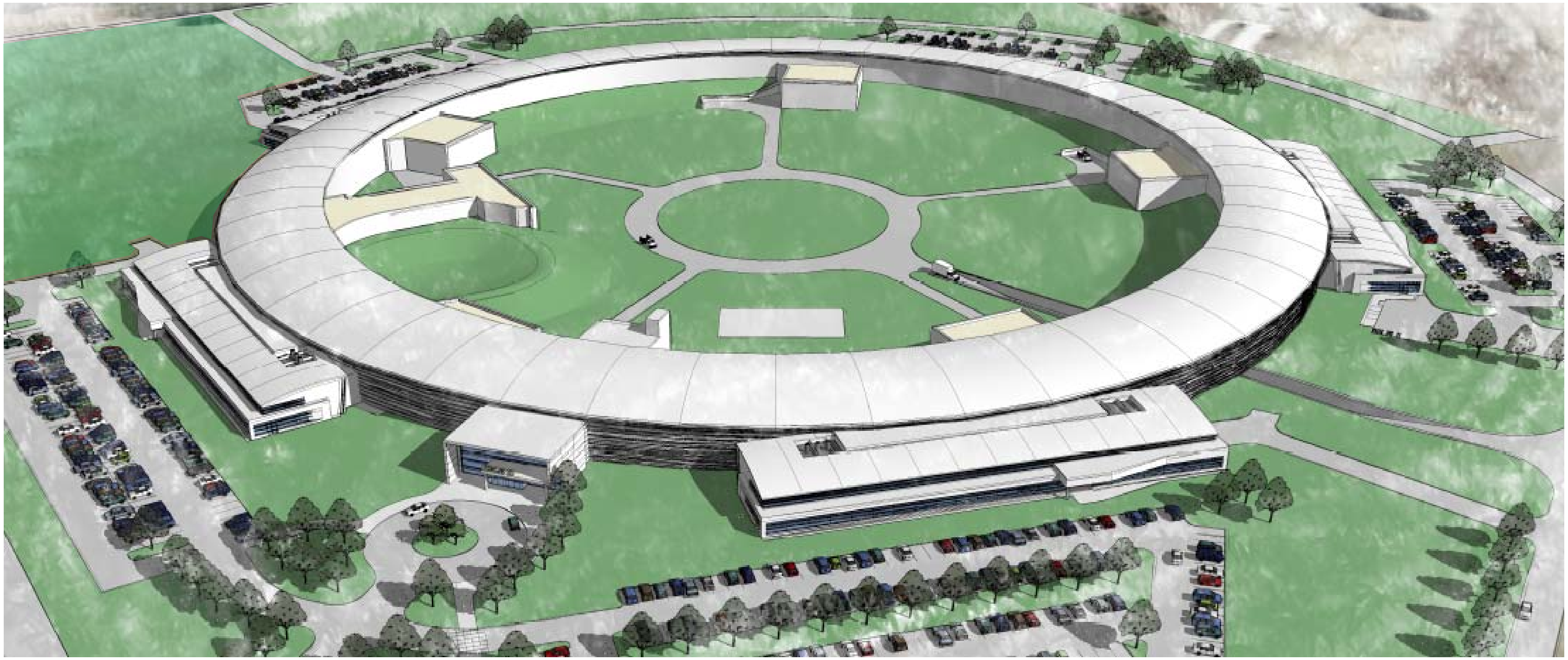


Overview of the NSLS-II Control System

Nikolay Malitsky

on behalf of

NSLS-II Control Group

BROOKHAVEN NATIONAL LABORATORY
BROOKHAVEN SCIENCE ASSOCIATES

Office of Science
U.S. DEPARTMENT OF ENERGY

EPICS

Acknowledgments

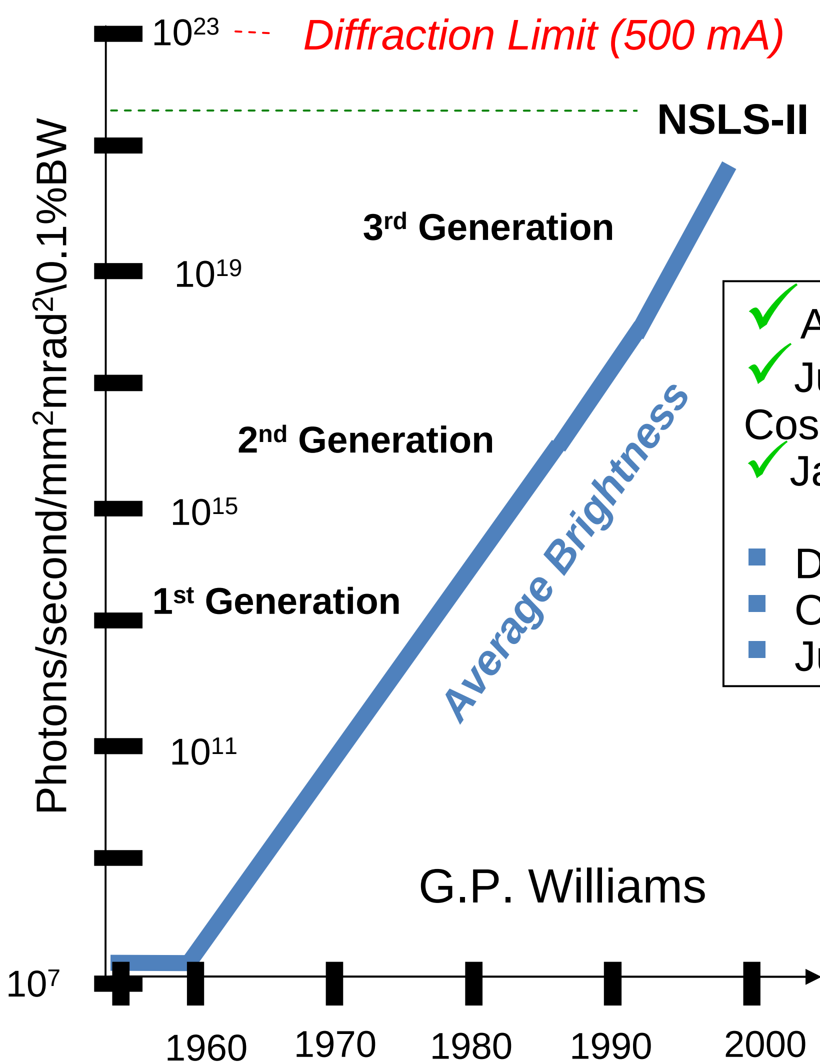
Control: B. Dalesio, G.Carcassi, D. Dohan, J. Shah, G. Shen, Y. Tian, Z. Yin

AP: J. Bengtsson, T. Shaftan

Outline

- **Overview of the NSLS-II Project**
- **Control System**
  - Scope
  - Requirements
  - Standards
  - Infrastructure
- **Areas For Technical Development**
  - Embedded Device Control
  - IRMIS: Integrated Relational Model of Installed Systems
  - High Level Applications
- **Concluding Remarks**

