



EPICS Deployment at Fermilab

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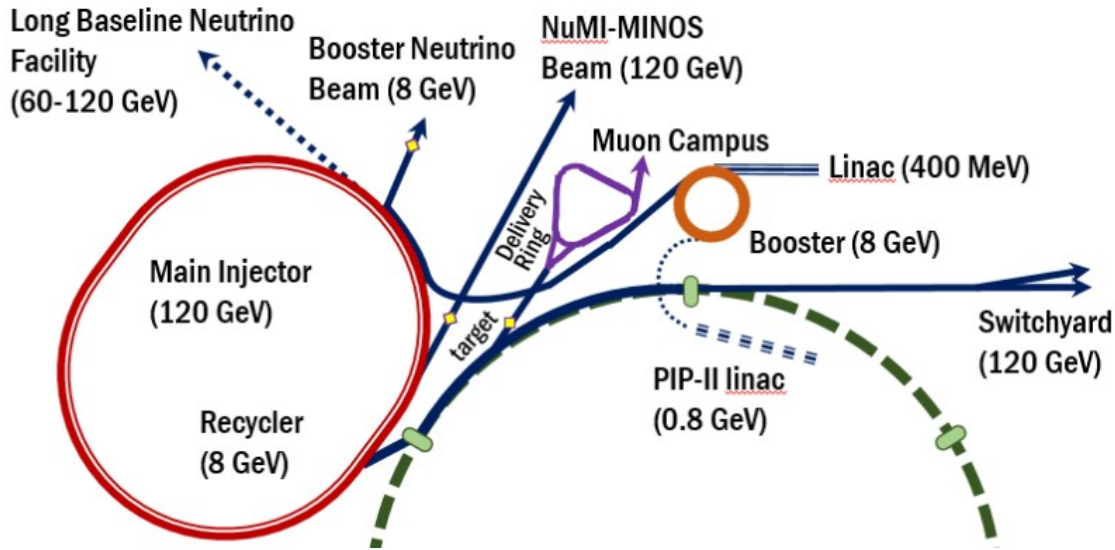
Poland/WUST



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Fermilab Accelerator Complex



Series of accelerators
Provides beam to several
experiments

- LBNF, DUNE
- NuMI
- muon campus
- local neutrino experiments
- test beams

PIP-II will replace the existing LINAC



PIP-II is the first US/DOE accelerator to be built with significant international contributions/partnerships.

PIP-II Mission

PIP-II is an essential upgrade to Fermilab accelerator complex to enable the world's most intense beam of neutrinos to LBNF/DUNE, and a broad physics research program for decades to come.

PIP-II Capabilities

Beam Power

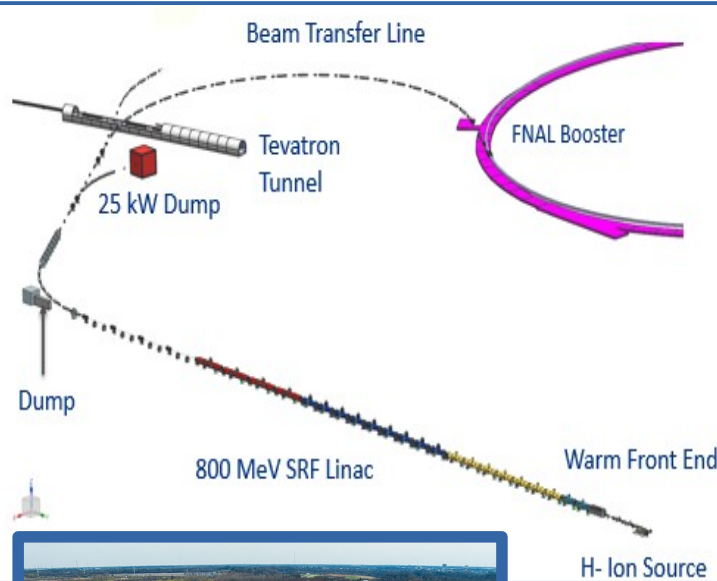
- 1.2 MW proton beam
- Upgradeable to multi-MW

