

NSLSII Control System Developments and Lessons Learned

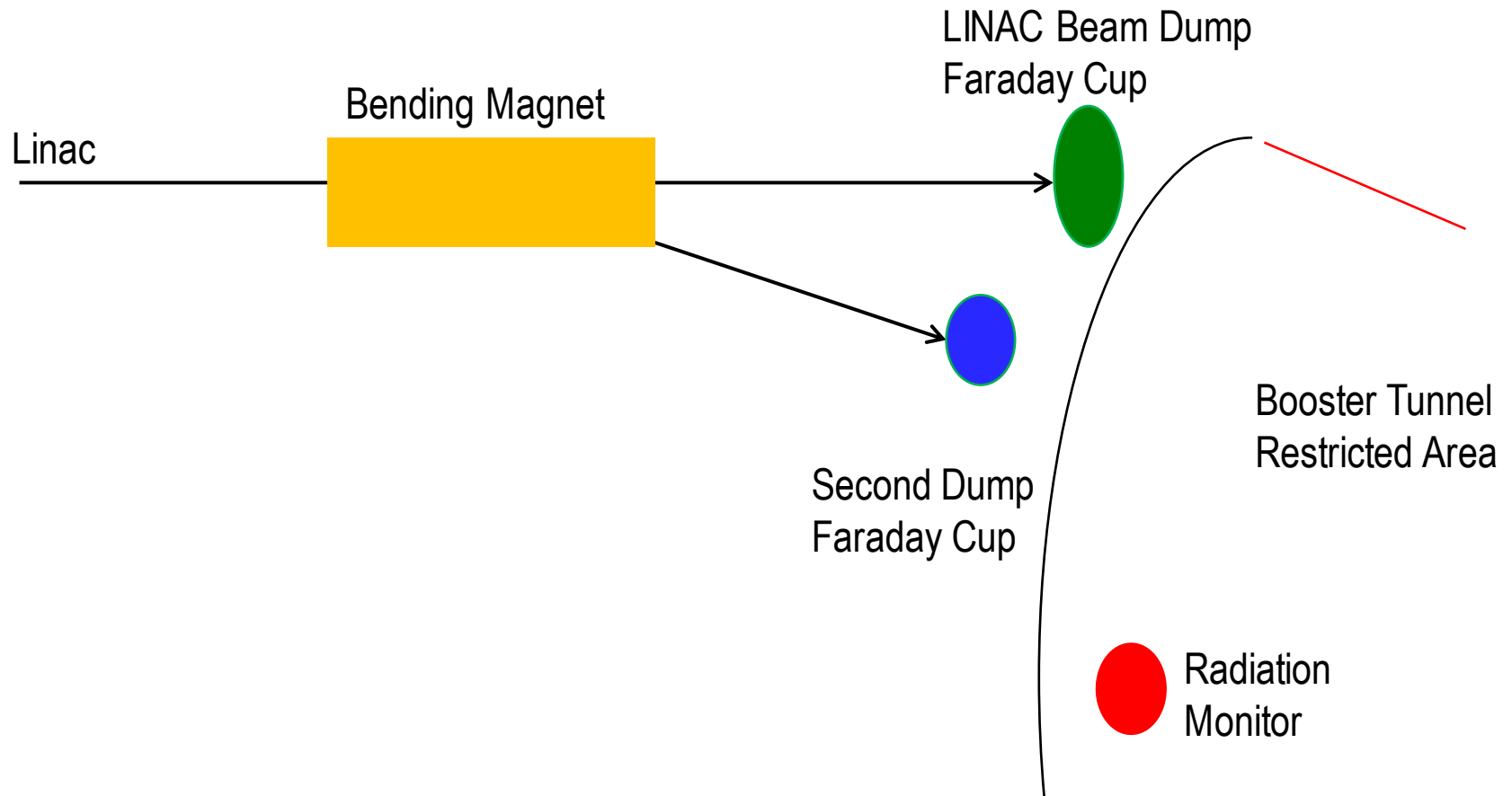


The Control Group – presented by Bob Dalesio
EPICS Meeting
April 24, 2010

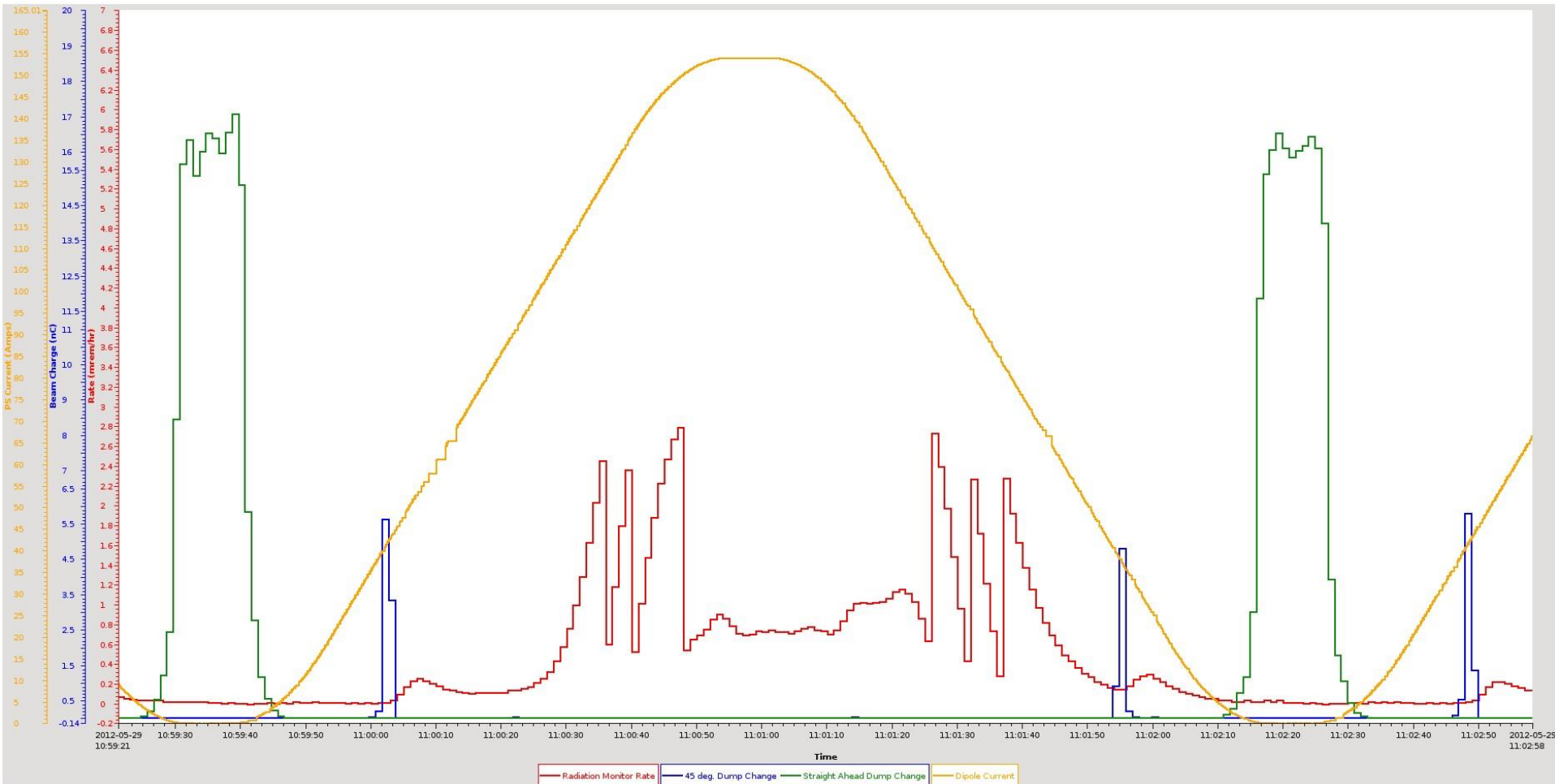
Outline

- Anatomy of an **Integration** shortcoming
- Setting Standards
- Fast Orbit Feedback Component Development
- V4 Based Architecture for High Level Application
- Relational Database Developments
- EPICS Extensions
- Control System Studio (CSS) Tools
- Conclusions

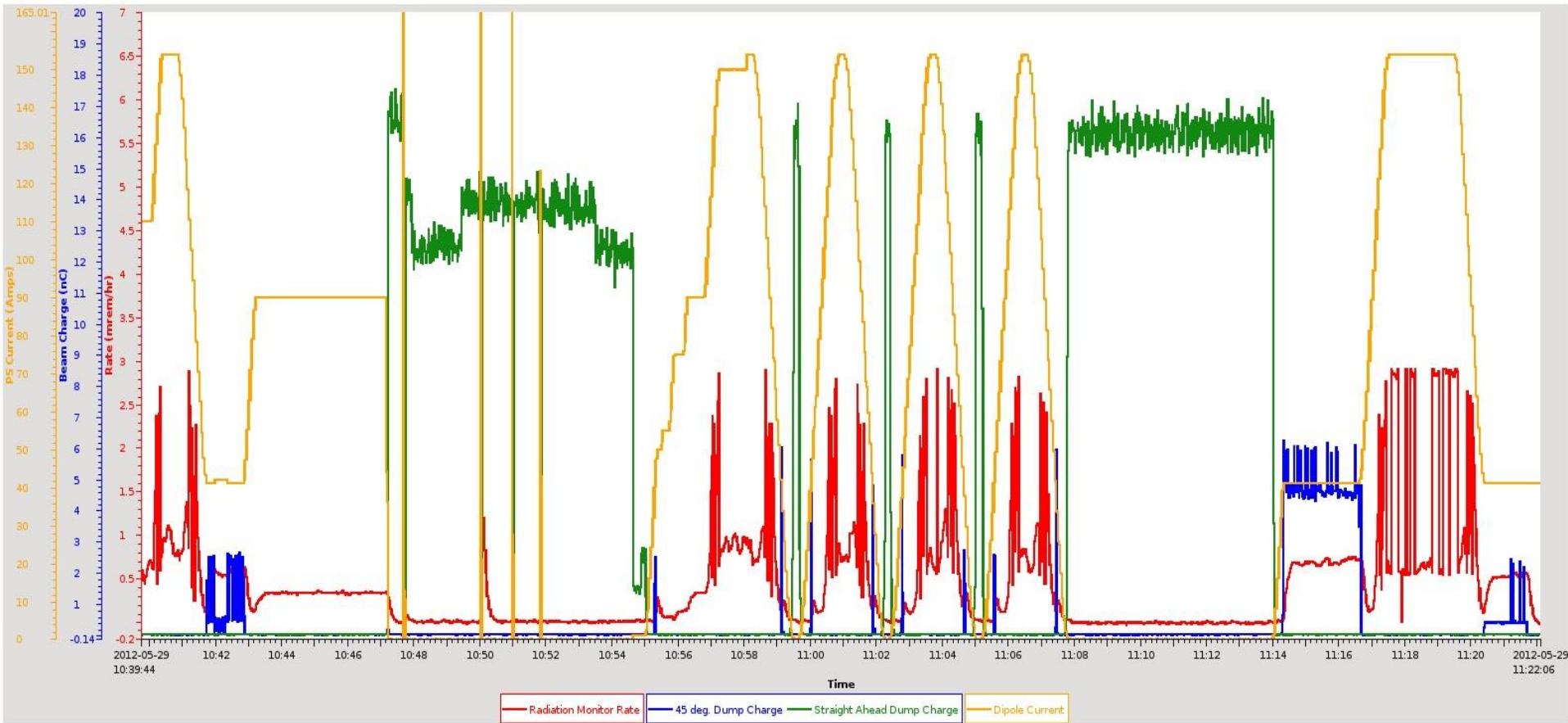
NSLS II Integration Lessons Learned (1 of 5)



NSLS II Integration Lessons Learned (2 of 5)



NSLS II Integration Lessons Learned (3 of 5)



NSLS II Integration Lessons Learned - Machine States (4 of 5)

The screenshot displays the OPI Runtime interface for the 'machStat.opi' window. It features three main sections for machine states: LN State, BR state, and SR state. Each section includes a row of control buttons and indicators, a 'Next state request' section, and an 'Inputs: Show' button.

