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SLAC LCLS-II INJECTOR SOURCE CONTROLS AND EARLY INJECTOR COMMISSIONING*

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Abstract

LCLS-II is a superconducting upgrade to the existing Linear Coherent Light Source at SLAC with a continuous wave beam rate of up to 1 MHz. Construction is underway with first light planned for 2020. The LCLS-II Injector source is based on the LBNL Advanced Photo-Injector Experiment (APEX), and is being provided by LBNL. In 2015, responsibility for controls design and fabrication was transferred to SLAC from LBNL to promote commonality with the rest of the LCLS-II controls subsystems. Collaboration between the LBNL APEX community and SLAC LCSL-II EPICS controls teams proved vital in advancing the controls architecture toward standardized implementations integrated with the rest of LCLS-II. An added challenge was a decision to commission the injector in January 2018, approximately 1.5 years ahead of the rest of the machine. This early injector commissioning (EIC) is embraced as an opportunity to gain valuable experience with the majority of the LCLS-II controls, especially the 1MHz high performance subsystems (HPS), prior to LCLS-II first light, planned for August 2020. This paper discusses the LCLS-II GUNB Injector Source along with the early injector commissioning controls scope, approach, and advantages.

LCLS-II GUNB INJECTOR SOURCE

The SLAC LCLS-II injector section that comprises low energy (<1 MeV) from the gun up to the location of the first cryomodule is based on a subset of the LBNL Advanced Photo-Injector Experiment (APEX). The LBNL controls and LLRF systems for APEX were designed as stand-alone systems since APEX is intended to be a demonstration injector with no future connection to a larger accelerator system.

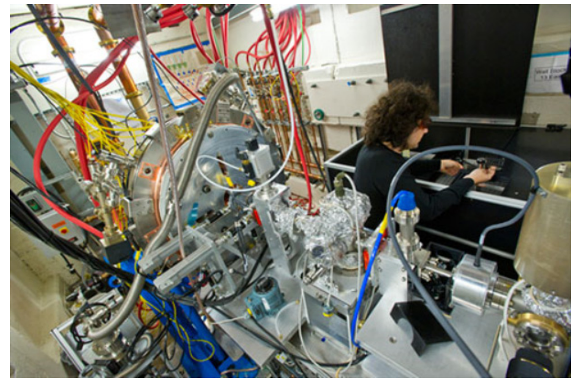

Figure 1: APEX “prototype” at LBNL.

LBNL is responsible for the Injector Source mechanical design, procurement, construction and commissioning support. LBNL has taken advantage of various performance and operational lessons learned from APEX in order to improve the design for use in LCLS-II. SLAC scope for the Injector Source includes the controls specification, procurement, and fabrication for the electronics plus associated control software, and will lead commissioning efforts.

The LCLS-II Injector Source, also known as GUNB, shown in Figure 2, includes the normal-conducting VHF RF gun, the buncher, the cathode vacuum load lock, the low energy beam line, including beam line components, and the VHF gun RF power supply and transmission lines.

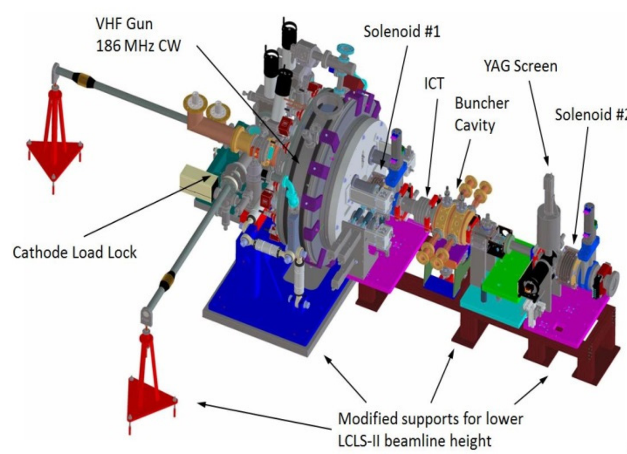

Figure 2: LCLS-II Injector Source.