Flexibility, multi-user capability

- CW-compatible
- Customized beams
- Multi-user delivery

Reliability

- Modernizes Fermilab accelerator complex



PIP-II Scope

800 MeV H⁻ SRF linac

- CW RF Operations

Linac → Booster transfer line

Accelerator Complex Upgrades

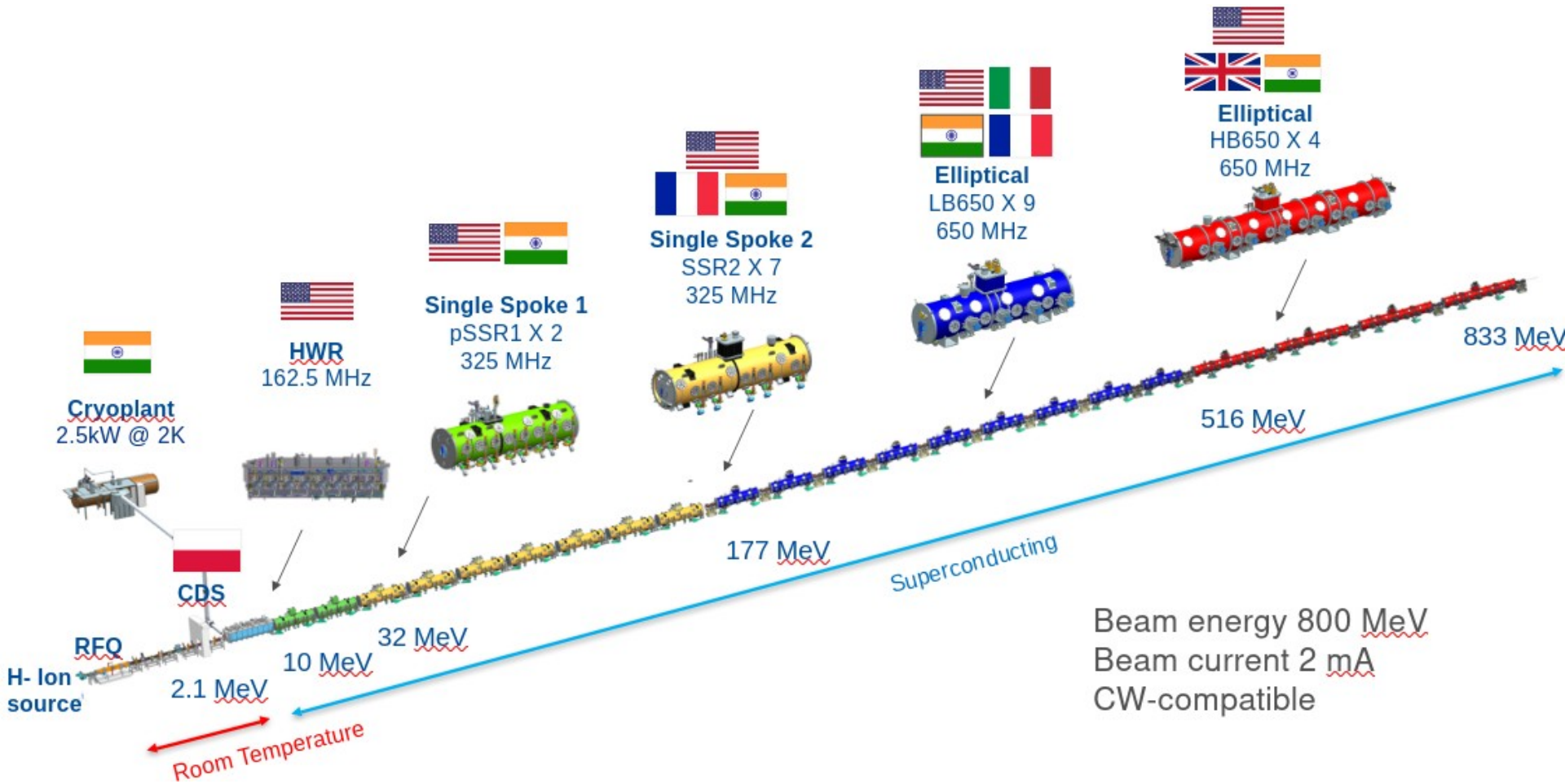
- Booster
- Recycler
- Main Injector

Conventional Facilities

- Space reserved for 2 CMs for 1GeV Upgrade

The PIP-II scope enables the accelerator complex to reach 1.2 MW p-beam on LBNF target

PIP-II Superconducting LINAC



Motivation

- Treating EPICS deployment as a green field to simplify deployment for non-experts
 - <https://ghe-pip2.fnal.gov/epics-controls/>
- Small controls team, therefore we require:
 - robust build of infrastructure
 - automated build procedures
 - extensive testing
 - minimal functionality to automate deployment/monitoring of IOCs
- Developed a standard EPICS infrastructure to simplify developing IOCs
 - “base” and “Support” are built (on all supported platforms): made available on controls network
 - developers start from template IOCs and build against production ./base and ./Support
 - template IOCs have minimal boiler plate functionality required of all FNAL IOCs
- Standard deployment and automated build for
 - robustness
 - ease in maintaining and debugging software
- Implement modern computing practices Continuous Integration/Continuous Deployment (CI/CD)
- Using PVXS protocol and disabled Channel Access (CA)
 - multicast
 - pvaccess protocol
 - structured data
 - already has ipv6
 - network security implemented to satisfy DOE “no trust”
- In kind contributions or commercial IOCs with CA will be accessible via pva-ify and p4p

Goals for Deployment

“Treating EPICS deployment as a green field to simplify deployment for non-experts”