LN State: The 'Standby' button is highlighted in yellow. The indicator row shows 'Standby' as a red circle, while 'Linac Off PPS Off' and 'Linac Off PPS ON' are green. The 'Next state request' section has 'Standby' and 'Apply' buttons.

BR state: The 'Standby' button is highlighted in yellow. The indicator row shows 'Standby' as a red circle, while 'BR Off PPS Off' and 'BR Off PPS ON' are green. The 'Next state request' section has 'Standby' and 'Apply' buttons.

SR state: The 'SR Off PPS Off' button is highlighted in yellow. The indicator row shows 'SR Off PPS Off' as a red circle, 'SR Off PPS ON' as a green circle, and 'Standby' as a green circle. The 'Next state request' section has 'SR Off PPS Off' and 'Apply' buttons.

A prominent red text box in the center of the interface reads: **This is only simulation !!!**

NSLS II Integration Lessons Learned (5 of 5)

- Archiving important control and monitor channels during commissioning is very important.
- Radiation Monitor Integration into the control system was tested for end to end communication, however it was not tested with a know radiation source for conversion and alarm accuracy.
- Although we have had a subsystem engineer embedded with each of the equipment groups, we did not include an embedded engineer with the physics group to understand the modes of operations. Although we do have an engineer embedded in the Personnel Protection System engineering group, this did not give us the insight into how the system in this area was working.
- We have since worked with the physics group to document the standard modes of operation for the accelerator. For each operational mode, the parameters that define the state and the main optics control ranges have been identified. The cognizant engineer is now working with each of the subsystem engineers to define the process variables (PVs) that are involved to stay in a given state and the control range for the subsystem PVs in that mode.
- The overall state work will be used directly to inform the alarm states that will be set in the alarm limit fields and the creation of composite alarms such as storage ring vacuum OK.
- The state machine will also drive the soft limits in the DRVH and DRVL fields for the PVs that have limited range in given modes.

Design Status - Standards (1 of 2)

- All Hardware Integration is achieved through EPICS
- Hardware standards are followed wherever possible through NSLS II
 - https://wiki.bnl.gov/nsls2controls/index.php/Beamline_Controls_Equipment#Standards
- Control System Studio is used for operator tools
- Archive Appliance or Channel Archiver to archive time series data
- BEAST – alarm server
- Channel Finder Service – Provides properties/tag searches of the Process Variables
- MASAR – save set manager and user interface
- Olog – Electronic log book
- MetaDataStore – store sweep information to search data sets

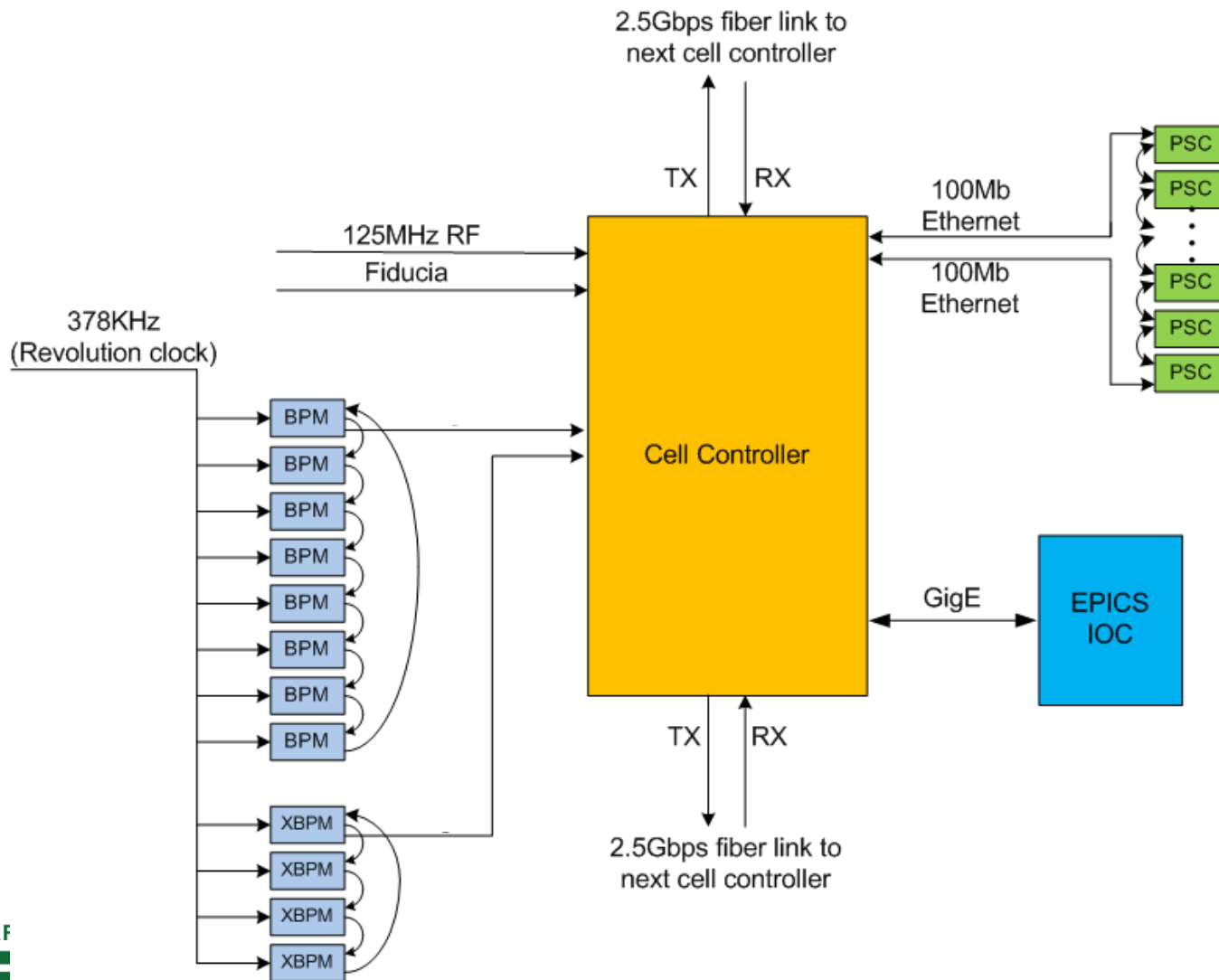
Design Status - Standards (2 of 2)

