Controls program at NSLS-II

Richard Farnsworth
SAC Sep 2017

U.S. DEPARTMENT OF ENERGY | Office of Science

BROOKHAVEN NATIONAL LABORATORY | National Synchrotron Light Source II

The Controls Program consists of:

- Beamline Controls
- Accelerator Controls
- IT – Networks, servers, storage, cyber, more
- Motion controls and equipment protection
- DAMA – Data Acquisition, Mgt and Analysis

Talk brief

In particular, prioritization of tasks across the programs and the interface between EPICS layer controls and DAMA

Controls Mission statement (WIP)

To enable productive scientific research by making specialist controls and computing technology work for both the facility and the user community. To create controls, data collection, analysis and storage systems that are reliable, standardized, customizable and secure to enable the scientific productivity of the facility for infrequent and expert users.

Program details

- Beamline controls engineers (15) support the controls for the beamline directly.
- IT staff (6) look after the complex core networks system, operation of servers, fiber and ethernet wiring, local disk infrastructure, certain application support, licensing, cyber protection and more.
- Accelerator (5) controls engineers look after the control room, the accelerator control system.
- Motion controls and EPS (6 + 2 fixed term) for Insertion devices, EPS PLC programming
- DAMA (7+4 new hires) – High level data acquisition, data management, analysis and archiving.
- Part of the EPICS collaboration.
- DOE "Hackathons" and more.

Current Org Chart

NSLS-II CONTROLS
R. Farnsworth
PROGRAM MANAGER

A. Heroux
K. Shroff

BEAMLINE CONTROLS
Z. Yin
GROUP LEADER
C. DeSilva
K. Gofron
O. Ivashkevych
J. Li
B. Luvizotto
J. Ma
D. Poshka
S-L. So
B. Sobhani
H. Xu
K. Zhang

BEAMLINE CONTROLS
J. Skinner
DEPUTY
S. Myers
K. Qian
B. Seiva Martins

ACCELERATOR CONTROLS
Y. Tian
GROUP LEADER
A. Derbenev
K. Ha
Y. Hu
J. Tagger

IT INFRASTRUCTURE
R. Petkus
GROUP LEADER
M. Cowan
L. Flaks
M. Karasawa
S. Sauter
T. Smith

MOTION CONTROLS
H. Bassan
GROUP LEADER
G. Bischof
B. Clay
C. Guerrero
Q. Tang

R. Skelaney
P. DeCaro
K. Harsch
T. Herbst
M. Nicoletta

DATA ACQUISTION, MANAGEMENT and ANALYSIS
S. Campbell
GROUP LEADER
S. Abeykoon (CSC)
D. Allan
A. Arkilic
T. Caswell
L. Li
N. Malitsky
Y-N. Tang

+ four students from Columbia and Stony Brook

Notes: Beamlines control is one group (Legacy division)
Some Temp positions
S. Abeykoon
P DeCaro, M. Nicoletta now complete.

Controls program - details

Beamline controls consist of:

- Local motion controls (Optics, samples, etc);
- EPICS IOCs;
- Vacuum controls;
- Interfaces to equipment & personnel protection systems;
- interfaces to other systems;
- Provision of user interface screens;
- Process Variables (PVs); and
- Provision of networks and servers

Other Controls program staff

- Accelerator (5)
- IT staff (5)
- Motion controls & equipment protection (7)
- DAMA (7) + Vacancies(4)
- + Students assistants, part time (4)
- + Summer students (4)

Retaining staff is proving to be difficult due to:

1) Transition to ops and resulting change in the nature of the work
2) Competition from industry and competition from other labs.
3) Controls Staff have a high value skill set.

Beamline controls complexity

Beamlines	PV count	IOC count
XF02 SIX	83,398	34
XF03 HXN	143685	127
XF04 XFM	50661	36
XF05 SRX	43257	45
XF08 ISS	32901	39
XF10 IXS	40540	43
XF11 CHX	55473	54
XF12 SMI	4101	4
XF16 LIX	58862	37
XF17 AMX/FMX	144060	103
XF19 NYX	2945	4
XF21 ESM	7793	43
XF23 CSX1/2	103642	84
XF28 XPD/PDF	39011	69
Accelerator	804966	655

Notes:

Factor in PV counts include:

- Complexity of system
- Nature of process
- Current state of development
- Scientist preference

Note also:

Only includes 'controlled' IOCs

Not a perfect measure, but at times useful

Transition to operations

- All of the beamlines were initially delivered with some controls by others. Some very recently.
- Many accelerator systems were delivered by others, but many others developed in house.
- The accelerator has been in operation much longer. Controls is very reliable and mature for accelerator systems. Therefore not the focus of this talk.
- Beamlines, as delivered for the IRR are at the very beginning of their life – from a controls development perspective.

