

## PHASE II AND III THE NEXT GENERATION OF CLS BEAMLINE CONTROL AND DATA ACQUISITION SYSTEMS \*

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### Abstract

The Canadian Light Source is nearing the completion of its suite of Phase II Beamlines and in detailed design of its Phase III Beamlines. The paper presents an overview of the overall approach adopted by CLS in the development of beamline control and data acquisition systems. Building on the experience of our first phase of beamlines the CLS has continued to make extensive use of EPICS with EDM and QT based user interfaces. Increasing interpretive languages such as Python are finding a place in the beamline control systems. Web based environment such as ScienceStudio have also found a prominent place in the control system architecture as we move to tighter integration between data acquisition, visualization and data analysis.

### PHASE II AND III BEAMLINES

The Canadian Light Source (CLS) is a 2.9 GeV Synchrotron facility[1] that contains six phase I beamlines in operation, an additional seven phase II beamlines in various stages of development (as listed in Table 1) and an additional seven Phase 3 beamlines under construction. Table 2 provides a comparison of underlying technology used across all of the CLS beamlines.

Table 1: Phase II Beamlines

Name	Application	State
BMIT-BM	Biomedical Imaging	Operational
BMIT-ID	Biomedical Imaging	Commissioning
CMCF2	Protein Crystallography	Operational
REIXS	Emission Spectroscopy Resonant X-ray Scattering	Operational Commissioning
SXRMB	XAFS Micro-Probe	Operational Commissioning
SyLMAND	Lithography	Commissioning
VESPERS	Spectroscopy & Micro-Probe	Operational

To minimise project risk and ensure the cost effective

\*Research described in this paper was performed at the Canadian Light Source, which is supported by the National Sciences and Engineering Research Council of Canada, the National Research Council of Canada, the Canadian Institute for Health Research, the Province of Saskatchewan, Western Economic Diversification Canada, and the University of Saskatchewan.

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delivery of the beamline control systems the underlying architecture developed for the first phase of beamlines[2] was to a large extent applied again to the Phase II and Phase III development.

EPICS was again used as the underlying platform of the development of CLS new round of beamlines. This permitted us to leverage significant earlier development.

### COMMON ELEMENTS

#### Operating Systems

Linux continued to be the primary operating system platform used at CLS. This was augmented with a more limited number of MS-Windows based data acquisition computers required to support specific commercial off-the-shelf (COTS) software.

Though CLS has extensive experience with the use of RTEMS, we have continued to find the need for hard-real time applications limited to certain accelerator applications. We continue to evaluate the potential application of RTEMS to our beamlines.

#### Hardware Platform

We find the use of the Moxa MIPS based controllers (Model UC-7408-LX and DA-662-16-LX) compelling[3]. Over the past four years CLS have deployed 120 of Moxa computers in the facility and has yet to experience any significant hardware failure. The Moxas are used as full fledged EPICS IOCs primarily interfacing Ethernet, USB and Serial devices into the control system.

Modicon Momentum PLCs continue to be used primarily for machine protection. These are interfaced into the CLS control system through Modbus over TCP/IP.

VME64x is primarily used for motion control and data acquisition applications. The Prodex MaxV is used with a combination of drivers [4]. Data acquisition is primarily accomplished with the use of SIS3820 scalar boards.

#### Network Setup

Each beamline has its own VLAN, with all of the beamline specific IOC and OPI computers located on the VLAN. Any computers that a user brings in to control a user-furnished end-station are also added to this VLAN.

EPICS IOC applications, home directories, applications and users data storage areas are accessed by NFS from a central SAN.

For added security, Ethernet devices are normally connected directly on a secondary network port on a Moxa and are not directly accessible on the VLAN. Beamline specific PLCs are also normally placed on the

accelerator VLAN and accessed through EPICS Gateway software.