- Naming convention
https://ps.bnl.gov/acc/controls/Shared%20Documents/NamingConvention/LT-ENG-RSI-STD-002_Rev4.docx
<https://ps.bnl.gov/acc/controls/Shared%20Documents/NamingConvention/LT-PRJ-STD-CO-NAM-001.xlsx>
- Coordinate system
https://ps.bnl.gov/phot/ProjectBeamlines/Controls/References%20and%20Standards/Coordinate%20System/LT-C-XFD-STD-BL-COORD-001_Ver3.docx
- Interfacing standards
https://ps.bnl.gov/phot/ProjectBeamlines/Controls/References%20and%20Standards/Wiring%20Standards/LT-C-XFD-SPC-CO-IIS-001_Ver5.docx
- Controls RSI
https://ps.bnl.gov/phot/DocumentReferenceLibrary/RSIDocuments/1.04.02%20%20Standard%20Local%20Controls%20and%20Data%20Acquisition%20Systems/Stnd%20Local%20Controls%20and%20DAQ%20RSI%20Development/LT-C-XFD-RSI-CO-001_Ver3.docx
- EPS standards (draft)
https://ps.bnl.gov/acc/controls/Shared%20Documents/BeamlineControls/Industrial%20Controls/LT-C-XFD-STD-BL-EPS-001_Ver1_draft.docx
- PMAC programming standards (based on Diamond standards):
https://ps.bnl.gov/acc/controls/Shared%20Documents/MotionSystems/Standards/LT-R-XFD-STD-BL-MC-002_RevA.docx



