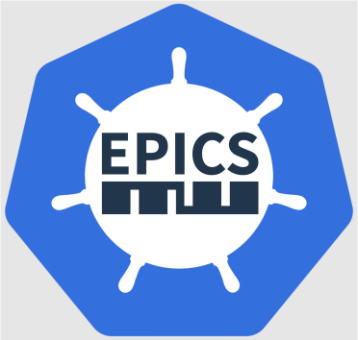
EPICS Collaboration Meeting @ ORNL

Sept 16th, 2024

giles knap & Marcell Nagy

Beamline Controls – Diamond Light Source

epics-containers workshop ORNL



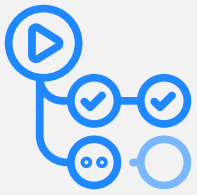
- 13:40 – Presentation: an overview of epics-containers
- 14:20 – Questions
- 14:30 – Hands On Tutorials: Create an IOC in a container
- 15:00 – Break
- 15:30 – Demo: Kubernetes and ArgoCD on a DLS test beamline
- 16:10 – Questions and discussion
- 16:30 – Hands On Tutorials continued
- 17:10 - End

Preamble

- This presentation is about how DLS will be building and managing IOCs using containers.
- However, we have applied the following principals to make this work useful to other facilities:
  - **Open source first**. All source, re-usable containers, example beamlines and documentation is available at https://github.com/epics-containers.
  - **Modular.** All parts of the framework are as far as practical independent – you may adopt just the features you find useful.
  - **Standard EPICS only.** We use the default EPICS build system, upstream versions of EPICS base and support modules.
  - **Standard Tools only.** The tools used in the framework are widely adopted FOSS only.
- The SPARC beamline at INFN-LNF in Rome is already using epics-containers in production.

What?

Applying modern industry practices for software delivery to EPICS IOCs



Containers: Package IOC software and execute it in a lightweight virtual environment

Kubernetes: Orchestrates all IOCs at a facility

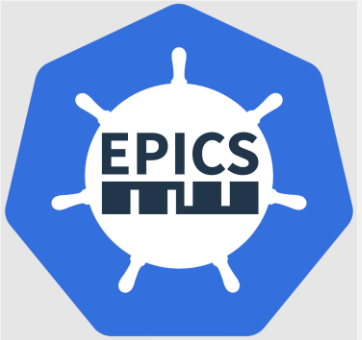
Helm Charts: Deploy IOCs into Kubernetes with version management

Repositories: Source and container repositories manage all the above assets

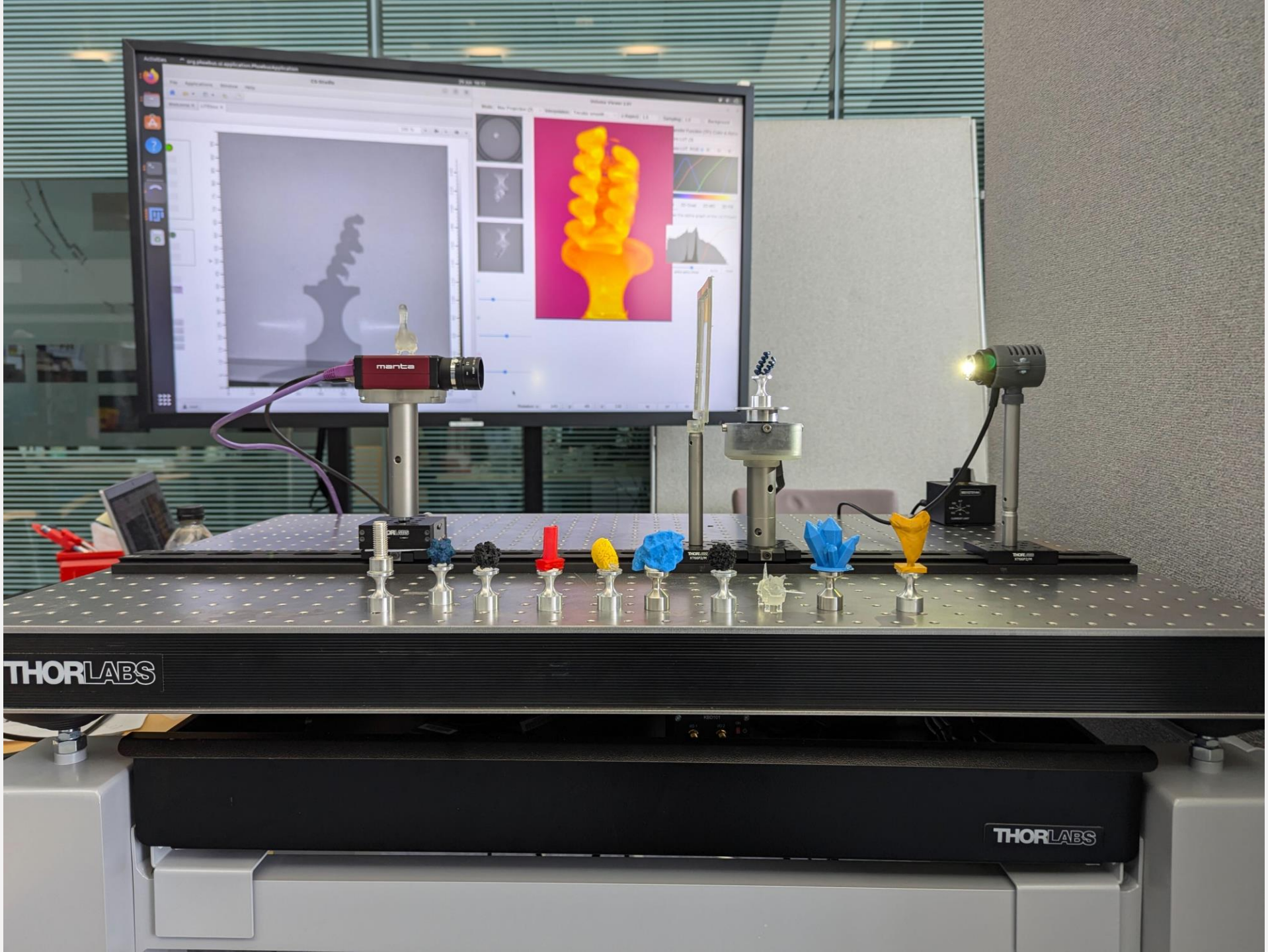
CI: Source repositories automatically build assets from source when updated

CD: Deployment repositories are automatically synced with the cluster

Why?



- IOCs are decoupled from the OS
  - No modifying support modules to suit facility infrastructure
  - Allows us to use upstream support modules with no need for local forks
  - Protection from many security vulnerabilities
- Simple server setup: any Linux + container runtime only.
  - Very easy server OS upgrades
- Remove maintenance of internal management tools
- Kubernetes provides (not just for IOCs!):
  - Shared software deployment and management
  - Shared Logging, monitoring, alerting
  - Shared resource management: Disk / CPU / Memory
  - Skills required are transferrable
  - A huge range of supporting tools and applications both FOSS and licensed
  - Just Google it when things go wrong



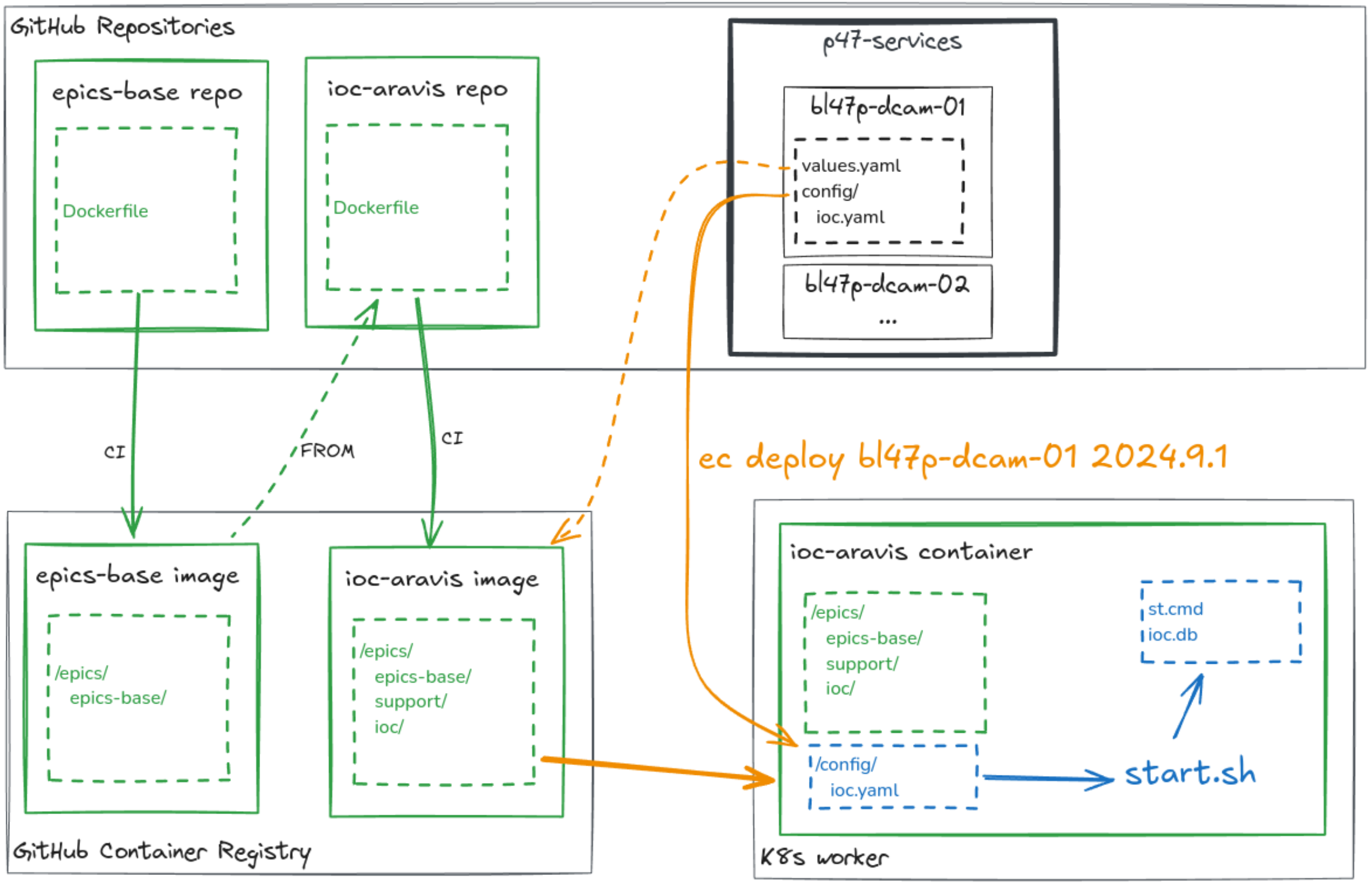
Why?

