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# PXIE/PIP-II Control System

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# Outline

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- PXIE Control System
- Thoughts on PIP-II Control System
- Focus on general infrastructure, not specifics
  - And not much on hardware



# Goals for PXIE Control System

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- Control/operate the PXIE accelerator
  - Learn what is needed for PIP-II design
- Test bed for for PIP-II
  - Try out new hardware and software
  - Without compromising the first goal



# Control System Scope

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- High level subsystem control and monitoring:
  - Power Supplies
  - Water
  - Cryo
  - Instrumentation
  - RF
  - Motion Control
  - Machine Protection
- Beam control applications
- Timing system



# PXIE General Plan

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- Based on ACNET
  - It is what we know and use in the main complex
- Similar to NML control system
- NML tries to be forward looking:
  - No CAMAC, C190/290 MADCs, CIA vacuum, IRMs, ...
  - Instead VME, PLCs, HRMs
  - Limited console style applications.
  - Instead use of synoptic displays, Java applications, ...
- Assume most development by FNAL
  - Need discussion with ANL on HWR subsystem



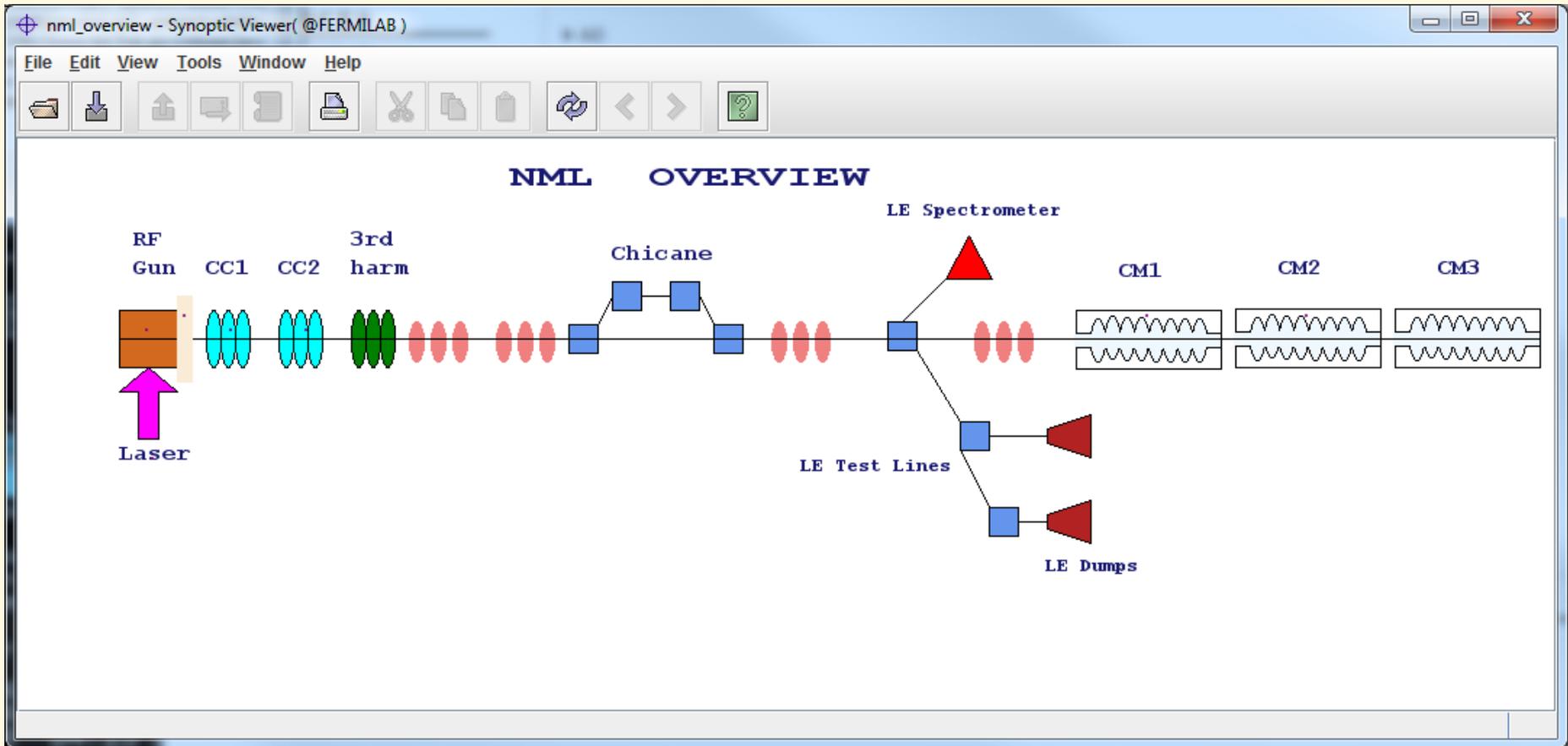
# Synoptic Display

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- Drag and Drop builder, no code writing required
- Launch via console index page, or from a web browser
- Web display available, no extra work required
  - Viewable on phones
- Supports plots, fetching data logger data
- Can create links to other displays
- Basic functional expressions available without writing code
- Possible to have Finite State Machine back-end
- Possible to attach ACL scripts for more complex things
  - Discouraged for very complicated things
- Heavily used at NML and by cryo in general



# NML Overview Synoptic





# NML Laser Room Synoptic

Laser\_Room - Synoptic Viewer (@FERMILAB)

