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# HPS Slow Controls Plan

# Overview

- Introduction
- Motorized applications
- Voltages for detectors
- SVT interlocks
- Miscellaneous HPS applications
- Summary

# Adding a Component to Controls

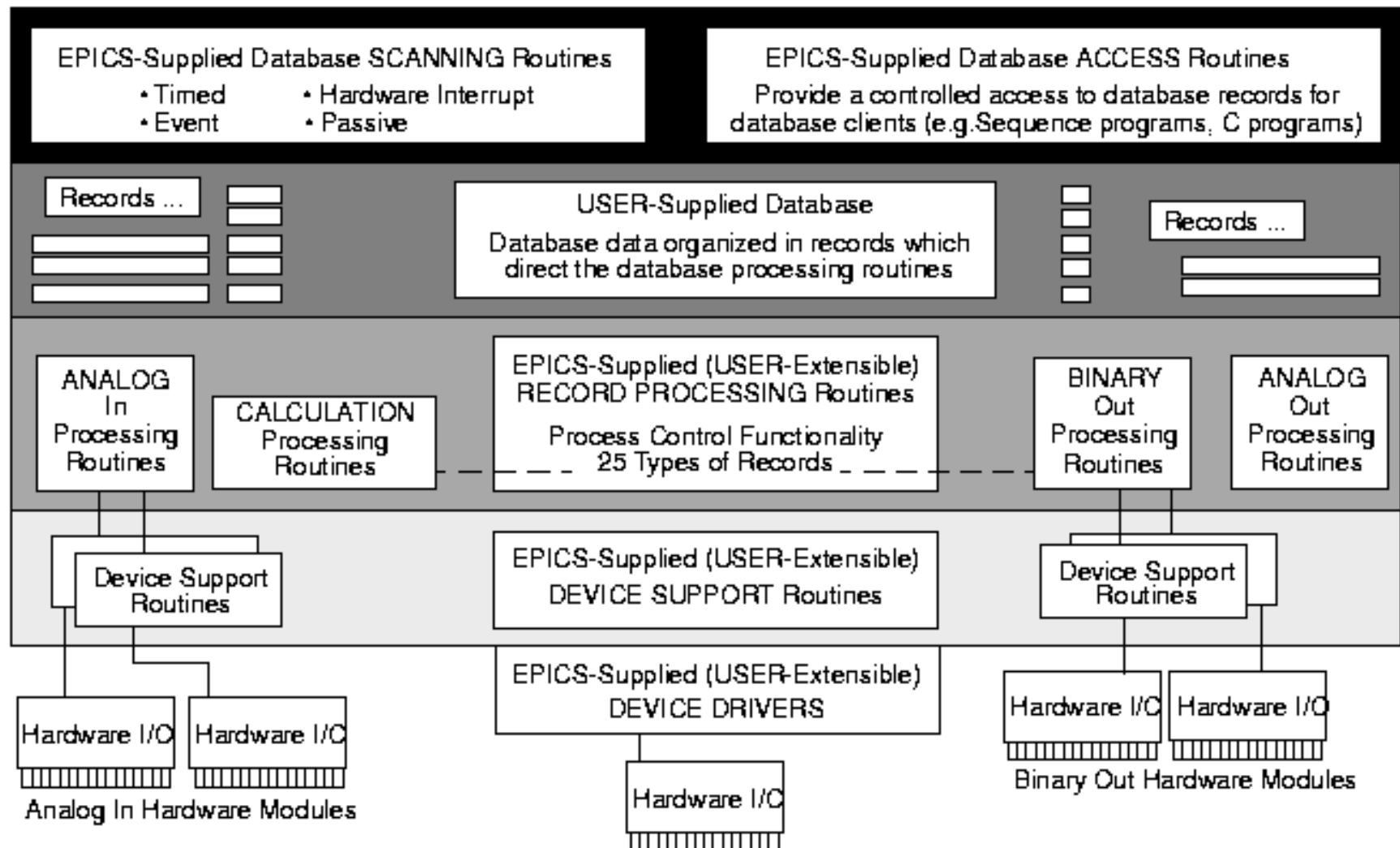
Below is what the Controls Group needs to do to implement the controls for a newly requested component:

- Get a request from detector group
- Study the existing hardware
- Make a basic design the controls system
- Purchase the hardware (I/O modules, CPU, cables, etc)
  - Usually a wide selection pool
- Write software (EPICS)
  - EPICS driver
  - Device support
  - Application
  - GUIs
  - Other

# Introduction to EPICS

- Experimental Physics and Industrial Control System
- Free Open Source software based on C with a large user base
  - Main controls framework of CEBAF
- Server/Client model:
  - Input/Output Controller (IOC) serves variables over Ethernet using ChannelAccess protocol.
  - Clients on different hosts communicate with IOC(s) displaying, modifying, archiving values.
- Applications are usually written in form of EPICS record database
  - Each EPICS record type has a variety of fields, like VAL, SCAN, STAT.
  - EPICS record can connect to hardware through device support layer
  - Each record type has a set of functionalities, hence function block programming
  - Individual EPICS record instances (PVs) can have different processing
    - Periodic, S/W Event, Passive, H/W Interrupt
- EPICS community provides various tools, like display management, alarm handling, archiving of variables.

# EPICS Structure



# Screens, Alarms, Archiving, etc

- Hall B has been using **MEDM** EPICS extension for display management
  - Very simple, limited capabilities
  - Old package from gos, but we do not have manpower to upgrade to newer framework.
  - Should provide sufficient functionality for HPS (used in test run)
- Hall B has been using the EPICS alarm handler **ALH**
  - Configurable through a text file
  - EPICS extension from gos
  - HPS can use this.
- Hall B has been using **StripTool** EPICS extension to display time evolution of PVs
  - Standalone packages, old technology, works well
  - HPS can use this too.
- Hall B will be using **MYA** for EPICS archiving for CLAS12
  - MySQL based archiving system developed and supported by JLab accelerator
  - C++ documented API exists, experts are at JLab
  - Hall B may need to procure some hardware for CLAS12

# HPS Slow Controls Applications

- Magnet power supplies and beamline
  - Use existing power supplies and probably control.
  - May need some work on GUIs if we use a new display management framework
  - Try to upgrade to newer VxWorks and EPICS versions
- Motion control
  - Harps, SVT scans, target, collimator, beam blocker
  - We need to develop the applications for SVT scans, others are pretty much ready
- High/Low Voltage control
  - Beamline, ECAL, SVT, Muon Detector
  - Need mostly to develop control and alarm screens
  - Interlock SVT power supplies
- Temperature monitoring
  - ECAL and SVT temperature monitoring, chiller for SVT, interlock for SVT
  - Can use a different approach to signal IO like PLC readout
- ECAL light monitoring system
  - Need to distribute pulses to LED to check ECAL channels
- Monitoring of scalers
  - Main feedback from detector components
  - Need to develop EPICS support for JLab modules

# Magnet Controls

- Our plan is to use existing Hall B magnet power controls.
  - No money allocated for these in the project.
- Control cables have been disconnected, not documented
  - The main dipole (PS magnet) control is simple, serial communications
  - Krister will need to spend some time on restoration of the following:
    - Frascati magnet controls (minitorus power supply)
    - Moeller polarimeter quads
    - Moeller target Helmholtz coil power supply
  - If some of the magnet controls are not easily restored then they become projects.
    - Hall B with accelerator division's help most likely will take care of these situations.
- Tagger magnet will be handled by the accelerator divisions controls group.
- Gaussmeter readout in the Pair Spectrometer and one Frascati magnet will use existing EPICS-based setup.
- No new application development is foreseen.
  - May need small modifications to the GUIs