In order to transfer GUNB controls from the responsibility of LBNL to SLAC, engagement between the two laboratories was essential. A web-based Smartsheet was shared between the two laboratories, which contains GUNB control element’s Z-position, description, major

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components, controller, connector, manufacturer, part number, and lab responsible. LBNL controls teams provided documentation for their APEX-based EPICS Input Output Controllers (IOCs), associated Process Variable (PV) names and metadata, diagrams, GUIs and scripts. Site visits to APEX at LBNL for controls leads were facilitated along with numerous control subsystem specific meetings between LBNL subject matter experts and SLAC teams. A comprehensive GUNB Interface Control Document was created to define scope and laboratory responsibilities for GUNB Controls [1].

LCLS-II EARLY INJECTOR COMMISSIONING (EIC)

By constructing a temporary shield wall before the first cryomodule in the LCLS-II linac, the LCLS-II injector may commission ahead of the rest of the machine, and without disturbing the running LCLS. Figure 3 depicts the configuration for EIC, which includes the Laser along with the GUNB Injector Source, and low energy beamline.

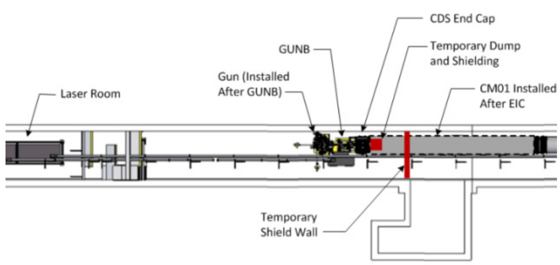

Figure 3: EIC LCLS-II Configuration.

With the Engineering and Design phase for all LCLS-II Controls subsystems complete in FY2017 Q3, procurement, fabrication, assembly, configuration and rack loading activities for the injector controls was successfully advanced in order to meet the aggressive EIC installation schedule. Figure 4 shows a high level LCLS-II timeline which includes Controls Final Design Reviews (FDRs), EIC duration, LCSL-II installation occurring during the one year LCLS-I/II complex downtime, LCLS-I/II commissioning, and LCLS-II first light, planned for August 2020.

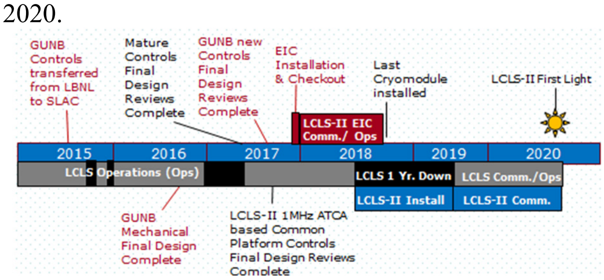

Figure 4: LCLS-II Construction Timeline.

EIC CONTROLS SUBSYTEMS

Early Injector Commissioning controls can be categorized into four main categories, as shown in Table 1: a) Partner Lab provided LLRF controls, b) GUNB Controls, c) 1MHz-based Controls, and d) Conventional Controls.

Table 1: EIC Controls Subsystems

Control Subsystem	Maturity/ Responsibility
Partner Lab LLRF Controls:	
Gun LLRF	New/Partner Lab
Buncher LLRF	New/Partner Lab
GUNB Controls:	
LLRF EPICS	
LLRF Interlocks	New/SLAC
Gun RF Cavity Motion	New/SLAC
Solenoid Motion	New/SLAC
SSA EPICS Interface	New/SLAC
1MHz-Based Controls:	New/SLAC
Timing	New/SLAC
Machine Protection	New/SLAC
Beam Position Monitor	New/SLAC
Bunch Charge Monitor	New/SLAC
Faraday Cup	New/SLAC
Conventional Controls:	
Laser	Mature/SLAC
Computing	Mature/SLAC
Networking	Mature/SLAC
Vacuum	Mature/SLAC
Personnel Protection	Mature/SLAC
Non-Ionizing Rad. Mon.	Mature/SLAC
Profile Monitor	Mature/SLAC
Racks & Cables	Mature/SLAC