Evolution of average brightness

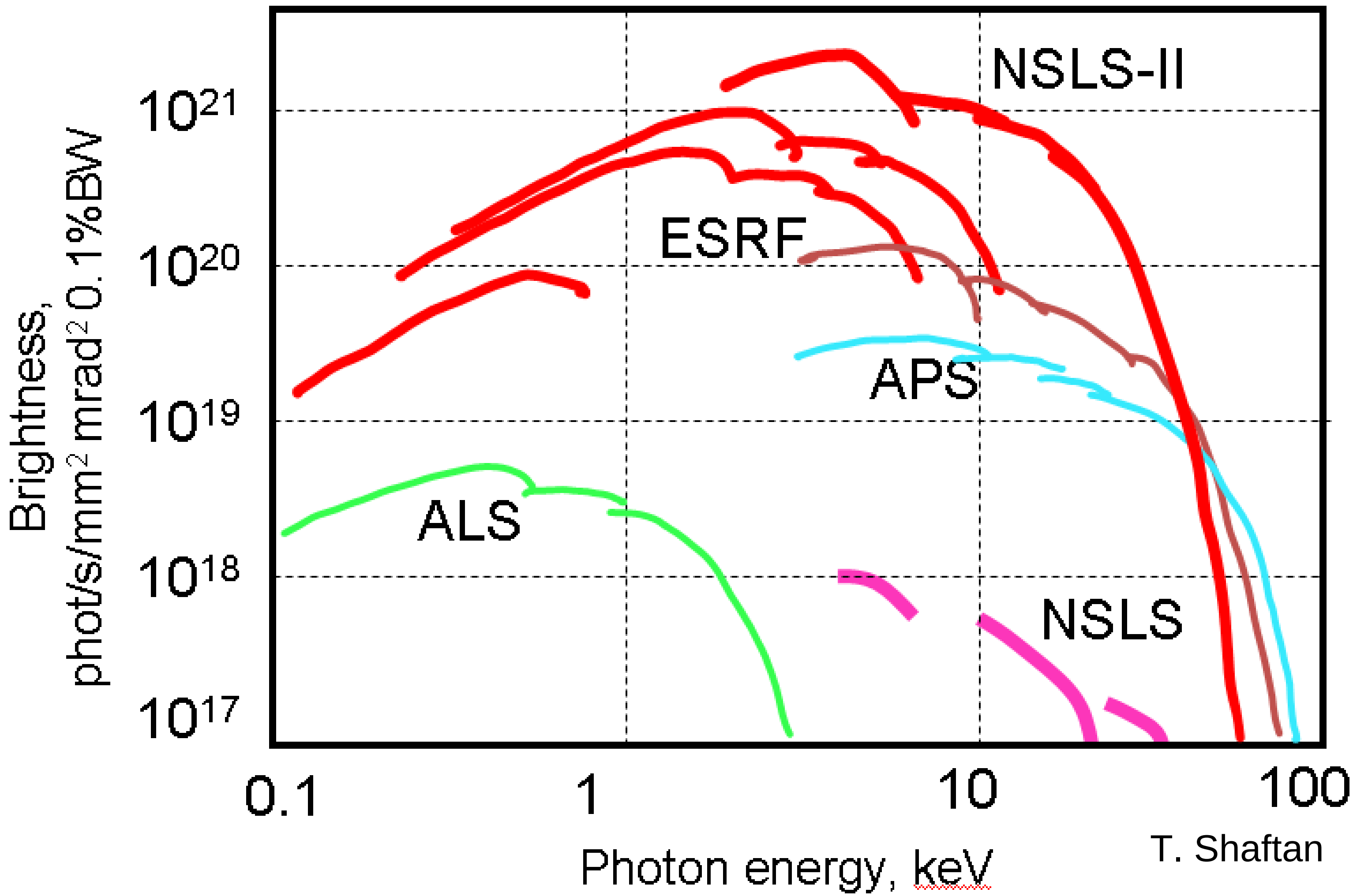


Key Project Milestones

- ✓ Aug 2005, **CD-0**, Approve Mission
- ✓ Jul 2007, **CD-1**, Approve Alternative Selection and Cost Range
- ✓ Jan 2008, **CD-2**, Approve Performance Baseline

- Dec 2008 **CD-3**, Approve Start of Construction
- Oct 2013 Start Accelerator Commissioning
- Jun 2015 **CD-4**, Approve Start of Operations

NSLS-II vs Synchrotron Light Sources



T. Shaftan

NSLS-II Design Features

Design Parameters

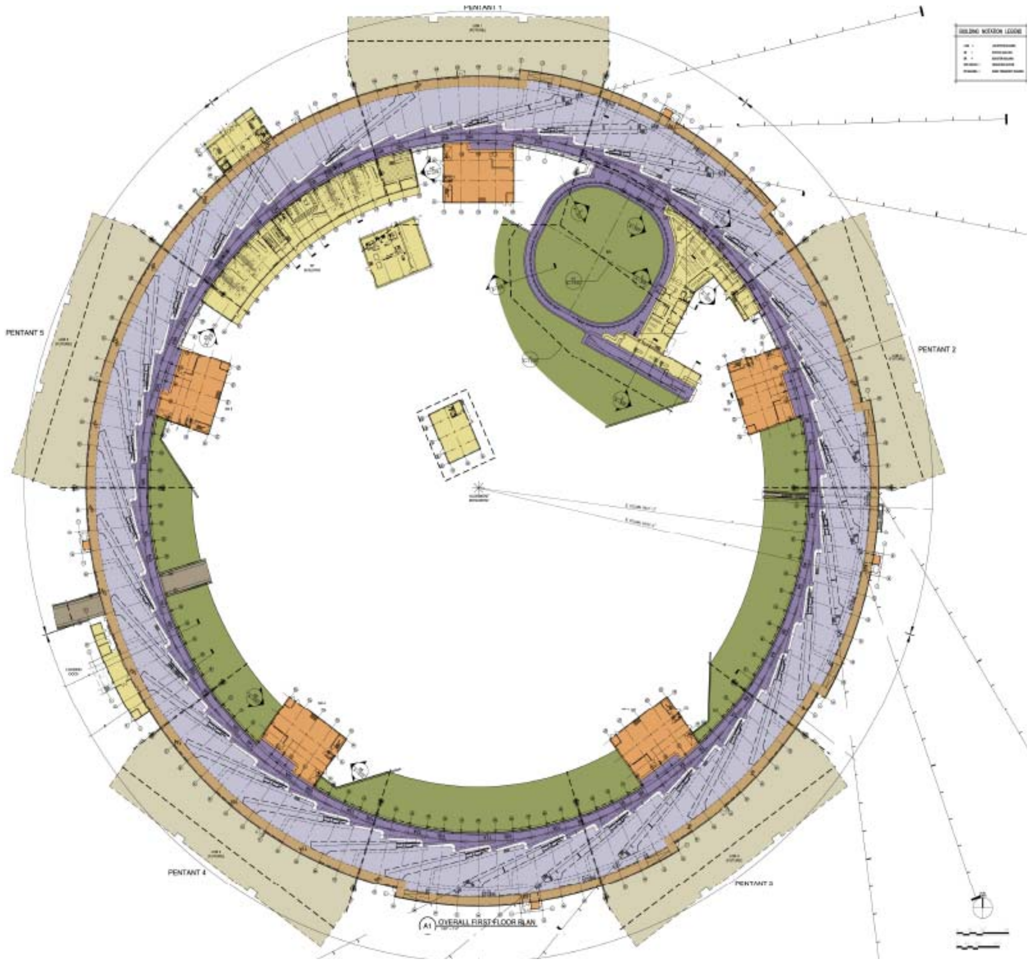
- 3 GeV, 500 mA, top-off injection
- Circumference 791.5 m
- 30 cell, Double Bend Achromat
  - 15 high-β straights (9.3 m)
  - 15 low-β straights (6.6 m)