# Motors

- Beamline Motors
  - 2C21 harp (1 axis)
  - Moller target (1 axis)
  - 2c24 harp (1 axis)
  - Collimator (1-axis)
  - 2Hoo harp (1 axis)
  - HPS target ladder (1 axis)
  - Beam blocker (1 axis)
- SVT motors
  - SVT sensor positioner (2 axes)
  - Need to send a setup to SLAC to test the full system before installtion
- We will use CLAS6 custom-made boxes with OMS drivers for motor controls
  - Each box can driver four axis
  - Each driver box needs an OMS VME control board
  - Krister built these boxes, installation of these should not be a problem
- We need one Hall-B motor control box with 4 axes upstream (space-frame), and 2 control boxes with total of 8 axes downstream (pie-tower)
- EPICS support for the basic operations of these motors exists.

# Stepper Motor Control

- The control modules from OMS has EPICS interface.
  - “motor” EPICS record type
- We did not use any of the HPS motorized stages during 2012 test run.
  - Interfacing to EPICS should be pretty straightforward since the hardware was selected Hall B controls framework in mind.
  - For potentiometer readout we need analog input channels.
- An application needs to be written if the motor is expected to do any automated motion
  - Create EPICS database or state code to set the appropriate fields of the motor record at appropriate times.

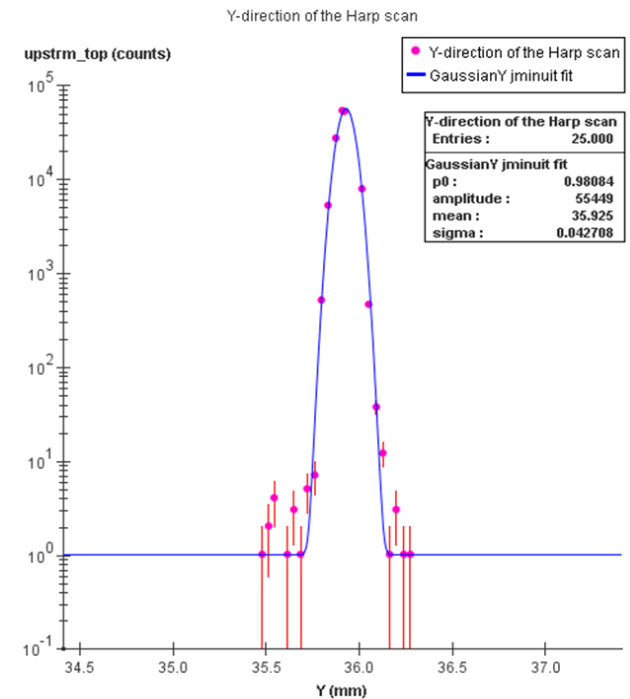
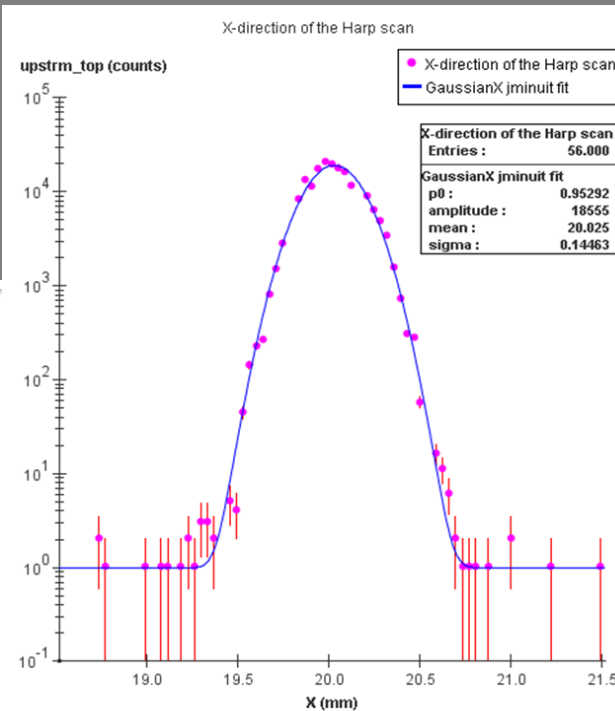
The screenshot displays the EPICS control interface for a stepper motor, titled "harp\_tagger (epics: harp\_tagger)". The interface is organized into several sections:

- Drive:** Contains fields for "Hi limit" (150,000), "Readback" (0,000), "MoveAbs" (0,000), and "Lo limit" (-150,000). It also features "JogR", "JogF", "HomR", and "HomF" buttons. A red "Stop" button is visible.
- Dynamics:** Includes "Speed" (0,500), "Base Speed" (0,010), "Accel." (0,010), "Backlash distance" (0,000), and "Move Fraction" (1,000). It also has "Normal" and "Backlash" tabs.
- Calibration:** Features "Cal" (Use, Set), "Off" (0,000), and "Dir" (Pos, Neg) buttons.
- Setup:** Contains fields for "Motor res." (0,001), "Encoder res." (0,001), "Readback res." (0,000), "Retry deadband" (0,001), and "Retries" (0, max: 10). It also has "Use Encoder" and "Use Readback" buttons (No, Yes).
- Status:** Displays various status fields: "State 0x" (0x105), "CurrDir" (1), "Moving" (0), "At Home" (0), "MotorPos" (0), "Encoder" (0), "MIP 0x" (0x0), "Err" (0,000), "Version" (4,30), "VME Card#" (0), and "Precision" (5).

# Scan procedure

- A harp is moving continuously at  $\sim 0.5\text{mm/s}$  speed across the beamline
  - The control modules for the motors are in a VME crate.
- VME scalers attached to the beam halo detectors or other detectors are continuously read out.
  - In Hall B scaler readout happens on VME bus.
- Every few millisecond both motor position and scaler readings are written to the disk.
- The scaler readout and harp motion needs to be synchronized.
  - The level of synchronization depends on the speed of the harp and required precision in the beam position.
  - Having both motors and scalers and motor controller on the same VME bus is sufficient.
  - If these are in different crates communicating over Ethernet:
    - The motor control module needs to send out strobe signals for scaler latching.
    - Scan needs to progress “sufficiently” slow, scans take long time

# Scans



- HPS needs 3 harp scans (3 motors):
  - Standard Hall B 2C21, 2C24, and 2Hoo harps
  - Hardware and software mostly exists
- Scans with SVT wires (2 motors):
  - New scans that will require
    - Detector channel that can be connected to scalers
      - Beam halo counters downstream of SVT
      - ECAL channel connected to a discriminator and scaler, unlikely, harder to implement.
    - New analysis software to determine the X- and Y- position of the SVT frame.

# Voltage Controls

- ECAL, beamline (and muon system) HVs will be provided by CAEN modules housed in SY1527 chassis
  - Used this in HPS Test, CLAS6, will be used by CLAS12 and GlueX
  - Need two SY1527 crates for HPS
  - We have experience with CAEN SY1527 EPICS support
- Wiener MPOD-based HV/LV system for SVT biases and LV
  - HPS SVT will use one MPOD crate
  - SNMP-based EPICS interface exists, used by Hall B and Hall D

# CAEN SY1527 and Wiener MPOD

- EPICS support for CAEN
  - From CLAS6 slow controls
    - Most likely HPS will use this approach since the framework for the rest of the HV application exists
  - From Canadian Light Source
- EPICS support for MPOD
  - MPOD voltage parameters are obtained using SNMP driver for EPICS
  - Hall D developed a driver and application to configure EPICS variables automatically using the information from the chassis and an SQLite DB.
- The list of channels for SVT biases and LV and ECAL voltage grouping are already available
  - The actual board/channel-to-detector mapping for SVT and ECAL will be determined later when the detector design is complete.
- EPICS IOC will be configured by YerPhI (Nerses)
  - Run on a Linux-based server in the counting house.
  - Schemes similar to what used in CLAS6 for CAEN and in GlueX for MPOD.
  - Some of the PV inputs will be CA channels that will be served from CA server in the SVT DAQ (Ryan).
- GUIs for SVT and ECAL will be handled by Glasgow (Bryan)
  - New main GUIs for HPS voltage controls
  - Use the CLAS6 scheme to autogenerate MEDM and alarm GUIs.