Partner Lab LLRF Controls

The LCLS-II partner labs comprised of LBNL, JLAB, and FNAL, provide the low level radio frequency (LLRF) controls electronics for GUNB. The gun is based on an LBNL 185 MHz system, while the buncher is largely based on the 1.3GHz superconducting LLRF controls being developed for the rest of the LCLS-II. The 1.3GHz LLRF controls are ahead in schedule of the gun LLRF controls due to the necessity of having controls ready for cryomodule testing facilities located at FNAL and JLAB years in advance of machine commissioning. Due to the compressed EIC schedule, the gun LLRF controls will field the hardware "prototypes". The EPICS IOC interfaces for LLRF are the responsibility of SLAC. The EIC LLRF IOCs will initially maintain the EPICS PV naming convention utilized at APEX so that high level physics applications developed for APEX operation at LBNL may be employed during early commissioning, and to fully engage LBNL Subject Matter Experts (SMEs) who will aid with early commissioning. Meanwhile the APEX LLRF PVs are aliased to adhere to the LCLS-II naming convention to enable a more seamless transition for EPICS clients.

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GUNB Controls

Along with EPICS GUNB LLRF controls, SLAC provides the new EPICS motion control for the gun RF cavity resonance control, the LLRF interlock system, which provides GUNB equipment protection, Solid State Amplifier (SSA) EPICS interface, and solenoid motion control.

1MHz –based Controls

The SLAC 1MHz-based high performance systems (HPS) include (1) Bunch Charge Monitor (BCM), (1) Faraday Cup located at the temporary shield wall, and (2) Beam Position Monitor (BPM) controls, Timing and Machine Protection. Due to the advance in schedule and the complexity of the systems, the Machine Protection System (MPS) provided will be basic and the Timing system has reduced requirements which limits the set of beam rates, has a maximum charge of 300pC, and contains one destination

Conventional Controls

The SLAC-provided conventional controls are largely based on LCLS and include Laser, Computing infrastructure, Networking, Vacuum, Personnel Protection, Non-Iodizing Radiation Monitoring (NIRP), Profile Monitor, and Racks and Cables.

EIC Controls Approach

EIC offers an opportunity to test and integrate the majority of the new controls subsystems required for the LCLS-II; the exceptions include the Beam Containment System (BCS), the Bunch LENgth Monitor (BLEN) diagnostic, cryogenics controls, and the superconducting RF (SCRF) controls.

In order to guide success, SLAC appointed a GUNB / EIC Project lead in order to manage both the GUNB and the EIC Controls scope, cost, and schedule. A weekly EIC meeting schedule was established that included all pertinent controls leads. A comprehensive GUNB Interface Control Document was created to define controls scope and responsibilities between SLAC and LBNL. Partner Lab Scope Handoff Agreements were created between SLAC and LBNL. Each pertinent control subsystem schedule was appropriately advanced to enable delivery of the scope required for EIC. As previously mentioned, for certain complex global controls, such as timing, and MPS, scope was minimized in order to meet the compressed schedule; also for timing, a shorter phase reference line was prototyped and will be fielded. For computing, it was decided to delay purchase of new servers in order to maximize the hardware lifetime and support. Instead, as shown in Figure 5, the existing scalable LCLS computing infrastructure was leveraged, along with an extensive codebase of EPICS machine-agnostic applications. For rack configurations, care was taken to implement the final rack configurations as closely as possible in order to reduce labor and integration costs.

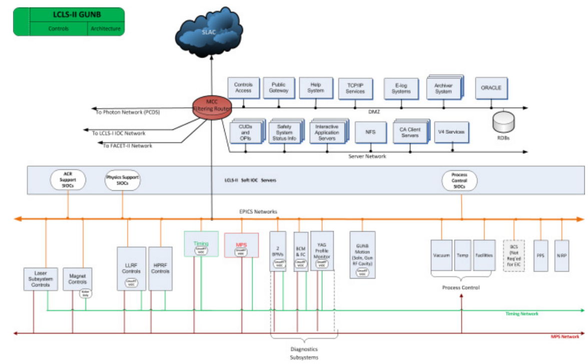

Figure 5: EIC Computing Infrastructure.

For most systems, LCLS-II control solutions were already designed and could be easily adapted for the GUNB injector source. Exceptions include motion controls unique to the GUNB mechanical design, as well as interlocks. As the gun RF cavity motion control mechanical design was enhanced for LCLS-II, it was important to work with the LBNL mechanical team early to further document requirements and to develop a new design. The LLRF interlock system represents another system wherein SLAC did not have an existing design in progress upon which the controls could be based. New leads were added to the existing team of controls leads to design these systems and to work closely with the LBNL APEX team.