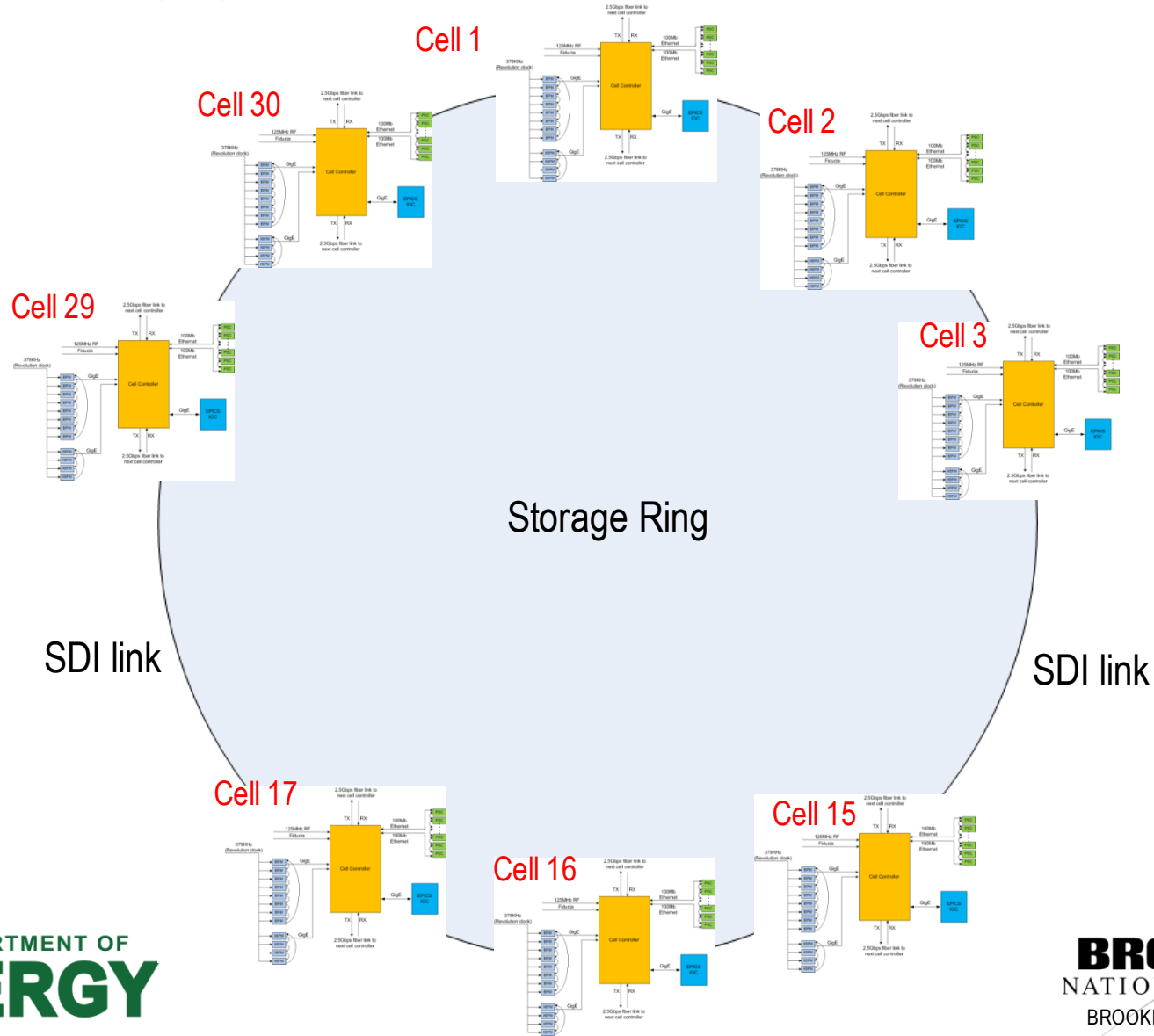
Orbit feedback system architecture

Fast orbit feedback system in one cell

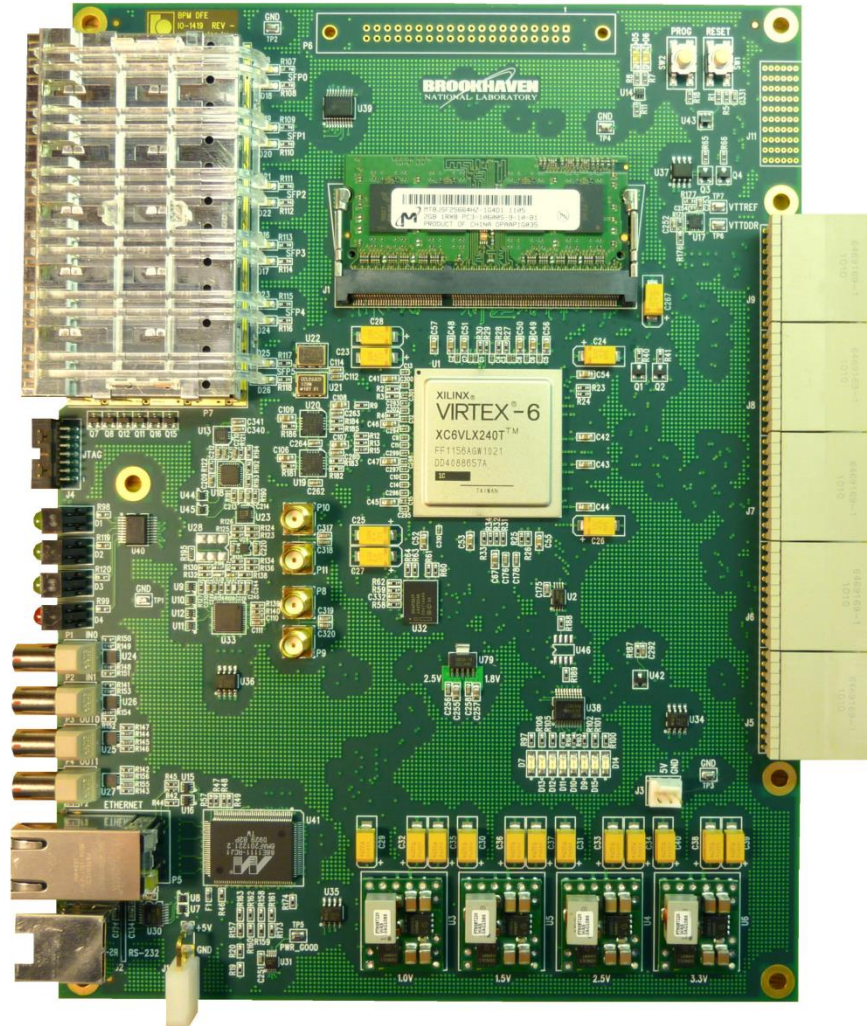


Orbit feedback system is built, installed, tested

NSLS-II two tier device controller architecture



Production DFE



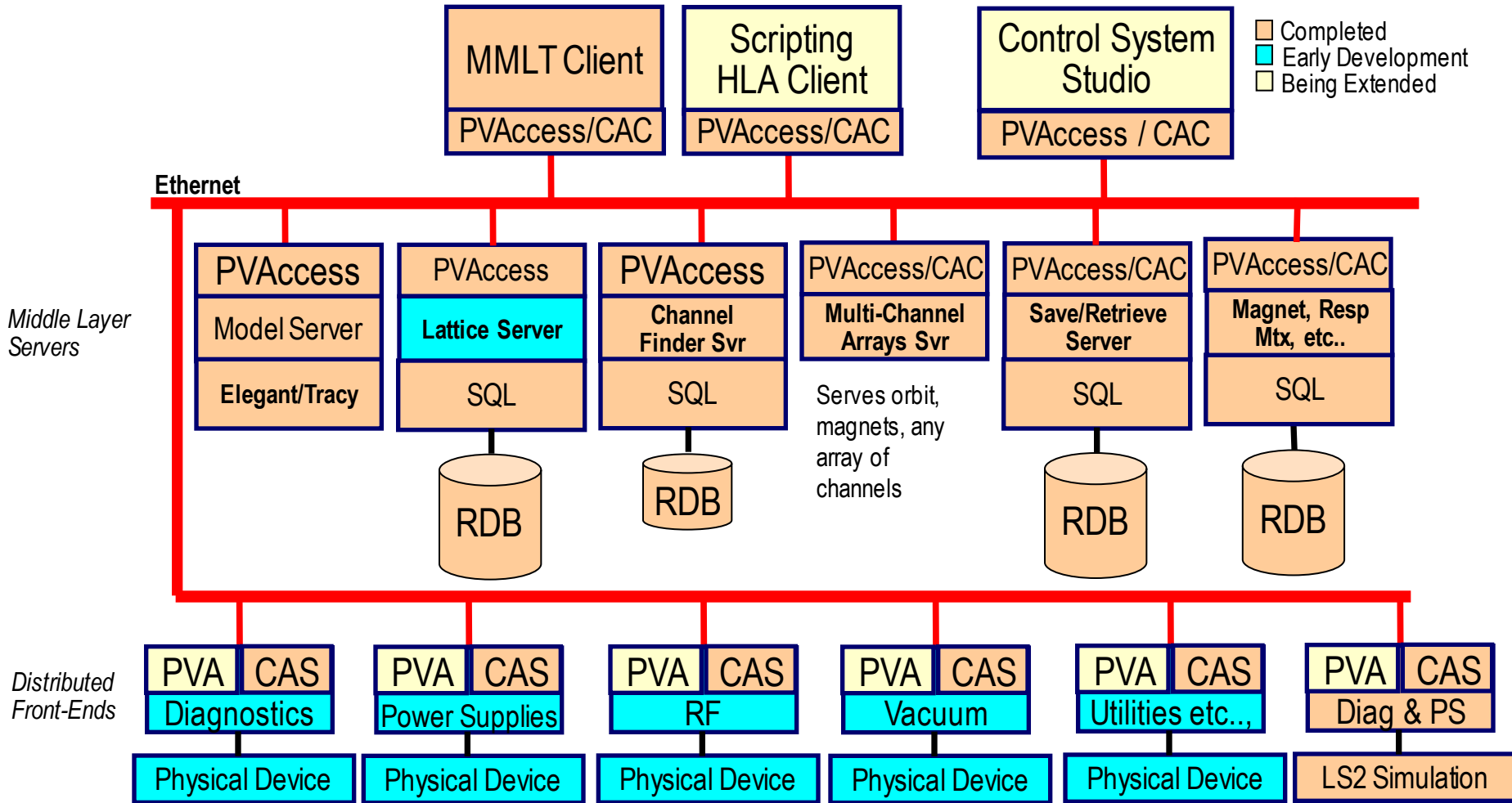
Fast Orbit Feedback – Time Budget

- 6.7 μs for BNL BPM Electronics delay to pipeline
 - 3.7 μs for analog value averaged from raw data
 - 3 μs estimated for BNL BPM Electronics (actual number 14 μs ?)
 - (FYI 57 μs measured on Libera BPM Electronics with minimum filter)
- 7 μs measured BPM data distribution by Redundant Data Link
 - 14 μs measured when one of the redundant links not operational
- 4 μs measured for FOFB calculation with separate mode compensation
- 5 μs measured for set power supply by PS Shared Memory link
- 8 KHz measured for fast corrector PS bandwidth w 10 deg phase shift.
- 1 KHz measured for corrector magnet/chamber bandwidth.
 - Measured on with Inconel beam pipe. This value is at 10 degree phase shift.
 - New magnet/chamber set up will be tested when they are available.
- Fast machine protection data is provided to a dedicated cell controller that uses ancillary IOC and BPM data to determine mitigation at the RF.

V4 High Level Applications (HLA)

- High level application architecture is client/server based on the EPICS version 4 network protocol, PVAccess
 - One server provides results to all clients
- Tables are used to serve database results