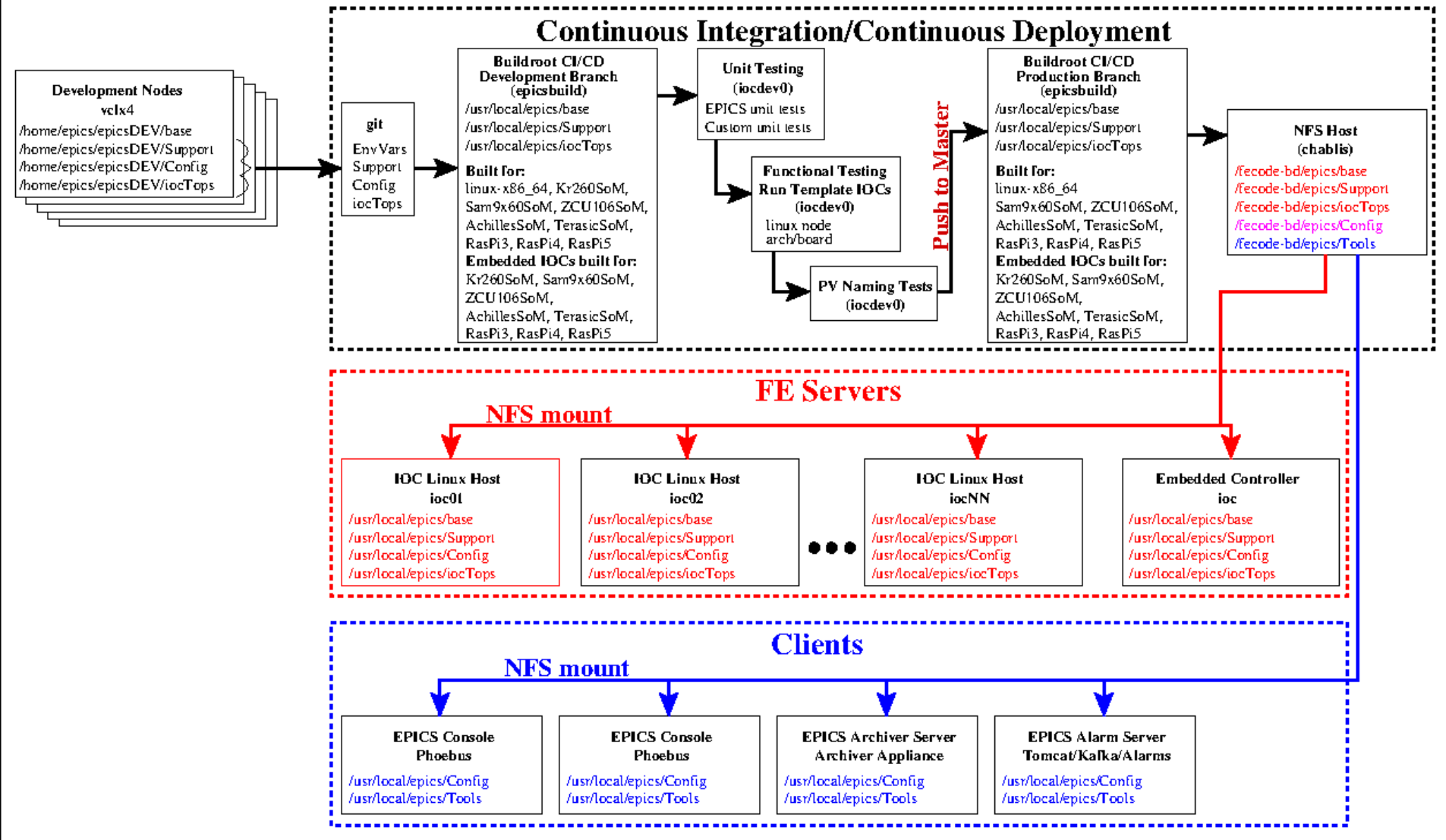
- PIP-II and possibly new components from ACORN will not rely on old hardware: VME, CAMAC
- Current EPICS versions work, and expected to continue to work, with the new hardware
- Leverage this to build current versions EPICS software in Continuous Integration/Continuous Deployment (CI/CD) pipeline and make all of EPICS base and EPICS Support/Modules “standard”
- Code is made available on the Controls network from NFS mount: **`/usr/local/epics/`**
- EPICS IOCs built against this boiler plate code base in CI/CD pipeline
- Future proofing with containers

CI/CD Pipeline: Supporting Multiple Platforms

- In addition to standardizing code, we are exploring standardizing platforms:
- EPICS base, Support, & iocTops are built for different architectures/platforms:
 - linux-x86_64, arm/Cyclone-V, arm/Arria-10, arm/ZCU106 Xilinx, arm/Kria260 Xilinx, arm/Sam9x60 Xilinx, arm/RasPi3, arm/RasPi4 arm/RasPi5
- Using Buildroot for raspberry pi builds and arm/SoM devices
- Adding Yacto for Xilinx
- These produce kernels, dtb files, and root file systems for each platform
 - build process copies these to tftp area
 - required for network booting embedded nodes
- Also generates Toolchains or SDKs for cross compiling
- Toolchains/SDKs used to build EPICS code base
- CI/CD artifacts are deployed on NFS host and available on NFS mounts:
 - /usr/local/epics/base/bin/
 - linux-x86_64
 - linux-arm_raspberrypi3
 - linux-arm_raspberrypi4
 - linux-arm_raspberrypi5
 - linux-arm_terasicSOC
 - linux-arm_achilles
 - linux-arm_zcu106
 - linux-arm_kr260
 - linux-arm_sam9x60
- Same for /usr/local/epics/base/lib, /usr/local/epics/Support/xxxMODULE/lib, etc

CI/CD Pipeline – Software Path to Deployment

Fermilab's EPICS Software Flow



CI/CD Pipeline

- Implementation developed by Mariana González.
- Using Github for code management, documentation and issue tracking.
- Using Github Actions tool to automate building and testing
- Full CI/CD chain is complete and successfully tested
 - Automated build of the 3-tier IOCs for all supported architectures
 - Automated unit testing – working for host architecture
 - Automated testing:
 - Unit tests
 - Basic functional tests (based on templateIOC tests)
 - Check for duplicate PV names
- Passing tests allows for code to be build, tagged, and pushed to NFS host

- IOC owner must register IOC before deploying
- Presently building base-7.0.10 on Alma Linux 9.7
- Presently building with C++20

- Still way behind on developing tests



CI/CD Pipeline: Template IOCs

Each Fermilab IOC running on the controls network will provide the following:

- heartbeat
- upgraded iocStats to linStat (for all platforms on which it builds)
- capability of 20 Hz scan rate
- use aSub record for interfacing with IOC specific custom code (C/C++ libraries)
- access to Acnet (acnetPV wrapper)
- tcast – interface to multicast clock system
- reccaster – Channel Finder
- CaPutLog → putLog?
- AlarmPush – used for combining legacy and EPICS alarms

Recommended procedure for new developers:

- run cpTemplate script (specific platform), create new IOC, populate file names and prefixes
- build and run the IOC as is to test operability of your soft or embedded IOC
- once established, modify template for specific application

CI/CD Pipeline: IOC Production Deployment

We have 2 classes of deployment:

- Soft IOCs
 - all soft IOCs are hosted on linux servers
 - Alma Linux 9.7 – presently
 - all code is based on CI/CD output
 - launched via procServ on different TCP ports
 - procServ scripts launched from *systemd*
 - log files in **/var/log/iocs** (NFS mounted)
- Embedded IOCs
 - Raspberry Pis, SoMs (Achilles SoM, TerasicSoM, Xilinx SoMs)
 - Raspberry Pi will be single process server
 - SD card or on board flash will have host specific network configuration
 - kernels, root file system, dtb files, etc. from tftp server for network boot
 - use u-boot
 - NFS mount **/usr/local/epics**
 - IOCs launched via procServ and launched from *systemd*
 - log files in **/var/log/iocs** (NFS mounted)

Registration and Monitoring IOCs

- PIP-II is the front of the accelerator chain and feeds into the remainder the existing complex
 - Uses legacy controls system, ACNET
 - EPICS and ACNET will need to work hand-in-hand
- Once IOCs are built and have passed unit/functional/naming tests, the IOC name is compared to the “registration” database to ensure that the IOC is registered
- Registration consists of IOC owner providing information (e.g. owner, contact info, ...)
 - Much of the information is automatically taken from alive record
 - Same information as given by ACNET front ends (FE – ACNET equivalent of IOC)
 - Allows for agnostic view for operators
- Database being developed and will become a single source of truth for this and all PVs
 - Developing toward use as a name server
 - Plan to use to scan for un-registered IOCs
- Monitoring of productions IOCs consists of same functional tests run in the CI/CD pipeline

Pure PVXS with multicast

- The last major hurdle to our infrastructure was the conversion to pure PVXS api
 - PVA
 - IPv6
 - Multicast
 - Cybersecurity
- Fermilab has large, distributed network with multiple VLANs
 - Broadcast traffic is controlled with multicast
- Turned off rsrv
 - not without repercussions
- All of the template IOC's have been built and tested with PVXS and multicast
 - This was **BIG!**
- All IOC's converted to PVXS

✓ - Specified iocStats for linux-arm_achilles, linux-arm_terasic, linux... #927

Summary

Jobs

- ✓ support-modules
- ✓ locTops
- ✓ test

Run details

Workflow file

Triggered via push 1 hour ago

Status: Success

Total duration: 27m 40s

Artifacts: 2

mariana pushed → 90bc2d7 master

build.yml

on: push

```
graph LR; support-modules[✓ support-modules 18m 7s] --> locTops_build[✓ locTops / build 3m 32s]; locTops_build --> locTops_test[✓ locTops / test 8s]; locTops_test --> locTops_deploy[✓ locTops / deploy 4m 35s]; support-modules --> test[✓ test 34s];
```

Secure PVA

- With the expectation that DOE will not relax it's requirements on laboratory cybersecurity, we are also evaluating Secure PVA (sPVA)
- SLAC multi-year project is underway that will add industrial-level security TLS-style security to the pvAccess protocol and key management
- Fermilab participating in testing – building for all of our teststands
 - /usr/local/epics → /usr/local/epics-sPVA
 - swap back and forth by redefining \$EPICS_PATH



Mutual:

Both client and server are authenticated via certificates

METHOD: **x509**,
AUTHORITY: **{Issuer Name}**
isTLS: **true**



Server-only:

Only server is authenticated via certificate

METHOD: **ca** or **anonymous**
AUTHORITY: not set
isTLS: **true**



Un-authenticated:

Credentials optionally supplied in AUTHZ message

METHOD: **ca**



Unknown:

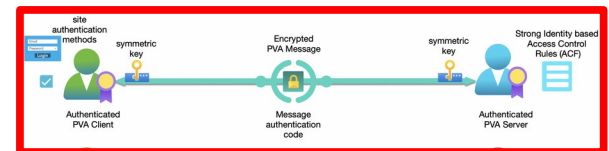
No credentials, legacy

METHOD: **anonymous**

Secure PVA

```
epics:~> pvxinfo -v FNAL:TMPL_IOC_RASPI3:alive
Effective config
EPICS_PVA_ADDR_LIST=239.128.1.6:5076,-1 239.128.1.6:5076,8@eno1
EPICS_PVA_AUTO_ADDR_LIST=NO
EPICS_PVA_BROADCAST_PORT=5076
EPICS_PVA_CONN_TMO=30.000000
EPICS_PVA_SERVER_PORT=5075
EPICS_PVA_TLS_KEYCHAIN=/home/epics/.config/pva/1.3/client.p12
EPICS_PVA_TLS_OPTIONS=on_expiration=fallback-to-tcp on_no_cms=fallback-to-tcp
EPICS_PVA_TLS_PORT=5076
XDG_CONFIG_HOME=/home/epics/.config/pva/1.3
XDG_DATA_HOME=/home/epics/.local/share/pva/1.3
# TLS x509:81763a32:12475230537084731998:FERMILAB Root CA/templateRasPi3@10.200.21.13:5076
FNAL:TMPL_IOC_RASPI3:alive from 10.200.21.13:5076
struct "epics:nt/NTScalar:1.0" {
  uint32_t value
```

- TLS - This is a TLS connection (could be mutually authenticated (client and server, or just server) in ACF RULE this is the PROTOCOL(tls)
- x509 - Server identified itself using an X.509 certificate. in ACF RULE this is the METHOD(x509)
- 81763a32:12475230537084731998 This is the certificate ID from the server's certificate (contains the issuer's id followed by colon and then the certificate's serial number)
- FERMILAB Root CA - This is the name of the Certificate Authority that signed the certificate. In ACF RULE this is the AUTHORITY("FERMILAB Root CA")
- templateRasPi3 This is the name in the server's certificate
- 10.200.21.13 this is the IP address we connected to the server on
- 5076 This is the TLS port we connected to, to get the PV value



Services and Clients

In addition to the infrastructure for IOCs, Fermilab has evaluated several EPICS services.