# Voltage GUI Prototypes

svtStatusPS.adl

HPS SVT POWER SUPPLIES

WARNING  
TO BE USED BY SVT EXPERTS ONLY !

Bias Voltage Setpoints 0

TOP SVT

TRIPS	ON/OFF	MEASURED CURRENTS			BIAS VOLTAGE	
		IVDD	AVDD	V125	MEASURED	DEMAND
Hybrid 0	<input type="checkbox"/>	0,000	0,000	0,000	0,000	0,000
Hybrid 1	<input type="checkbox"/>	0,000	0,000	1,000	0,000	0,000
Hybrid 2	<input type="checkbox"/>	0,000	0,000	0,000	0,000	0,000
Hybrid 3	<input type="checkbox"/>	0,000	0,000	0,000	0,200	0,000
Hybrid 4	<input type="checkbox"/>	0,000	0,000	0,000	0,000	0,000
Hybrid 5	<input type="checkbox"/>	0,000	0,000	1,000	0,000	0,000
Hybrid 6	<input type="checkbox"/>	0,000	0,000	0,000	0,000	0,000
Hybrid 7	<input type="checkbox"/>	0,000	0,000	0,000	0,000	0,000
Hybrid 8	<input type="checkbox"/>	0,000	0,000	0,000	0,100	0,000
Hybrid 9	<input type="checkbox"/>	0,000	0,000	0,000	0,000	0,000

BOTTOM SVT

TRIPS	ON/OFF	MEASURED CURRENTS			BIAS VOLTAGE	
		IVDD	AVDD	V125	MEASURED	DEMAND
Hybrid 0	<input type="checkbox"/>	0,000	0,000	1,000	0,000	0,000
Hybrid 1	<input type="checkbox"/>	0,000	0,000	2,000	0,000	0,000
Hybrid 2	<input type="checkbox"/>	0,000	0,000	0,000	0,100	0,000
Hybrid 3	<input type="checkbox"/>	0,000	0,000	0,000	0,100	0,000
Hybrid 4	<input type="checkbox"/>	0,000	0,000	0,000	0,000	0,000
Hybrid 5	<input type="checkbox"/>	0,000	0,000	2,000	0,000	0,000
Hybrid 6	<input type="checkbox"/>	0,000	0,000	0,000	0,000	0,000
Hybrid 7	<input type="checkbox"/>	0,000	0,000	0,000	0,100	0,000
Hybrid 8	<input type="checkbox"/>	0,000	0,000	6,000	0,000	0,000
Hybrid 9	<input type="checkbox"/>	0,000	0,000	3,000	0,000	0,000

VOLTAGES MORE PARAMETERS

Hybrid 0	Hybrid 0
Hybrid 1	Hybrid 1
Hybrid 2	Hybrid 2
Hybrid 3	Hybrid 3
Hybrid 4	Hybrid 4
Hybrid 5	Hybrid 5
Hybrid 6	Hybrid 6
Hybrid 7	Hybrid 7
Hybrid 8	Hybrid 8
Hybrid 9	Hybrid 9

Power Supply Interlock

Channel Name	Group#	Measured V	Demand V	Input V	Measured I	Status
R3S1STS1720 (Mf, Slot, Chan):	1 01 06 06	1503,600	1495,000	1495,000	8,040	2771,00