Portability:

Develop anywhere.
Execute anywhere.

e.g.
DIAD's portable tomography demo made for the RAL public open day.

How?


GitHub Repositories
epics-base repo
Dockerfile
ioc-aravis repo
Dockerfile
p47-services
bl47p-dcam-01
values.yaml
config/
ioc.yaml
bl47p-dcam-02
...
CI
FROM
CI
ec deploy bl47p-dcam-01 2024.9.1
epics-base image
/epics/
epics-base/
ioc-aravis image
/epics/
epics-base/
support/
ioc/
GitHub Container Registry
ioc-aravis container
/epics/
epics-base/
support/
ioc/
st.cmd
ioc.db
/config/
ioc.yaml
start.sh
K8s worker

Supporting Tools

- **ibek –** IOC builder for EPICS and Kubernetes
  - Runs inside the container at build time
    - Helpers for building Support and Generic IOC in the container environment
  - Runs inside the container at runtime startup
    - Makes IOC instance startup script and database from a YAML description
    - Extracts IOC instance engineering screens from the container

- **ec –** the epics containers CLI for developers
  - Runs outside the container
    - Helpers for building and deploy IOC Instances
    - Helpers for local debugging and testing of Generic IOCs
    - Thin wrapper around the tools git, helm, kubectl and argocd – can be used to learn these tools too

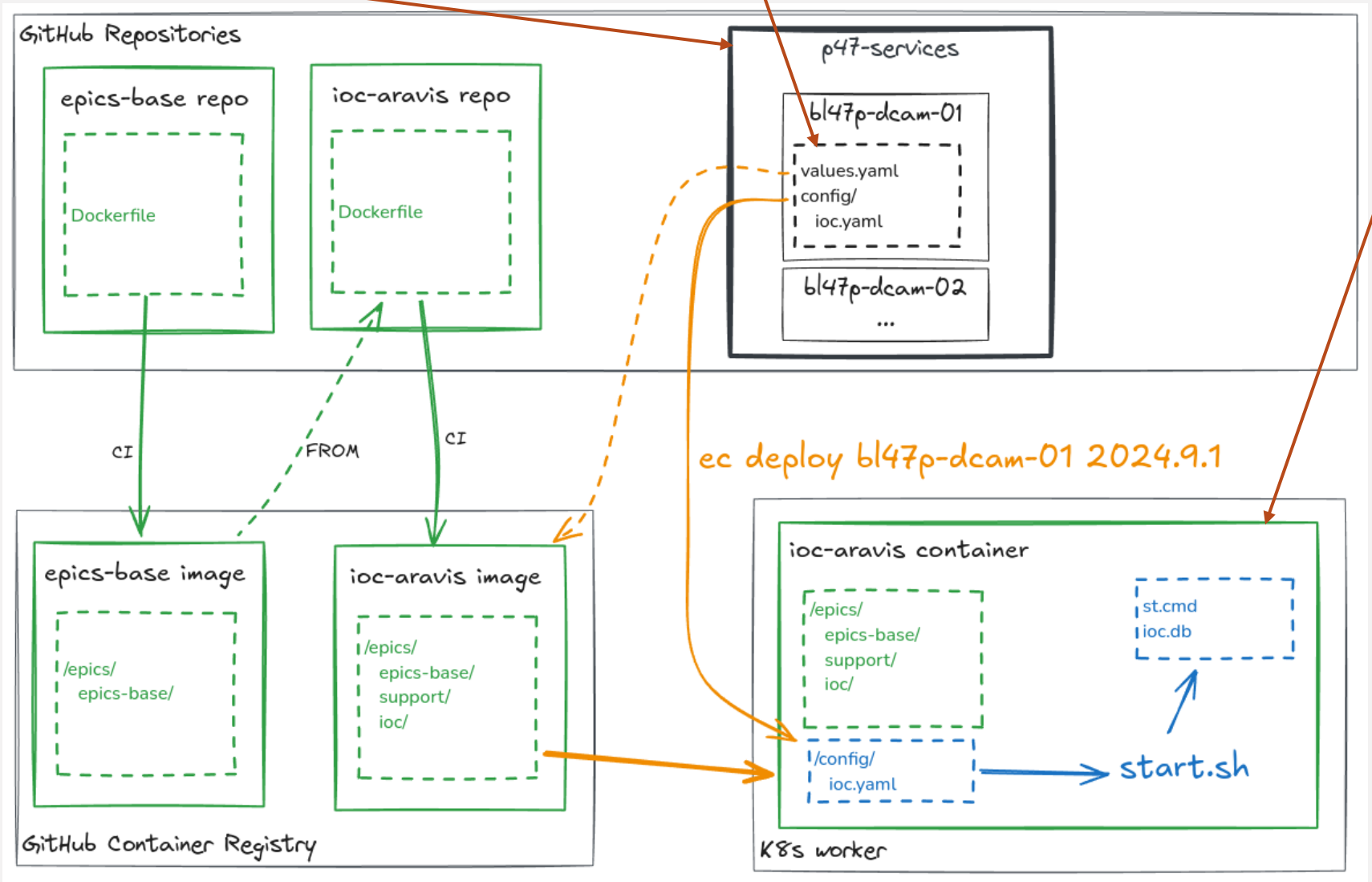
- **PVI -** Process Variables Interface
  - Provides structure for the PV interface to a device
  - Auto generates engineering screens for the device (bob/edm/adl)
  - Supplies DB metadata for use with Bluesky

How to make an IOC Instance?

1. Create a services repository

2. Edit the new IOC Instance config

3. Deploy the IOC instance



How to make an IOC Instance?

1. Create a services repository

- copier copy gh:epics-containers/services-template-helm .
- cp –r services/.ioc-template services/my-new-ioc

2. Edit the new IOC Instance config

2a. *A helm chart values override file. The only required field is the URL of the Generic IOC to use.*

p47-services > services > bl47p-ea-dcam-01 > ! values.yaml > {} ioc-instance > image

```yaml
ioc-instance:
  image: ghcr.io/epics-containers/ioc-adaravis-runtime:2024.8.1

```

2b. *An **ibek** IOC YAML file listing the support 'entities' that we want to instantiate for this IOC instance.*

p47-services > services > bl47p-ea-dcam-01 > config > ! ioc.yaml > [ ] entities

```yaml
# yaml-language-server: $schema=https://github.com/epics-conta
ioc_name: bl47p-ea-dcam-01
description: GigE Sample camera for beamline p47

entities:
  - type: epics.EpicsCaMaxArrayBytes
    max_bytes: 3000000

  - type: ADAravis.aravisCamera
    CLASS: AVT_Mako_G234B
    ID: 192.168.250.3
    P: BL47P-EA-DET-01
    PORT: DET.CAM
    R: ":DET:"
```