Novel design features:

- Damping wigglers
- Soft bend magnets
- Three pole wigglers
- Large gap IR dipoles
- Elliptically polarizing undulators

Ultra-low emittance

- ε_x, ε_y = 0.6, 0.008 nm-rad
- Diffraction limited in vertical at 12 keV
- Small beam size: σ_y = 2.6 μm, σ_x = 28 μm, σ'_y = 3.2 μrad, σ'_x = 19 μrad

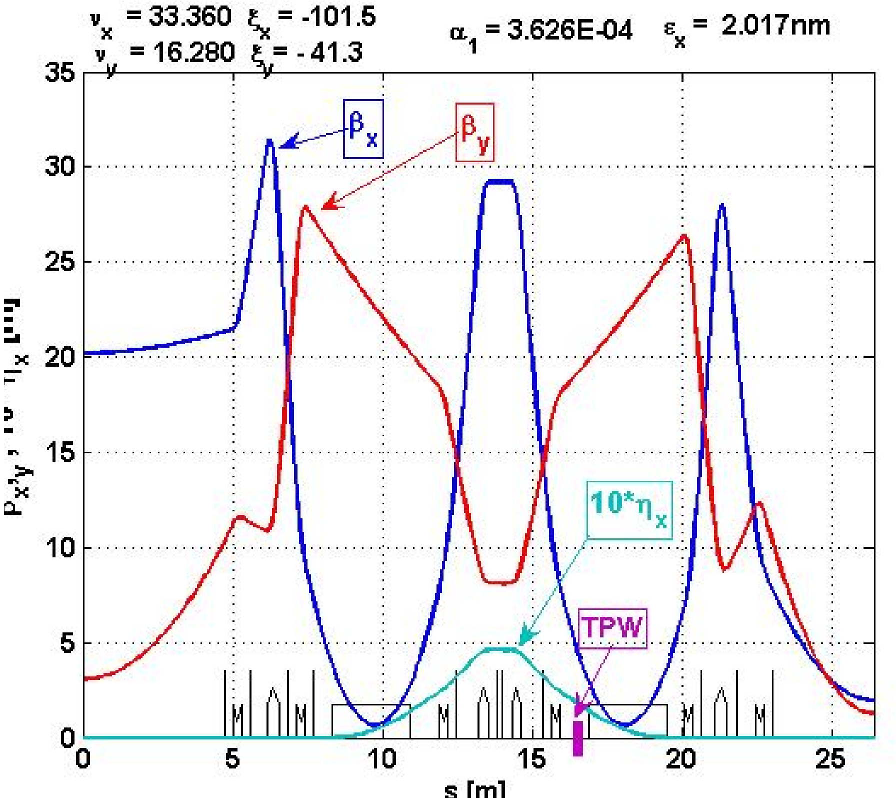


S. Dierker, F. Willeke

Storage Ring

Table 1: The NSLS-II storage ring parameters

Energy	3 GeV
Circumference	791.96 m
Harmonic Number	1320
Bending Radius	25.019 m
Dipole Energy Loss Uo	286.5 keV
Emittance Bare Lattice ε_o: Hor/Ver	2.05/0.01 nm-rad
Emittance for 8-DWs ε_{nat} Hor./Ver	0.51 /0.008 nm-rad
Momentum Compaction	0.000368
RMS Energy Spread: Bare Lattice Energy Spread with 8-DWs	0.051% 0.099 %
Tunes (Q_x , Q_y)	(32.42,15.15)
Chromaticity (ξ_x , ξ_y)	(-99, -33)
Peak Dispersion	0.489 m
β Function at 8.6m ID (β_x, β_y)	18/3.8 m
β Function at 6.6m ID (β_x, β_y)	1.9/2.1 m
Alignment Tolerance Girder & Dipole (x, y, Φ)	(0.1, 0.1 mm, 0.5mrad.)
Alignment Tolerance. Quad. & Sext..(x, y, Φ)	(0.03, 0.03 mm, 0.2 mrad.)



Long ID

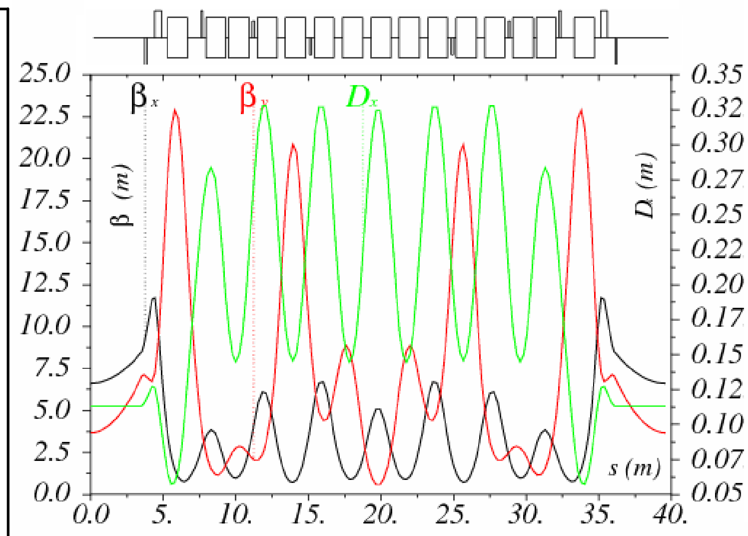
Short ID

S.Ozaki, J.Bengtsson, S.L. Kramer, S.Krinsky, V.N. Litvinenko. PAC 07

Injection Systems

Booster:

Injection Energy	0.2 GeV
Extraction Energy	3.0 GeV
Circumference	154 m
Emittance	30 nm-rad
Cycle Frequency	1Hz
RF frequency	500 MHz
Charge	10-15nc @ 30 mA
Tunes: x, y	10.25, 4.2



Designed after ASP Booster

T.Shaftan, W.Guo, Y.Li, B.Nash

Linac:

Energy	0.2 GeV
Frequency	S-Band
Charge	15 nC/pulse
$\Delta E/E$	< 1%

Close to NSLS-II requirements:

ASP (ACCEL):

3 GHz, 100 MeV, 4/0.25 nC/pulse

- SOLEIL (THALES):

3 GHz, 100 MeV, 10/0.5 nC/pulse

Scope of the Control System

The control system integrates all subsystems:

- Power supply
- RF
- Timing
- Vacuum
- Diagnostics
- Insertion devices
- Beam lines
- Facility
- Equipment protection and personal safety

Control System Requirements – 1 of 2

- Bunch Length 1-40 psecs
- 2.6 usec ring revolution
- Top off every 1 minute
- Top off bunch train 140-300 nsec
- Top off damping time 10-50 msecs (no extraction)

- Manual control of orbit trims, quadrupoles, sextupoles, and insertion devices are asynchronous
- ~10 Hz write/read is suitable for "turning knobs" for a power supply
- 5 Hz updates to operators of up to 1000 chosen parameters
- Archive up to 6000 parameters at a rate of 2 Hz continually