- These are being implemented in PVAccess
- Servers are completed that provide:
 - Channel Finder - List of process variables based on function and attributes
 - MASAR – save set service
 - Model/lattice services
- Developer document for thin clients development
- Standard clients in CSS can be used to display HLA data

V4 HLA Architecture



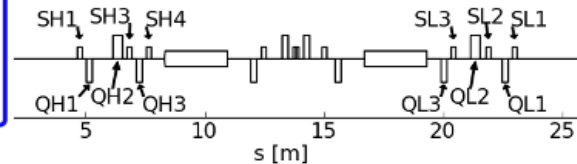
V4 HLA – Physics View

- They talk about PV/IOC, we talk about element/cell/girder
- PVs are associated with properties and tags, which are used to construct a lattice familiar to physicist.
- “the BPM readings in cell 10 girder 2” is easier than PV name

Accelerator Physicists:

On top of Channel Finder:

1. Lattice elements and PVs are linked.
 2. elements in groups: type, cell, girder
 3. elements in orders (has neighbors)
 4. element has default read/set PV
- Remember properties/tags instead of PV



Controls Engineers

Channel Finder Service

IRMIS PV Database

V4 HLA – Use Case

- HLA uses several thousand PVs. Each have properties like “elementname”, “elementtype”, “cell”, “girder”, “s_position”, ...
- Some PVs are tagged with “HLA.X”, “HLA.EGET”, “HLA.EPUT” which means that PV is a “horizontal reading/setting”, “default reading” and “default setting”
- The lattice object is a list of elements, each owns several PVs. All of the data is initialized from channel finder service: pv, properties and tags.
- No need to remember PV when writing a normal script.

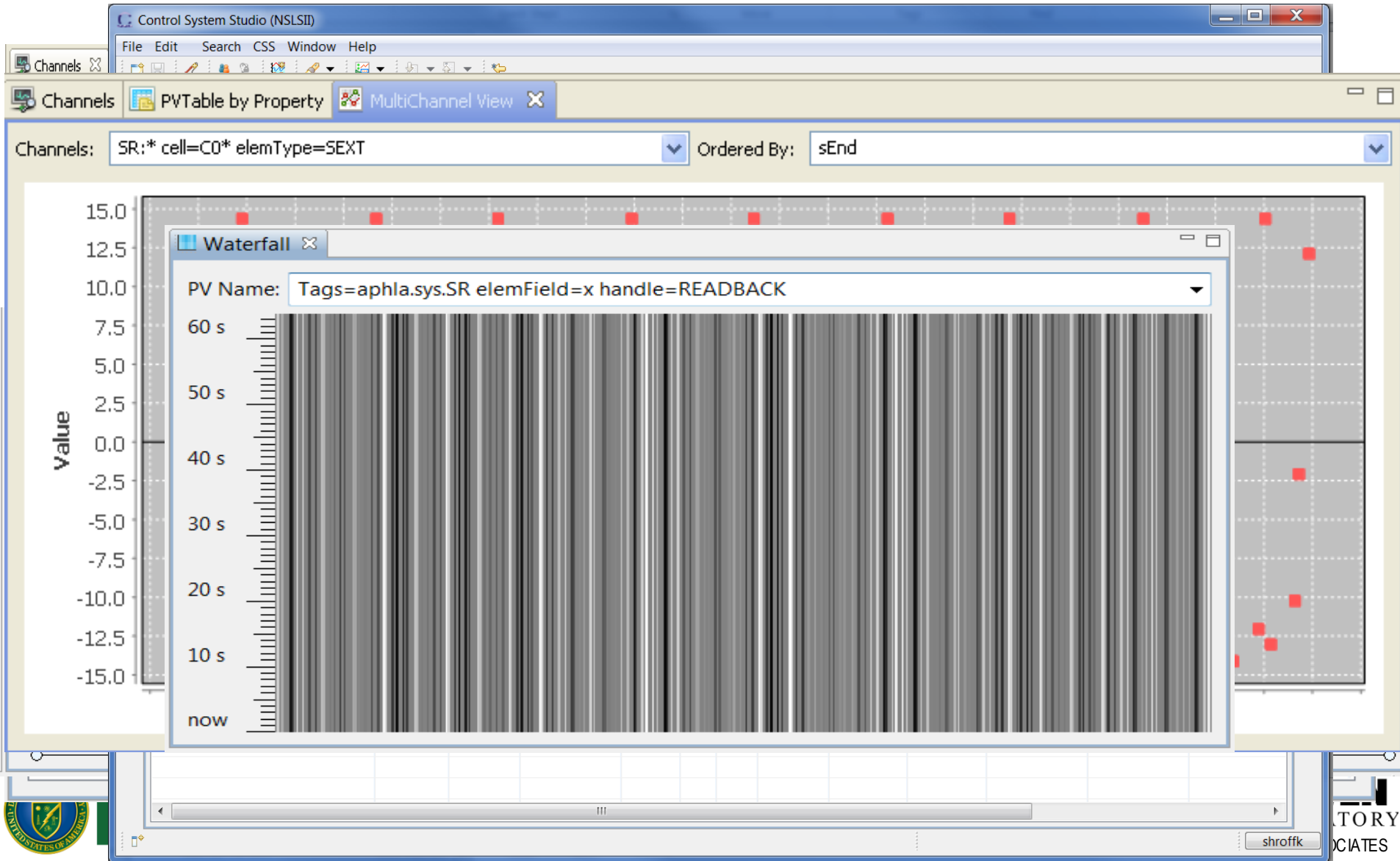
V4 HLA – Channel Finder Tags and Properties