Table 2: Comparison between All CLS Phase I,II, III Beamlines

Beamline Name	Machine Protection	Motion Control	Beamline Display	Experiment Control	Experiment User Interface
Brockhouse	Modicon Momentum	Prodex MaxV Newport XPS	EDM	CLS Scan Lib	ScienceStudio Others TBD
BioXAFS	Modicon Momentum	Prodex MaxV Newport XPS	EDM	CLS Scan Lib	CLS-IDA TBD
BMIT-BM	Modicon Momentum	Prodex MaxV Labview	EDM	BMIT Specific	3 <sup>rd</sup> Party Vendor
BMIT-ID	Modicon Momentum	Prodex MaxV Bosch-Rexroth Labview	EDM	BMIT Specific	3 <sup>rd</sup> Party Vendor
CMCF1	Modicon Momentum	Prodex OMS58 Prodex MaxV	EDM	Python	MxDC MxLive
CMCF2	Modicon Momentum	Prodex MaxV	EDM	Python	MxDC MxLive
Far-IR	Modicon Momentum	Prodex MaxV	EDM	3 <sup>rd</sup> Party Vendor	3 <sup>rd</sup> Party Vendor
HXMA	Modicon Momentum	Prodex MaxV Newport XPS	EDM	CLS Scan Lib	CLS -IDA Spec
IDEAS	Modcon Momentum	Prodex MaxV	EDM	CLS Scan Lib	CLS -IDA
Mid-IR	Modicon Momentum	Prodex MaxV	EDM	3 <sup>rd</sup> Party Vendor	3 <sup>rd</sup> Party Vendor
QMSC	Modicon Momentum	Prodex MaxV	EDM	CLS Scan Lib	3 <sup>rd</sup> Party Vendor
SGM	Modicon Momentum	Prodex OMS58	EDM	CLS Scan Lib	CLS-IDA
PGM	Modicon Momentum	Prodex OMS58	EDM	CLS Scan Lib	CLS-IDA
REIXS	Modicon Momentum	Prodex MaxV	EDM	CLS Scan Lib	Aquaman Spec
SM	Modicon Momentum	Prodex OMS58 Newport XPS	EDM	Beamline Specific	3 <sup>rd</sup> Party Vendor
SXRMB	Modicon Momentum	Prodex MaxV Newport XPS	EDM	CLS Scan Lib	CLS -IDA
SyLMAND	Modicon Momentum	Proxed MaxV	EDM	3 <sup>rd</sup> Party Vendor	3 <sup>rd</sup> Party Vendor
VESPERS	Modicon Momentum	Prodex MaxV	EDM	CLS Scan Lib	CLS -IDA Aquaman ScienceStudio

Centrify is used to provide unified cross-platform user authentication for access to networked resources such as password authentication and networked file access. This ensures account information is the same on all workstations in the facility, and changes to account information are available immediately.

### Virtual Machines

CLS now has two years of experience in the use of VMware ESX based virtual machines in the control system[5]. A common ESX cluster is used for the control system across the accelerator and all of the beamlines. softIOC applications and data analysis applications that do not require specific hardware access are deployed on virtual machines.

## EPICS

EPICS continues to be used as the common software platform for integrations of the various sub-systems. The EPICS Gateway provides access to storage ring devices, such as insertion devices.

From the synApps toolkit [6], developed at APS, CLS makes use of asyn and areaDetector libraries. These two libraries are used to interface most of the serial devices found and detectors found on the beamlines.

## CLS Extensions to EPICS

The base EPICS software is supplemented by the use of locally developed scanning libraries and experiment specific higher level beamline applications [7].

CLS makes extensive use of the Qt toolkit in building custom extensions. The CLS-IDA and Aquaman are two example of such applications.

Increasingly Python has started to play a more significant role in the development of user applications. The CMCF 1&2 beamlines operator interface software is based on Python and work is underway on the development of an EDM compatible display tool based on Python.

## Relational Databases

Predominantly mySQL is used for relational databases. MxLIVE, MxDC, and ScienceStudio all make use of mySQL.

## BEAMLINE SPECIFIC ELEMENTS

### BMIT

The BMIT beamlines use standard CLS motor controls (EPICS, VME, MaxV) for operation of the beamline equipment installed in the optics hutches (including monochromators, filters, slits, shutters etc.). High-level software for device control and beamline monitoring has also been developed using EPICS and EDM screens. Wherever possible, high-level beamline software used by researchers provides an abstraction layer to hide the details of operation of physical beamline components from the user, allowing them to instead specify and achieve their end goal.

Standard CLS control software is supplemented on BMIT with the use of additional software products. LabView programs are used to operate smaller positioning devices within the experimental hutches. Use of this equipment varies widely for different experiment types and sample sizes, and LabView provides beamline staff with the ability to quickly adapt to various experimental configurations. The three large positioning systems on BMIT use Bosch servo motors with low level control functionality provided by Bosch Rexroth IndraMotion MLD drive-integrated PLC programs developed using IndraWorks software. Data acquisition on BMIT is primarily via vendor software particular to the detectors in use on the beamline.