- Must scale to support 150,000 physical I/O connections and 400,000 computed variables
- 99.99% availability 24/7

Control System Requirements – 2 of 2

- Transient Recording
  - Take coherent turn by turn orbit data for up to 800 channels 1024 turns
  - Latch the last 10 seconds of data from all parameters in the storage ring
  - Beam line needs 1 msec archiving over 1 minute for temperatures and positions

- Provide data for all control aspects
- 5 KHz RF Feedback on beam phase
- 10 kHz orbit feedback, (100 usec loop time)
  - 300 BPMs (10 per cell)
  - 2 * 120 Corrector PS in 30 I/O Controllers (IOC)

- 20 msec equipment protection mitigation
- 1 Hz model based control
- 10 kHz power supply read backs triggered from timing system

Open-Source Control System Standards

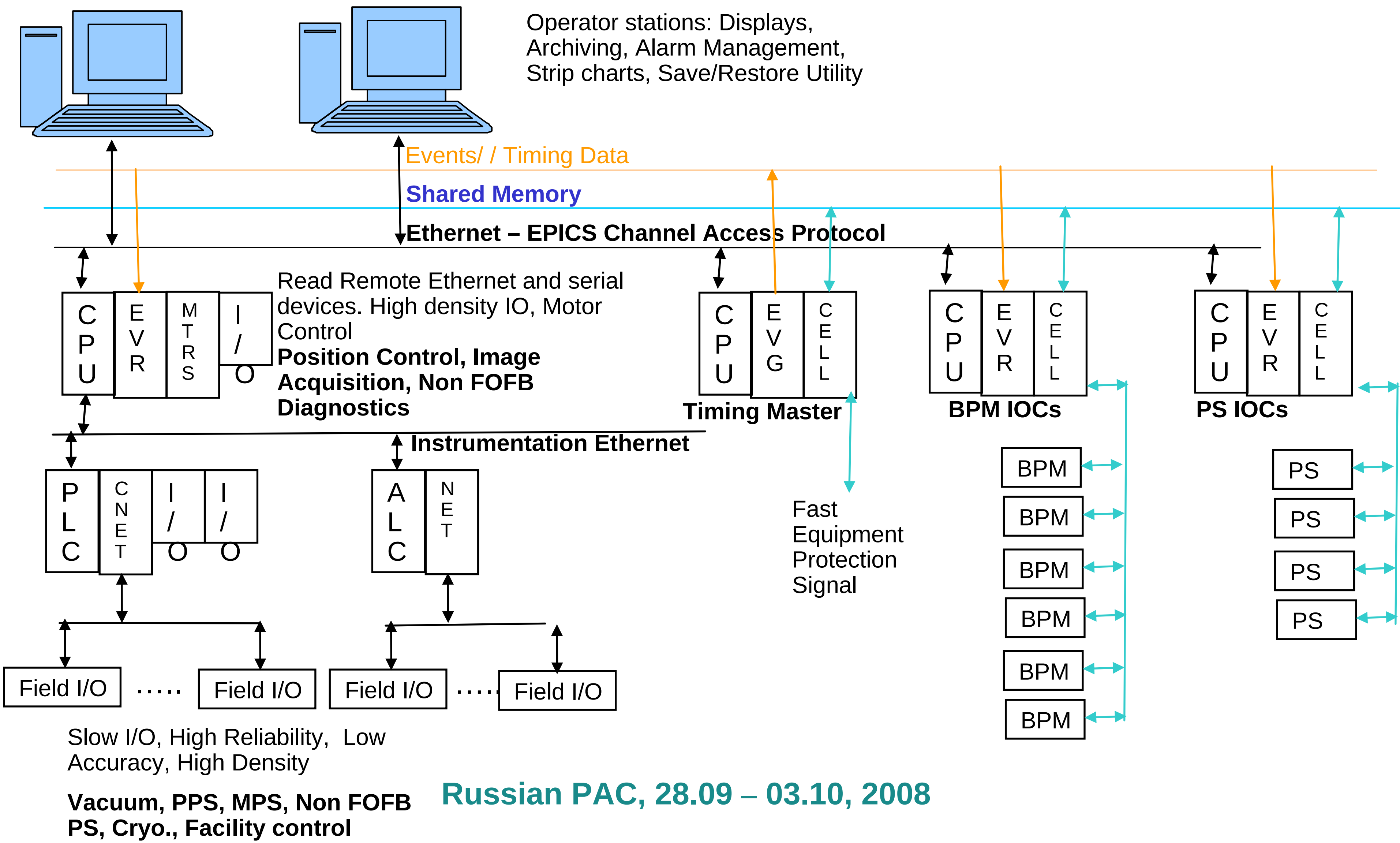
EPICS (Experimental Physics and Industrial Control System) Collaboration:

- Began in 1989 between LANL/GTA & ANL/APS (B. Dalesio & M. Kraimer)
- Over 100 independent projects in North America, Europe and Asia
- Applications in particle physics, astronomy, and industrial control
- Independent development, co-development and incremental development by the numerous distributed groups of developers
- Large biannual collaboration meetings to report new work, discuss future directions, explore new applications, and explore new requirements for existing codes

RTEMS (Real-Time Executive for Multiprocessor Systems) Operating System:

- Free open-source code for OS, support components, tests, documentation, development environment
- Standard compliant
- Highly portable across CPU architectures, many Board Support Packages (BSP) available
- Several successful accelerator control projects: LCLS, Spear, CLS, …

Control System Infrastructure



Areas For Technical Development

- **Embedded Controllers** need an open standard for high speed, deterministic functions. Work with other labs and board manufacturers to develop one.
- **Relational Databases support data management** through the life of a project. Development of adequate tools to enter and report this data is required early.
- **High Level Applications** currently tie together functions through data or file structures. To make the components of High Level Applications modular and distributed, a client/server architecture is needed.

