ISBN: 978-3-95450-193-9 doi:10.18429/JACoW-ICALEPCS2017-THPHA022

ROADMAP FOR SLAC EPICS-BASED SOFTWARE TOOLKIT FOR THE LCLS-I/II COMPLEX*

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Abstract

With the advent of LCLS-II, SLAC must effectively and collectively plan for operation of its premiere scientific production facility. LCLS-II presents unique new challenges for SLAC, with its electron beam rate of up to 1MHz, complex bunch patterns, and multiple beam destinations. These machine advancements, along with long-term goals for automated tuning, model dependent and independent analysis, and machine learning provide strong motivation to enhance the SLAC software toolkit based on EPICS V3 to take full advantage of EPICS 7[1], which supports structured data and facilitates a language-agnostic middle-ware service layer. This paper provides an overview of a few main goals for the software platform upgrade path in support of controls, online physics and experimental facilities for the LCLS-I/II complex.

SLAC SOFTWARE WORKING GROUP

An inter-departmental SLAC Software Working Group was assembled in 2017 to review the existing status of controls and physics software at SLAC. Going forward, the working group will share plans, priorities, and set common practices for software toolkits and standard implementations to service their accelerators and photon beamlines. A roadmap was formed[2], with emphasis on the near-term timeframe (2017-2020) which includes: 1a) establishment of a SLAC-wide common EPICS version 3.15.5, 1b) migrating EPICS to git version control, along with establishment of a centralized git repository, 2) adapting a new python/QT based Display Manager, 3) leveraging the existing suite of High Level Applications (HLAs), 4) add to the existing EPICS 7 middle services layer, and finally, 5) start integrating EPICS 7 components for handling of structured data. To accomplish further EPICS 7 development and integration, SLAC is committed to strengthening its engagement with the EPICS Collaboration and to allocating resources.

SOURCE CONFIGURATION MANAGEMENT

Lab-wide at SLAC there are multiple controls groups, multiple EPICS repositories, and multiple version control tools in use, with CVS and SVN historically being the tools of choice. An effort is in place to unite the EPICS source configuration management using Git[3], a modern distributed revision control system aimed at speed, data integrity, support for distributed, non-linear workflows, and provision of superior web-based graphical user interface tools. The plan for EPICS source management includes:

- Shared SLAC Git repos with SLAC department specific branches as needed
- Upgrading to EPICS base version 3.15.5, with department specific releases for each target architecture
- Upgraded EPICS 3.15.5 modules will be shared across base releases and departments.

It is anticipated that this plan will reduce duplication of core software maintenance effort and facilitate SLAC-wide collaboration.

DISPLAY MANAGER

The Extensible Display Manager (EDM), which has been in heavy use for all SLAC accelerators and beamlines for the past decade, is nearing end-of-life, is no longer actively supported, and has no EPICS 7 upgrade path. PyDM, a python and QT based display manager presently being developed at SLAC, has been chosen as the EDM upgrade path. There are currently PyDM displays being introduced for LCLS; the intention is to use PyDM for new displays for new machines (LCLS-II, FACET-II).

Python was chosen as the basis for our display manager because it is widely used by SLAC developers and users, has strong community support, and has a large ecosystem of libraries (particularly in the scientific and numerical domains). By building the entire PyDM system in Python, it is easy to extend with new widgets, and create customised versions of existing widgets for special purposes, which encourages code re-use. The ease of development in Python and the extensibility of PyDM, are a significant advantage over other EPICS GUI systems.

PyDM includes a scripting system that lets developers add code to displays. One way this code can be used is to make dynamic displays that generate themselves from middleware services. For displays like magnet control panels, this eliminates a very large amount of work; currently, LCLS-I requires about 75 EDM files just to list the various magnets in each accelerator region. By building a generic PyDM 'magnet list' display that can retrieve a list of magnets for a region (from the directory service) and populate itself with user interface elements, the same magnet interface can be provided by a single file.

As shown in Figure 1, this Python and PyDM capacity for both display generation and code is the basis for new

* Work supported by the U.S. Department of Energy under contract number DE-AC02-76SF00515

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physics high level applications and represents a future path alongside MATLAB applications.

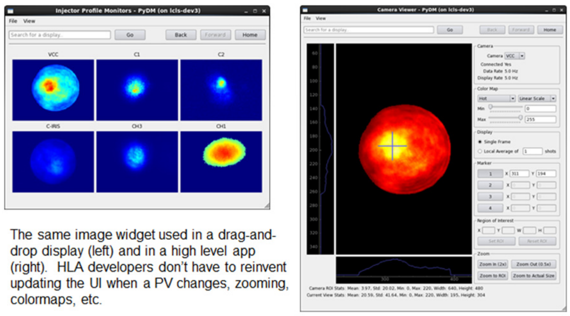

Figure 1: PyDM screen (left) and HLA (right).

