2016 BCDA Controls Strategy

The Beam line Controls and Data Acquisition group (BCDA), recognizes its most important role is to make beam line instrumentation work for scientists, so the scientists can focus on the delivery of scientific instruments and user science. This document describes the strategy through which BCDA will fulfill that role.

The Mission Statement of the BCDA group guides the group philosophies, objectives, goals, and decisions, as well as shapes the group strategy. The strategy is also described in terms of goals for the next few years.

1. Our Mission

To develop software and electronic hardware for synchrotron radiation beam lines that serves the common needs of APS researchers, and to implement that software for the APS beam lines. Our commitment, to maximize the measurement efficiency of the beam lines we serve, shapes the culture and character of our group and how we behave and make decisions. Through collaboration with APS researchers, we design, develop, deploy, and maintain control system software and hardware that capture and create economies of scale and keep the APS at the forefront of science.

2. Core Philosophies

The BCDA group works by several core philosophies to support our Mission. One central philosophy underscores our commitment to maximize measurement efficiency: *Our work should minimize the X-ray beam dumped into the shutter.*

- ***Conservative deployment***

  Initially, deploy the latest, most advanced control systems possible, then upgrade each system with a view to maximize the incremental value added while keeping in mind that integral to the upgrade process is the possibility of roll-back.

- ***Continuous incremental improvement***

  Improvements are implemented on a continuous basis rather than waiting for a few defined intervals, yet still guided by the philosophy of conservative deployment.

- ***Community engagement***

  Constant engagement with the community of resident staff, visiting users, and distant collaborators is essential to support the mission.

- ***Capabilities* vs. *requirements***

  Control systems are often built to engineering requirements. Yet, the process of scientific discovery demands flexibility. To expand the range of their measurements and push the limits of discovery, scientists are more interested in the *capabilities* of their control systems.

- ***COTS* (commercial off the shelf)**

  A strong preference for *commercially-available solutions* whenever possible.

These philosophies influence the group in each of the major areas of activity: software, hardware, communication, and training.

3. Core Objectives

These core objectives comprise a vision for the group.

- Deliver and support the most advanced and flexible controls systems for beam lines, where these systems are useful to the instrument teams and users.
- Design the control systems with the most standardization possible, with strongest preference for commercial-off-the-shelf solutions when available, yet gain more flexibility in integrating equipment or methods using other control systems.
- Ensure the control system propositions from the group become the preferred choice by the beam lines.
- Cross-train group members in support of all control system aspects, to better support, increase peer review, apply continuous improvement, and minimize risk of single points of failure.
- Promote and engage continuous career development of staff, including training, conferences, mentoring, and a student intern program.
- R&D program: Encourage innovation, explore new or advanced control system possibilities, new capabilities for beam lines, staff enrichment

4. Roadmap (3-5 year Goals)

While continuing to support our existing control systems, we set additional goals, covering the next few years, to improve the beam line control systems:

- **area detectors**

  make the process of integrating new detectors routine

- **synoptic display software**

  It is time to replace MEDM, the current software used for graphical user interface at most X-ray beam lines.

- **scripting environment**

  Beam lines need a common scripting environment in which to describe the activities for each of their measurements and experiments. The environment should describe a complete set of activities and record all data necessary for automation of the data reduction. For most experiments, it should become possible to provide a provisional (at least) data analysis as part of near instantaneous feedback for the next measurement.

- **high-speed signal handling**

  As science at the APS continues to push towards more fundamental scientific processes, the need increases for electronics to monitor, measure, and control signals at shorter time intervals.

5. Strategies

Strategies to reach these goals are varied. Some of the goals may be realized through existing efforts while other goals will require resources beyond what is currently available and coordination with other groups both within the APS and the worldwide controls community.

5.1. Collaboration

Continued collaboration with various APS support groups, beam line staff, CAT staff, and international controls community, is essential for the delivery of control systems, such as the AES-IT group which manages the network infrastructure and beam line computers on which BCDA establishes the control systems. In addition to direct communications with APS researchers, BCDA participates in beam line group meetings, email discussion lists, technical forums, scientific presentations, conferences, publications, and collaborative software development groups. The group's main software package, synApps [1] [2], is now posted to an

open-source version control repository. Other software projects from the group are also posted in appropriate open-source version control repositories.

In collaboration with the IT group, BCDA has established and maintains */APSshare*, a networked file storage that makes available useful software tools ready for use at every APS beam line. Among these tools are EPICS clients for extracting and visualizing data at beam lines, software for the operation of EPICS servers, and software for the development of scientific data analysis and development of beam line control systems.