- The EPICS paradigm is (typically) to have all of the smarts built into the IOCs:
 - ACNET paradigm is to build “smarts” into application
 - Calibrations
 - Sequences (one of the downfalls of turning off rsrv)
 - Alarm limits and severity for each alarm
- Each service/user application has all information available to it without further processing
- Services include (see Mariana’s presentation):
 - Consoles/HMIs -> Phoebus
 - Archiver
 - Alarm Handler
 - Channel Finder
 - Save & Restore
 - putLog

Services – Consoles

- Inspired by SLAC main HMI
- Status at a glance
- Launcher

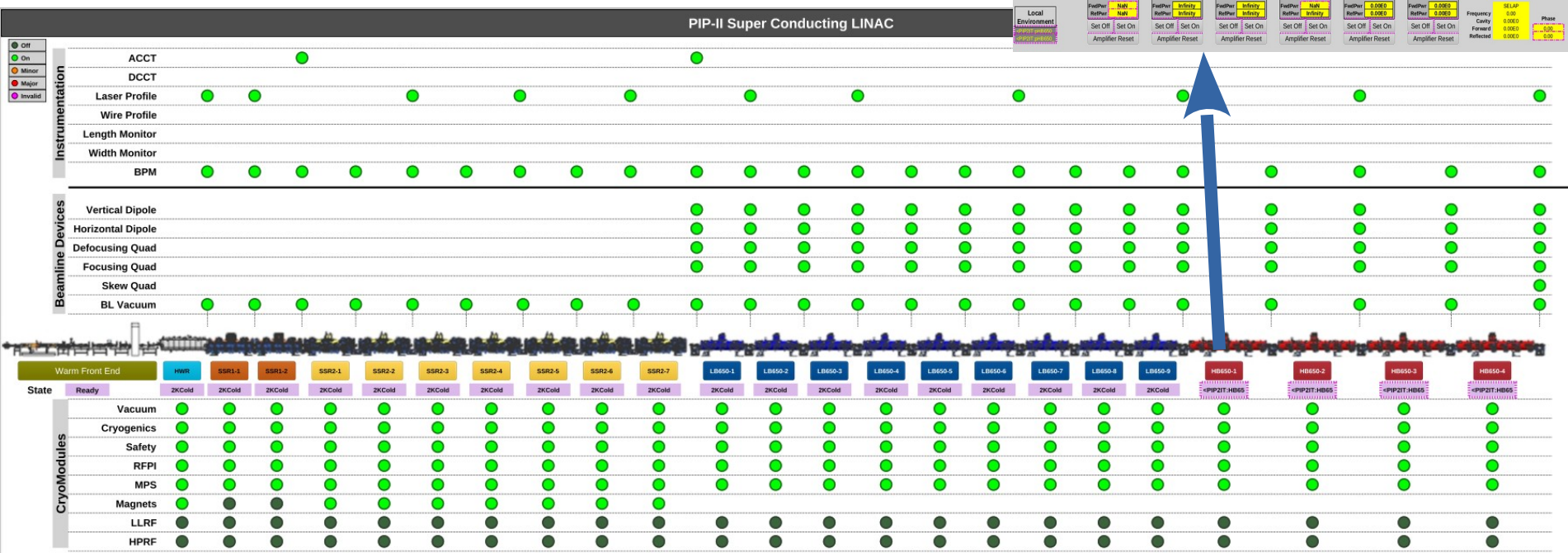
PIP2IT pHBE50-1 Overview

Fluids: Vacuum, CRYO, RFPI, MPS, LLRF

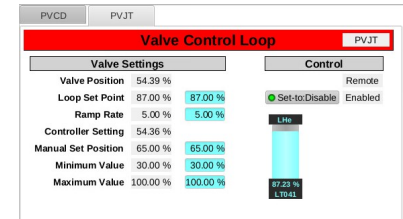
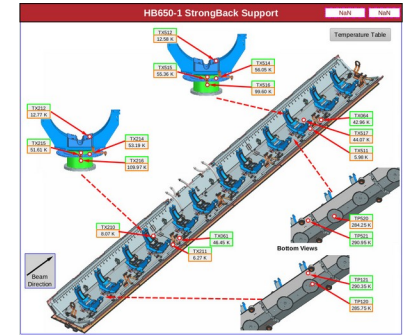
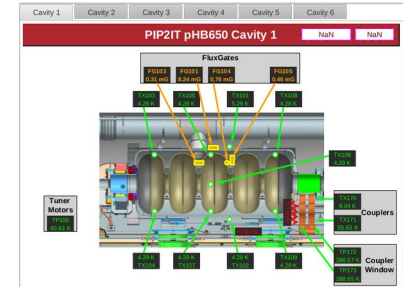
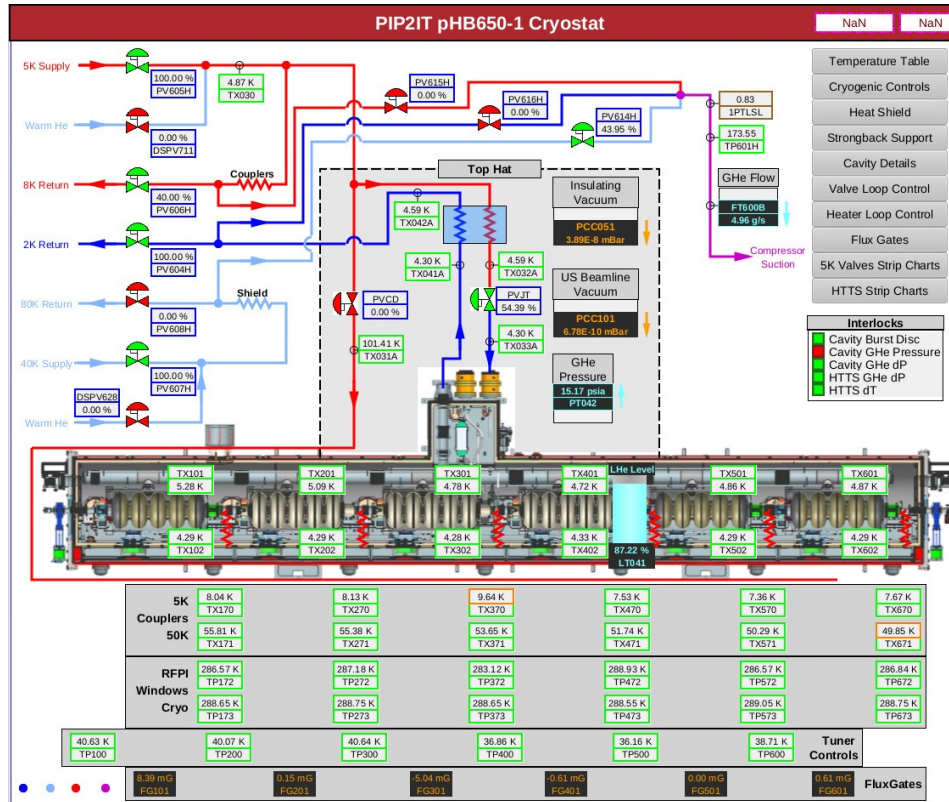
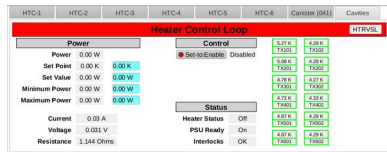