File Edit View Tools Window Help

10.2.2014 12:35:08

### NML Gun Laser Room

**General**

Room Temp: 67.7°F 19.8°C  
 Humidity: 40.9 %  
 Dew Point: 7.9°F -12.5°C  
 Xport Alignment Laser:

Digitized Signals

**Seed Laser**

Voltage: -0.003 V  
 Phase: 17.5 ps  
 PD Gain: 1.41 dB

**Amplifiers**

	Pre-Amp	SPA #1	SPA #2	SPA #3	NGA
Diode Current:	70.8 A	91.1 A	90.1 A	84.2 A	79.6 A
Trigger Delay:	1.480 mS	1.920 mS	2.105 mS	2.000 mS	1.880 mS
Pulse Width:	0.833 mS	0.393 mS	0.213 mS	0.353 mS	603 us

Chillers: Termotec  PolyScience

ON

**UV Section**

Green Crystal: 0  
 UV Crystal: 0  
 Waveplate: 50.0%  
 UV Photodiode: 4.87 μJ/p  
 9-Way: 4.27 μJ/p

Area: 192" x 47"

The diagram illustrates the laser beam path starting from the Calmar Seed Laser (λ=1053nm). It passes through a Pulse Picker, Isolator, and a series of amplifiers: Pre-Amplifier, SPA #1, SPA #2, and SPA #3. Each amplifier stage includes a 1054nm Half Wave Plate and a PC Diode. The beam then passes through a 9-Way XPort and a Streak Camera. A Filter Wheel is positioned before the UV Half Wave Plate (λ=263nm). The UV section includes a Green Diode, UV Shtr, UV Diode, Green Shtr, and NGA Diode. An Alignment Laser (λ=543nm) is also shown. The system is controlled by PC #1 and PC #2.

**Timing**

Pulse Number: 40

Timing Diagram

**Shutters**

Seeds  NGA  GR  UV  Xport

Yb-FA  Nd:YLF

**Diagnostic**

Streak Camera: Green:  UV:

Filter: OD\_0.5

Xport Simulation

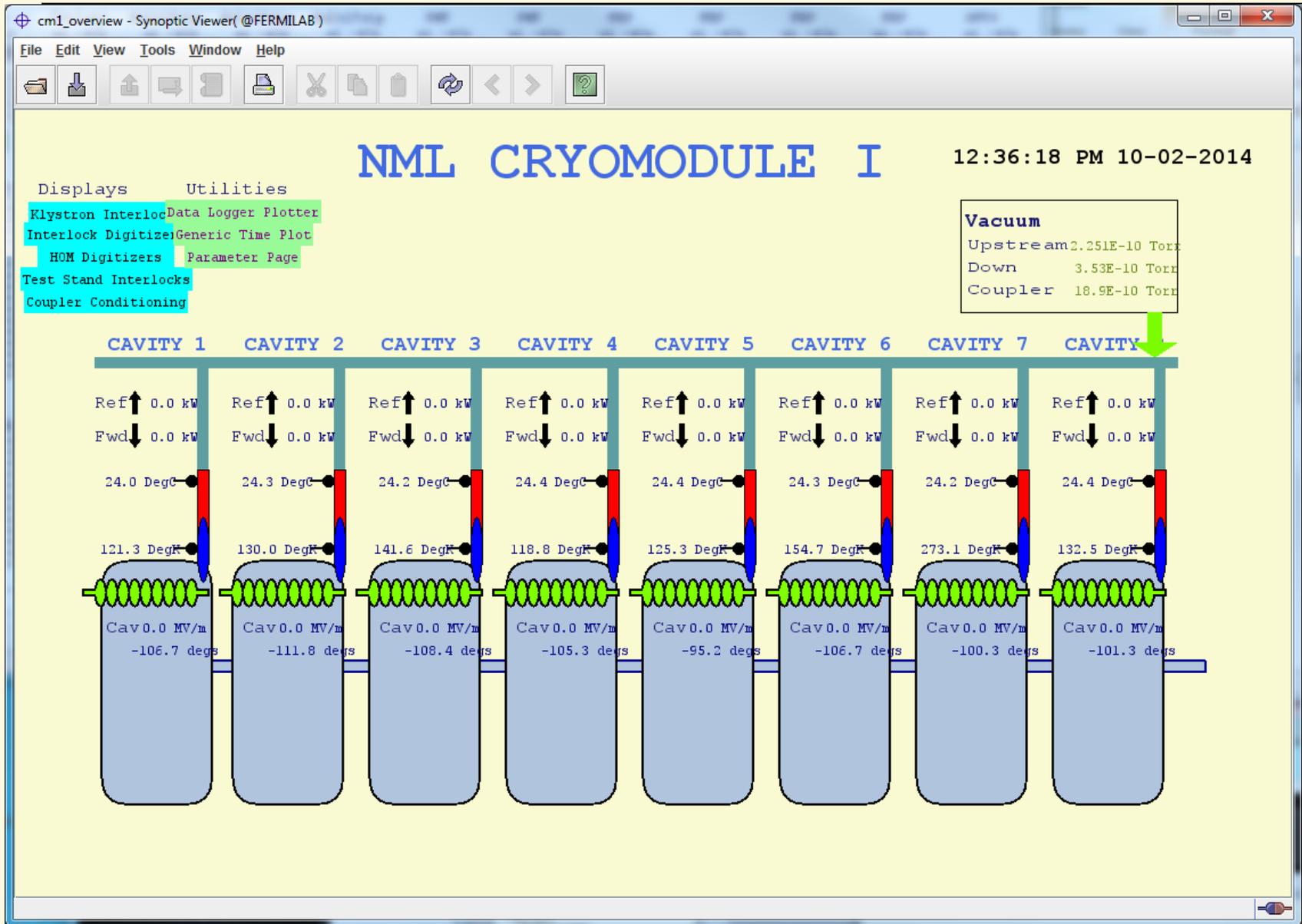
Camera View

Summary

ASTA Overview



# NML Cryomodule Synoptic





# Nova Near Detector (Web version)





# NML Coupler Conditioning

Backed by FSM

**coupler\_conditioning - Synoptic Viewer**

File Edit View Tools Window Help

**CM1 Coupler Conditioning**

Coupler #

<b>Sequence Control</b> <input type="checkbox"/> OFF <input checked="" type="checkbox"/> Enabled FSM Status <input checked="" type="checkbox"/> FSM ON	<b>RF Source</b> <input type="text" value="Marconi"/> Amplitude 0.100 Center Freq «57 -33» <input checked="" type="checkbox"/> RF Power OFF Pulse Width 0.020 MS	Hard Trips «1 -3» Soft Trips «1 -3» Elapsed Time NaN	<input type="button" value="Show Sequence"/> <input type="button" value="Timing Diagram"/> <input type="button" value="Time Plot"/>																		
	<b>Starting Power (dbm)</b> <input type="text" value="0"/> Power Step Up <input type="text" value="B"/> Power step soft trip <input type="text" value="G"/> RF Fraction@trip <input type="text" value="F"/> Steps after trip <input type="text" value="N"/> Step Time (s) <input type="text" value="A"/> Step time soft trip <input type="text" value="H"/> Post trip delay (s) <input type="text" value="K"/> Step time recovery <input type="text" value="C"/> Dwell time(s) <input type="text" value="I"/> Power Chg Thresh <input type="text" value="L"/> Power Step Up 2 <input type="text" value="M"/>	<b>Soft Limits</b> <input type="button" value="Clear"/> <input type="button" value="FFEEVVVVTTT"/> <table border="1"> <thead> <tr> <th>T1</th> <th>T2</th> <th>Vacuum</th> <th>e- «1 -3»</th> <th>PMT</th> </tr> </thead> <tbody> <tr> <td>«0 0»</td> <td>«0 0»</td> <td>10E-12</td> <td>«0 0»</td> <td>«0 0»</td> </tr> <tr> <td></td> <td></td> <td>11E-12</td> <td>«0 0»</td> <td></td> </tr> <tr> <td></td> <td></td> <td>11E-12</td> <td>«0 0»</td> <td></td> </tr> </tbody> </table>	T1	T2	Vacuum	e- «1 -3»	PMT	«0 0»	«0 0»	10E-12	«0 0»	«0 0»			11E-12	«0 0»				11E-12	«0 0»
T1	T2	Vacuum	e- «1 -3»	PMT																	
«0 0»	«0 0»	10E-12	«0 0»	«0 0»																	
		11E-12	«0 0»																		
		11E-12	«0 0»																		

PWidth(ms)	Max Power
0.020	0.90
0.050	0.88
0.100	0.88
0.200	0.88
0.300	0.38
0.400	0.38
0.600	0.30
0.700	0.28
0.900	0.23
1.300	0.20

<b>RF Trip</b> «1 -3» «1 -3»	<input type="text" value=""/>
RFInh0t	safety
ModInh	contact2
RF Ant	ModIn
RFInh02	SigIn7
RFInh03	MOD Rdy
MultiRF	SigIn23
PMTRF	SigIn21
FEPFRF	SigIn22
PhotoRF	opt iso1
RelayRF	opt iso2
RF Ant Ch	opt iso3
RF on Sw	opt iso4
	opt iso5
	opt iso6
	PMT PS
	FEP PS