Embedded Device Control – 1 of 2

+T0

+ - Settling time on BPMs

+0.0 usecs - BPM to Compute Controller

384 bits = 64 bits * 6 BPMs

4.9 usecs = 384 bits over 100 MBit enet

+4.9 usecs - Compute Controllers to each other

10,290 bits = 30 nodes * 384 bits

10.5 usecs = 10,290 bits over 2 GB enet

+15.4 usecs – Compute local matrix

0 usecs

+ 15.4 usecs - Communicate t Power Supply Controllers

24 = 4 PS * 4 bytes each

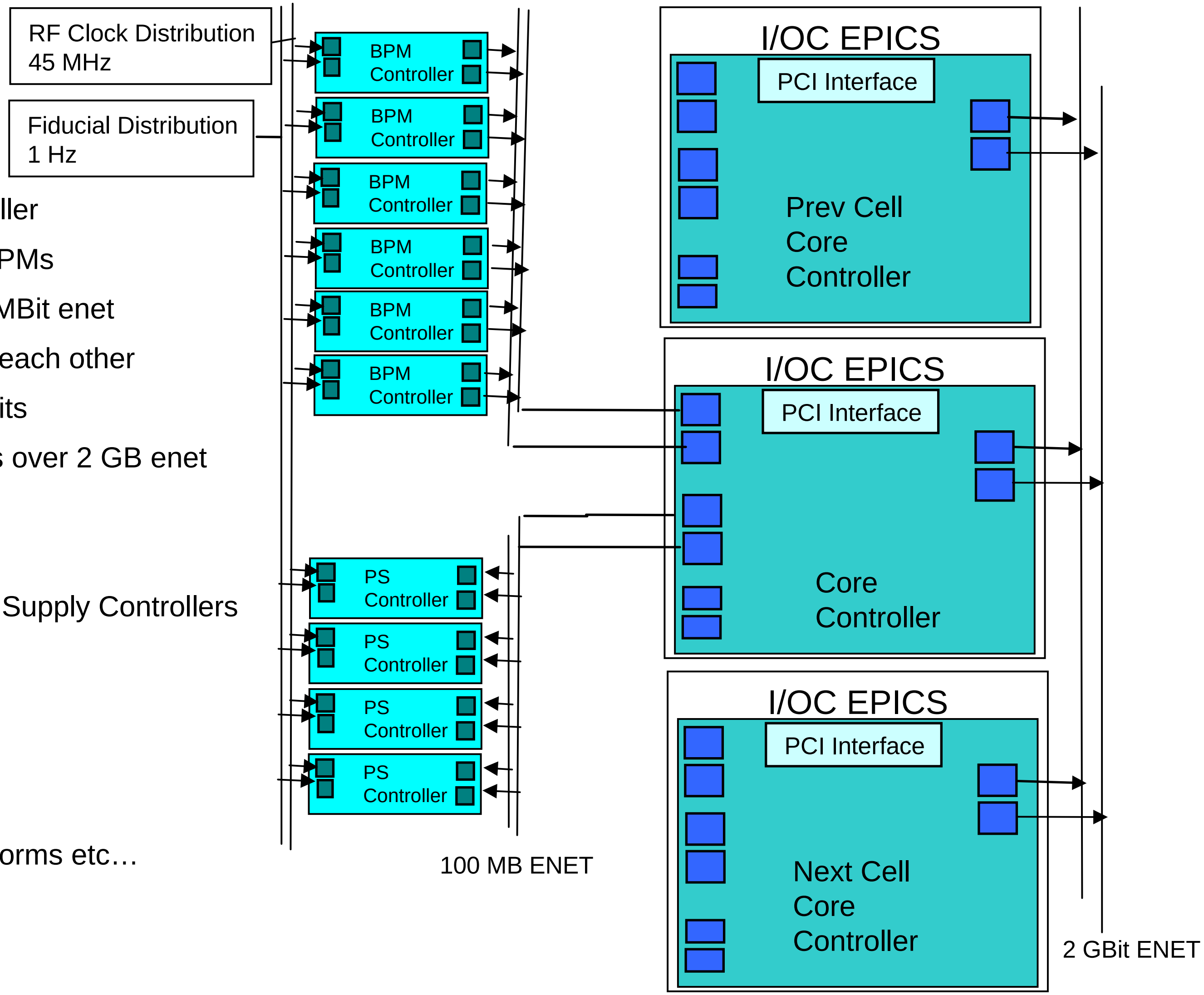
3.5 usecs

+18.9 usecs – loop complete

settling time for magnets

communicate diagnostic waveforms etc…

+200 usecs – start again

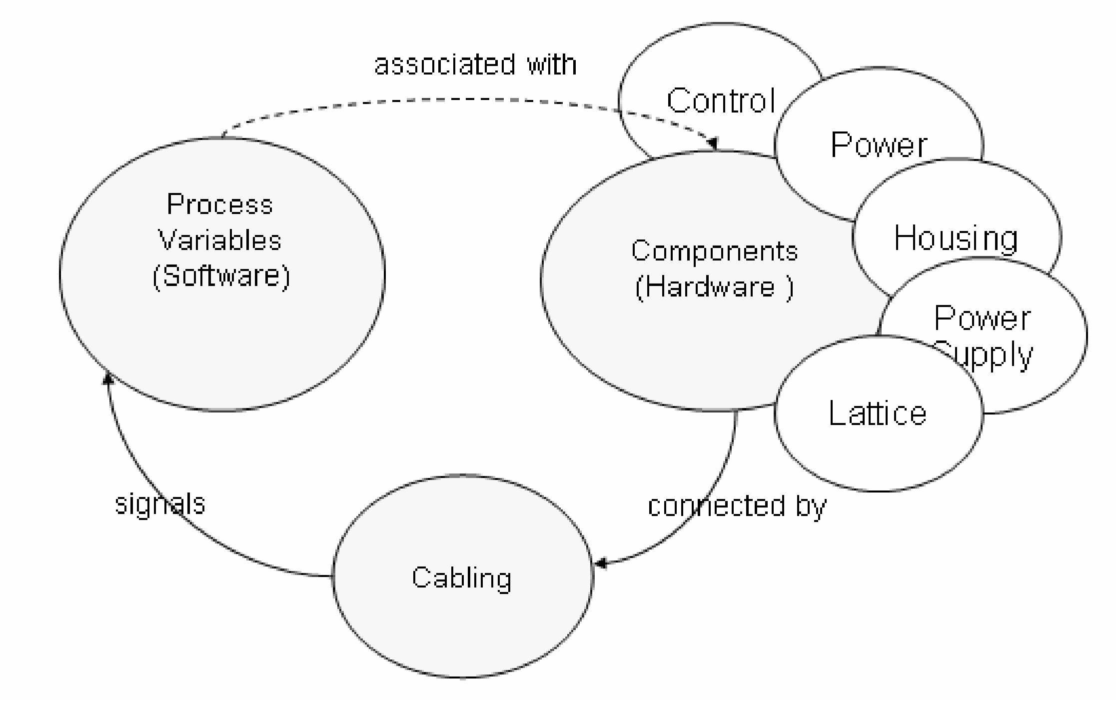


Embedded Device Control – 2 of 2

- **FY 08**
  - Purchase order in place with LBL (Alex Ratti and Larry Doolittle)
  - Develop a prototype cell controller:
    - Redundant 2 Gbit communication paths for peer to peer communication
    - RF timing signals
    - Verify communication and timing jitter meet requirements
  - Develop the interface from the cell controller to a processor for integration into EPICS (PCI Express)
- **FY 09**
  - Develop the inexpensive device controller with redundant 100 MBit controllers
  - Develop the 100 Mbit receive and transmit circuits for the Cell Controllers
  - Begin integration of these device controllers
    - Libera
    - Power supply control
    - LLRF control

IRMIS – 1 of 4

IRMIS: Integrated Relational Model of Installed Systems



IRMIS – 2 of 4

The IRMIS RDB effort began at the APS. After several iterations and meetings with other laboratories, the emphasis shifted to a global perspective in developing the schema and support applications.

