LCLS-II Controls & Safety Systems Status
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Outline

• Introduction
• What will LCLS-II Look Like?
• Controls & Safety Systems TUC3007
  - What’s Mature
  - What’s New Development
• Summary
LCLS: World’s First Hard X-Ray FEL

- Delivering science since 2009
- A billion times brighter than previous sources
- Study of ultra-fast and ultra-small phenomena
- Can capture images of atoms & molecules in motion
- Delivers to ~600 scientists/year (1300 user visits)
- ~25% of proposals are allotted time
Recent Science Highlights

How do our brains tweet (release neurotransmitters)? New results have implications for treating depression, schizophrenia & anxiety.

Major breakthrough, a decade in the making...understanding of body's pathways have broad impacts on development of targeted drugs with fewer side effects to treat high blood pressure, diabetes, depression, some types of cancer.

Now that's green...“All life that depends on oxygen is dependent on photosynthesis”; by studying how nature does it, one can apply the design principles to artificial systems, such as the creation of renewable energy sources.
What’s Next? Next Generation LCLS-II.....
LCLS-II Layout - Project scope

- LCLS-II adds a 4 GeV SC linac to the first kilometer of the SLAC linac tunnel.
  - The copper linac in that region will be removed
- The new beam will run CW at up to 1 MHz
  - The LCLS-1 linac is not altered, retains performance
- The new beam can be directed at either of two new undulators
  - The LCLS-1 beam can be directed to the new Hard X-ray Undulator (HorizGapVertPolUnd)
New Injector
New SC Linac
Existing Bypass Line
New Cryoplant
New Transport Line
Two New Undulators Replacing the Existing
Repurpose Existing Experimental Stations
Controls System High Level Schedule

Linac Controls Ready for Commissioning: 3/2019

Undulator Controls Ready for Commissioning: 9/2018
Advancing Controls for LCLS-II

Mature Subsystems:

* Except for fast shutoff electronics

Highly Leverage LCLS Designs

PDR Complete

FDR Fall ‘16

LCLS-II Status
PDR = Preliminary Design Review
FDR = Final Design Review
Mature Controls/Operations Software

• Share mature EPICS subsystems code base and dev. environment
• LCLS Operational software will be shared with LCLS-II for dual use, but clearly identified for each machine (FACET & other facilities already share – machine agnostic)
• Physics High Level software (mostly MATLAB based) for beam diagnostics and machine tuning mostly from LCLS
• New EPICS V4 services for high level apps (Directory, Name, RDB, Model Manager, Archive Appliance,..)
• EPICS V3/V4 Gateway Desired
• New model manager based on MATLAB and MAD
• LCLS is evaluating next generation EDM display manager alternatives
• Archive Appliance (new HTML5 viewer) for millions of PVs
New Controls for LCLS-II

High Rep Rate Subsystems
- Timing, BSA, MPS,
- Diagnostics (BPM, BLEN, BCM),
- BCS fast beam shut-off,
- Beam Based Feedback

Brand New Subsystems
- SCRF, ODH, Cryo I/Fs

New Requirements due to higher beam power rep rate

PDR Spring ‘16
FDR Winter ‘16

PDR Spring ‘16
FDR Winter ‘16

PDR = Preliminary Design Review
FDR = Final Design Review
New Controls for LCLS-II

• MPS & Timing systems most challenging
  • Must handle different beam rates from low-rate to full CW 1Mhz, complex burst patterns at each rate, interleaved energies, different destinations for each pulse
  • Shared beamlines must be backward compatible with LCLS
• Fault to beam shutoff <100uS for fast faults
• LCLS & LCLS-II controls interoperability necessary due to simultaneous operation and beam lines fed from either accelerator
• Full beam rate Diagnostic Devices - Faster digitizers
Common Platform for High Rep Rate Systems

Common Platform & Architecture
- Standard ADC + FPGA Electronics
- 4-10 channels of 120-250 MHz >11 effective bit ADC’s.
- FPGA containing common platform FW plus applications for daughter cards
- Memory to buffer several million consecutive readings.
- Computer interface for setup/read-back.

Prototyping in progress with ATCA (not mTCA) and NADs
- As appropriate for application and convenient for prototyper
- ATCA in-house expertise; leverage to other projects
- LLRF NAD expertise and experience at partner labs
- ATCA time to market unhindered by an emerging standard
- ATCA relieves certain real estate issues (e.g. for BPM application)
- Final packaging will be determined by performance, schedule, and implementation cost
Common Platform

Carrier Board (AMC)
- Carrier hosts 1 or 2 application specific daughter boards
- Common: Timing/BSA, MPS, EPICS Comms., FF, I/Fs to external networks
- Each App Card associates w IOCs in Linux host
Platform Packaging

Common ATCA module can be mounted in multi-slot crate (only 1 RTM required for Timing/MPS)

OR single slot pizza-box
Timing Receiver: Common Platform Design

Interface to the common platform is the embedded timing receiver firmware and software to execute common acquisition functions.
Stripline and Cold Button BPM: Common Platform Design

