NSLS-II Control System

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U.S. DEPARTMENT OF ENERGY

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Outline

- Project planning and execution
- Integration shortcomings (Lessons learned)
- Setting standards
- Middle Layer Services for High Level Application
- (Relational) Database Developments
- Conclusions

Project Planning

- Identify critical requirements
- Define scope and interfaces
- Recruit, Recruit, Recruit
- Project Execution

Control System Requirements – 1 of 3

- 2.642 usec ring revolution
- Injection system runs up to 1 Hz
- Top off every 1 minute
- Top off bunch train ~20 psec
- Top off damping time 10-50 msecs (inform beam lines)
- 80% Fill – 1056 of 1320 buckets filled
  - different fill patterns
  - high charge single bunch at mid-gap
- Orbit stability to .3 microns at injection
- 5 Hz updates to operators of up to 1000 chosen parameters
- Archive up to 20,000 parameters at a rate of 1 Hz continually
- Must scale to support 150,000 physical I/O connections and 400,000 computed variables
- 99.7% availability during operation

Control System Requirements – 2 of 3

- 80 psecs pulse to pulse timing jitter.
  - During top off, some beam lines will need 1.1 - 1.8 psecs of timing jitter
- Timing resolution
  - 2 nsec for bunch to bunch timing
  - 200 psec for single bunch injection
  - Provide electron detector as event for beam line
  - 10 kHz power supply read backs triggered from timing sys
  - All data available to system with revolution identifier for turn by turn data correlation.
- 20 msec equipment protection mitigation
  - Sub 1 msec at other labs when undulator gap is closed – it's the xrays
  - Also – slow detection/shut down on RTDs on beam pipe for beam studies when beam emittance is wide
  - Plc provides voltage to comparator to bpm signal – forward/reflected to give current – with fiber optic transmission of this signal to the RF – one from each cabinet. 10's of micro seconds
  - 200 turns to loose energy after RF is off
  - Photon shutter – can take full energy?
- Transient Recording
  - Take coherent turn by turn orbit data for up to 800 channels for 1024 turns (each turn is 2.36 usec)
  - 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 (no hidden parameters)
- Conventional facilities
  - Tunnel and experimental floor Vibration < 25nm from 4-50Hz
  - Thermal stability of storage ring tunnel enc +- .1 dgc
  - Experimental floor +- .5 dgc

Control System Requirements – 3 of 3

- 5 KHz RF Feedback on beam phase
- 10 kHz orbit feedback, (100 usec loop time)
  - 360 BPMs (12 per cell)
  - 90 Corrector PS (3 per cell)
- Slow orbit correction
  - 180 Slow PS (6 per cell) synchronized with fast orbit feedback
  - 1 Hz model based control
- 10's of Hz Data Collection for RF loop correction.
- 200 MeV to 3 GeV in 400 msec ramp in booster for gap changes
- Transverse feed back Bunch to Bunch
  - 1 H and 1V stripline
  - RF cavity control
- BPM Requirements
  - Turn by turn on demand
  - Fast 10 kHz output
  - Slow 10 Hz data
  - ADC Raw data
- **Requirements at an accelerator evolve!! Standard engineering flow is iterative – Requirements-specification-design-implement-test-integrate, so flexible designs and attention are required. Learn from other facilities.**

Be Clear on Control System Software Scope

Develop Control Algorithms

Populate RDB

Experiment Control

Client Tools

Configuration Tools

Engineering Applications

Engineering Screens

Physics Applications

XAL/RDB Tools

EPICS Database

EPICS Device Support

Drivers

I/O

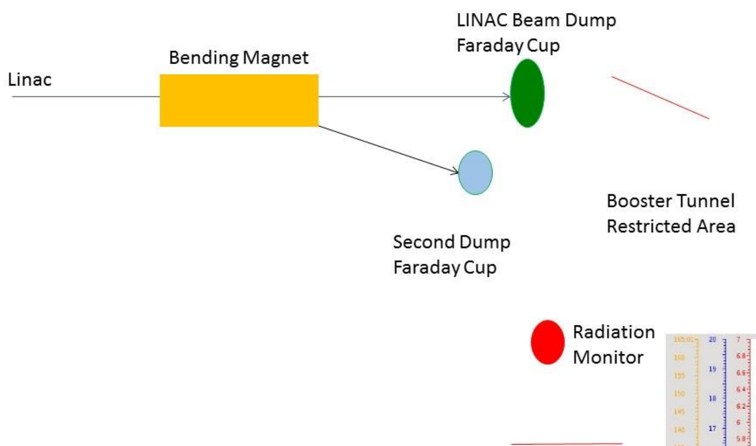
Device test / subsystem integration
Includes: LINAC, Booster, and Storage Ring, Facility, Undulator, Beamline