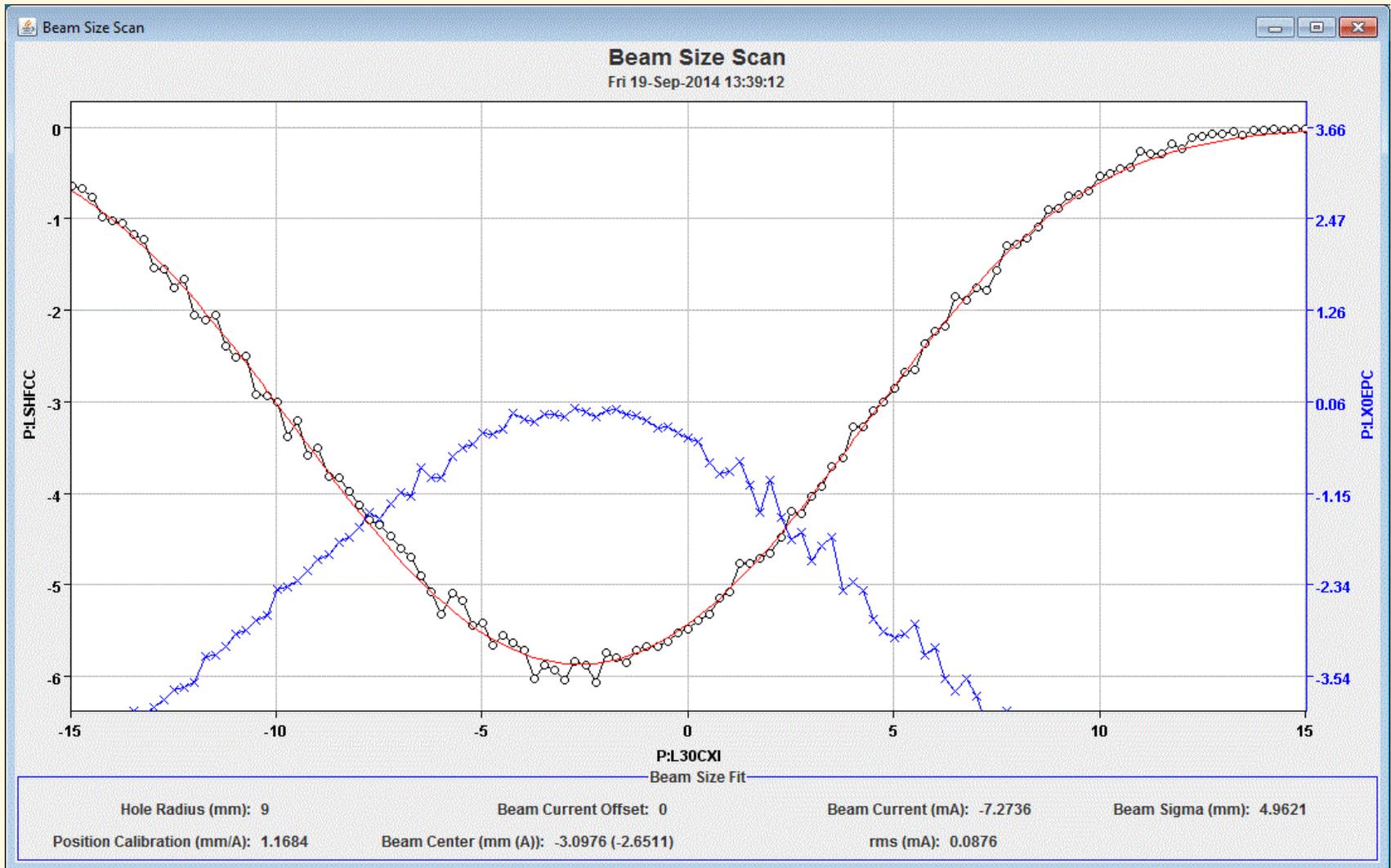
# Applications at PXIE

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- Currently no synoptic displays at PXIE
- Scan application recently written for use at PXIE
- Other work uses Labview or console plots
- Need to agree on what is needed, how they will be written, and who will write them
- We do have an interface to Matlab if there is interest
  - Currently no code management or launch from console



# PXIE Scan Tool





# NML Camera Image Tool

Image Tool

File Edit Tasks Tools Help

Front End: NML / ASTA (NMLDC1)

Camera Station: 9-way YAG/Target (Selected)