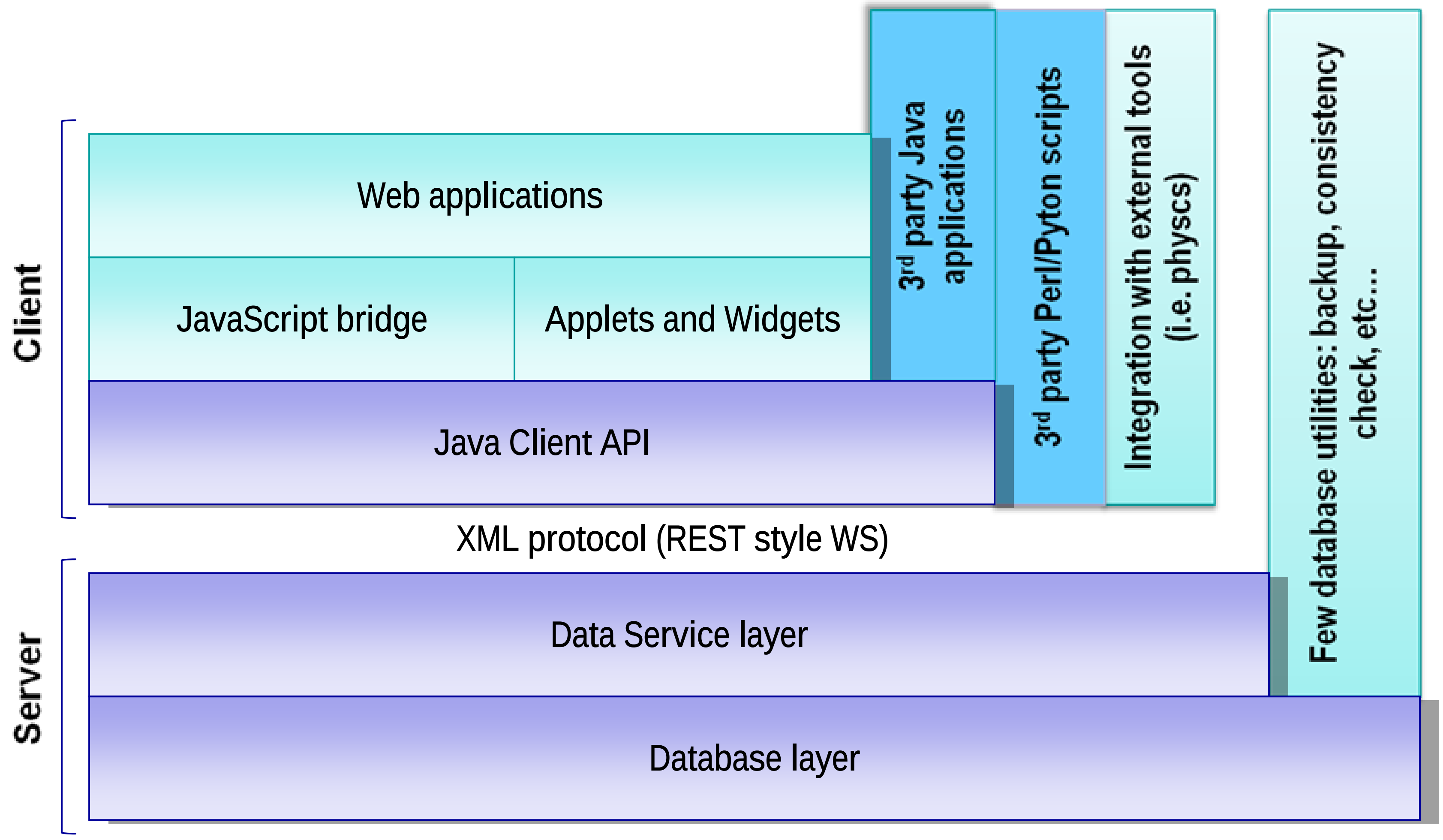
IRMIS is a collaborative effort involving SNS, Triumf, SLAC, CLS, SLS, ...

- IRMIS Inaugural Meeting, APS, March 2005
- IRMIS Collaboration Meeting, APS, May 2006

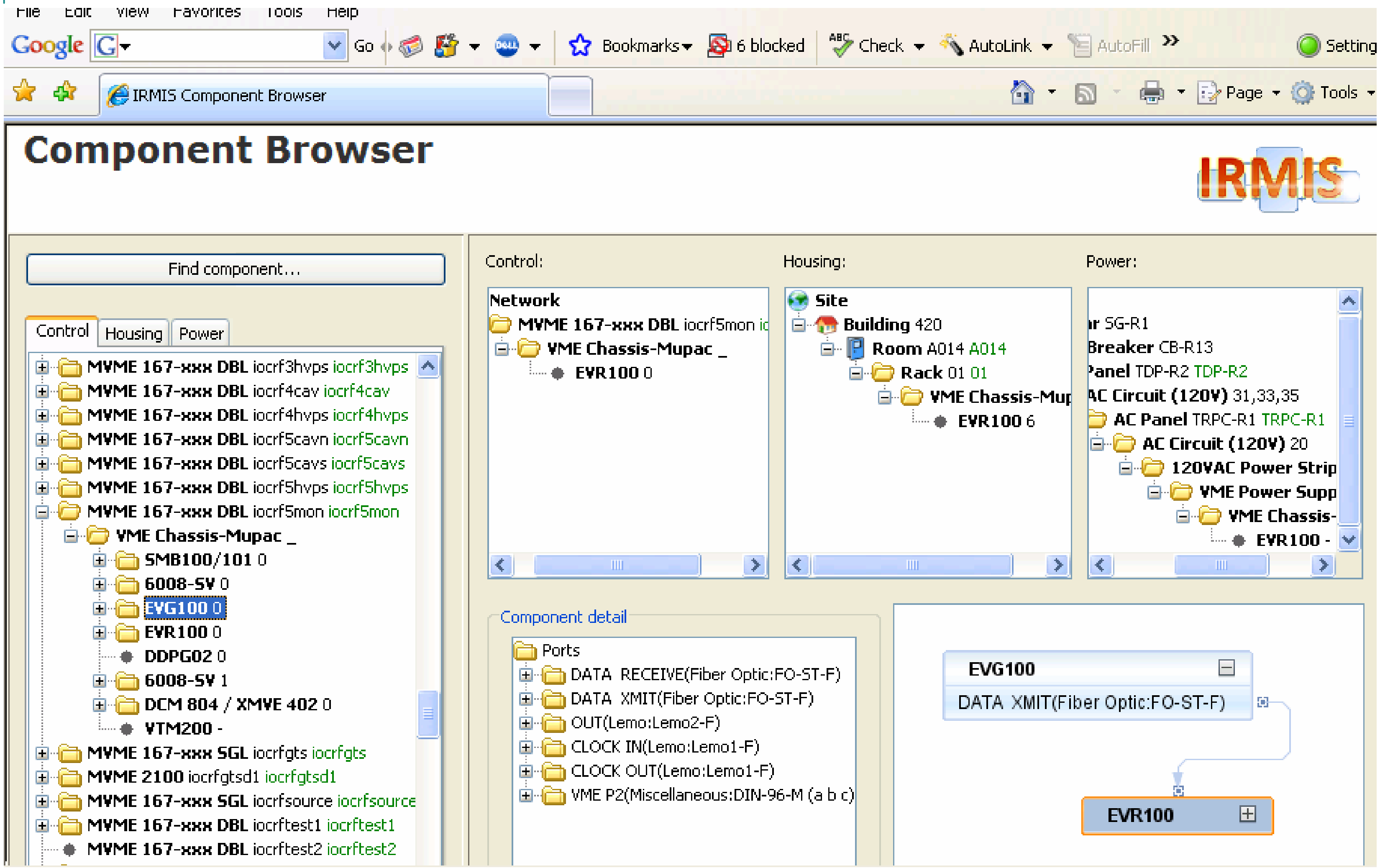
  www.aps.anl.gov/epics/irmis
- IRMIS meetings are usually held in collaboration with EPICS meetings.