In order for PyDM to be compliant with present and future EPICS 7 middleware services as well as future EPICS 7 IOCs, the following EPICS 7 components will be required:

- pvaPy or equivalent pvAccess to python binding (currently under development by the EPICS community)
- Aggregation/throttling of PV monitor client callbacks
- EPICS 7 IOCs (requires a robust qSrv, currently in development by the EPICS community; refer to section entitled “Middle Layer Services”)

Additionally an EDM to PyDM conversion utility is desired to convert static EDM displays to PyDM, as there are approximately 5000 EDM screens utilized for LCLS currently.

LEVERAGE LCLS MACHINE AGNOSTIC APPLICATIONS

After analysis, the SLAC Working Group deemed the existing suite of SLAC physics High Level Applications (HLAs) used in the Accelerator Control Room (ACR) as sufficient for the upcoming commissioning phases of the new LCLS-II facility (for the next 1-2 years). This applications suite, largely based on MATLAB, is mature, feature rich, extensive, and has served LCLS well; it would be costly to migrate all existing code to Python.

Similarly, the core EPICS client tools (EDM, Save, Compare, Restore (SCORE), archiver, electronic logbooks, etc) currently available are also sufficient in the near-term. A path forward for the core EPICS client applications to migrate to PyDM/Python is desired, but premature in plans at this time.

MIDDLE LAYER SERVICES

Middle layer services have served LCLS well, as they provide a centralized language-agnostic Application Programming Interface (API) for applications. The following EPICS 7 middle layer services are currently in use at LCLS:

1. **Directory service**. All devices and elements of the accelerator, and their metadata such as device type and beam path, are made available to applications, and soon also PyDM displays for automatic display generation
2. **Optics service**. The reference (or "Golden") optics computed from lattice definitions from design and extant accelerator PV set points by XAL, are recorded in an Oracle database. An EPICS 7 service makes Twiss and R-matrices available to applications. As other modelling systems are added, they may be added as services as requirements suggest
3. **Archive service**. High performance service for EPICS PV archived data available to applications
4. **Infrastructure service**. Operations pertinent data in Oracle is made available to applications
5. **Polynomials service**. Electromagnet response function (I->B) polynomials from the magnet metrology database used for LCLS-II IOC configuration

Another service to be developed is the Beam Synchronous Data (BSA) interface service. Presently, the LCLS BSA data result sets have some shortcomings. BSA is implemented in IOC record processing, (non-deterministic) resulting in the more heavily burdened IOCs to miss their time budget, which results in missing BSA data. Applications collecting BSA data from many devices at the same time invariably get data arrays of different length. Working out which data are missing is possible, but laborious for physicists, especially for ad hoc software. Second, the pulse ids of acquired data are hidden in the low order bytes of the timestamp, which is obscure, and that data doesn't make it into the archiver. Third, long term (many seconds worth of) contiguous BSA data isn't available due to an FPGA architecture limitation in LCLS IOCs.

Consequently, a BSA service is needed that makes well-conditioned deep-buffered BSA data available to applications, advanced modelling and machine learning systems. The overall architecture, along with the future BSA service, is shown in Figure 2.

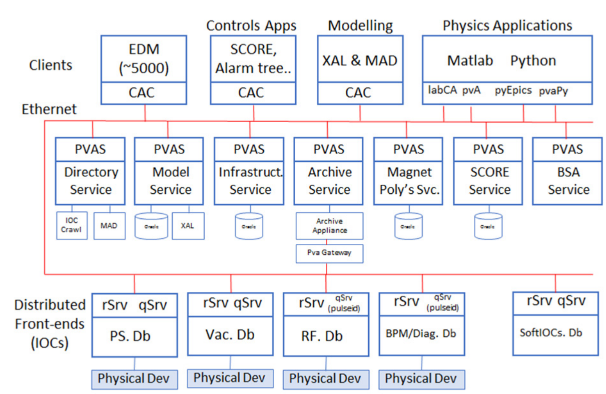

Figure 2: Middleware Services – present and planned.

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SLAC plans to better support the beam pulse synchronized acquisition (BSA) data collection at the IOC level using an EPICS 7 extension now in development, called "qSrv". QSrv is the component of EPICS 7 IOCs that mediates requests coming over the new protocol pvAccess, for data from the EPICS database. That is, qSrv is the pvAccess equivalent of Channel Access's "rSrv."

In addition to accessing data from the EPICS database for satisfying pvAccess requests, qSrv has two key features indicated for LCLS-II.