After the readiness review – Ongoing Ops.

- There is a difference between a beamline that works well enough to take beam, and a beamline running efficiently and easily for full user time operations. (Not just true of controls.)
- While this varies greatly from one to the next, it takes substantive effort to make a beamline controls software and hardware run well for General User operations.

Priority setting – current state

- We are starting to maintain a never quite accurate task list and try to get everybody happy or at least equally miserable.
- Control Program does not set priorities, but discussions at the Beamline Program Manager level are held often, both individually and in a group setting.

Task lists sample (for SIX) shown

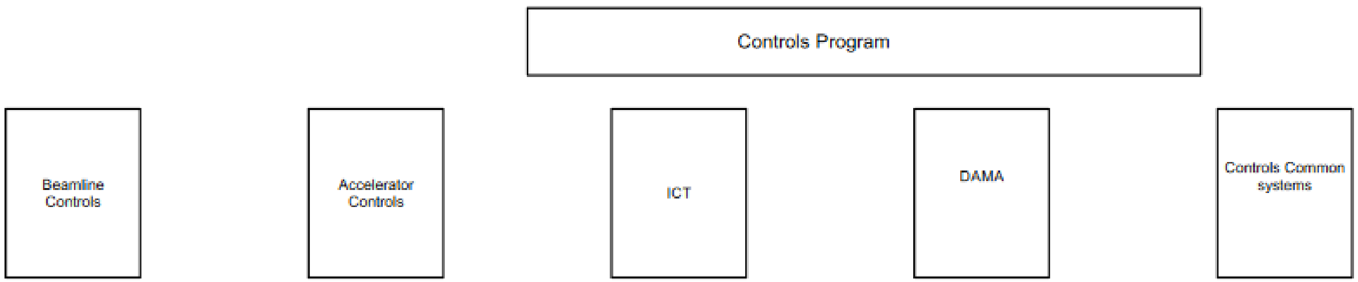
Motion Controls Activities for SIX Commissioning

Completion date	Controls activities required
August 15	Cryostat B manipulator motions tuning and CSS screen
	M5 optics wheel motion tuning and CSS screen (1
	Navitar camera lens motion tuning and CSS screen (
	Cryostat B manipulator motions in bluesky
	M5 optics wheel motion in bluesky
	Questar camera lens motion tuning and CSS screen (
	Questar prosilica camera integration in CSS (1 ur
	Sample chamber Prosilica camera integration in CSS (Sample chamber Mako camera integration in CSS (4
	Electrometers setup (4 units)
September 30	M5 hexapod motions work by Wayne
	Spectrometer monochromator motions tuning and CSS scr (note: Jun did a similar work for the beamline monoch
	Energy coordinated motions for both PGM and spectr
	EPS vacuum logic implementation for spectrometer arm and v
	Vacuum CSS screens for spectrometer arm and vacuum
	CCD detector integration in bluesky
	CCD detector thermal sensor integration in CS
	CCD 2D image processing, centroiding algorithm for single photor analysis in bluesky
December 1	Spectrometer arm rotation motions in CSS by Wa
	Spectrometer arm rotation motions in bluesky
	EPS safety system for spectrometer arm rotatic
	CSS screen for diffractometer motions (6 kinematic
	Diffractometer motions in bluesky and reciprocal space calcu
	Wavefront analyzer control and data analysis in CSS an
	Sample transfer system motion tuning and CSS screen, integratior

Priority setting - future

- Individual Beamlines generate Controls Program tasks list extended with: Completion date, Activities required, labor estimate.
- Priorities will be more formally set, reflecting the facility priorities and in accordance with facility lines of authority.
- Lists of upcoming and unallocated items will be maintained.
- Transparency in the process is very important.
- Consistency across Controls Program is important.
- There is a resistance to a process change.