The present BNL work extends this collaborative effort.

IRMIS – 3 of 4


Client
Server
Web applications
JavaScript bridge
Applets and Widgets
Java Client API
3rd party Java applications
3rd party Perl/Pyton scripts
Integration with external tools (i.e. physcs)
Few database utilities: backup, consistency check, etc…
XML protocol (REST style WS)
Data Service layer
Database layer

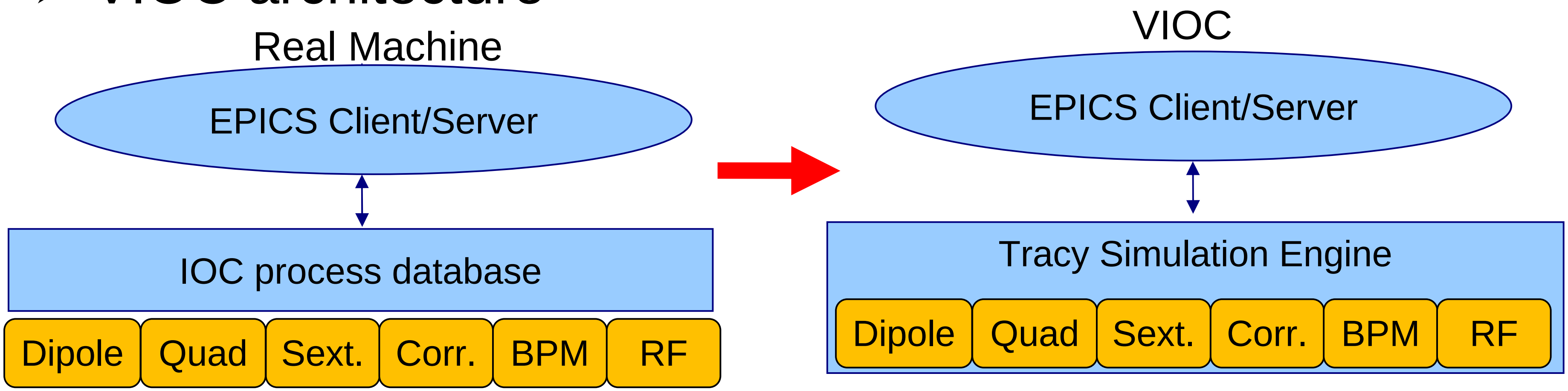
IRMIS – 4 of 4



IRMIS Component Browser
Component Browser
IRMIS
Find component...
Control
Housing
Power
MVME 167-xxx DBL iocrf3hvps iocrf3hvps
MVME 167-xxx DBL iocrf4cav iocrf4cav
MVME 167-xxx DBL iocrf4hvps iocrf4hvps
MVME 167-xxx DBL iocrf5cavn iocrf5cavn
MVME 167-xxx DBL iocrf5cavs iocrf5cavs
MVME 167-xxx DBL iocrf5hvps iocrf5hvps
MVME 167-xxx DBL iocrf5mon iocrf5mon
VME Chassis-Mupac _
SMB100/101 0
6008-SV 0
EVG100 0
EVR100 0
DDPG02 0
6008-SV 1
DCM 804 / XMVE 402 0
VTM200 -
MVME 167-xxx SGL iocrfgts iocrfgts
MVME 2100 iocrfgtsd1 iocrfgtsd1
MVME 167-xxx SGL iocrfsource iocrfsource
MVME 167-xxx DBL iocrftest1 iocrftest1
MVME 167-xxx DBL iocrftest2 iocrftest2
Control:
Network
MVME 167-xxx DBL iocrf5mon
VME Chassis-Mupac _
EVR100 0
Housing:
Site
Building 420
Room A014 A014
Rack 01 01
VME Chassis-Mup
EVR100 6
Power:
SG-R1
Breaker CB-R13
Panel TDP-R2 TDP-R2
AC Circuit (120V) 31,33,35
AC Panel TRPC-R1 TRPC-R1
AC Circuit (120V) 20
120VAC Power Strip
VME Power Supp
VME Chassis-
EVR100 -
Component detail
Ports
DATA RECEIVE(Fiber Optic:FO-ST-F)
DATA XMIT(Fiber Optic:FO-ST-F)
OUT(Lemo:Lemo2-F)
CLOCK IN(Lemo:Lemo1-F)
CLOCK OUT(Lemo:Lemo1-F)
VME P2(Miscellaneous:DIN-96-M (a b c)
EVG100
DATA XMIT(Fiber Optic:FO-ST-F)
EVR100