Camera Configuration

Description: 9-way YAG/Target

FNAL Tag #: 120417

Manufacturer ID: 138752

IP Address: 192.168.53.26

Frames Completed: 71682.0

Pixel Calibration: 9.2 um/px

Maximum X: 2448.0 px

Maximum Y: 2050.0 px

Set

Camera Controls

Pixel Format: Mono8

Shutter: 1000.0 us

Gain: 6.0

Binning X: 1.0

Binning Y: 1.0

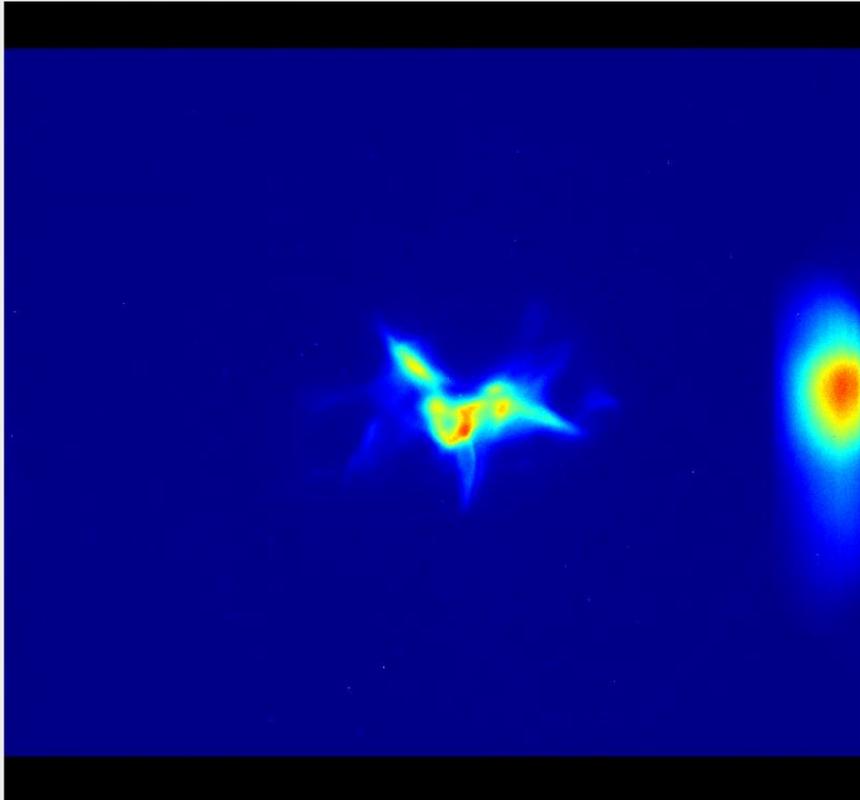
Trigger: SyncIn2

Set

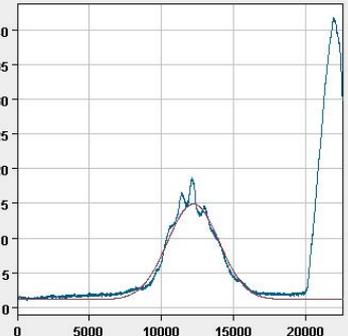
Screen Carriage Actuator

Position: Unknown

Set

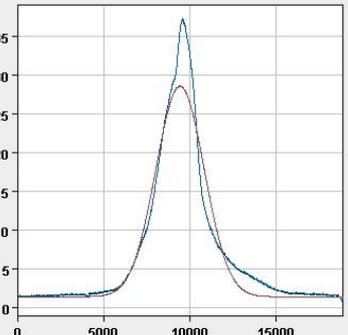


Baseline: 0 Sigma: 5



Fit 1 - Off: 2.4 Amp: 13.8 Pos: 12195.2 Sig: 1782.7

Baseline: 0 Sigma: 5



Fit 1 - Off: 1.5 Amp: 27.3 Pos: 9438.5 Sig: 1398.8

Pixels  Microns

Position Line

Marker Circle

Rotate Horz Flip

Vert Flip Saturation

Pseudo Color ROI

Acquire BG BG On

2014-09-26 09:49:16.022 (419 ms ago) Size: 26.3 KBytes Quality: 68 Scale: 2  
Position: 579.6um, 18823.2um Intensity: 1  
Saturated Pixels: 6

Live Acquisition One-shot Acquisition Load from File

Image Transfer Size: 30,000

Image Transfer Rate: 1 Hz

Analysis:  Front End  Image Tool

Start Stop

Connected to Front End / Reading Live Images



# PXIE Summary

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- Follow NML control system philosophy
- Current control system but with
  - Modern hardware/front-ends
  - Emphasis on synoptic displays
  - Java applications for complicated things
  - A good place to try something else if someone has an idea



# Thoughts on PIP-II

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- Major Constraint:
  - Large existing complex
  - PIP-II linac must interoperate with it
    - Ideally common a common control system
    - Timing and Machine Protection
  - Not practical to completely replace the current control system
- Major Unknown:
  - Role of India
- The following concerns the general infrastructure
  - Limited discussion of details
  - No discussion of hardware platforms
    - An equally intense religious issue



# Current Control System

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- Operates a very large and complicated complex
- Largest and most complicated aside from CERN
- Major increase in complexity beginning with start of BNB
  - No fundamental architectural changes required
- Very accessible – anyone can run a console
- Very large code base well managed (mostly...)
- Great flexibility in data acquisition (event+delay)
- Major evolution during Run II
  - Data acquisition engines, greatly expanded data logging
  - VAXes -> Linux
  - Many new hardware systems (BPMs, BLMs, instrumentation...)
  - The very modular nature of the system allowed this to happen



# Some Issues

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- Console user interface is not very modern
  - Java applications have existed for many years
  - Some have been useful but most were not successful
  - Attempts at modern C++ GUI framework have not been successful
    - However several MI programs use the ROOT C++ package
- Lots of old hardware
- Lots of old software
- Large data packets not well supported (images)
- Structured data supported in ad hoc way
- Limited capacity for logging large arrays
  - Images and waveforms
  - Note cataloging and fetching them out is harder than logging them



# Often Asked Question

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- Why don't we use EPICS?
- Everyone else does
- Then we just download it and we are mostly done



# What is EPICS?

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- EPICS is a toolkit, not a complete control system
- It specifies a communication protocol and front-end architecture, these are common among all installations
- It includes a basic set of tools which are fine for getting started or small installations, but not at all suitable for a large complex.
- Not only are machines different, but so are the people who build and operate them.



# EPICS cont.

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- So every large installation does something different for
  - Core applications (time plots, device viewer, etc.)
  - Synoptic display
  - Application framework and programming language
  - Alarms
  - Data logging
  - .....
- With multiple large projects currently in progress, there is an attempt at more commonality
  - NSLS-II, FRIB, ESS, LCLS-II, ITER, ...
  - But there are still very major differences for each
  - And other light source labs are not so much involved in this effort



# Other Labs & EPICS

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- SNS
- LCLS-I & II
- NSLS-II
- XFEL
- ESS
- FRIB
  
- Fermilab
  
- There are many other users, but the theme is similar



- SNS began operating in 2007, and was the largest EPICS system at the time.
- They developed a new everything on the previous list
  - Synoptic display (EDM)
  - Machine application framework (**XAL**)
    - Including common machine description and online model
  - Device database (and other databases)
  - Alarm system (multiple iterations)
  - Data logging (multiple iterations)
  - E-log (multiple iterations)
  - ...
  - Developed Control System Studio after started operations
    - Integrated framework for “core” applications, more later



# LCLS(-I)

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- Had custom legacy control system + hardware
- About as old as the Fermilab control system
  - Less evolution over the years, less modular system than ours
- General strategy was:
  - Keep old system for the part of the linac used for LCLS
  - Use EPICS for new things
  - Some interoperability between the two
- Several SNS people moved to SLAC
  - Original plan was to reuse SNS code, but in the end not much was
  - SLAC had a long history of doing things in a certain way
  - Different machine model format, different programming languages
- Machine control migrated to EPICS but in a different way
  - Matlab primary application language going forward