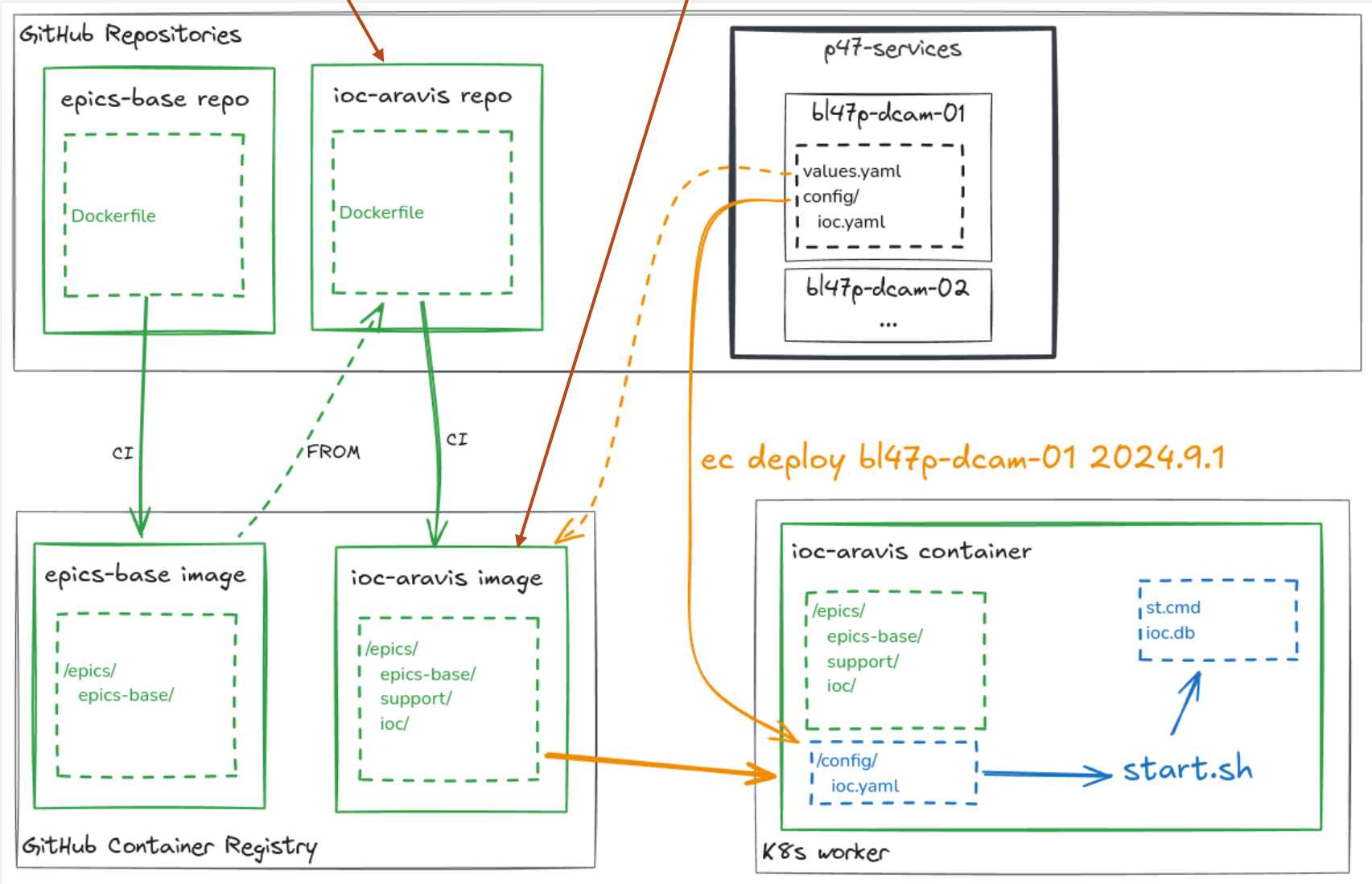
3. Deploy the IOC instance:

- Tag and push the beamline repo
- **ec** deploy bl45p-ea-ioc-01 2024.9.1

How to make an IOC Instance?

1.Create a Generic IOC repo

2. Deploy Generic IOC to your container registry



How to make a Generic IOC?

1. Create a Generic IOC repo:

- copier copy gh:epics-containers/ioc-template
- edit Readme.md
- edit Dockerfile: add COPY and RUN for each support module using ibek-support recipies

2. Deploy Generic IOC to your container registry:

- Tag and push the generic IOC repo
- CI then:
  - Builds the container image
  - Publishes it to GHCR
  - Publishes a JSON schema for the ibek 'entities' provided inside the container

Dockerfile: iocStats serves as an example for how to add additional support modules

```
3  ARG BASE=7.0.8ec2
4  ARG REGISTRY=ghcr.io/epics-containers
5  ARG RUNTIME=${REGISTRY}/epics-base${IMAGE_EXT}-runtime:${BASE}
6  ARG DEVELOPER=${REGISTRY}/epics-base${IMAGE_EXT}-developer:${BASE}
7
8  ##### build stage ##############################################################
9  FROM  ${DEVELOPER} AS developer
10
11 # The devcontainer mounts the project root to /epics/generic-source
12 # Using the same location here makes devcontainer/runtime differences transparent
13 ENV SOURCE_FOLDER=/epics/generic-source
14 # connect ioc source folder to its know location
15 RUN ln -s ${SOURCE_FOLDER}/ioc ${IOC}
16
17 # Get the current version of ibek
18 COPY requirements.txt requirements.txt
19 RUN pip install --upgrade -r requirements.txt
20
21 WORKDIR ${SOURCE_FOLDER}/ibek-support
22
23 # copy the global ibek files
24 COPY ibek-support/_global/ _global
25
26 COPY ibek-support/iocStats/ iocStats
27 RUN iocStats/install.sh 3.2.0
28
29 ###############################################################################
30 #  TODO - Add further support module installations here
31 ###############################################################################
32
33 # get the ioc source and build it
34 COPY ioc ${SOURCE_FOLDER}/ioc
35 RUN cd ${IOC} && ./install.sh && make
36
37 # install runtime proxy for non-native builds
38 RUN bash ${IOC}/install_proxy.sh
39
40 ##### runtime preparation stage ################################################
```

How to Add a new Support Module 1.

1. Add a folder in the ibek-support repo

- Shared ibek-support on GitHub
- Or private ibek-support per facility
- Public Generic IOCs should only use shared ibek-support
- Internal Generic IOCs may use both

2. Add a new install.sh file:

- Use the new support in your Generic IOC Dockerfile

Install.sh example for ADSimDetector. Most install.sh would look almost identical to this but You can add custom steps as needed –it's just bash.

ioc-template-example > ibek-support > ADSimDetector > $ install.sh

```
#!/bin/bash
###############################################################################
###### install script for ADSimDetector Module ################################
###############################################################################

# ARGUMENTS:
#  $1 VERSION to install (must match repo tag)
VERSION=${1}
NAME=ADSimDetector
FOLDER=$(dirname $(readlink -f $0))

# log output and abort on failure
set -xe

# get the source and fix up the configure/RELEASE files
ibek support git-clone ${NAME} ${VERSION} --org http://github.com/areaDetector/
ibek support register ${NAME}

# declare the libs and DBDs that are required in ioc/iocApp/src/Makefile
ibek support add-libs simDetector
ibek support add-dbds simDetectorSupport.dbd

# global config settings
${FOLDER}/../_global/install.sh ${NAME}

# compile the support module
ibek support compile ${NAME}
# prepare *.bob, *.pvi, *.ibek.support.yaml for access outside the container.
ibek support generate-links ${FOLDER}
```

How to Add a new Support Module 2.

1. Add a folder in the ibek-support repo

- Shared ibek-support on GitHub
- Or private ibek-support per facility
- Public Generic IOCs should only use shared ibek-support
- Internal Generic IOCs may use both

2. Add a new install.sh file:

- Use the new support in your Generic IOC Dockerfile

3. Add an ibek support YAML description:

- This allows us to describe our IOC instances as ibek IOC YAML.

Support YAML example for ADSimDetector. Declares instance arguments, startup script lines and database template substitutions.

ioc-template-example > ibek-support > ADSimDetector > ! ADSimDetector.ibek.support.yaml > [ ] entity_models > {} 0 >

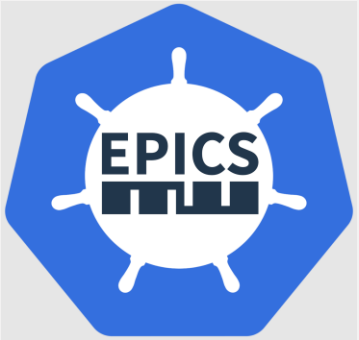
```yaml
# yaml-language-server: $schema=https://github.com/epics-containers/ibek/r
module: ADSimDetector

entity_models:
  - name: simDetector
    description: Creates a simulation detector
    parameters:
      P:
        type: str
        description: Device Prefix
      R:
        type: str
        description: Device Suffix
      PORT:
        type: id
        description: Port name for the detector
      # ------ Other Parameters omitted for clarity ----------

    pre_init:
      - type: text
        value: |
          # simDetectorConfig(portName, maxSizeX, maxSizeY, dataType, maxB
          simDetectorConfig("{{PORT}}", {{WIDTH}}, {{HEIGHT}}, {{DATATYPE}

    databases:
      - file: $(ADSIMDETECTOR)/db/simDetector.template
        args: { P, R, PORT, TIMEOUT, ADDR }
```