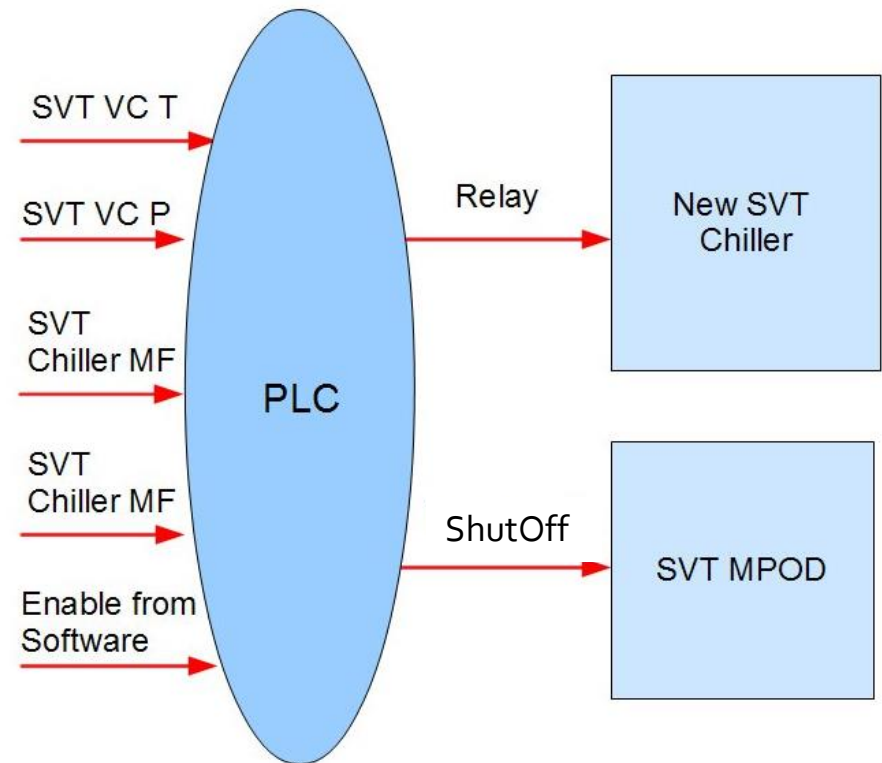
# MPOD Chassis and Boards

- Many labs use MPOD power supplies as standard equipment.
  - Hall D already has experience with using MPOD based chassis
    - Used them during 2012 beam test of GlueX miniBCAL
      - No hardware interlocks are required for GlueX, no in-house experience with this.
      - Interlocks for voltages needs to be designed.
- Interlocks for the MPOD supplies can be either on board level or chassis level
  - Boards can have option for interlock:
    - ISEG EHS HV modules have SL LEMO connector for safety loop (ENABLE) requiring 5mA current to enable channels on the board. Fast shutoff of all channels on the board there is no current.
    - Wiener MPV 8008 modules can have DSUB-37 with ENABLE per group of 4 channels. If TTL level is zero all channels are turned off.
    - Wiener MPV8008 modules have safety loop connectors for DSUB-37 connector for groups of 4 channels. If the loop is open the 4 channels are turned off.
  - HPS chassis will have controller with a DSUB9 connector with ENABLE and SHUT\_OFF
    - All channels on a chassis can be ENABLED by a TTL level (ramp down if zero level)
    - All channels on a chassis can be shut off by a TTL level (delay of 190msec)