# NSLS-II

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- Developed separately from RHIC – separate accelerator
  - New technologies, initially less influence of past culture
  - But influenced by the tastes of those who developed it
- No reuse from original SNS or SLAC
  - They do pick up Control System Studio from SNS
- New database for machine model and everything else
  - IRMIS-II.
- Different framework for machine applications (python)
- Initiated extending EPICS communication protocol to support structured data (EPICS v4; pvAccess)
- New data logger based on "big data" technology



# FRIB and ESS

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- SNS machine application framework and core applications have been refactored to make it more modular, modern, and usable by other places (OpenXAL)
- FRIB and ESS have contributed and expect to use it
- They also expect to use Control System Studio
- They are also jointly working on basically a next iteration of the NSLS-II database architecture (DISCS)
  
- How much and how long they will stay in sync is not clear
  
- Note ESS plans to have a small core group and outsource much of the development to CosyLab



- Marriage of four different control systems
  - DOOCS (updated from FLASH)
  - TINE (updated from HERA)
  - EPICS (cryo system)
  - Tango (experimental beamlines)
- Each is a complete control system and has its own user interface framework, logging, alarms, etc. etc.
- User interfaces in one system can access quite a lot on the other systems
  - Several different interface technologies developed
- I don't consider this a good model...



# Control System Studio

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- Integrated package of “core” applications
- Plotting, alarms display, device viewer, synoptic display, logbook, hardware configuration, ....
- Based on Eclipse development framework
- Plugin based architecture
  - Plugins can communicate context with each other
  - You can create an instance with a selected set of plugins
- Originated at DESY, intended to be system agnostic
  - Picked up by SNS, became mostly EPICS-centric
- In operational use by SNS, NSLS-II
  - XFEL, ESS, FRIB, ITER and others plan to use it
- And here at Fermilab! – Nova Detector Control System



# CSS Data Browser

File Edit CSS Window Help

Data Browser CSS

Archive Search Navigator

URL:  Info

Name	Description	Key
RF/AnalogData		1
RF/BinaryData		2
BT/BTMagnets		3
VA/CCG		4

Pattern:  Search

Add...  Replace search re:  Reg.Exp.

PV Name	Name
BM_DCCT:HCUR	Misc/Base
BM_DCCT:LCUR	Misc/Base
BM_DCCT:HCUR	BM/DCCT
BM_DCCT:LCUR	BM/DCCT

BM\_DCCT.plt HX00E\_CREG.plt

Value 2 (left axis): 3707.51, 3000, 2500, 2000, 1500, 1000, 500, -161.52

Value 1 (right axis): 1102.13, 500, 0, -500, -1000, -1303.61

Time: 12 00:00, 13 08:00, 14 08:00, 15 08:00, 16 08:00, 17 08:00, 19 00:00

Legend: BM\_DCCT:HCUR (blue line), BM\_DCCT:LCUR (red line)

Properties Export Samples Inspect Samples Inspect Waveforms Progress

Show	Item (PV, Formula)	Display Name	Colo	Scan Peri	Buffer Siz	Width	Axis	Trace Type	Request
<input checked="" type="checkbox"/>	BM_DCCT:HCUR	BM_DCCT:HCUR		0.0	5000	2	Value 1	Area	Optimized
<input checked="" type="checkbox"/>	BM_DCCT:LCUR	BM_DCCT:LCUR		0.0	5000	2	Value 2	Area	Optimized

Archive Data Sources

Name	Key	URL
BM/DCCT	12	kblog:///KEKBlog

Not logged in



# Alarms Display w/Link to Other Tools

Alarm Table

Current Alarms

PV	Description	Time	Current Severity	Severity	Status	Value
RFQ_Vac:Pump2:Pressure	Demo pump 2	2009/03/17 16:48:10	OK	MAJOR	HIHI_ALARM	9.0
RFQ_Vac:Pump6:Pressure	Demo pump 6	2009/03/17 16:48:08	OK	MINOR	HIGH_ALARM	5.0
RFQ_Vac:Pump5:Pressure	Demo pump 5	2009/03/17 16:48:08	OK	MINOR	HIGH_ALARM	5.0
RFQ_Vac:Pump4:Pressure	Demo pump 4	2009/03/17 16:48:08	OK	MINOR	HIGH_ALARM	5.0
RFQ_Vac:Pump3:Pressure	Demo pump 3	2009/03/17 16:48:08	OK	MINOR	HIGH_ALARM	5.0
FE_MPS:MIOC1A:status_sum	MPS Beam permit	2009/03/17 16:46:28	MAJOR	MAJOR	LOLO_ALARM	2
ICS_Tim:Gate_BeamOn:Switch	Beam awf	2009/03/17 16:46:27	MINOR	MINOR	STATE_ALARM	Shift
CF_KL:DIWS_AIT4303B:Rs	CF_KL:DIWS_AIT4303B:Rs	2009/03/17 16:10:06	MINOR	MINOR	HIGH_ALARM	18.5
MEBT_CHOP:PS_2:V	mebbit chopper power supply two voltage fault		MAJOR	MAJOR	LOLO_ALARM	0.00