Developer Containers



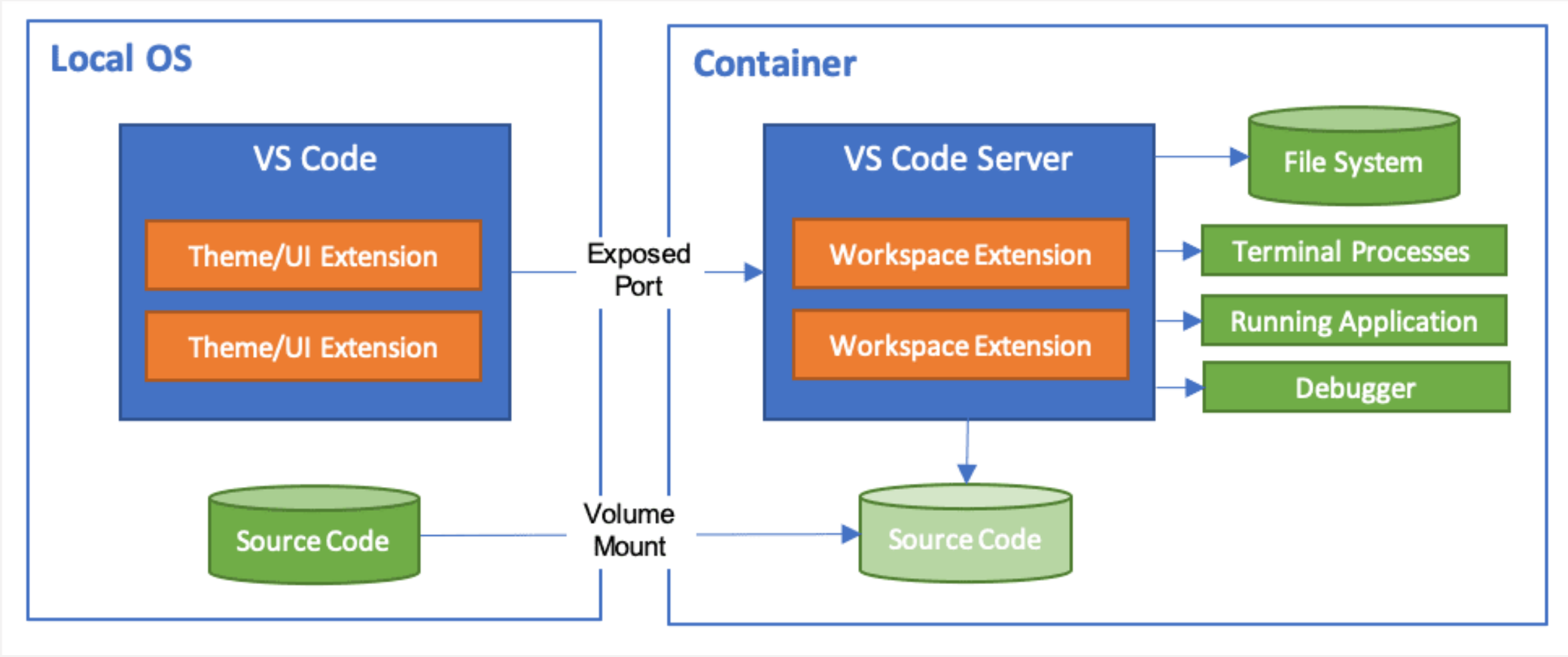
epics-containers development defines 3 levels of changes:

1. Changing IOC instance details only
   - Edit values.yaml or ioc.yaml in your beamline repository
   - Push and tag the changes, re-deploy the update instance
2. Changing a Generic IOC
   - Edit Dockerfile or ibek-support sub-module in a Generic IOC repository
   - Push changes to publish a new container image
   - Go to 1. to update affected instances
3. Changing Support Modules
   - Edit the support module, verify and push and tag source changes.
   - Go to 2. to update a Generic IOC to include the new support version

2 and 3 require rebuilding and deploying containers. For this reason, we use Developer Containers for a fast "inner loop".

For epics-containers the generic IOC container image is an ideal developer container.

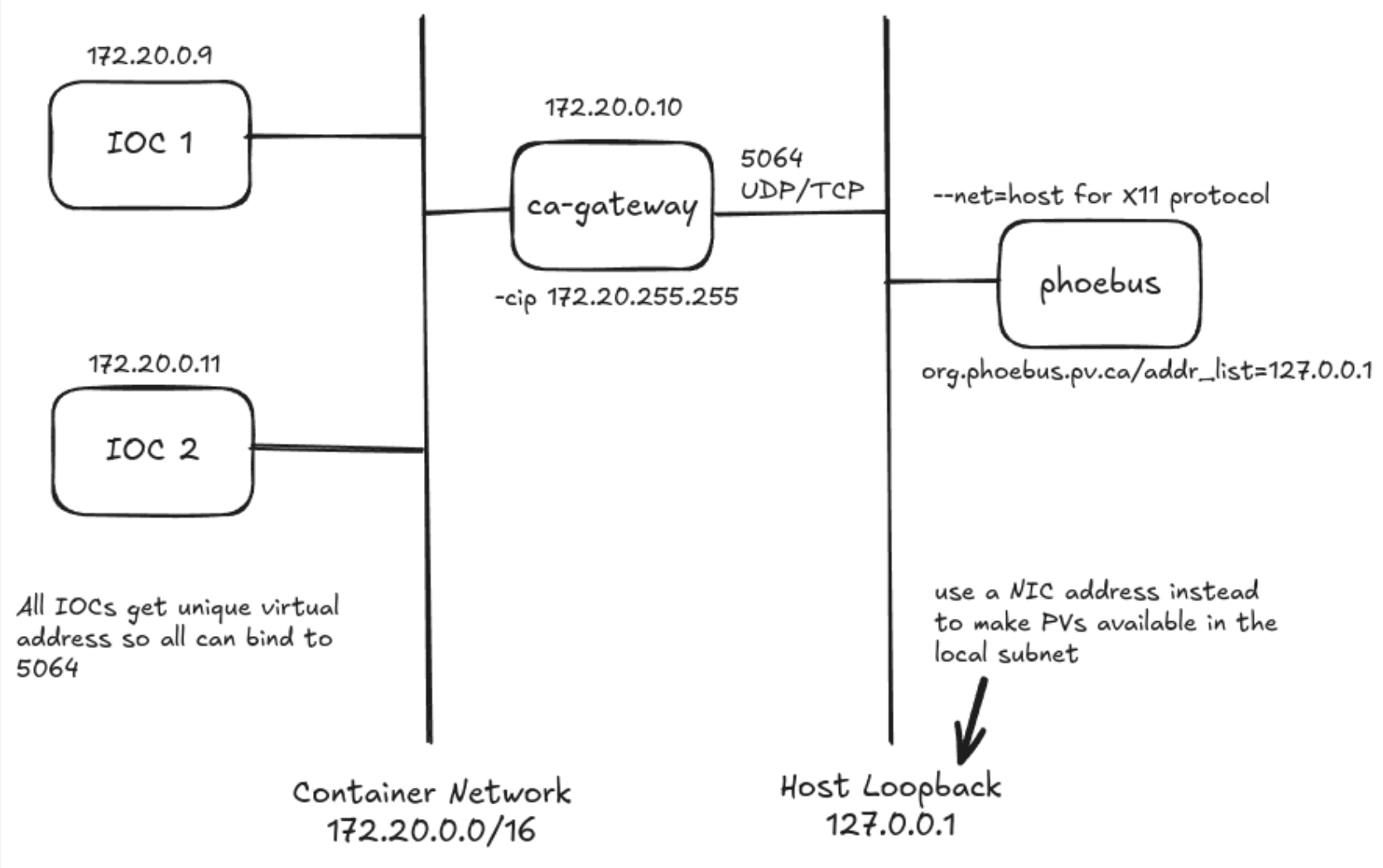
Developer Containers



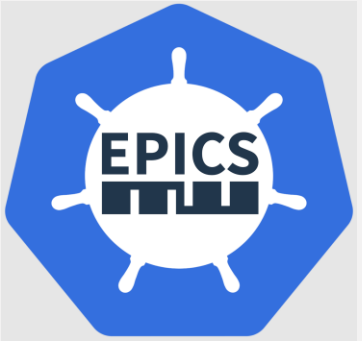
See developer target in https://github.com/epics-containers/ioc-template/blob/main/template/Dockerfile

Networking

For local development and testing we configure the network like this:



Networking network=host



At DLS we use network=host for Kubernetes IOCs

- This means IOCs run without network isolation and look exactly like traditional IOCs from the client's perspective

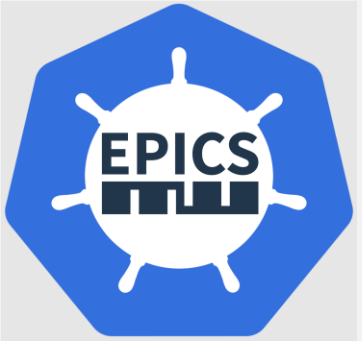
Motivation

- Channel Access cannot route into the container network
- We did not want to pass all PVs through a ca-gateway
- Channel Access is not the only protocol that will not route into CNI
- For example, GigE streaming protocol will also fail
- Any protocol that does not like NAT will have this problem

Current Status - Sept 2024

- The epics-containers framework is ready for wider exposure and feedback
- There are tutorials to get people started using the framework
- There are a growing number of reference generic IOCs
- Example beamline repositories are also available
- DLS has several beamline clusters running a handful of containerized IOCs in production, plus some fully containerized test beamlines.
- DLS aims to have a representative set of production beamlines fully containerized before the DII dark period 12/2027.
- And all beamlines fully containerized at the end of the dark period 06/2029.

One Take Away



https://github.com/epics-containers

- Includes:
  - Tutorials
  - Documentation
  - Templates
  - Source code
  - A small but growing number of Generic IOC images
  - Example beamlines
  - A Simulation beamline

Questions ?

Hands On: Tutorials

- https://epics-containers.github.io/main/tutorials/intro.html
- Work through the tutorials at your own pace
  - Try out the simulation beamline
  - Create a services repository with docker compose
  - Create an IOC instance
  - Work with developer containers (stretch goal for today!)