device FM1G4C02A

Channel Name	SR:C02-MG:G04A{HFCor:FM1}		SR:C02-MG:G04A{VFCor:FM1}	
	Fld-I	Fld-SP	Fld-I	Fld-SP
handle	READBACK	SETPOINT	READBACK	SETPOINT
elemName	FXM1G4C02A		FYM1G4C02A	
elemType	HFCOR		VFCOR	
elemField	x		y	
devName	FM1G4C02A			
sEnd	65.5222			
cell	C02			
girder	G4			
symmetry	A			
length	0.044			
ordinal	263		264	
tags	eget	eput	eget	eput
	x		y	
	sys.SR			



HLA – V4 CSStudio Integration



HLA - Thin Clients Can Be Developed

The screenshot shows the 'nsas2d' software interface. At the top, a menu is open with options: New, H Orbit, V Orbit, H Corrector, V Corrector, Quad, Sext, and Quit. The 'New' menu is highlighted. Below the menu, there are two plots. The left plot shows 'x [m]' vs '30' with red data points. The right plot shows 'y [m]' vs '280' with blue data points. A red arrow points to the right plot with the text 'field vs. location'. Another red arrow points to the 'New' menu with the text 'name & location'. A third red arrow points to the 'H Orbit' option with the text 'sys & subsystem'. A fourth red arrow points to the 'Element Editor' window with the text 'elem field'. A fifth red arrow points to the 'Filter' field in the Element Editor with the text 'unit conv.'. A sixth red arrow points to the 'Step Range' field in the Element Editor with the text 'step size (physics)'. A seventh red arrow points to a tooltip in the Element Editor with the text 'extra info'. The tooltip contains the following information: family = QUAD, sb = 146.2, length = 0.25. The Element Editor window shows a table of elements with columns for Field, None(Raw), and phy. The table contains the following data:

Field	None(Raw)	phy
3	smlg4c05b	
k2_r	-13.05 m ⁻³	
k2_w	-13.05 m ⁻³	
4	pmlg4c05b	
x_r	-3.437e-09 m	-3.437e-06 mm
y_r	1.661e-08 m	1.661e-05 mm
5	qmlg4c05b	
k1_r	-0.8032 m ⁻²	
k1_w	-0.8031 m ⁻²	
6	cmlg4c05b	
x_r	1.991e-08 rad	
x_w	1.991e-08 rad	

The log window at the bottom shows the following text:

```

2013-04-24 09:57:25,802 - aphla.gui.orbit [WARNING]: using previous initialized machine 'nsas2v2'
2013-04-24 09:57:39,568 - aphla.gui.orbit [INFO]: searching for '*' in range [144.689556701, 281.756525773]
2013-04-24 09:57:39,570 - aphla.gui.elementeditor [INFO]: Found elems: 211
2013-04-24 09:57:39,630 - aphla.gui.elementeditor [INFO]: full update takes 0.00485515594482 (0.00485515594482+0.0)
    
```

At the bottom left, there is a logo for the U.S. Department of Energy, Brookhaven National Laboratory. At the bottom right, there is a logo for AVEN ORATORY and BROOKHAVEN SCIENCE ASSOCIATES.

HLA – MASAR Use

- Snapshots taken with time
 - Events (by 2014-07-14 05:12:08) total taken: 1226. approved: 862

Date	Snapshots taken	Snapshots Approved
3-21-2012 9:28 AM	0	0
3-29-2012 10:32 AM	30	8
3-30-2012 6:01 PM	31	9
4-24-2012 8:02 PM	144	41
5-11-2012 10:27 AM	210	63
5-24-2012 2:25 PM	279	79
6-7-2012 6:28 PM	331	96
6-14-2012 4:13 PM	338	98
6-27-2012 5:02 PM	347	100
4-17-2013 11:30 AM	351	101
4-26-2013 11:13 AM	355	102
4-26-2013 5:24 PM	362	104
5-23-2013 4:03 PM	364	104
9-4-2013 3:38:15 PM	368	108
...
7-14-2014 5:12:08 AM	1226	862