Acknowledged Alarms

PV	Description	Time
TMod:Summary_MPS:Alarm	Moderator System MPS Trip	2009/03/17 16:48:08
MEBT_CHOP:PS_1:V	mebbit chopper power supply one voltage fault	2009/03/17 16:48:08
HEBT_Coll:CT2:Cond	HEBT_Coll:CT2:Cond	2009/03/17 16:48:08

Filter

21:44:56

- Check MEBT PS 2 Chopper
- MEBT Chopper PS 2 Screen
- Logbook...
- Acknowledge
- Copy Pv Name to Clipboard
- CSS
- Configure Item
- Auto-size Columns
- Alarm Perspective

- Data Browser
- Data Browser View
- PV Table
- Rack View
- PV Utility
- PV Fields Viewer
- Probe
- EPICS PV Tree



# SNS Operational Displays

## SNS Operations

Power on Target **954.41 kW**

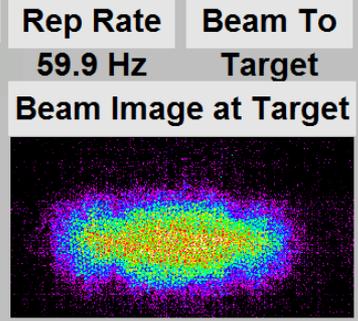
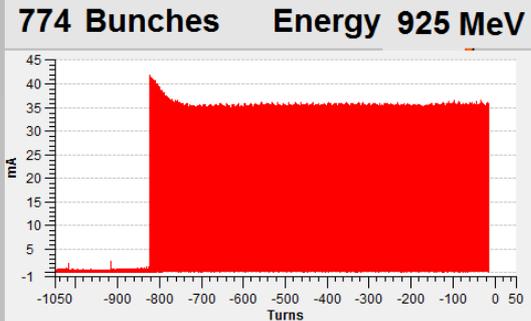
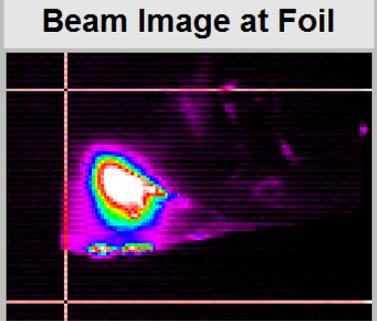
05/26/10 11:18:16

Ramp/Beam On	Beam Gate	Avg Current	Max Current	Rep Rate
50	774	850	21.8 mA	43.7 mA
PW On Flavor 1		I-Dump Charge		
Linac RF Status		44	1.8E-7 C	

## SNS Central Control Room

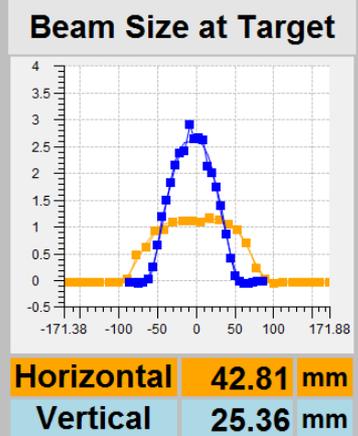
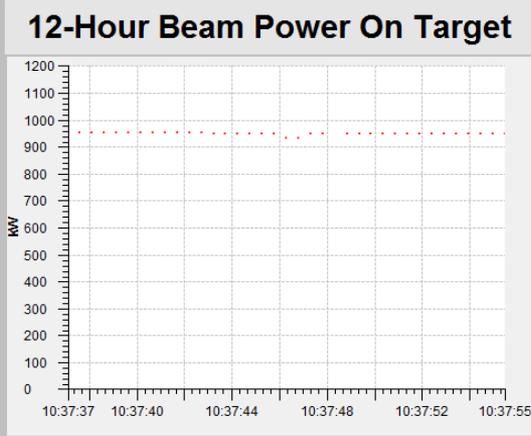
Power on Target **952 kW**

05/26/10 10:37:56



### Primary Shutter Status

USANS	NOMAD	<b>BASIS</b>
SNAP	<b>Magnetism</b>	<b>Liquids</b>
CNCS	<b>EQ-SANS</b>	<b>VULCAN</b>
8	CORELLI	10
<b>POWGEN</b>	MaNDi	TOPAZ
FNPB	HYSPEC	<b>NSE</b>
VISION	SEQUOIA	ARCS



### CCL

2	3	4
M2	M3	M4
X2	X3	X4

03c	04a	04b
07b	07c	
10c	11a	
13c	13d	
16a	16b	
18c	18d	
21a	21b	
23c	23d	



- HINS and NML both started as EPICS only systems
- Used mostly older core EPICS tools
  - Striptool for plots, old alarm system, etc.
- EDM synoptic display from SNS
- Data logger from SNS
- Some python applications written
- Lacked the organization of the main control system
  - Independent code management
  - No central console – run from command line
- To set it up properly was significant work and was not done initially.



# Transition at HINS/NML

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- HINS mostly transitioned to ACNET, NML did completely
- EDM synoptic displays put in MECCA
- Made launchable from ACNET consoles
- Dual EPICS/ACNET front-end developed
  - Selected instrumentation front-ends + all IRMs
- Possible to access ACNET devices in EDM
- Front-ends eventually all converted to pure ACNET
- Synoptic displays completely replaced EDM displays
- Python applications ported to Java



# Lessons Learned

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- It was interesting to try
  - We all learned a lot
- To do it in a scalable, maintainable way requires work
  - Ideally with some thought before doing the work
- Especially for a small system, there really wasn't any advantage to doing this in EPICS.
  - Expected collaboration with other labs never developed, at least for EPICS related things
  - It did take significant resources to do this. CD was involved also.