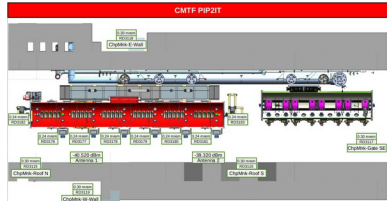
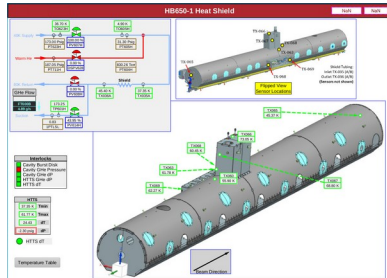
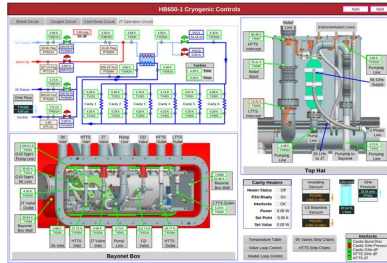
Radiation Detectors: Flux Gates, New RFPI

External ILKs: Water Temp Fault A, Water Temp Fault B, Water Temp Fault S, Test Load Flow Fault, Cric. & Load Flow Fault, Cavity Load Flow Fault

Local Environment: Frequency, Phase



Services – Consoles



Services – Consoles

BL8 Collimator

PLC HeartBeat

Primary Jaws

Secondary Jaws

Horizontal Primary Jaw Positions

Vertical Primary Jaw Positions

Motor M1V Status

- Enabled
- Direction Positive
- Moving
- Stopped
- At Lower LS
- At Upper LS
- Set LLim Error
- Set ULim Error
- Comm. Error
- Motion Error
- General Error
- Motor Network

Motor M2V Status

- Enabled
- Direction Positive
- Moving
- Stopped
- At Lower LS
- At Upper LS
- Set LLim Error
- Set ULim Error
- Comm. Error
- Motion Error
- General Error
- Motor Network