## CMCF2

The phase 1 and phase 2 Protein Crystallography beam lines have two major components, the local data collection software, and a web interface. The data collection software, called MxDC [8], was written in house by Michel Fodje, in python using GTK+ (Glib) (reference) as the main application framework with Twisted and Avahi. Access to the beam line for control is accomplished through Epics Channel Access for Python (reference). MxDC was deployed onto the beam line for production use in 2007 and has seen extensive feature additions through constant use and testing as well as user feedback. Using python as the development language has made it easier to interface the data collected locally by users at the beam line with the web based interface MxLIVE.

MxLIVE allows users to describe their samples, submit their experiments, approve strategies, and review results over the web. Developed on the django web framework (Python), MxLIVE is independent of the data collection software, as all communication is through a relational database (MySQL, json). Users may view results as soon as they are collected, and download individual images as well as full datasets directly from MxLIVE. MxLIVE is very popular with both “mail-in” users and users who are coming to the CLS to collect their own data. It was first made available to users in May 2011.

Some sophisticated users who prefer not to travel to the CLS are also enabled to use the data collection software remotely, via a NoMachine interface.

## REIXS

REIXS beamline control was based on CLS standard EPICS controls including MAXv motor control and an EPICS based energy application originally developed for the Spectro Microscopy (SM) beamline. The energy application allows simultaneous setting of the monochromator mirror and grating and the gap and girders of one or two elliptically polarizing undulators (epus). Energy scans can be accomplished with one epu or two epus in conjunction with a chopper. Spec is used for RSXS data acquisition and “Aquaman”[9] software developed in a collaboration between the University of Saskatchewan and CLS for XAS and XES data acquisition.

REIXS also contains a limited amount of SPEC to meet some user specific requirements.

## SXRMB

The success of the controls at SXRMB is a reflection of the greater success of software standards at the CLS. Commonality of drivers allows quick reuse of software at both the driver and GUI levels. The initial XAFS commissioning experiments used the HXMA beamline’s C++/Qt IDA application, as well as a number of EDM support screens. This was followed by a customized version of the XAFS software (C++/Qt) used at the SGM beamline, which gives a more integrated data acquisition environment. The microprobe endstation is near

completion, and will be able to use the multi-dimensional scanning and acquisition software (C++/Qt/Root) in use at the VESPERs and HXMA beamlines.

### SyLMAND

SyLMAND is also an EPICS based beamline. The Endstation is a pre-packaged scanner with vendor furnished software running on an MS-Windows platform. To facilitate integration with the beamline, the vendor was provided with EPICS interface libraries for Visual Studio C++.

### VESPERs

VESPERs makes use of two different high-level experiment management frameworks: (1) Aquaman and (2) ScienceStudio. Both systems are the same underlying EPICS IOC applications and frameworks for device control permitting rapid switching between the two systems.

Acquaman [9] is an experiment-centred framework that encapsulates low level control into coherent objects and exposes, to the end user, only what is necessary to run scientific experiments on the beamline. This enables users with varying levels of synchrotron experience to take data effectively without the need for extensive software training. The primary benefits are three-fold. First, the process of switching between experiment settings is presented in obvious ways without the need of exposing low level hardware. As well, where only the pertinent pieces of the beamline are exposed to users, the chances of a user accidentally accessing part of the beamline that they should not are minimized. The Acquaman framework has been applied on VESPERs to create a tailored user interface capable of seamlessly supporting XRF and XAS. Lastly, all data that is collected using the Acquaman framework is automatically saved into a database to ensure that no data that is collected can be inadvertently lost and can be exported at the leisure of the user.

Currently, the user interface handles all general features of the beamline, such as photon shutters, slits, sample position, and positions for all detectors. The Acquaman framework allows for easy control of the beamline while enforcing logic that prevents users from entering situations that may damage the beamline (ie: colliding detectors together). The user interface also configures the silicon drift detectors (SDD) for setting up X-Ray Fluorescence (XRF) 2D maps and allows easy access to configuring regions of interest which provides tools to quickly assess the elemental composition of the samples.

Finally, encapsulation of all necessary controls to perform X-ray Absorption Spectroscopy (XAS) while still hiding low level control that will enable users to concentrate on their experiment, rather than compromising their data with low level software.

Science Studio [10] is a web portal, and framework, that provides scientists with a platform to collaborate in

distributed teams on research projects, and to remotely access scientific resources. Like Aquaman ScienceStudio only exposes the aspects of the beamline that are pertinent to the user experience. The core component of Science Studio is a web-based experiment management system which allows users to organize and share their sample information, experimental data and analysis results. The VESPERs beamline has been integrated into Science Studio to provide remote control and data acquisition capabilities. ScienceStudio has been extended to provide on-line realtime analysis of both XRF and XRD data, while using high performance computing to process the XRD data.

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