BCDA identifies common needs for certain electronic hardware used in the beam line control systems it serves and maintains sufficient quantities to ensure continuity of operations should beam line components fail.

5.2. EPICS

BCDA has relied upon *EPICS* [3] to provide the hardware abstraction layer and communications libraries to provide efficient, flexible, and highly-adaptive controls in the support of APS control systems. APS has developed significant expertise in the use of *EPICS* for its control system. The international *EPICS* community maintains various open-source software version control repositories, and is quite active, holding two technical meetings each year in addition to a mailing list with direct access to subject matter experts, and copious tools and tutorials. BCDA sees continued investment in *EPICS* as an underpinning of its core philosophy of conservative deployment.

5.3. Communications

Each XSD beam line is assigned a BCDA staff member as a liaison, directly responsible for the beam line control systems. This liaison acts as the primary point-of-contact for the beam line and is the steward of support requests from the beam line. The liaison may involve other subject matter experts to assist in support of specific parts of the control system. Through this liaison relationship with additional assistance from subject matter experts (SME), BCDA has a team approach to maintaining the beam line control systems. To preserve a long-term relationship with the beam line, the designated BCDA liaisons are not changed routinely. Liaisons are often attending the group meetings of their respective beam lines. BCDA also engages the user community through other means including monthly controls meetings with beam line staff and other support groups, monitoring the *EPICS tech-talk* email traffic for relevant contributions, and maintenance of a web site with various control system documentation.

The APS upgrade is an opportunity to introduce significant new directions in beam line control systems, including new hardware, new capabilities, and end-of-life for existing components. The user community can provide significant guidance as new beam lines are to be built, as well as upgrades of existing beam lines. To help identify, compare, and contrast those directions of significance to the user community, BCDA plans to host a **Workshop** on *Beam Line Controls for the APS Upgrade and Beyond*. Tentative dates for that workshop are in June or July 2016 at the APS. One obvious outcome from this workshop would identify **common standards for various controls** electronics (such as motion controllers and drivers) with the aim of reducing the diversity and number of spares.

5.4. Area Detector

The use of **area detectors** at the APS has expanded in the last decade and the software systems are just beginning to catch up. A collaborative software system to support area detectors [4] has been established by one of the APS CATs. Some APS staff are contributing members of this collaboration. Need for continued support for area detectors falls into several key areas:

- *Driver software* is needed for each specific detector model to provide control of the detector through *EPICS*. APS support groups have developed a prioritized list of the drivers to be written. BCDA has a project team working now to build drivers and is expected to finish the current queue by summer 2016.

- *Deployment* of *EPICS* IOC software is necessary to implement controls for each detector. BCDA will develop a prioritized list of the detectors for which new IOCs must be created. This list will be used to support the *maintenance* of the detector software as scientific needs expand.
- The staff and instrument teams need *training* to use the features of the detectors and software. This training is provided in several venues, including direct hands-on training as detector IOCs are delivered, class-room and online training for general or popular features of the area detector software suite, and group training organized on an *ad hoc* basis.
- *Detector selection support* is often requested by instrument teams as their scientific needs expand. BCDA can advise about software support to assist detector selection, based on experience and collaboration with the EPICS community.

Additionally, *enhanced user interface software support* should be considered within the context of a common *scripting environment* (as described elsewhere in this document). Amongst the feature requests from beam line users, are requests for improved, interactive data visualization tools to direct smarter data collection (such as automatic selection of optimal collection time based on pixel saturation, graphical selection of regions of interest for next scans and/or avoidance of strong signals).

5.5. Synoptic Display Software

Over the past few years, we have investigated three candidates to replace MEDM, the **synoptic display software** (also known as a Graphical User Interface or GUI) used at most beam lines. Each of these software candidates was created by other user facilities in the EPICS community and is already available for use at the APS. In coordination with other groups at the APS, including the AES Controls group and the APS Main Control Room, and in recognition of our users' clear preference, we have identified *caQtDM* [5] as the successor to *MEDM*. A recent version of *caQtDM* has been posted to the Linux shared file system (*/APSshare*) for use at beam lines. BCDA staff are becoming familiar with it and have begun to build display screens for use at beam lines. Over the next year, we will start to transition beam lines to use *caQtDM*.

The biggest challenge faced to replace MEDM is to train instrument teams to prepare screens for use with this software tool. This training may require a special effort but that activity has a lower priority than the remedial effort to bring our area detector software to a common standard.

We will need to develop or acquire tools to help in using caQtDM, such as the software translation of screen descriptions between MEDM, caQtDM, and other synoptic display software used by our collaborators. These needs will be addressed as they arise, with a strong preference for acquiring if they have been developed elsewhere.