Kubernetes

- Kubernetes is by far the dominant container orchestration platform today
- Open-sourced by Google in 2014
- Managed by the Cloud Native Computing Foundation, part of the Linux Foundation
- CNCF looks after a large list of open-source applications that run in Kubernetes
- At DLS we will have a Kubernetes Cluster per beamline, one for the accelerator and a large central cluster for centralized services.

Demo: a Kubernetes Beamline at DLS

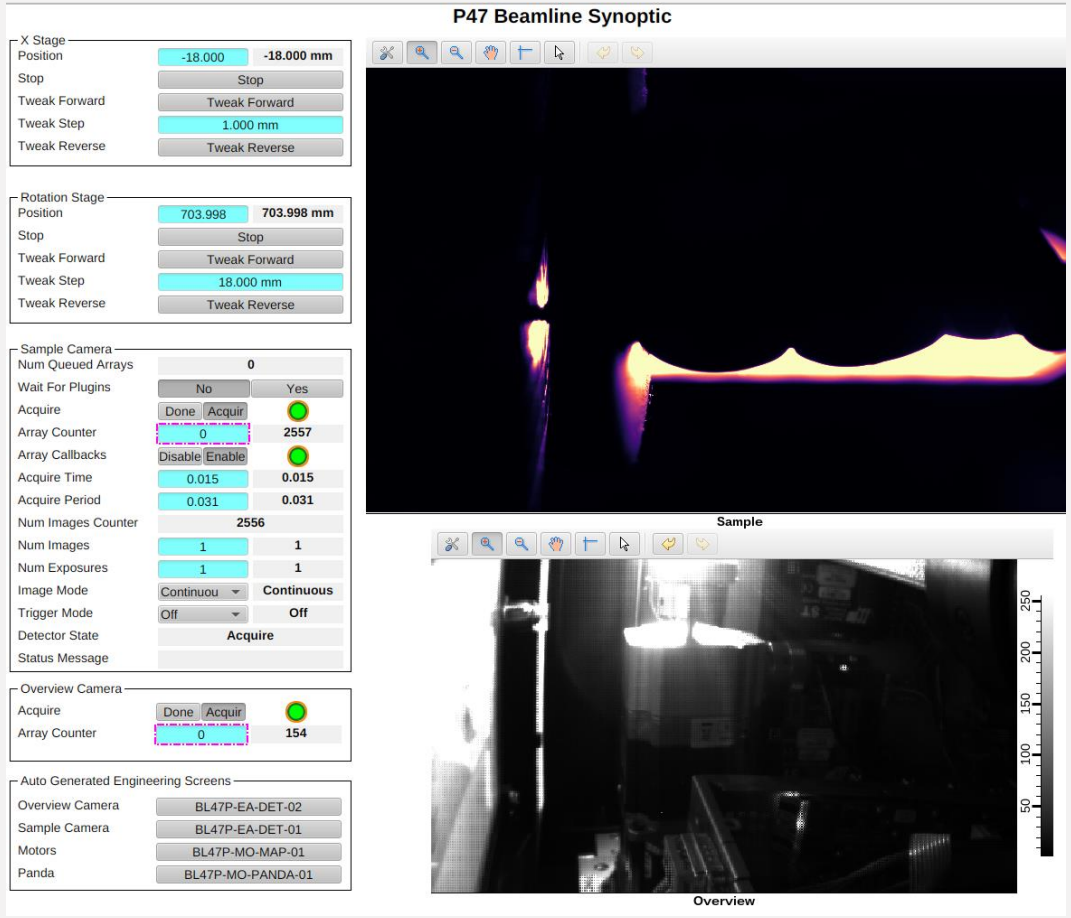
- p47 is a training beamline with 2 detectors, 2 motors, 1 pandabox
- Each Kubernetes Clusters at DLS runs standard services including:-
  - A landing page to access all user services
  - Kubernetes Dashboard – manage resources in the cluster
  - Alert Manager – sets thresholds and configures recipients of alerts
  - Prometheus – monitoring with time series Database
  - Grafana – rich visualization of the above data
  - StacksRox – monitor running containers for Common Vulnerabilities and Exploits
  - Keycloak – single sign on authorization service
  - Kynervo – policy engine
  - Argo CD – declarative GitOps continuous deployment

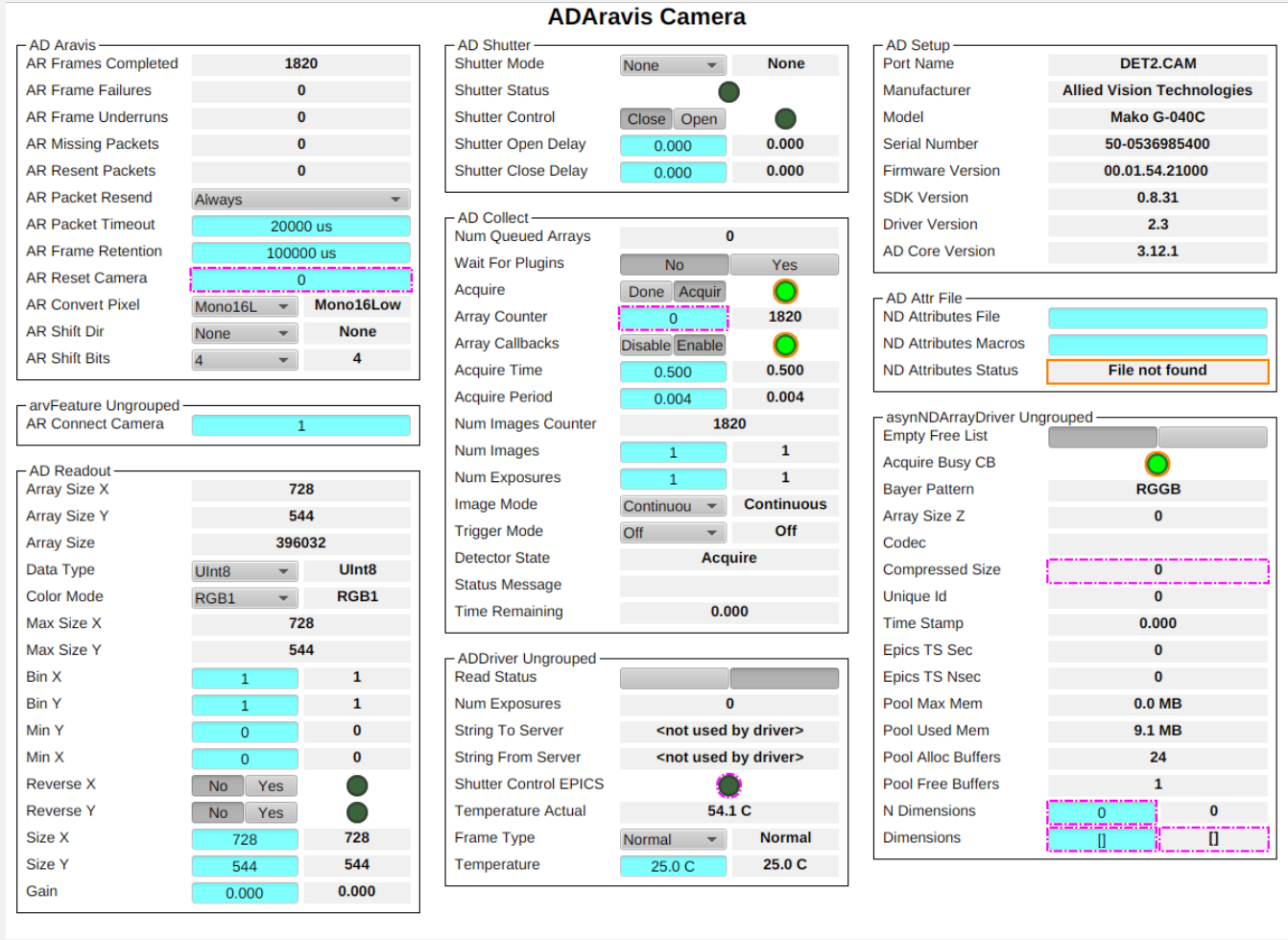
Questions ?