Along with the GUNB unique controls, EIC will deploy many brand new LCLS-II controls, including most of the fast, 1MHz-based HPS based on the newly developed SLAC Common Platform (CP). The CP, based on use of the Advanced Telecommunication Computing Architecture (ATCA), includes the common hardware, firmware, and software components for all HPS; refer to Figure 6. Each sub-system then adds sub-system specific hardware, firmware, and software on top of the common platform core. The main advantage of this commonality is to eliminate duplication of engineering design and lower maintenance costs. It is important for controls teams to gain experience with CP configuration, integration, testing, and support for these new electronics in advance of further mass production for the LCLS-II.

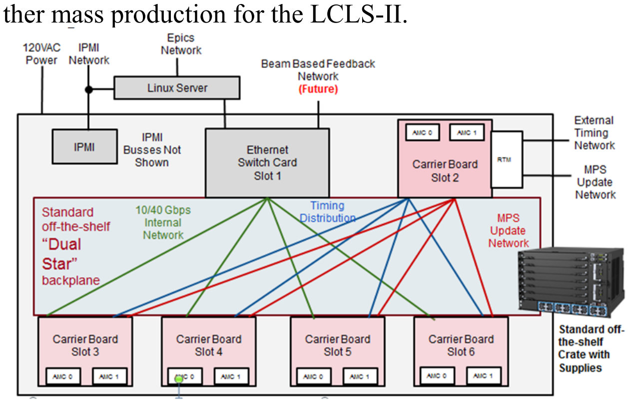

Figure 6: SLAC Common Platform Components.

EIC Controls Advantages

Along with a new platform for fast electronics, EIC affords the opportunity for controls teams to gain experi-

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ence with configuration, integration, testing, and support for all new electronics in advance of the LCLS-II. In order to reduce overall project risk by gaining early integration experience, the following areas are of particular interest:

- LCLS-II 1MHz ATCA Common Platform based controls
- Partner Lab Gun & Buncher LLRF controls
- Gun Resonance control
- Particle free vacuum (new to SLAC)
- EPICS 3.15.5 & git version control;
- Software global controls Integration

Additionally, there are many procurement, production, and pre-commissioning activities in direct support of Controls that will be initiated for EIC. These support procedures and their associated tools may be further fine-tuned for full LCLS-II production after gaining valuable EIC experience. These EIC activities include:

- Procurement and asset tracking and tools
- Quality control for hardware drawing packages
- Quality control for vendor and in-house fabrications
- Rack loading processes
- Controls subsystem check-out procedures; both pre-beam and with beam
- Accelerator Readiness Review (ARR) planning and implementation
- Commissioning, support processes
- Partner Lab Scope Hand-off agreements

SUMMARY

Collaboration between the LBNL APEX controls community and SLAC LCSL-II EPICS controls teams proved vital in advancing the controls architecture toward standardized implementations integrated with the rest of LCLS-II. Early Injector Commissioning, planned for January 2018, affords an excellent opportunity to gain valuable hands-on experience with the controls implementations in advance of mass production for the rest of the LCLS-II machine. EIC also affords the opportunity to initiate procurement and production processes that may be further tuned prior to large scale roll-out for LCLS-II, whose first light is planned for August, 2020.

ACKNOWLEDGMENT

Special acknowledgement extends to the entire team of LCLS-II controls engineers, associates, physicists and colleagues working on construction of LCLS-II. Regrettably, individuals are too numerous to reference by name.

The “LCLS-II Final Design Report"[2] has a comprehensive list of all engineering design specifications for the controls subsystems referenced herein.

REFERENCES

[1] D. Rogind, “SLAC Injector Source Controls to LBNL Injector Source Systems”, SLAC, Menlo Park, USA, Rep. LCLSII-2.7-IC-0852

[2] P. Emma, “LCLS-II Final Design Report”, SLAC, Menlo Park, USA, Rep. LCLSII-1.1-DR-0251-R0