Virtual IOC – 1 of 2

- VIOC architecture

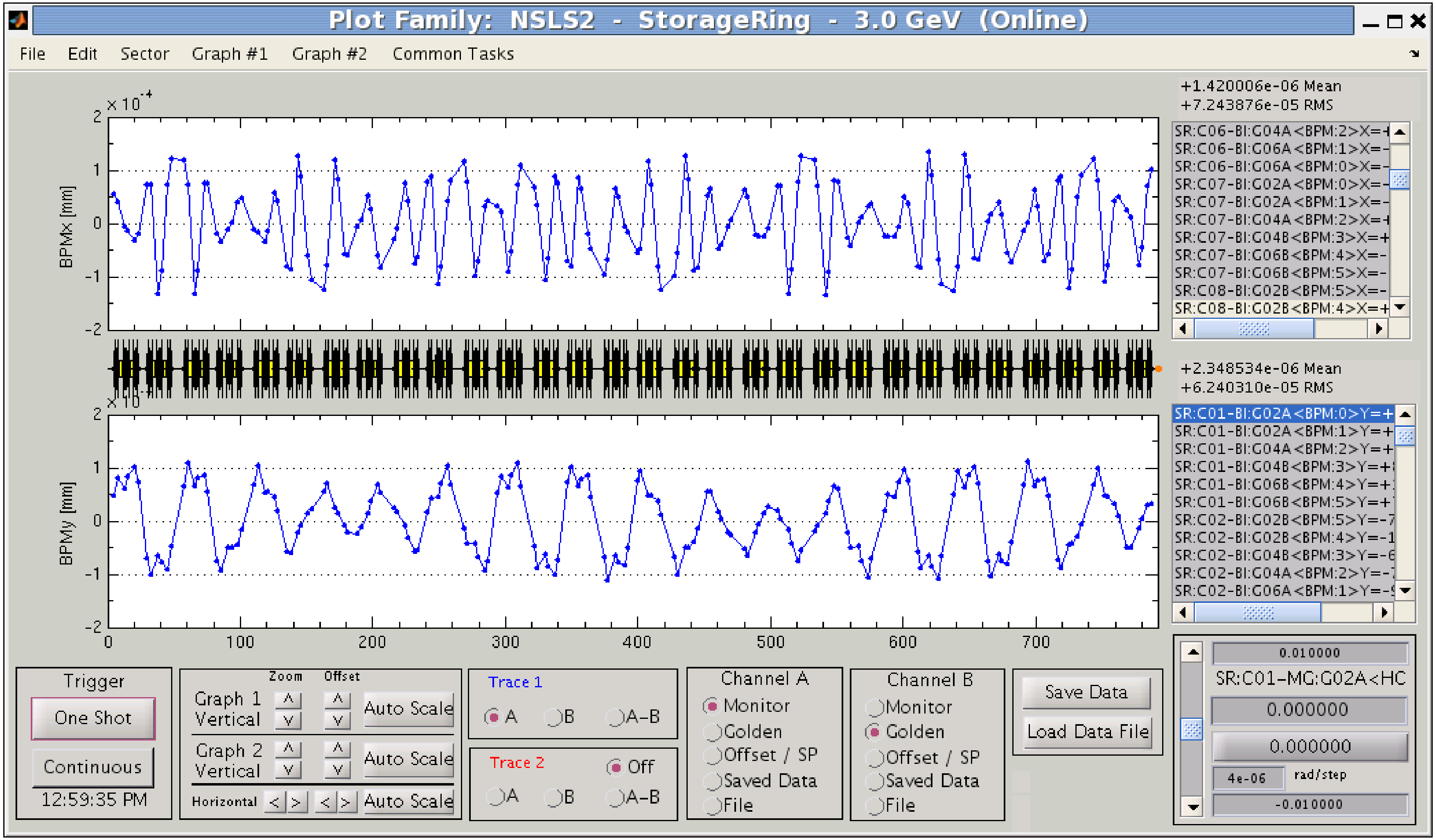


- Tracy simulation engine

Version	Track	Repetition	Lattice(30 Cells) (Idea, no error)	Support function	
				Set	read
3.5	linear	0.5Hz	CD3-Jun20	Magnets, & RF	Magnets, RF, & BPM

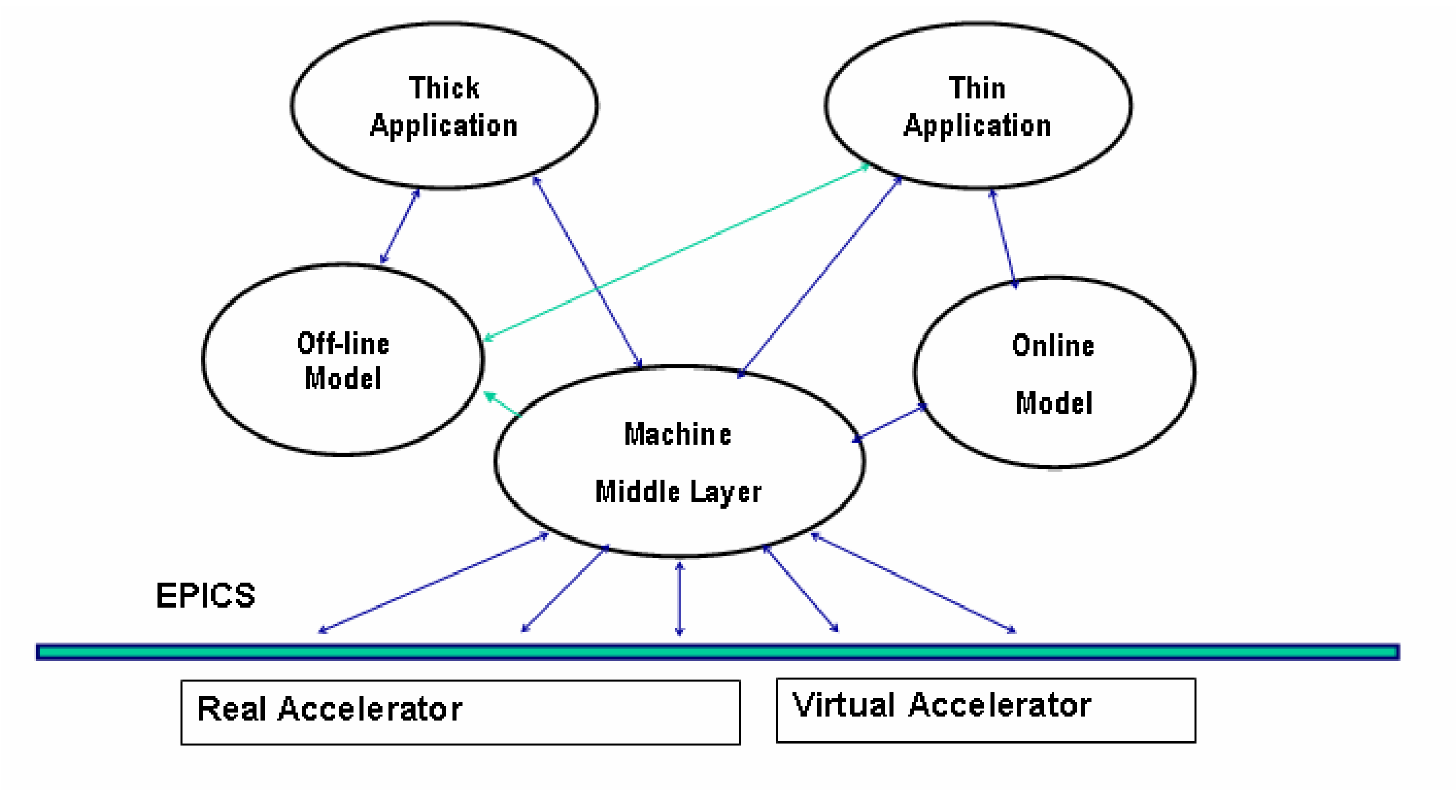
Virtual IOC – 2 of 2

Closed Orbit from VIOC:



High Level Application Environment – 1 of 3

Rationale: Open environment based on the **standard publish/subscribe specification** addressing the different types of the accelerator high level architectures and applications



High Level Application Environment – 2 of 3

Standard Publish/Subscribe Specifications

Middleware	Language	Data Type	Data Content Filtering	QoS	Complexity	Year
CORBA Event Service	C++, Java, …	Generic and typed events	no	no	hard	1997
CORBA Notification Service	C++, Java, …	Structured events	yes	yes	hard	~2000
Java Messaging Service (JMS)	Java	five types: text, map, bytes, stream, object messages	filters are message properties	no	easy	~2000
High Level Application (HLA)	C++, Java, …	Sequence of octets	no	yes	TBD	~2000
Data Distribution Service (DDS)	**C++, Java, …**	**User-specific data types**	**yes**	**yes**	**easy**	**2004**

High Level Application Environment – 3 of 3

- DDS/DCPS specification addresses the different types of the high level accelerator architectures and applications
- Functionality of two major DDS products has been evaluated:
  - OpenSplice offers an immediate commercial solution
  - openDDS is a free open source software that implements core DDS services. But it has to be extended with the content filtered topic and Java support
- In one year we plan to build the alpha/beta version of the DDS-based accelerator high level architecture and deploy the composite full-scale application providing the comparison of design and operational optics extracted from turn-by-turn data of a virtual accelerator.

Concluding Remarks

- 50% of Control System Design is completed
- Hardware standardization is being aggressively pursued with PLCs, processors, and crates being evaluated.
- All areas of development are making good progress.
- All subsystems should be prototyped in FY09, early FY10 time frame.