Remaining Slides

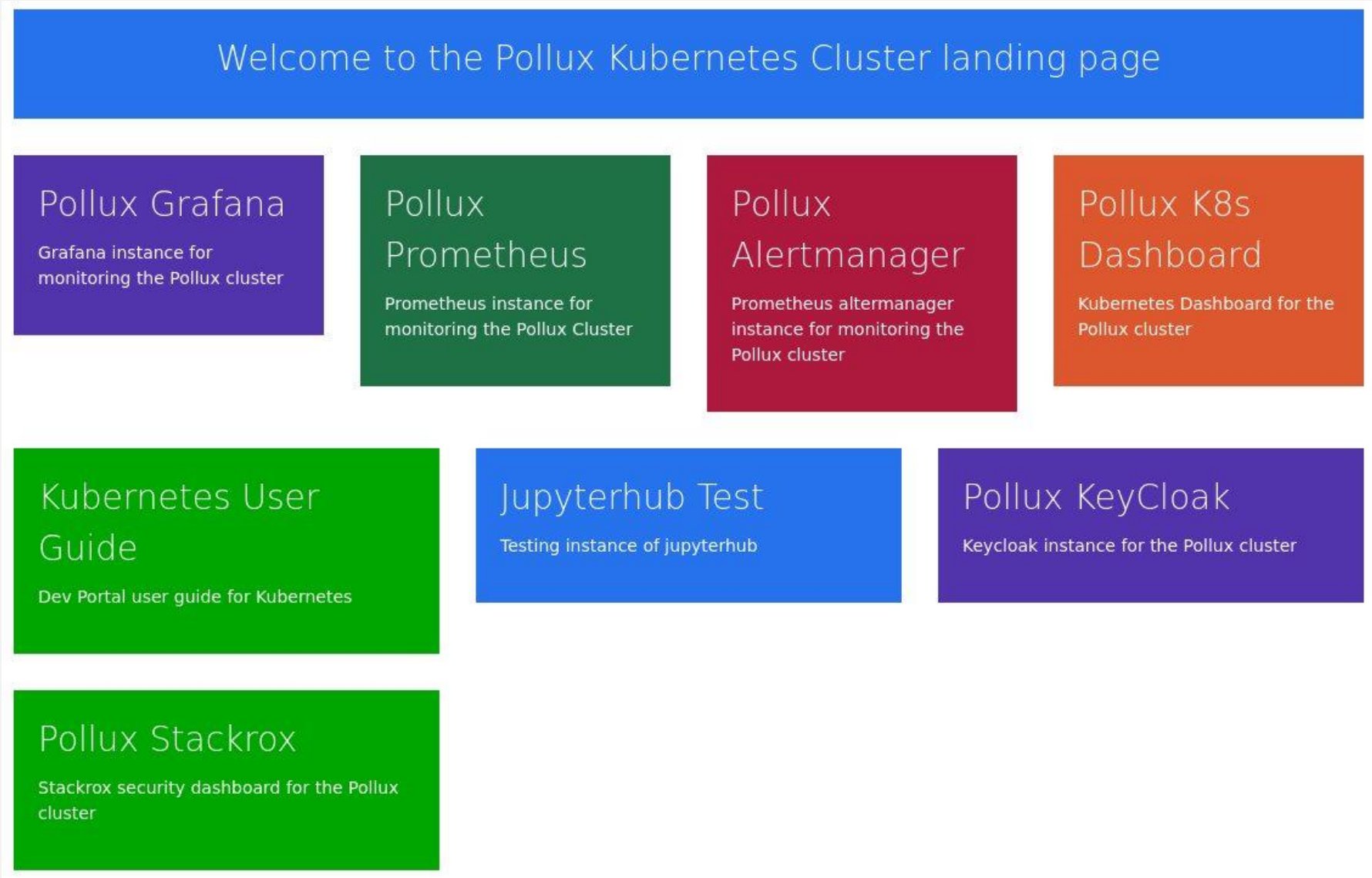
- Images of demo screens in case I can't connect to DLS
- Some overview diagrams for discussion if needed