Set Parameters

Compare Motors & LVDTs

Set Calibrations

Set Position Limits

Horizontal Jaw Pair Positions

Vertical Jaw Pair Positions

0.00 Stop Wall

Set Point (mm) Pause Move Move Go

Jaw enabled

Expert Controls

M3H & M6H - mSHW

Jaw Skew Detection: no skew

0.00 Stop Top

Set Point (mm) Pause Move Move Go

Jaw enabled

Expert Controls

M3V & M6V - mSVT

Jaw Skew Detection: no skew

0.00 Stop Aisle

Set Point (mm) Pause Move Move Go

Jaw enabled

Expert Controls

M4H & M5H - mSHA

Jaw Skew Detection: no skew

0.00 Stop Bottom

Set Point (mm) Pause Move Move Go

Jaw enabled

Expert Controls

M4V & M5V - mSVB

Jaw Skew Detection: no skew

Motor M3H Status	Motor M6H Status	Motor M4H Status	Motor M5H Status	Motor M3V Status	Motor M6V Status	Motor M4V Status	Motor M5V Status
Enabled	Enabled	Enabled	Enabled	Enabled	Enabled	Enabled	Enabled
Direction Positive	Direction Positive	Direction Positive	Direction Positive	Direction Positive	Direction Positive	Direction Positive	Direction Positive
Moving	Moving	Moving	Moving	Moving	Moving	Moving	Moving
Stopped	Stopped	Stopped	Stopped	Stopped	Stopped	Stopped	Stopped
At Lower LS	At Lower LS	At Lower LS	At Lower LS	At Lower LS	At Lower LS	At Lower LS	At Lower LS
At Upper LS	At Upper LS	At Upper LS	At Upper LS	At Upper LS	At Upper LS	At Upper LS	At Upper LS
Set LLim Error	Set LLim Error	Set LLim Error	Set LLim Error	Set LLim Error	Set LLim Error	Set LLim Error	Set LLim Error
Set ULim Error	Set ULim Error	Set ULim Error	Set ULim Error	Set ULim Error	Set ULim Error	Set ULim Error	Set ULim Error
Comm. Error	Comm. Error	Comm. Error	Comm. Error	Comm. Error	Comm. Error	Comm. Error	Comm. Error
Motion Error	Motion Error	Motion Error	Motion Error	Motion Error	Motion Error	Motion Error	Motion Error
General Error	General Error	General Error	General Error	General Error	General Error	General Error	General Error
Motor Network	Motor Network	Motor Network	Motor Network	Motor Network	Motor Network	Motor Network	Motor Network

Motor Jaw Motion Test

Beam Losses

BSTR:BPLOT BLI BLM:wflntLosses

Primary Jaw Temperatures

[Sensor names: P1WU(C), P2WU(C), P3WU(C), P4WU(C), P5WU(C), P6WU(C), P7WU(C), P8WU(C), P9WU(C), P10WU(C), P11WU(C), P12WU(C), P13WU(C), P14WU(C), P15WU(C), P16WU(C), P17WU(C), P18WU(C), P19WU(C), P20WU(C), P21WU(C), P22WU(C), P23WU(C), P24WU(C), P25WU(C), P26WU(C), P27WU(C), P28WU(C), P29WU(C), P30WU(C), P31WU(C), P32WU(C), P33WU(C), P34WU(C), P35WU(C), P36WU(C), P37WU(C), P38WU(C), P39WU(C), P40WU(C), P41WU(C), P42WU(C), P43WU(C), P44WU(C), P45WU(C), P46WU(C), P47WU(C), P48WU(C), P49WU(C), P50WU(C), P51WU(C), P52WU(C), P53WU(C), P54WU(C), P55WU(C), P56WU(C), P57WU(C), P58WU(C), P59WU(C), P60WU(C), P61WU(C), P62WU(C), P63WU(C), P64WU(C), P65WU(C), P66WU(C), P67WU(C), P68WU(C), P69WU(C), P70WU(C), P71WU(C), P72WU(C), P73WU(C), P74WU(C), P75WU(C), P76WU(C), P77WU(C), P78WU(C), P79WU(C), P80WU(C), P81WU(C), P82WU(C), P83WU(C), P84WU(C), P85WU(C), P86WU(C), P87WU(C), P88WU(C), P89WU(C), P90WU(C), P91WU(C), P92WU(C), P93WU(C), P94WU(C), P95WU(C), P96WU(C), P97WU(C), P98WU(C), P99WU(C), P100WU(C)]

Secondary Jaw Temperatures

[Sensor names: S1WU(C), S2WU(C), S3WU(C), S4WU(C), S5WU(C), S6WU(C), S7WU(C), S8WU(C), S9WU(C), S10WU(C), S11WU(C), S12WU(C), S13WU(C), S14WU(C), S15WU(C), S16WU(C), S17WU(C), S18WU(C), S19WU(C), S20WU(C), S21WU(C), S22WU(C), S23WU(C), S24WU(C), S25WU(C), S26WU(C), S27WU(C), S28WU(C), S29WU(C), S30WU(C), S31WU(C), S32WU(C), S33WU(C), S34WU(C), S35WU(C), S36WU(C), S37WU(C), S38WU(C), S39WU(C), S40WU(C), S41WU(C), S42WU(C), S43WU(C), S44WU(C), S45WU(C), S46WU(C), S47WU(C), S48WU(C), S49WU(C), S50WU(C), S51WU(C), S52WU(C), S53WU(C), S54WU(C), S55WU(C), S56WU(C), S57WU(C), S58WU(C), S59WU(C), S60WU(C), S61WU(C), S62WU(C), S63WU(C), S64WU(C), S65WU(C), S66WU(C), S67WU(C), S68WU(C), S69WU(C), S70WU(C), S71WU(C), S72WU(C), S73WU(C), S74WU(C), S75WU(C), S76WU(C), S77WU(C), S78WU(C), S79WU(C), S80WU(C), S81WU(C), S82WU(C), S83WU(C), S84WU(C), S85WU(C), S86WU(C), S87WU(C), S88WU(C), S89WU(C), S90WU(C), S91WU(C), S92WU(C), S93WU(C), S94WU(C), S95WU(C), S96WU(C), S97WU(C), S98WU(C), S99WU(C), S100WU(C)]