Program Point of Contacts (POC)



Program	Program Manager	POC Controls
Soft X-ray	Stuart Wilkins	John Sinsheimer
Hard X-ray	Klaus Attenkofer	Bruno Luvizotto
Complex scattering	Ron Pindak	Kaz Gofron
Imaging and Microscopy	Young Chu	Jun Ma
Diffraction	Eric Doohyee	Oksana Ivashkevych
Structural Biology	Sean Mc Sweeney	John Skinner

Standards

Standardized hardware means that better software support can be given. Expertise is better shared.

Expand

- EPICS for every control system – supervisory at least. Standard version (3.14.x)

Others

- Bluesky everywhere for Data acquisition – 1.0 before Nov 1 2017.
- Standard Motion Controllers – Delta tau geobrick V, standard software
- Standard Naming – by convention
- Standard User interfaces – CSS_BOY
- Standard Controls data – EPICS archiver
- Standard Networks – single Core switch from Brocade
- Standard EPS (AB PLC, IEC-6113-2 coded)
- Standard operating systems (Debian Linux)
- Standard server hardware (transitioning)

Standards can be over ridden, but only when strong needs are presented
We have potential issues with some Partner beamlines in this regard.

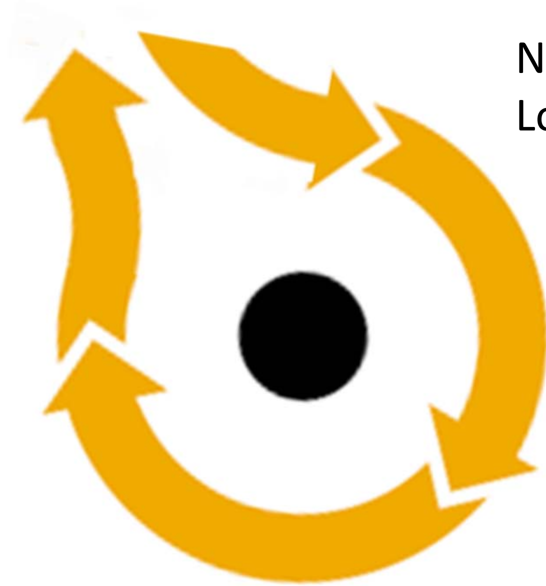
Data Lifecycle

Collect – Detector,
Controls, Bluesky
NSLS-II

CSI Remote data transfer
(+ NERSC+ NIST+others)

Near Real time Analysis
Local computing NSLS-II

CSI Remote analysis



Data curation – Metadata
Data format conversion
NSLS-II

CSI – High performance
Analysis - clusters

Very short term
Storage – Beamline

CSI Long term storage

Short/Med term Local
storage – Facility
NSLS-II

Computer Science Initiative (CSI) and NSLS-II

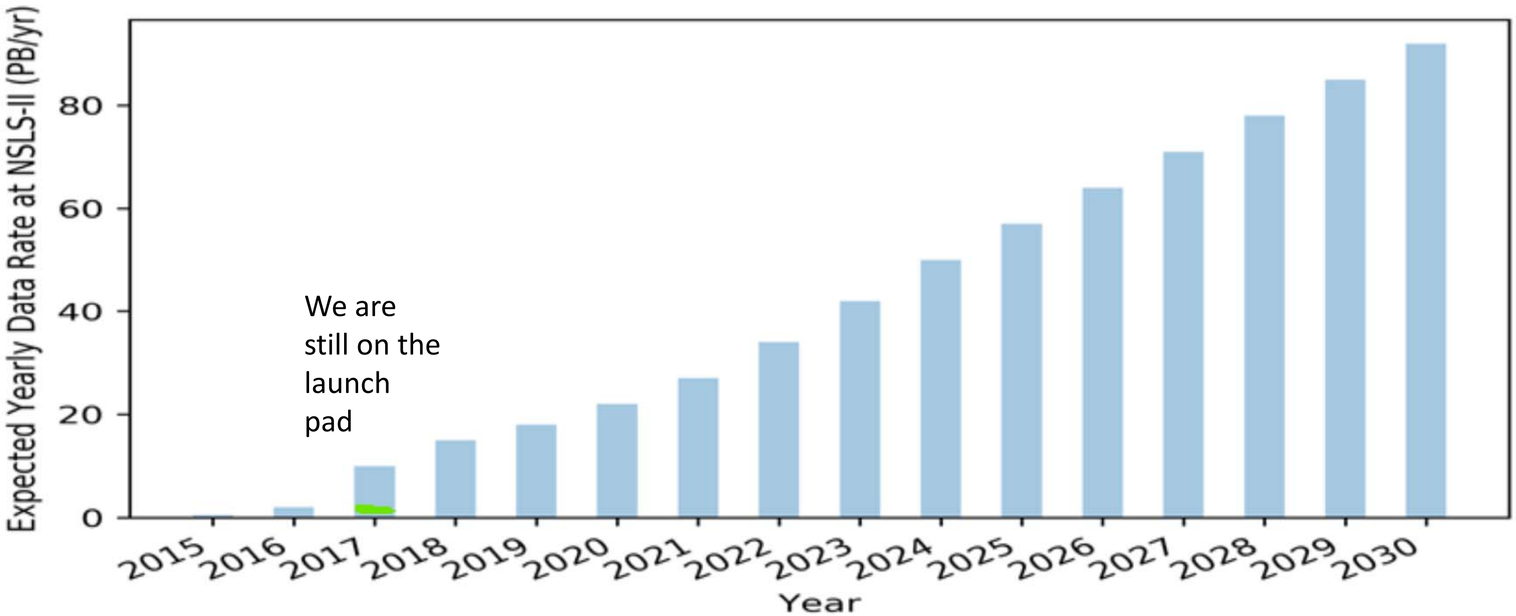
Working with CSI to provide the following goals