- It can process the data prior to assembly in a pvAccess Record, which we can use to extract pulse ID, bunch charge, and other timing associated metadata, and insert it *right into* the functional beam data returned (such as position offsets X, Y, of a beam monitor, or the fast phase read back of a klystron). That metadata then stays with the data into applications and the long-term data archive.
- qSrv can assemble sets of EPICS database record data together, synchronously, and deliver them as a package as a single PV, for instance BPM X, Y and TMIT together, or X, Y and TMIT for the last 10000 pulses together.

The EPICS 7 component requirements for the BSA service upgrade path include:

- Timing metadata in NTScalar user tag, qSrv (equivalent of V3 rSrv),
- pvAccess client applications
- Archiver requires pvAccess Gateway
- EPICS 3.15.5 will be the common basis from which SLAC upgrades to 3.16 and the coming EPICS 7.

EPICS V7 INTEGRATION PLAN

The BSA Middleware service, for one, requires structured data, necessitating EPICS 7. The necessary EPICS 7 Components for future upgrades are listed in Table 1.

Table 1: Necessary EPICS V7 Components

Component	Status & Plan
PyDM	Near completion; contribute to community; collaborate
qSrv	From collaboration; make robust & contribute back
pvaPy	From collaboration; improve performance
Archiver	Already V4-enabled; further enhance to embed timing frame; store/view complex data; contribute back
BSA Service	Beam Synchronous Acquisition Service for LCLS & LCLS-II. Start near-term with LCLS
pvAccess Gateway (pva2pva)	From collaboration; make robust; add functionality; contribute back
Data Aggregator	Evaluate options and develop to throttle pvAccess client callbacks

Referring to Figure 3, High Level SLAC Software Roadmap, LCLS-II Early Injector Commissioning (EIC), planned for January 2018, will use EPICS V3.15 IOCs, EDM, and Channel Access (CA). From now through the FY 2020 timeframe (LCLS-II first light), the following components will be developed, tested, and deployed, as prioritized and guided by the SLAC Software Working Group:

- PyDM Display Manger adds features; will be productized
- Timing metadata will be embedded in NTScalar
- qSrv is made robust & incorporated into V3 IOCs, producing EPICS 7 IOCs; pvAccess & CA co-exist
- Structured data (w timing metadata) served via EPICS 7 IOCs & pvAccess is served to EPICS 7-aware clients
- pvAccess Gateway is further tested, developed, and integrated
- Structured data archived to EPICS 7-enabled Archive Appliance and viewable by enhanced Archive Viewer
- LCLS BSA Service incorporates LCLS-II BSA data

In order to accomplish these tasks in this near-term, SLAC plans to commit resources to development along with increased engagement with the EPICS Collaboration.

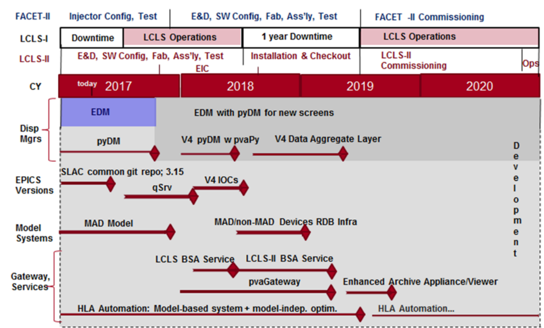

Figure 3, High level SLAC Software Roadmap.

SUMMARY

SLAC is committed to establishing commonality amongst its software toolkits and standard implementations to service their accelerators and photon beamlines. Due to the complexity of the LCLS-II machine under construction, along with SLAC long-term goals for automated tuning, model dependent and independent analysis, and machine learning, there is strong motivation to enhance the SLAC software toolkit based on EPICS V3 to take full advantage of EPICS 7, which supports structured data and facilitates a language-agnostic middle-ware service layer.

The EPICS Version 3 upgrade path to EPICS 7 key points include:

- LCLS-II Early Injector Commissioning (EIC), planned for January 2018, will be all Version 3, EPICS 3.15.5 IOCs.
- Later, as qSrv is certified, LCLS-II will use EPICS 7 IOCs (base 3.15.5 + qSrv), particularly for BSA IOCs
- Hence, Channel Access (CA) and pvAccess protocols will exist on the network simultaneously, at least until all IOCs are pvAccess aware
- The end of life of CA will depend on the EPICS community, and speculation on how that will look at SLAC is premature.

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ACKNOWLEDGMENT

The authors would like to extend a special acknowledgment to the EPICS Community members at large, as without their development support and dedication, this upgrade path would be insurmountable for one laboratory to accomplish.

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