5.6. Scripting Environment

A **scripting environment**, including visualization, for instrument teams to use when describing and directing experimental procedures has been a long-sought objective for APS beam lines. For scripting, *SPEC* [6] satisfies parts of this goal in that it provides a well-known macro capability that is used by diffraction experimentalists around the world. Yet, *SPEC* lacks many capabilities and features to the extent that beam lines still explore a more flexible scripting environment. Consensus from many user facilities is to provide tools and libraries based on the *Python* [7] programming language. It is believed that *Python* offers us the best possibility to reach the goal of an improved scripting environment for use at all beam lines.

For several years, BCDA has been distributing *PyEpics* [8] on */APSshare* (mentioned above), as part of a Python distribution for beam lines to use as a scripting environment. Developed by one of the APS CATs, *PyEpics* provides a library to integrate EPICS with Python. At present, the Python distribution provides a set of tools that can be used to construct applications for beam lines yet falls short of providing, for example, enhanced user interface software support tools for area detector as described above. Python tools currently

developed by BCDA staff (such as *caputRecorder* [9], *PvMail* [10], and *PvWebMonitor* [11]) are built using *PyEpics*.

BCDA continues to build expertise in Python for coding, packaging, and documentation and shares that with APS staff. We do not have the effort now to advance the project of providing a comprehensive scripting environment with visualization for beam lines in any realistic sense without compromising the other goals in our support of beam line controls.

The *APSpy* project [12] developed for APS beam line 1-ID, scripted basic controls activities. Continued development of that code, with the intention of generalizing it for use at other APS beam lines, ceased in 2012 due to lack of sufficient effort.

The NSLS II is developing Python tools and libraries (such as *BlueSky* [13]) for use at its beam lines. Adapting such tools for use at the APS may become a major project since BlueSky requires significant local resources (computer databases, storage, and mining software) not present at the APS today to record data and provide that data for analysis. We will continue to monitor the EPICS community, especially NSLS-II, for the announcement of such tools under development elsewhere and evaluate the suitability for testing and possible deployment at the APS.

5.7. High-Speed Signal Handling

With the continued scientific exploration into the fundamental processes of atomic interaction, there is present demand on the control systems to handle **signals** at kilohertz frequencies and there will be an increased demand to handle signals at frequencies orders of magnitude greater than some megahertz. These signals arise from positioner readbacks such as are necessary for scans with continuous motion scans (so-called *fly scans*) as well as high-speed and/or high frame-rate detectors. We must attract, educate, and retain staff with skills in FPGA, high-speed electronics, signal conditioning, and metrology to continue to address the persistent demand for novel signal handling at high frequencies.

5.8. Core Objectives

BCDA is also interested in engaging various projects that will address core objectives:

- To encourage **cross-training** amongst group members, we set a goal to identify one or two topics and begin a regular-meeting approach for cross-training this year.
- **Schedule for periodic review** of beam line control systems to ensure no beam line misses out on important upgrades. Periodic review can identify opportunities for improvement and standardization, replacement of obsolete components, as well as cross-training for staff. We set a goal to identify a review procedure for beam line control systems and apply it to one or more beam lines this year.
- Establish a **student intern program**. The APS provides a rich experience for students learning about real-time control systems. Student intern projects can provide a realistic assessment of potential future directions and have, in the past, expanded our library of Python codes for scripting and graphical user interface. We set a goal to recruit a student intern for the summer term or a cooperative education student for longer term.
- To enable higher sample throughput at beam lines, a facility approach to the details of **automation support** (user and controls interfaces, sample mounting, database) is needed, involving various APS support groups. Previously, this project was submitted by others as a proposal for an LDRD to increase the sample throughput of the USAXS instrument but was not funded at that time. Presently, we have no effort available to initiate this project on our own but we would be interested in working with others.

1 *synApps* : https://github.com/EPICS-synApps
2 *synApps modules*: https://github.com/epics-modules
3 *EPICS* : http://www.aps.anl.gov/epics/
4 *areaDetector* : https://github.com/areaDetector
5 *caQtDM* : http://epics.web.psi.ch/software/caqtdm
6 *SPEC* : http://certif.com/content/spec
7 *Python* : http://python.org
8 *PyEpics* : http://cars9.uchicago.edu/software/python/pyepics3/
9 *caputRecorder* : https://github.com/epics-modules/caputRecorder
10 *PvMail* : http://pvmail.readthedocs.org
11 *PvWebMonitor* : http://pvwebmonitor.readthedocs.org
12 *APSpy* : https://subversion.xray.aps.anl.gov/bcdaext/APSpy
13 *BlueSky* : http://nsls-ii.github.io/bluesky/