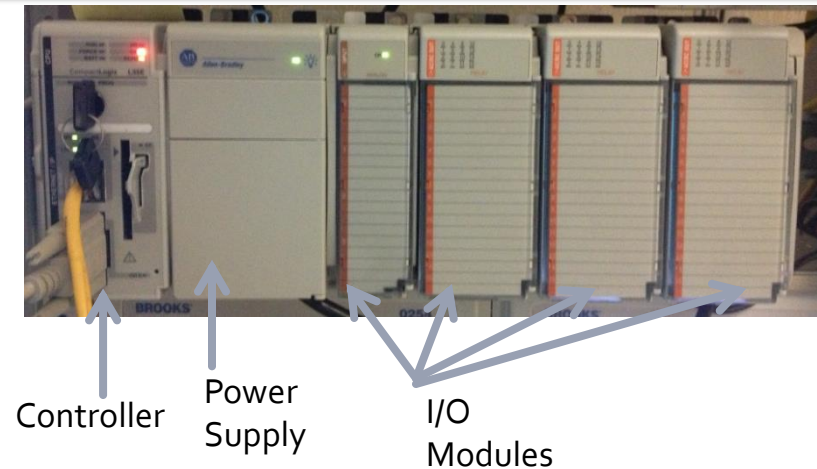
# SVT Interlocks

- SVT cooling and power need to be interlocked to avoid damaging SVT equipment. Power and coolant flow needs to be shut off when there is a problem with:
  - SVT temperature
  - Pressure in the vacuum chamber
  - Flow in the cooling line
  - Fast-Shut-Down (FSD) from accelerator
  - Software input
- The timing requirements from the SVT group are not very strict, on the order of zooms.
- Preliminary design based on Allen-Bradley PLC chassis
  - Still need to spec it and procure the hardware



# A-B CompactLogix 1769 PLC

- Need to have at least three analog inputs.
- At least one digital (TTL) input.
- Fast shutdown signal generation (~200ms).
- 5V digital output for SVT power supplies
- Relay for the chiller shutdown



- Allen-Bradley Programmable Logic Controller (PLC)
  - Modular system, can easily add more I/O modules.
  - Relatively inexpensive hardware (<\$10K for interlocks only).
  - Can program any logic at any time if we have a software license.
  - Easily inefaceable with EPICS to see the statuses and values of the inputs.
  - Hall D developed an interlock system based on A-B CompactLogix.
  - Decisions can be taken and output can be produced on ~50ms time-scale.
  - Used in Hall D, some local expertise and development platforms are available.

# PLC for Analog and Digital I/O

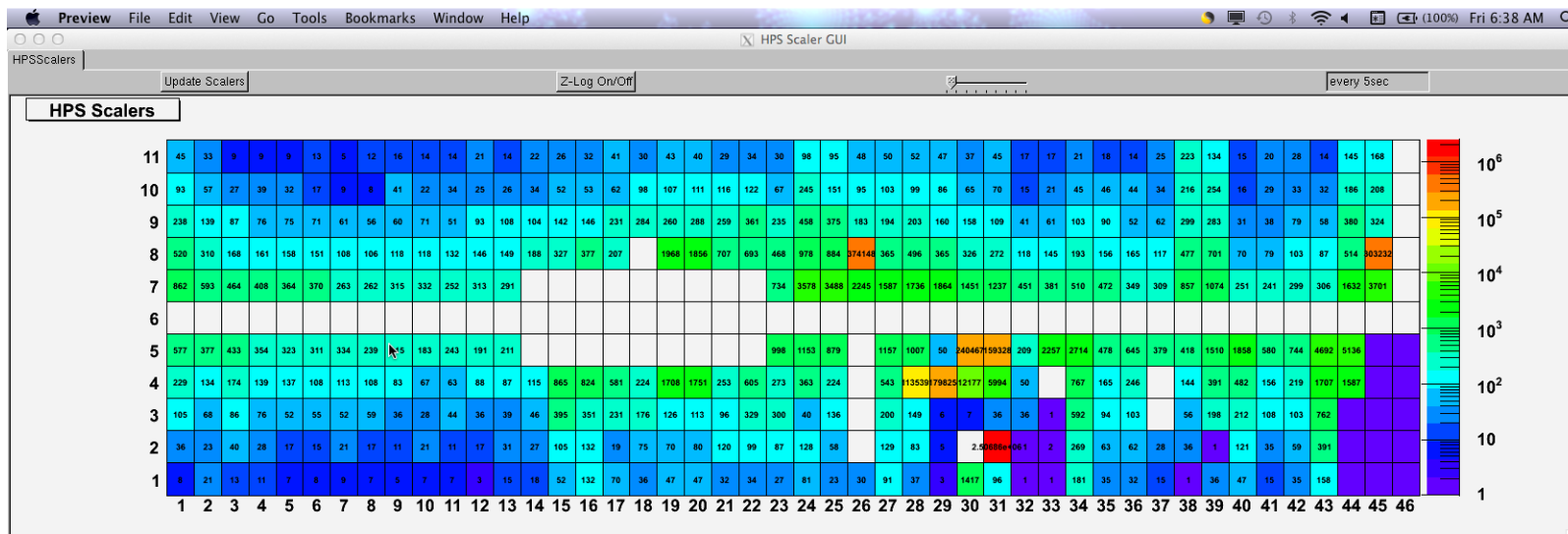
- We can use PLC chassis for the SVT interlocks for Analog and Digital IO
  - Thermocouple/RTD inputs
  - Mass flow meter, vacuum chamber pressure readback
  - Potentiometer from motorized stages
  - Any other last minute requests will be simple enough to implement
- Allen-Bradley ControlLogix and CompactLogix PLC are easily interfaced with EPICS through Ethernet (EthernetIP protocol).
  - Extensively used in Hall D for the lowest layer of the control system
  - Developed a set of Python scripts to generate EPICS database with simple record types from the RSLogix5000 project file (PLC program in XML format).
- Programming PLC requires expertise
  - If only used to obtain the reading for EPICS then not much PLC programming will be required.
  - HPS probably can borrow Rockwell software licenses from Hall D for short amounts of time.