Relational Database Experience

- All relational data information integrated in IRMIS
- IRMIS table evolution and application development conflicted
- IRMIS table redesign broke all JDBC production code
.....so domains were separated out except
- New IRMIS tools were being developed for
 - Component type editor
 - Component editor
 - Component Browser
 - Wiring Editor
 - BUT..... never completed in time to deploy

..... other domains developed into deployed applications

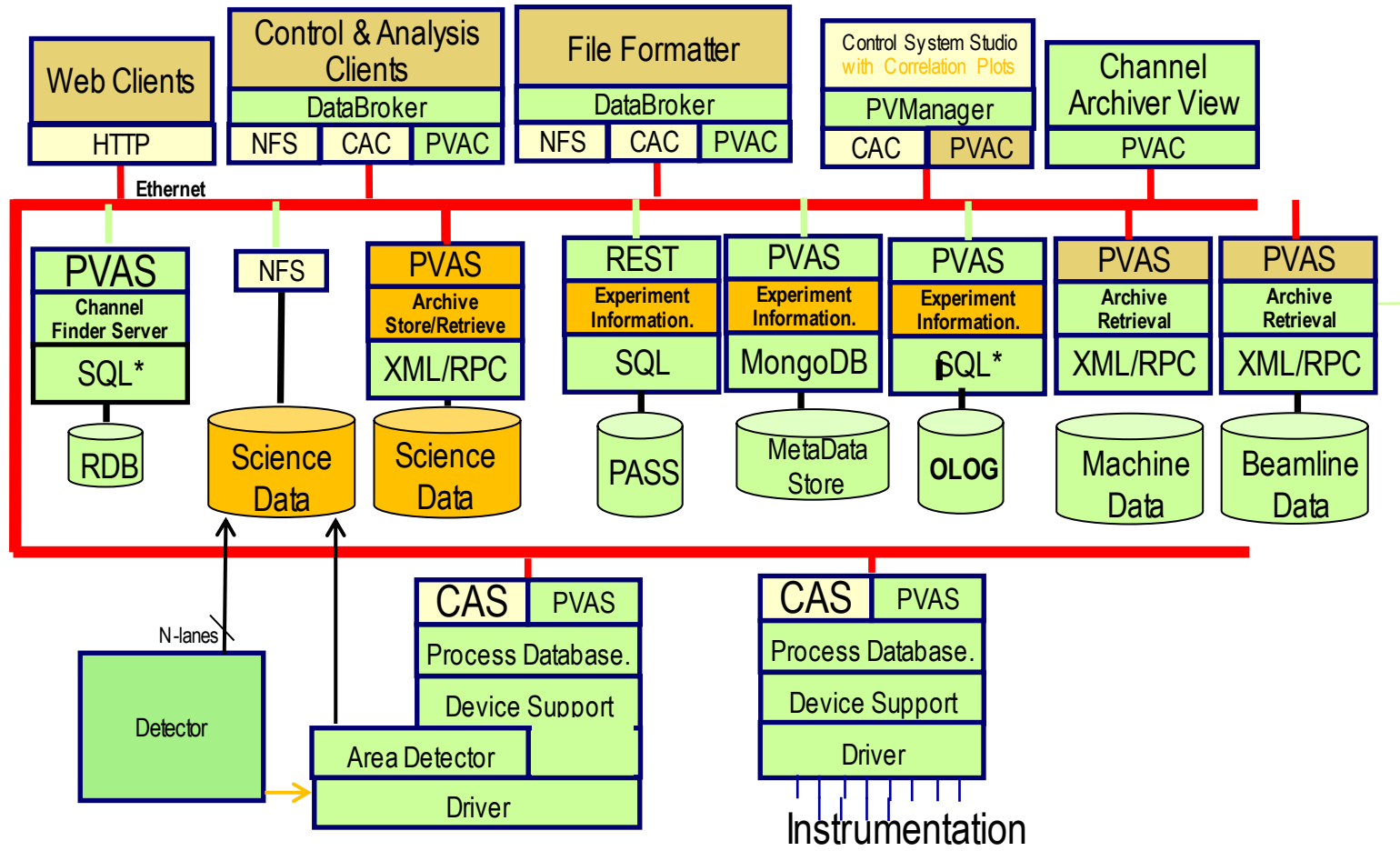
Relational Database Experience

- **Channel Finder application uses MySQL (moving to MongoDB) (V4 service in development)**
- **Lattice development with MySQL (V4 service deployed)**
- **Electronic log uses MySQL (moving to MongoDB) (No V4 service)**
- **Save Retrieve uses MySQL (V4 service deployed)**
- **Unit conversion uses mySQL for Magnet Measurements (deployed into an IOC application)**
- **New metaDataStore uses MongoDB (V4 service in development)**

Relational Database Experience

- **One large database with all of the facility data was not possible .**
- **There are around thirty some identified database domains.**
- **Collaboration led by MSU with ITER, ESS, NSLS II and others to develop applications**
- **We have serious questions to answer on cross domain queries and technology evaluations that are ongoing.**

Experimental Data Architecture



Control System Studio

- Adopted CSS for our user interface after evaluation
- Developed ChannelFinderService to return process variables by function, location, device, etc...
- Developed a channel access package to provide all client functions and time synchronous vectors from an arrays of process variables (PVMManager)
- Developed multichannel visualization tools
- Developed an Integrated Log Book
- Developed a multi-controller application (ChannelOrchestrator)
- Developed a save/restore application (MASAR)
- Developed standard extension points in CSS for services such as log book and directory service.
- Developed standard extension points in CSS for plots.
- This first deployment of CSStudio for a facility is exposing many new requirements and some shortcomings that need to be handled.

Conclusions

- NSLS II have leveraged off of years of development from the community: CSStudio, database applications, and middle layer service architecture and service development.
- We have invested in several areas of development (3.15 extensions, V4, CSS, middle layer services, fast orbit feedback hardware) and most of them greatly improved our productivity and functionality.
- We are starting to deploy these services for data acquisition and have been able to reuse several of the services.
- There are several key areas that need development in the future: PVAccess as the primary protocol for EPICS, CSStudio data layer maturation, an open-source hardware platform, to name a few.