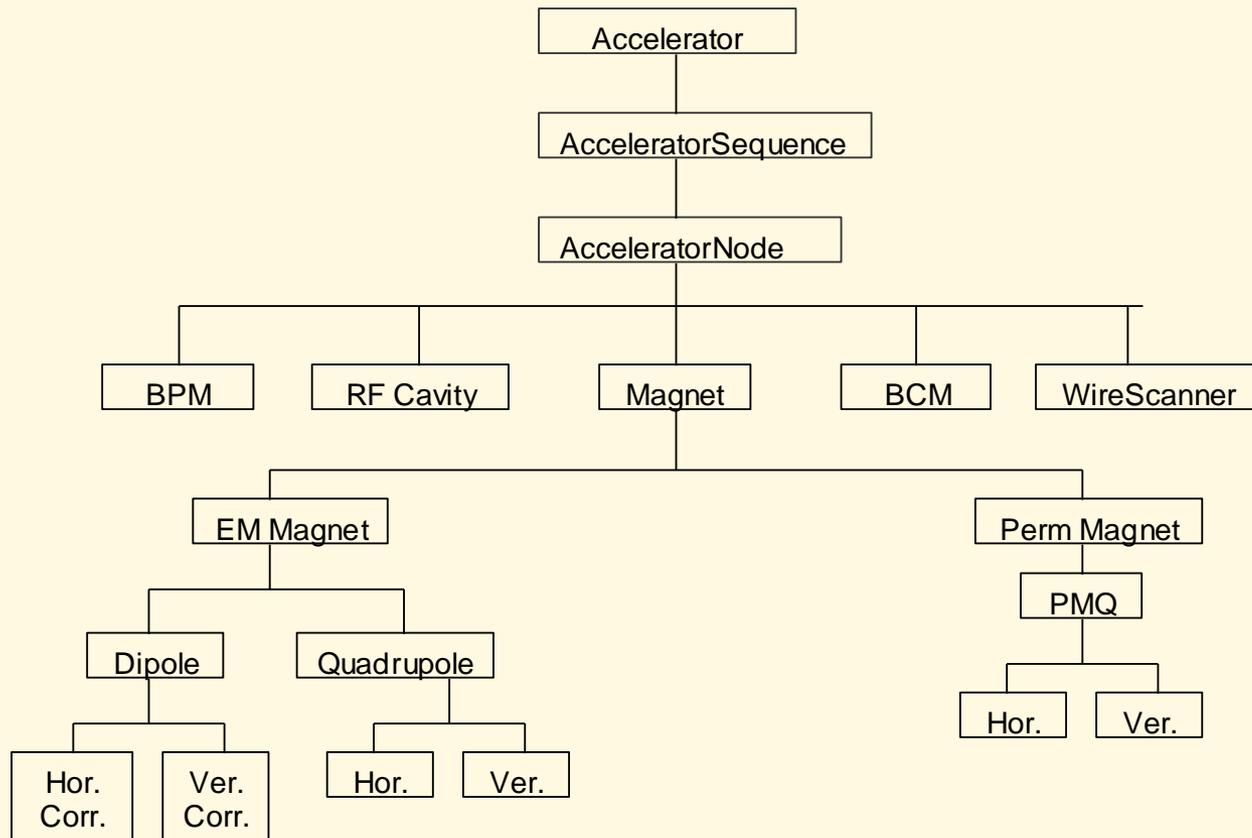


# Timing System

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- PIP-II would benefit from a new system
- New system for pulsed Project X prototyped in 2010
  - 1 GHz bandwidth
  - Much larger number of possible events (TCLK limited to 256)
  - Data payload associated with clock event
    - Removing need for separate MDAT link
  - Counter cycle stamp associated with clock event
    - Aid in correlating data across front-ends
- Should rethink this in context of new accelerator design
- Collect requirements – make suitable for future CW?
- Try out at PXIE?
  - Significant lead time will be required

# Accelerator Hierarchy (SNS)



- Accelerator hierarchy from the accelerator physicist point-of-view

# XML Accelerator Representation (partial example)

---

```
<sequence id="MEBT" len="3.633">
  <attributes>
    <sequence predecessors="RFQ"/>
  </attributes>
  <node type="marker" id="Begin_Of_MEBT" pos="0" len="0"/>
  <node type="QH" id="MEBT_Mag:QH01" pos=".128" len=".061" status="true">
    <attributes>
      <magnet len=".061" polarity="-1" dfltMagFld="-34.636"/>
      <align x="0.0" y="0.0" z="0.0" pitch="0" yaw="0" roll="0"/>
      <aperture shape="0" x=".016"/>
    </attributes>
    <ps main="MEBT_Mag:PS_QH01"/>
    <channelsuite name="magnetsuite">
      <channel handle="fieldRB" signal="MEBT_Mag:QH01:B" settable="false"/>
    </channelsuite>
  </node>
```



# Summary

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- Common control system for PIP-II & existing complex
- Start with what he have and evolve it
  - Can't disrupt operations between now and then
- Modernization of both hardware and software is needed!
  - Plan needed for the existing complex too!
- If parts of EPICS help us get there, we should consider it
  - We have experience in running a mixed system
  - There needs to be a benefit to justify any extra needed resources
- EPICS is different at every large accelerator
  - There is a variety of past experience and personal tastes
  - And EPICS constantly evolves along with computing technology