Commissioning Support

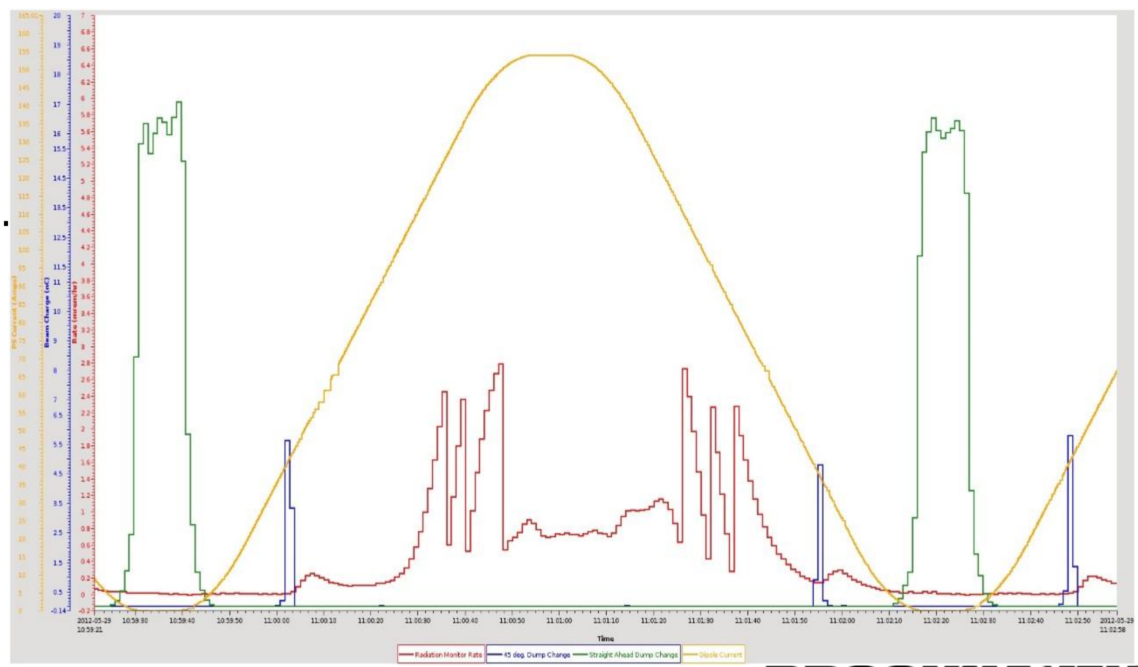
Project Execution

- Scope includes:
  - **FPGA code for power supplies (1000), BPMs (300), Fast Orbit Feedback (30), Position Capture / Detector Triggering, Single Channel Correlator, Fast Machine Protection, Timing, and Active Interlock**.
  - PLC code for low speed IO: utilities on the accelerator, all PLC IO on beam lines including EPS
  - EPICS Driver for all hardware (most provided by community)
  - EPICS Databases for all subsystem and facility IO
  - **CSS Synoptic Displays**
  - **Middle layer services for physics applications including a model server**
  - Network and computer layout
  - Choose EPICS tools where they are adequate
  - New EPICS tools and services: channel finder, save/restore, metaDataStore, Olog, CSS build, extended Boy widgets, unit conversion, areaDetector PVAccess Plugin,
- No. of EPICS records 985K Accelerator + 180K for 6 beam line delivery systems
  No. of IOCs 163: 45 VME, 7 cPCI, 111 IBM Servers (Instr Bus – Ethernet)
  No. of 19" racks 485
  No. of devices 61 unique device types
  No. of drivers 26
  No. of signals 200K
  lines of code for EPICS tools: 1.8M
  lines of in-house application code 185K

NSLS-II Integration Lessons Learned



One klystron was out
Steering magnet bent beam past second dump
Radiation monitor did not alarm in control room.



Incomplete Requirements Consideration.
Modes of operation must be considered.
Instruments must be tested – full range.

Standards

- 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

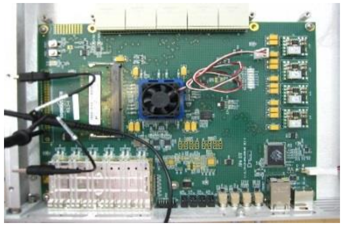
Standards

- Naming convention
- Coordinate system definition
- Instrumentation interfacing standards
- PLC standards
- Motion controller programming standards

Successful Developments Deployed

- CS Studio – new build, data layer, PVManager, integration of middle layer services, and new applications: Channel Finder, Logbook, Channel Orchestrator.
- This first deployment of CSStudio for a facility is exposing many new requirements and some shortcomings that need to be handled.
- Middle Layer Services: Channel Finder, Save Set Manager (MASAR), metaDataStore for use in physics and experiment control, DAQ, and data management.
- Standard digital board along with a variety of instruments.




- Talks MOC3O05, TUC3O05, WED3O02, THHC3O02 and posters

Middle Layer Services for High Level Apps

- Middle layer services reduce the development time and complexity of high level applications.
- Developing Application Programming Interfaces (APIs) to support thin applications requires time and collaboration that is not needed in monolithic codes.
- Narrow APIs that can be used by applications and tools, such as CSS, requires enough action to get it done and enough collaboration to get it right.
- Most physics applications are now layered: IOC, Middle Layer Services, python and/or CSS.
- See WEA3O02 for more on EPICS v4

(Relational) Database Experience

- **Goal: 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

- Channel Finder application uses mySQL (moving to MongoDB) (middle layer service in development)
- Lattice development with mySQL (middle layer service deployed)
- Electronic log uses mySQL (moving to MongoDB) (Python API allows scripts to make log entries)
- Save Retrieve uses mySQL (middle layer service deployed)
- Unit conversion uses mySQL for Magnet Measurements (deployed into an IOC application)
- New metaDataStore uses MongoDB (middle layer service in development)

Conclusions

- **NSLS-II has leveraged off of years of development from the community**.
- We have invested in several areas of development (3.15 extensions, V4, CSStudio, middle layer services, fast orbit feedback hardware) and they have greatly improved functionality and productivity. They are now being used for experimental data acquisition also.
- Setbacks/oversights were uncovered painlessly with cautious commissioning plans. They were used to productively resolve the issue and uncover any related issues.
- There are several key areas that need development in the future: PVAccess as the primary protocol for EPICS, CSStudio data layer maturation, and an open-source hardware platform.
- Scientists are doing limited science. Serious scope that was required was not in the scope of the project nor in the plan for commissioning and operations.