- Longer term data storage and retrieval
- Provision of high performance Computing resources for data analysis
  - This includes both the hardware and the software
- Remote data access in a secure fashion
- Remote data analysis
- Computer science support
  - Parallelization, visualization…

Costs still being explored:
200 nodes = $193k/yr (purchased)
= $1051k/yr (rent)
Storage = $8.33/Tb/month

Lab wide goals:
Cheaper, Reliable, Secure, Expert computing and storage.

Estimated NSLS-II Storage Needs



- Estimated for the 28 NSLS-II beamlines under development
- Was based on current information on operating beamlines
- Takes into account estimated increases in both detector and beamline operational reliability.

- Fortunately, we are not generating huge amount just yet – but it's coming…

DAMA

Bluesky

- Data acquisition –
- Data curation – Storage within a database, Add Metadata
- Data conversion to other formats

Other

- Data transfer to
- Local data processing and High Performance Computing.

Bluesky Data Collection Framework

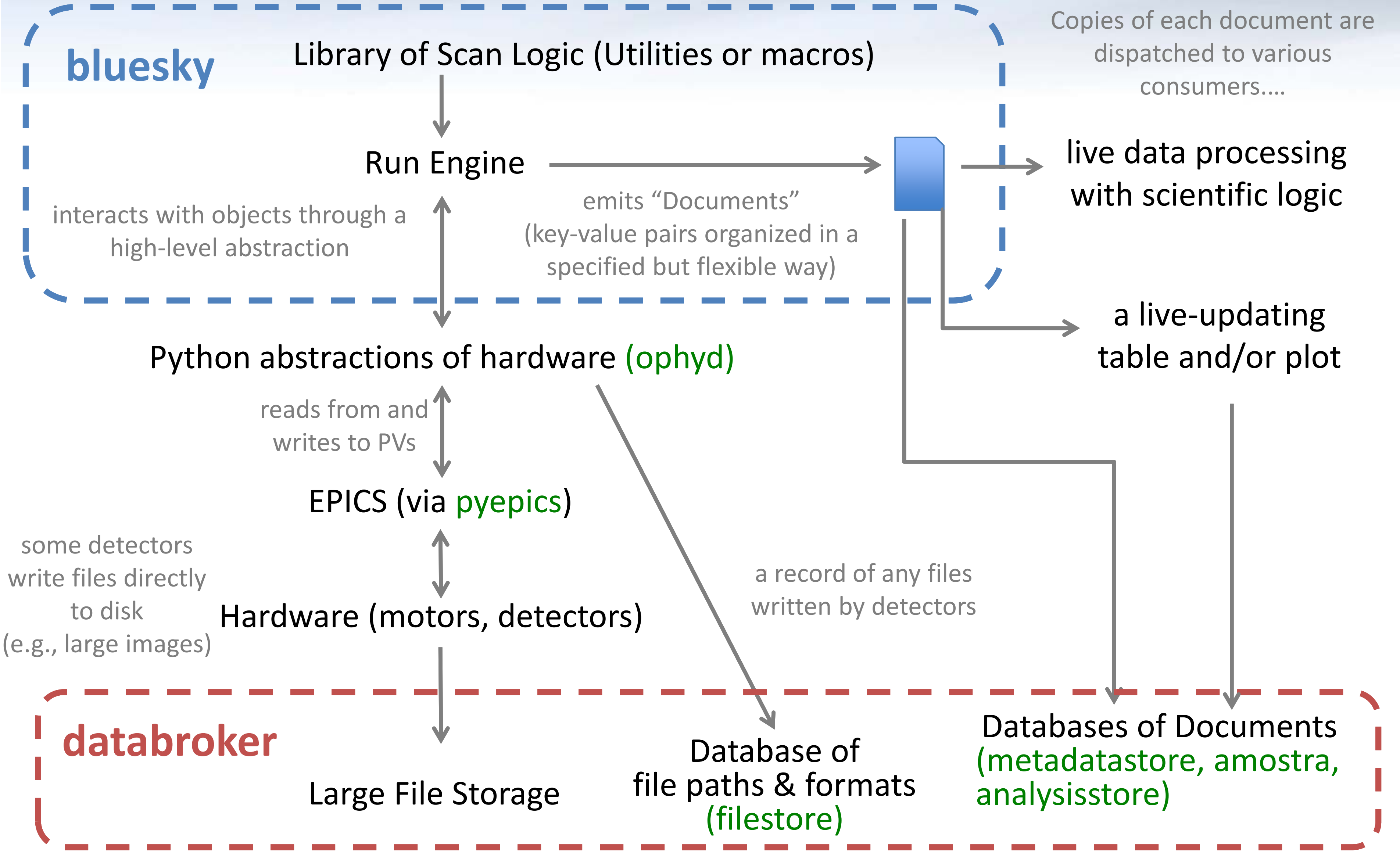
Bluesky is a light-weight Python package for interactive data collection.