Two BPMs serviced by a single Common Carrier Board

BPMs
Vacuum Structure

BPMs
Vacuum Structure

BPM Front-end

2 x
ADC
370Msps

Calibration Trigger

AMC Board

AMC Board

BPM Front-end

2 x
ADC
370Msps

Calibration Trigger

Common Carrier Board

FPGA

BPM App.
Firmware

Common
Platform
Firmware

BPM App.
Firmware

Crate Timing Input

10Gbps Eth/UDP

MPS Output
To MPS Board

Eth/UDP

Zone 2

LCLS-II Controls & Safety Systems Status

ICALEPCS 2015, October 17-24, 2015
MPS Input Processing: Common Platform

Diagram showing the flow of signals from PIC, PLIC, and BLM to the Generic ADC AMC Card, then to the ADC, and finally to the FPGA. The image also shows a Patch Panel with 32 Buffers connected to the Generic ADC AMC Card and the AMC Carrier.
MPS Chassis Example

**Example deployment with 8 BPMs and 6 MPS beam loss monitors**

**ASIS 7 slot ATCA crate**
Possible to support 10 BPMs plus MPS link node in 6U
Summary

• The requirements for LCLS-II controls are well understood
• Detailed cost estimates & schedules have been developed
• Extend successful EPICS Controls for LCLS to LCLS-II
• Preliminary design reviews have been held for all mature controls subsystems – ready for final design
• High rep rate systems progressing well in preliminary design stage, with FDR by the end of 2016
• A common platform architecture is under development
• Teams at SLAC and partner labs have been identified with the capability and capacity to develop brand new systems
Acknowledgements
Backup Slides
LCLS-II Layout in SLAC Linac Tunnel

(only approximately to scale)

See PRD: LCLSII-2.4-PR-0041
Two Refrigeration Systems in the Cryoplant

- A second cryoplant was adopted after the CD3b review to mitigate the risk of the required heat load of cryosystem (2) 4.5K and (2) 2K cold boxes – copy of jlab design
Project Collaboration: SLAC couldn’t do this without…

Fermilab
- 50% of cryomodules: 1.3 GHz
- Cryomodules: 3.9 GHz
- Cryomodule engineering/design
- Helium distribution
- Processing for high Q (FNAL-invented gas doping)

Jefferson Lab
- 50% of cryomodules: 1.3 GHz
- Cryoplant selection/design
- Processing for high Q

Berkeley Lab
- Undulators
- e⁻ gun & associated injector systems

Argonne National Laboratory
- Undulator Vacuum Chamber
- Also supports FNAL w/ SCRF cleaning facility
- Undulator: vertical polarization

Cornell University
- R&D planning, prototype support
- Processing for high-Q (high Q gas doping)
- e⁻ gun option
## Key Performance Parameters

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Threshold</th>
<th>Objective</th>
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<tbody>
<tr>
<td><strong>Variable gap undulators</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 (soft and hard x-ray)</td>
<td>2 (soft and hard x-ray)</td>
</tr>
<tr>
<td><strong>Superconducting linac-based FEL system</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Superconducting linac electron beam energy</strong></td>
<td>3.5 GeV</td>
<td>≥ 4 GeV</td>
</tr>
<tr>
<td><strong>Electron bunch repetition rate</strong></td>
<td>93 kHz</td>
<td>929 kHz</td>
</tr>
<tr>
<td><strong>Superconducting linac charge per bunch</strong></td>
<td>0.02 nC</td>
<td>0.1 nC</td>
</tr>
<tr>
<td><strong>Photon beam energy range</strong></td>
<td>250–3,800 eV</td>
<td>200–5,000 eV</td>
</tr>
<tr>
<td><strong>High repetition rate capable end stations</strong></td>
<td>≥ 1</td>
<td>≥ 2</td>
</tr>
<tr>
<td><strong>FEL photon quantity (10^-3 BW)</strong></td>
<td>5x10^8 (10x spontaneous @2,500 eV)</td>
<td>&gt; 10^{11} @ 3,800 eV</td>
</tr>
<tr>
<td><strong>Normal conducting linac-based system</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Normal conducting linac electron beam energy</strong></td>
<td>13.6 GeV</td>
<td>15 GeV</td>
</tr>
<tr>
<td><strong>Electron bunch repetition rate</strong></td>
<td>120 Hz</td>
<td>120 Hz</td>
</tr>
<tr>
<td><strong>Normal conducting linac charge per bunch</strong></td>
<td>0.1 nC</td>
<td>0.25 nC</td>
</tr>
<tr>
<td><strong>Photon beam energy range</strong></td>
<td>1,000–15,000 eV</td>
<td>1,000–25,000 eV</td>
</tr>
<tr>
<td><strong>Low repetition rate capable end stations</strong></td>
<td>≥ 2</td>
<td>≥ 3</td>
</tr>
<tr>
<td><strong>FEL photon quantity (10^-3 BW)</strong></td>
<td>10^{10} (lasing @ 15,000 eV)</td>
<td>&gt; 10^{12} @ 15,000 eV</td>
</tr>
</tbody>
</table>

\[1\] Fractional bandwidth. The specified KPPs are the number of photons with an energy within 0.1% of the specified central value.
Advancing Controls to Meet Future Needs

- Extend the successful LCLS EPICS Controls to LCLS-II
- Some systems have substantial new requirements due to higher beam power and high rep rate
  - SC LLRF, Timing System, Diagnostics (BPM, BLEN, BCM), Beam-Based Feedback
  - Faster beam abort mechanisms for MPS, BCS
  - New radiation containment system