Demo: a Kubernetes Beamline at DLS
P47

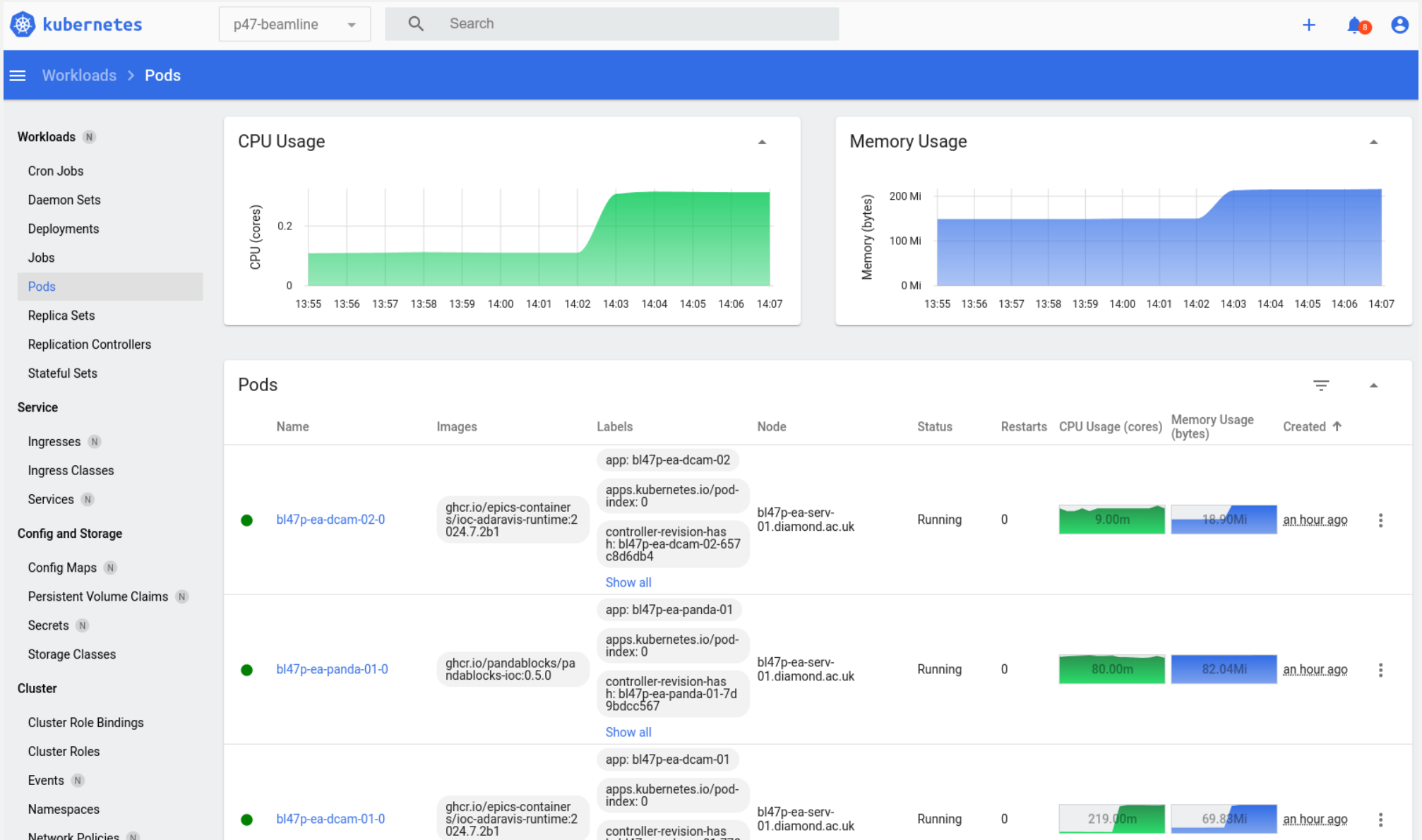




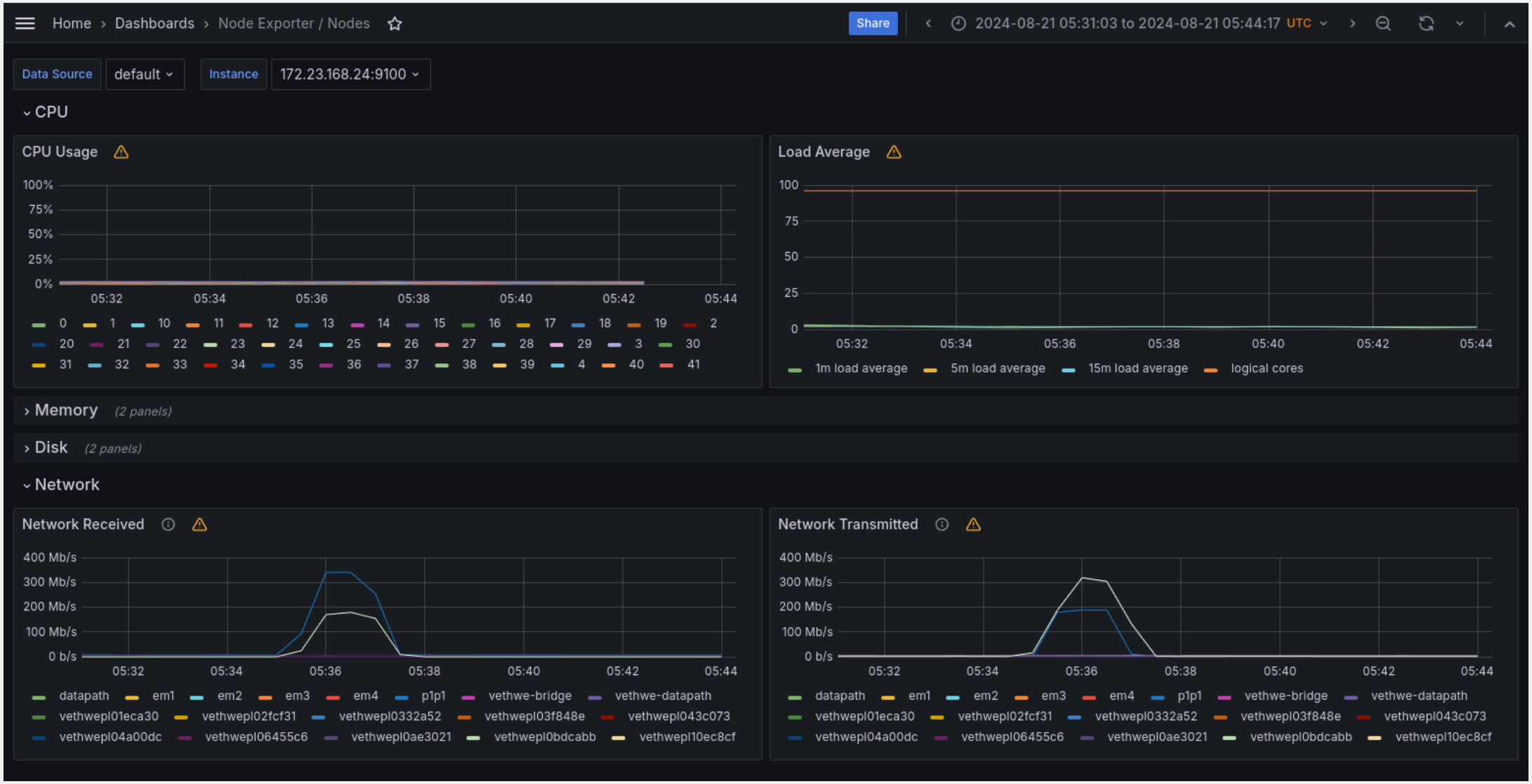
Cluster landing page



Kubernetes Dashboard

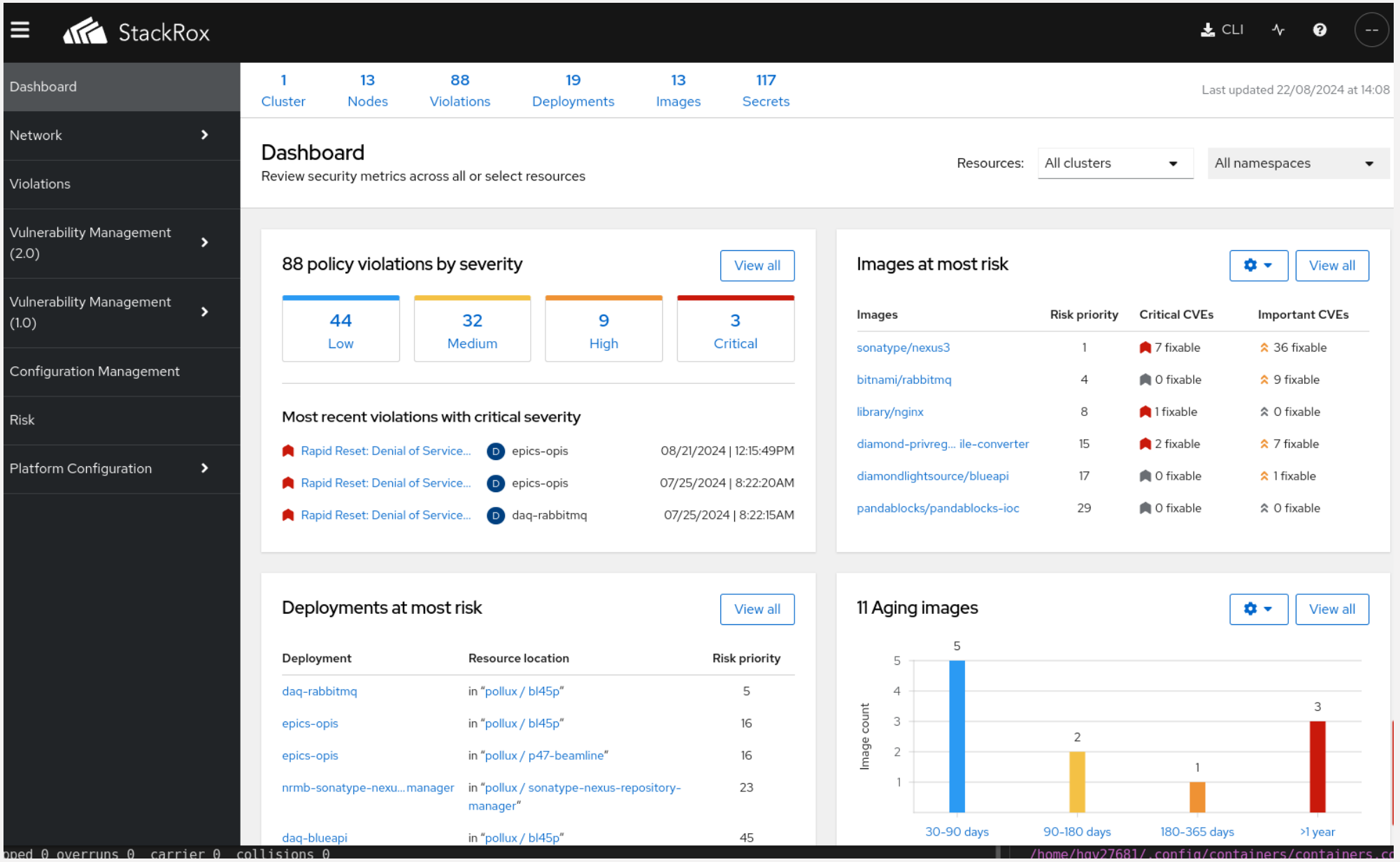


Grafana

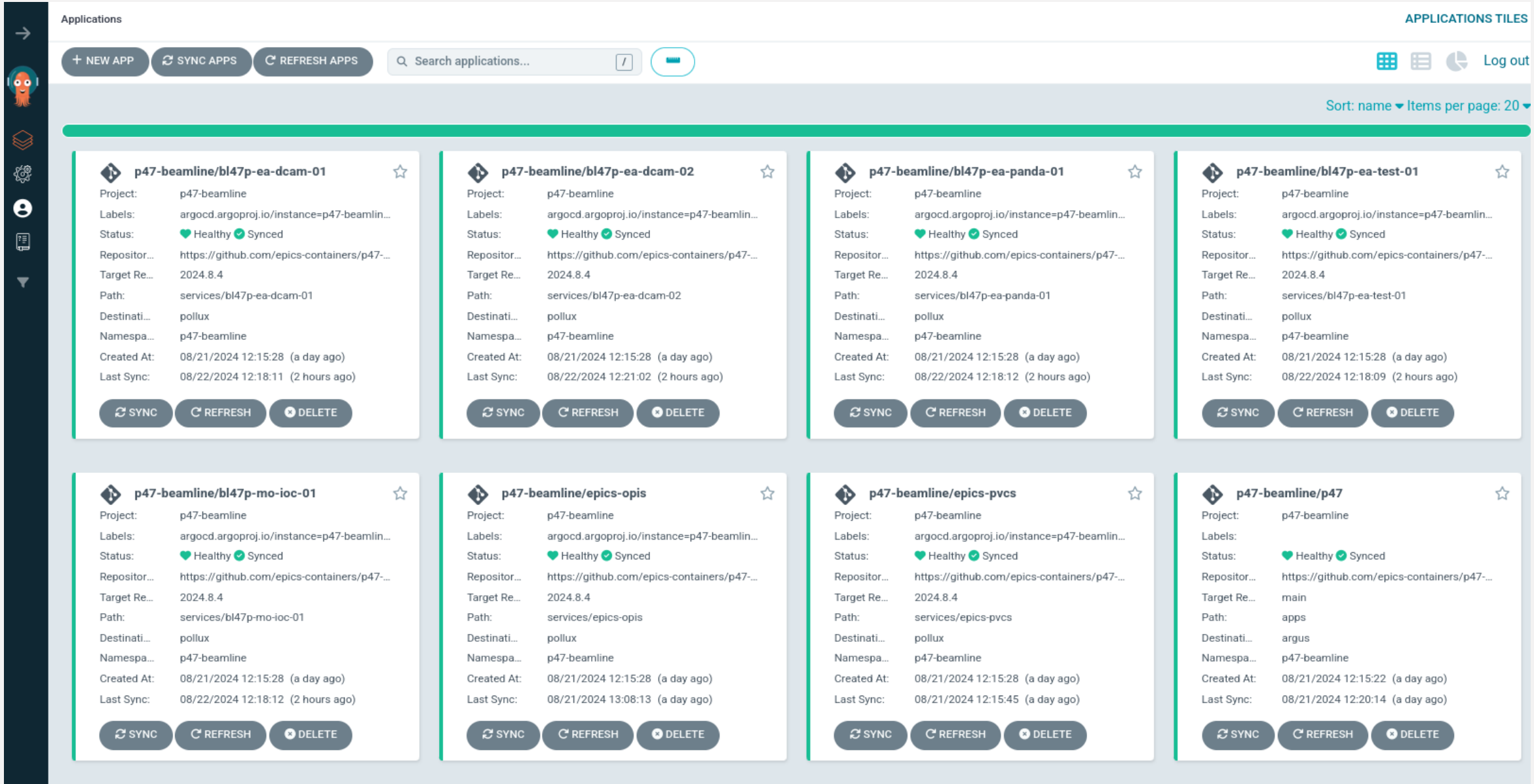

Home › Dashboards › Node Exporter / Nodes
Share
2024-08-21 05:31:03 to 2024-08-21 05:44:17 UTC
Data Source
default
Instance
172.23.168.24:9100
CPU
CPU Usage
100%
75%
50%
25%
0%
05:32
05:34
05:36
05:38
05:40
05:42
05:44
0 1 10 11 12 13 14 15 16 17 18 19 2
20 21 22 23 24 25 26 27 28 29 3 30
31 32 33 34 35 36 37 38 39 4 40 41
Load Average
100
75
50
25
0
1m load average
5m load average
15m load average
logical cores
Memory (2 panels)
Disk (2 panels)
Network
Network Received
400 Mb/s
300 Mb/s
200 Mb/s
100 Mb/s
0 b/s
datapath em1 em2 em3 em4 p1p1 vethwe-bridge vethwe-datapath
vethwepl01eca30 vethwepl02fcf31 vethwepl0332a52 vethwepl03f848e vethwepl043c073
vethwepl04a00dc vethwepl06455c6 vethwepl0ae3021 vethwepl0bdcabb vethwepl10ec8cf
Network Transmitted