There are three components:

- *Messages,* simple, granular instructions,
- a *Run Engine,* which processes the messages and coordinates collection,
- and *Documents*, Python dictionaries containing data and metadata, organized in a specified but flexible way.

Python is a powerful general purpose programming language that has become one of the most popular in use for scientific purposes.

Data Acquisition Using Bluesky



How Bluesky Interfaces with Hardware

Overview

Bluesky interacts with hardware through a high-level abstraction, leaving the low-level details of communication as a separate concern. In Bluesky's view, *all* devices are in a sense "detectors," in that they can be read. A subset of these devices are "positioners" that can also be set (i.e., written to or moved).

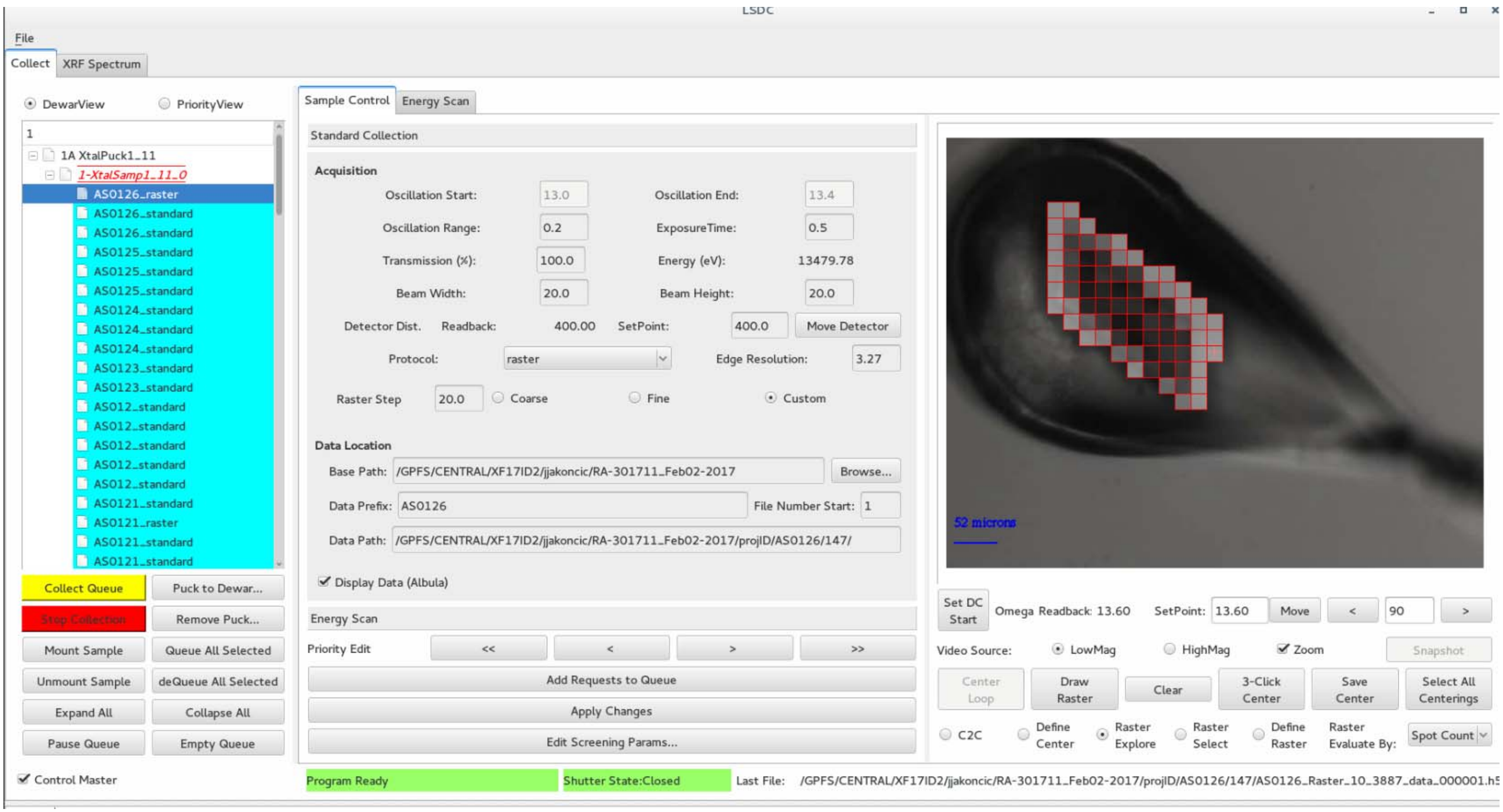
Each device is represented by a Python object that has attributes and methods with certain established names.

Implementations - Real Hardware

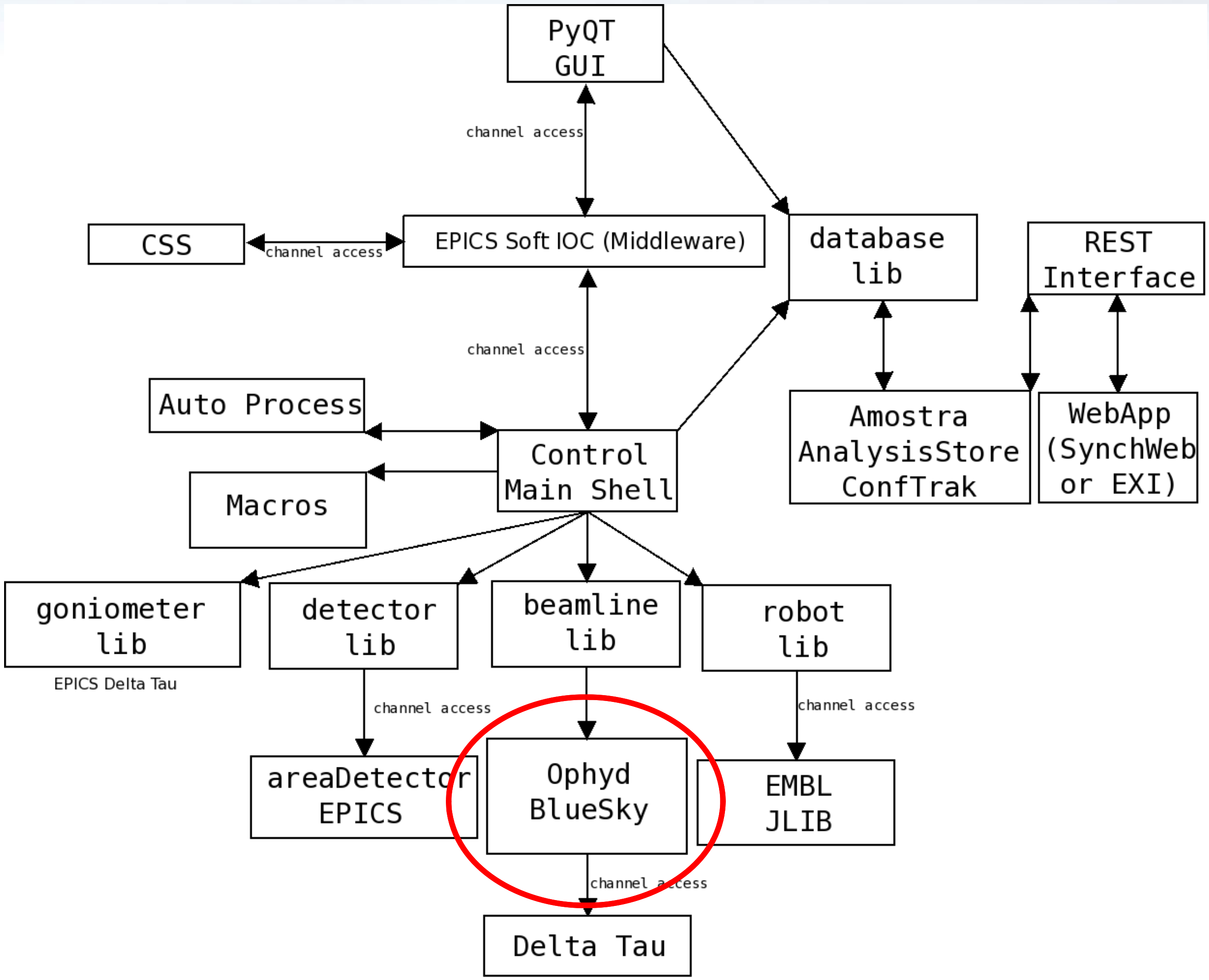
The ophyd package implements this interface for a wide variety of hardware, communicating using EPICS via the Python bindings pyepics.