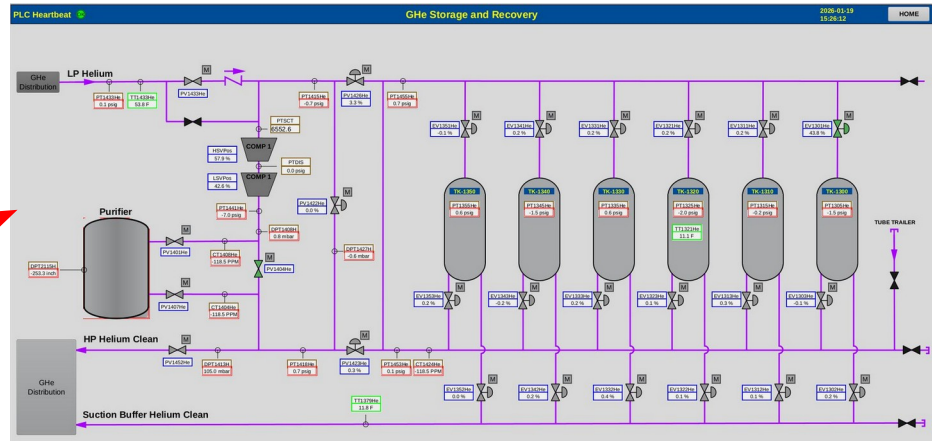
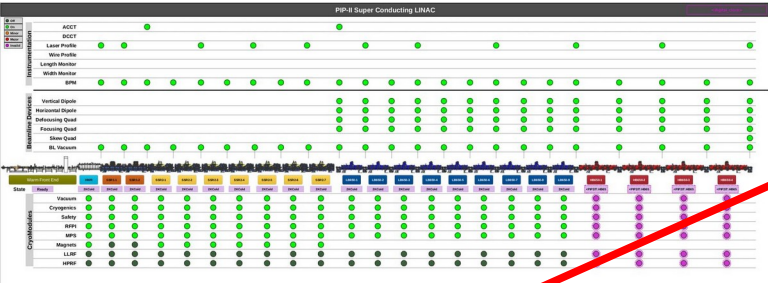
20/24 2026-04-20

Pierrick Hanlet, Fermilab

EPICS CM Spring 2026

Services – Consoles

Not just Controls group!



PIP-II Cryogenics Overview 2026-01-19 15:59:59

Cryoplant Screens

- Storage and Recovery S7 PLC (Operational) Mycom PLC (Operational)
- Purifier
- Mycom
- Helium Dewar
- Building
- ICL Loop

Coldbox Screens

CS-Studio MYCOM X

PIP-II Cryoplant Mycom

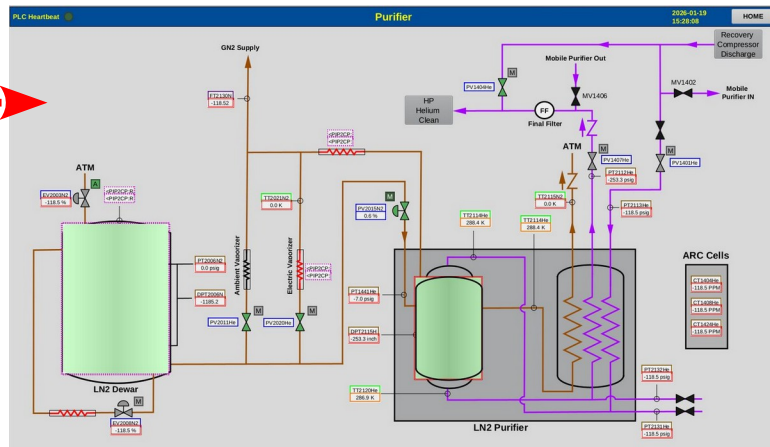
High Stage Slider: 57.90 %

Low Stage Slider: 42.60 %

Common Suction Pressure	6552.60 psf
Lube Oil Pressure	0.00 psig
Interstage Pressure	0.00 psig
Discharge Pressure	6553.30 psf
Discharge Temperature	5.22 C
HX Oil Temperature	9.89 C
Oil Manifold Temperature	9.78 C

Average Current	0.00 A
Average Voltage	0.00 V
Power Factor	1.00
Power	0.00 kW
kV-A	0.00 kV-A
Number of Starts	10.00

Oil Pressure	Operational
Shaft Sensor	Operational
Electric Monitor	Operational
Oil Temperature	Operational
Discharge Temperature	Operational
Discharge Pressure	Operational
Cooler Level	Operational
Motor Temperature	Operational
Drive Fault	Operational
Unload Time	Operational
Drive Ready	Operational
Emergency Stop	Operational
Starter Communication	Operational
Slider Response	Operational
Compressor Unloaded	Operational



Test Stands and Production

- PIP-II is all EPICS
- All IOCs are to be deployed with the full stack EPICS infrastructure
 - not yet considering legacy systems
- Three immediate deployments (2026):
 - Ion Source test stand
 - Cryo Plant
 - CMTF (Cryomodule Test Facility)
- Will test full service stack with IOCs
- Will test securePVA with sPVA between IOCs and services
 - Controls test stand (my office)
 - CMTF
 - perhaps the others?

PIP2IT Lessons Learned

- After initial rapid development, we are now progressing more slowly
- PIP2IT is the CM test stand – successfully tested first CM in June 2023
- Also test stand for EPICS IOCs and services
- IOC deployment works well
- Big Lesson: cannot install & deploy services and forget them
 - Phoebus worked well but slow when hosted from linux servers on windows and not well configured
 - GUI updates – need better defined CI/CD path
 - need proper configuration of Phoebus alarms, Archiver Appliance, Channel Finder, cannot simply install and ignore
- **This is now our principle focus** – Mariana's presentation

Concluding Remarks

- EPICS is now well established at Fermilab and is here to stay
- Green field allows us to build with latest software versions
- Our CI/CD pipeline is fully functional
- Many tests still to write
- Network booting embedded systems and NFS mounted EPICS code (IOCs)
- Deploying several EPICS services (Consoles, Alarms, Archiver Appliance, Save & Restore, and Channel Finder)
- Now pure PVXS/multicast
- Services are our main focus
- Testing sPVA