# Temperature Monitoring

- ECAL needs to be thermally stabilized, temperatures need to be monitored.
  - In 2012 the monitoring was done using Omega thermocouples and RS-485 readout modules.
  - If new thermocouples/RTDs are installed, we can use PLC readout modules; otherwise use the existing system.
- SVT board temperature is monitored using temperature sensors readout by SVT DAQ when DAQ is running
  - ChannelAccess server within DAQ is developed by Bryan.
  - Interfaced with EPICS, but not reliable to be used in interlocks or alarms.
  - We may need thermocouples/RTDs on the SVT vacuum chamber to monitor temperature.
- SVT cooling requires a chiller that needs to be operated remotely
  - Primex chiller did not match well the SVT needs, caused some confusion.
  - HPS will procure a dedicated chiller with remote control that can be interfaced with EPICS through RS-232.
- Extra temperature sensors not yet implemented can be read out using PLC
  - Hall D uses A-B CompactLogix for a large number of temperature measurements.

# Scaler Monitoring

- It is very important to have as much scaler information displayed online as possible, waiting for offline analysis may lead to time waste.
- During spring run we had scaler values for ECAL in ROOT
  - Sergey wrote the software to read the scalers from the discriminators and plot them in ROOT.
  - Hall D test run had a scaler read out from FADC and plotted them in ROOT.
- It is desirable to have scalers from JLab discriminators and FADC250 in EPICS
  - Can be view from many locations
  - Can be archived in MYA
  - Can setup alarms.



# ECAL Light Monitoring



- ECAL will have a light monitoring system with two custom-made controllers.
  - The same type as for CLAS12 Forward Tagger
- INFN/Genova is developing the firmware for the control module of the pulsing system.
- Glasgow group is developing EPICS support for the CLAS12 Forward Tagger controller and the monitoring procedure which we can use for HPS.
  - Accelerated schedule for Glasgow/INFN groups to meet HPS schedule.
- The hardware and software are expected to show up at Jefferson Lab ready to be used.

# Summary

- The slow controls group has been meeting since the summer
  - Identified contact for different detectors
  - Have discussion on each slow controls component during the meetings.
- HPS slow controls group received the requirements for controls from the detector groups.
  - Some details will be finalized at a later time.
- We have experience with most of the type of applications needed in HPS.
  - PLC-based interlock is new type of application for Hall B.
- Need to develop some EPICS drivers
  - Chiller, discriminators, FADC, ECAL light monitoring.
- We have a basic design for the control systems
  - Preliminary designs for each components.
  - No show-stoppers identified.
- Manpower assignments to the controls project are underway.
- A lot of exciting work ahead of us!

# End

- Thank You !