Other control systems (Tango, LabView, etc.) could be integrated with Bluesky in the future by implementing this same interface.

FMX user interface



The engine



PyQT GUI
channel access
CSS
channel access
EPICS Soft IOC (Middleware)
database lib
REST Interface
channel access
Auto Process
Amostra AnalysisStore ConfTrak
WebApp (SynchWeb or EXI)
Control Main Shell
Macros
goniometer lib
detector lib
beamline lib
robot lib
EPICS Delta Tau
channel access
channel access
areaDetector EPICS
Ophyd BlueSky
EMBL JLIB
channel access
Delta Tau

Interest from other facilities

- Bluesky *et al* is planned to be implemented at
  - APS
  - LCLS
- Interest has been shown by
  - Australian Synchrotron (visited us in July)
  - European Spallation Source
  - Swiss Light Source
- We want to encourage collaborations

Argonne NATIONAL LABORATORY
OAK RIDGE National Laboratory
SLAC
Australian Synchrotron
EUROPEAN SPALLATION SOURCE
PAUL SCHERRER INSTITUT PSI

IT and Networks

- NSLS-II has a full separation of the network from the lab systems.
- The network is part of the control system
- The provision of many servers is part of the control system
- Working closely with Campus IT (ITD) is important
- Single sign on (SSO) or just one username and password for the entire user experience is coming.

Existing IT systems – outside of NSLS-II

- The user experience in accessing BNL's IT system from proposal to badging, IT on site and data processing and removal is convoluted, long and painful.
- Steps to reduce the administrative overhead are underway. Single Sign On or one universal BNL account is one of the first, but not the only area. Better scheduling, a better "portal" system and easier data access are all on the list to be improved
- The integration of separate systems is tricky.

Collaborations

- EPICS. We have a formal charter and contribute with EPICS 3,4 and 7. Drivers, CSS-Studio development, bug fixes, Debian packaging and others.
- Continue to develop using an "open model"
- Ensure that the DOE Science User Facilities (ExFaC) "Hackathons" continue
- Participate in community developments and standards
- We are hosting the next NOBUGS conference in 2018/2019

Controls Staff Retention

The end of project work, staff with low ties to the area, attractive projects at other facilities and other (non work) reasons have contributed to a higher than optimum staff turnover.

Actively looking at better staff responsibility sharing, flexibility with salary and conditions, better recognition, access to conferences and peer support, more responsiveness to INS needs and management changes in order to reduce the turnover.

Summary

- The Controls program covers controls, data collection, analysis, storage and IT technologies all working together.
- The priority setting and task management for beamlines are being addressed.
- The program aims to facilitate full data management - from collection to processing and analysis to storage to post experiment access for all users.