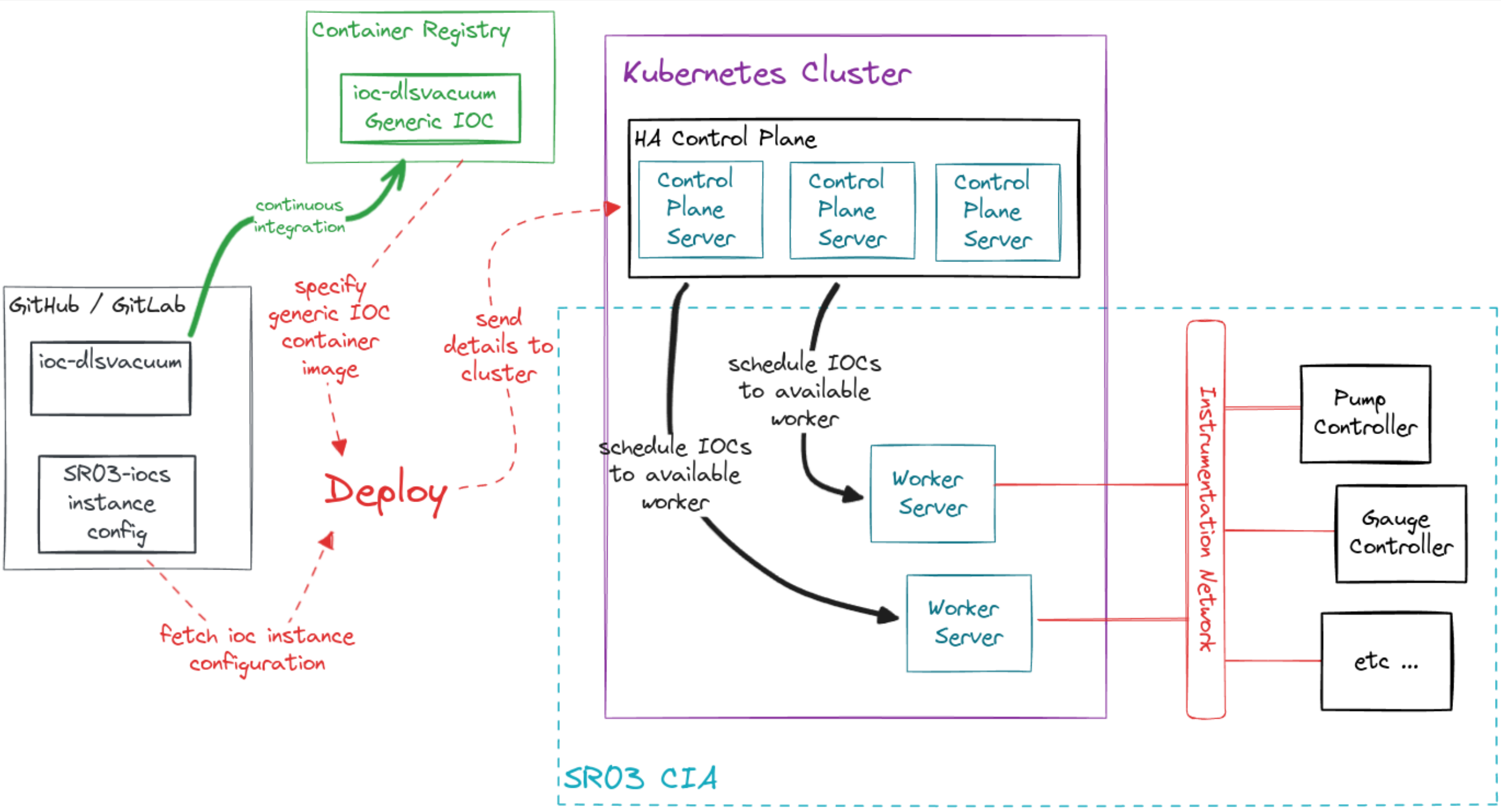
StacksRox

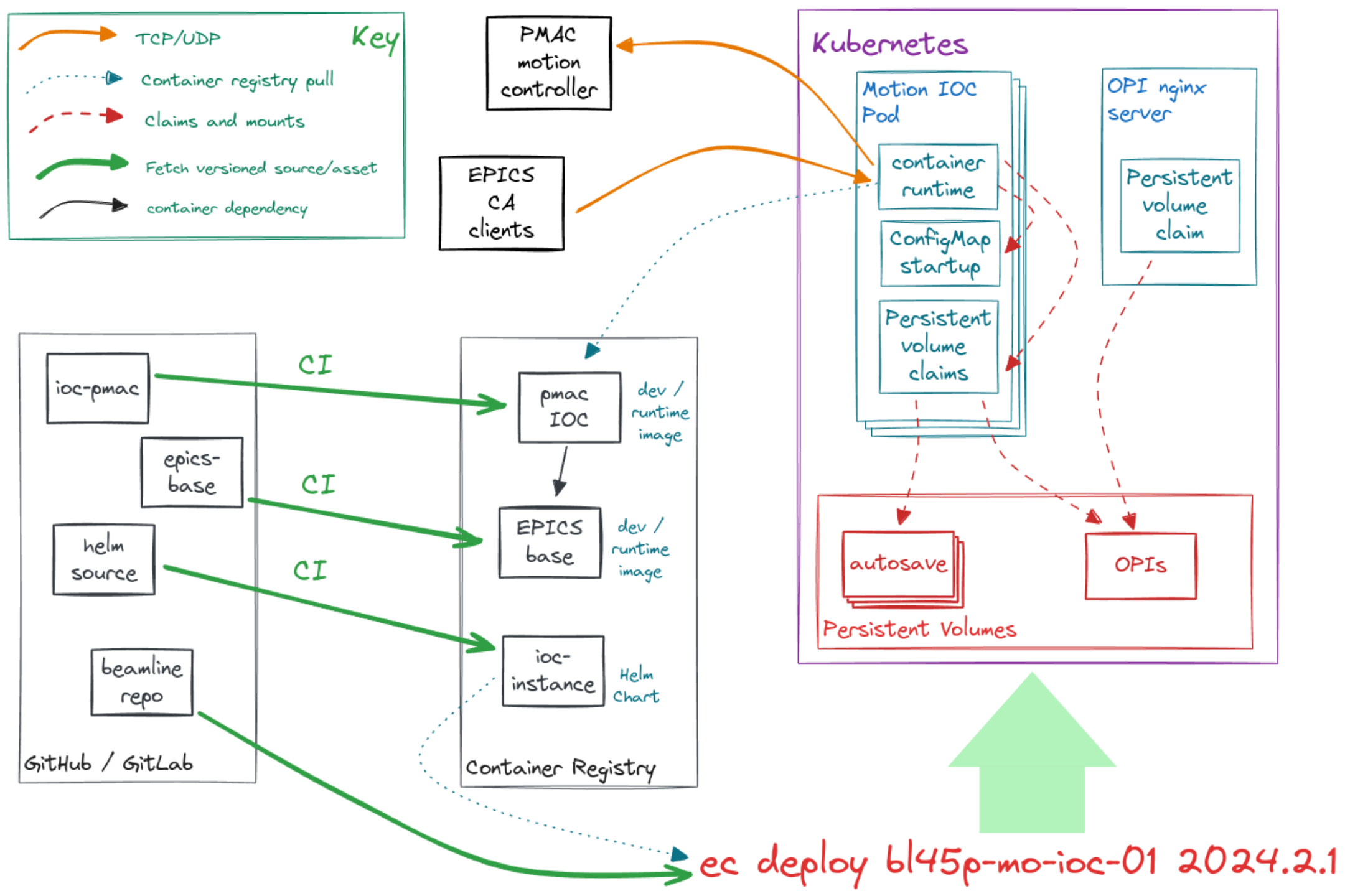
[Investigate CVE 2024-3094]



Argo CD for p47-beamline




Container Registry
ioc-dlsvacuum
Generic IOC
Kubernetes Cluster
HA Control Plane
Control Plane Server
Control Plane Server
Control Plane Server
continuous integration
GitHub / GitLab
ioc-dlsvacuum
SR03-iocs instance config
specify generic IOC container image
send details to cluster
Deploy
fetch ioc instance configuration
schedule IOCs to available worker
schedule IOCs to available worker
Worker Server
Worker Server
Instrumentation Network
Pump Controller
Gauge Controller
etc ...
SR03 CIA


Key
TCP/UDP
Container registry pull
Claims and mounts
Fetch versioned source/asset
container dependency
PMAC motion controller
EPICS CA clients
Kubernetes
Motion IOC Pod
container runtime
ConfigMap startup
Persistent volume claims
OPI nginx server
Persistent volume claim
autosave
OPIs
Persistent Volumes
ioc-pmac
epics-base
helm source
beamline repo
GitHub / GitLab
CI
CI
CI
pmac IOC
dev / runtime image
EPICS base
dev / runtime image
ioc-instance
Helm Chart
Container Registry
ec deploy bl45p-mo-ioc-01 2024.2.1