Questions?

Supplemental Slides

Data collection and analysis -1

- Deploying an event-based data collection and analysis framework.
- **Design Goals**
- Provide an integrated, **end-to-end solution** for data collection and analysis.
- Support **streaming** data analysis, variously called “in-line” or “live”.
- Support **prompt** data analysis: immediate, semi-automated data analysis that can inform decisions made during an experiment
- Capture **metadata** to record a detailed snapshot of the hardware and — as much as possible — represent the user intention, the meaning of the measurements.

Data collection and analysis - 2

- Make datasets **searchable** with rich queries on metadata and data.
- Use **existing, open-source technologies and languages**; avoid inventing a domain-specific language.
- Leverage tools from the **open scientific software** community and in particular the **scientific Python** community, a mature and widely-used ecosystem of scientific code used in trusted, critical applications in research and beyond.
- Establish **clear, consistent interfaces** (meaning inputs and outputs, APIs) that allow project components to be used independently, extended, and interfaced with other, outside projects.
- Adhere to good software practices, especially code review and automated testing, with the goal of enabling **large-scale collaboration** while maintaining **stability and robustness**.

Other Controls staff

Five accelerator staff looking after

- RF system control, Diagnostics, Vacuum
- Power supplies, Front Ends
- Timing systems

Exactly 804966* Process Variables over 655 IOCs

* As of 9/8/2017

Beamlines, and IT

IT priorities are set somewhat separately as most of the infrastructure is common

Bluesky Data Collection Framework

- **Bluesky Data Collection Framework**
- Bluesky is a light-weight Python package for interactive data collection.

There are three components:

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Future focus for the DAMA Group

Authentication and Authorisation will be added to applications. The implementation is in concert with some measures taken by the IT group to grant access to beamline computers for remote data collection. In the middle of developing different schemas accommodate users' need to analyse their data during and after their visit.

Moving data:

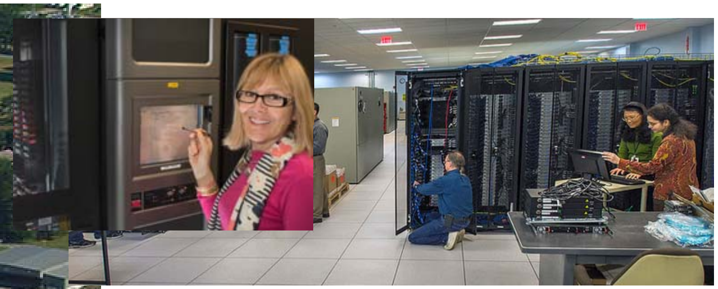
We want the ability to move data from a local storage and move it to a different system (centralised storage or different device on same beamline). This could be to make space - could be scheduled transfer) or to address failure of a system. A more robust procedure is being evaluated. We need to interact with beamline staff and our IT group.

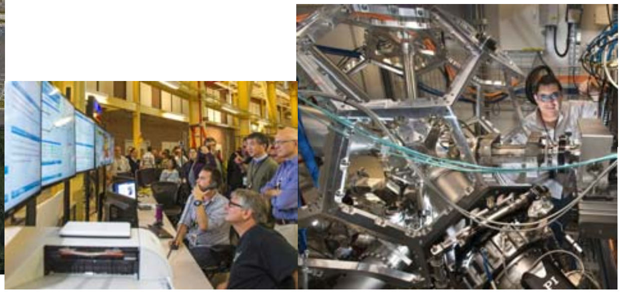
Standards for all beamlines

Standarised hardware means that better software support can be given. Expertise is better shared. We have standards for

- EPICS
- Soft IOCs
- CSS-Boy
- Delta-tau
- Debian Linux
- AB PLC for EPS

Computer Science initiative (CSI) and NSLS-II





Controls on Beamlines

Fifteen controls engineering staff

Transitioning from a "cognizant" engineer per beamline to a point of contact per program + specialists.

CHX – Example of Beamline work

- Complex optics table with rotation and elongation motorized. Delta Tau controls motors.
- Used EPICS motor record.

“**Computer System”**

- Beamline control is achieved from EPICS via the "Control System Studio" (CSS) which is a set of graphical users interfaces allowing to control each instrument, or "ophyd", a python-based command line interface for scanning. Local data analysis is performed in python with tools provided for standard XPCS analysis.
- Data can be taken away by users, or analyzed further on site.

CHX layout and racks