Recent and Future Upgrades to the Control Systems of LCLS and LCLS-II Scientific Instruments

ICALEPCS2017
Barcelona · Spain, October 8-13
Palau de Congressos de Catalunya
www.icalepcs2017.org

Daniel Flath et al

October 9, 2017

U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

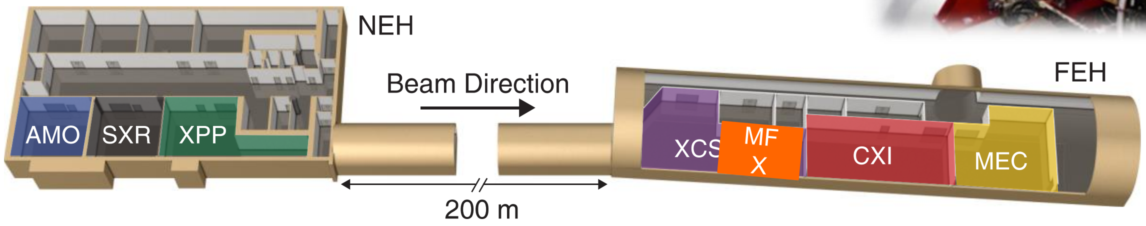
LCLS Controls System Overview

- **Photon Areas**
  - 7 beamlines + Front End Optics & Diagnostics
- **LCLS (and Accelerator) use EPICS**
- **Diskless (network-boot) hosts:**
  - 400 sioc (x86 / Linux)
  - 10 hioc (VME / RTEMS)
  - 6 sioc (cPCI / Linux)
- **Motion:**
  - 750 Stepper motors
  - 160 Newport motors
  - 100 pico/piezo-motors
- **Diagnostics (and Data Acquisition):**
  - Beam Profile Cameras, Energy Spectrometers, Digitizers, Photodiodes
- **Vacuum, A/D-I/O, Power Supplies, Temp-control, Machine Protection, …**

Current LCLS Experimental Configuration





AMO:	Atomic, Molecular and Optical	[0.22 ; 2.0]	XCS:	X-ray Correlation Spectroscopy	[4.0 ; 24.0]
SXR:	Soft X-ray Research	[0.22 ; 2.0]	CXI:	Coherent X-ray Imaging	[5.0 ; 11.0]
XPP:	X-ray Pump Probe	[4.0 ; 24.0]	MEC:	Matter in Extreme Conditions	[4.0 ; 24.0]

Architecture - EPICS

- **LCLS uses EPICS for controlled devices**
- **EPICS provides many core services:**
  - Hardware abstraction
  - Distributed control
  - Network access
  - Security
  - Data Archiving & Retrieval
  - Command-line interfaces
  - Graphical User Interfaces
- **EPICS is widely used by DOE facilities**
- **EPICS has an active user/contributor-base**
- **EPICS supports a deep list of devices & protocols**
  - Easily extended to support new hardware

Version	Ratio
3.14.9	17%
3.14.12	78%
3.15.5	5%

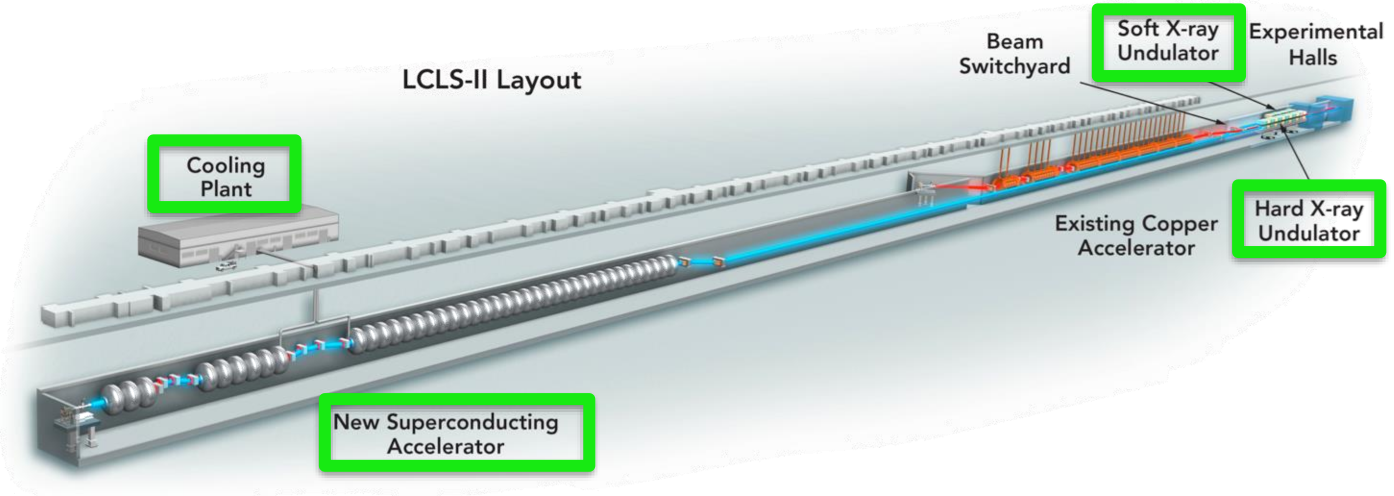
Past Improvements (1)

- **Adopted python for client-side tools**
  - Faster to develop smart client tools than put all logic in IOC
  - Accessible to more facility staff and users than C/C++
- **Gateway exits instead of suspending threads**
  - auto-restart with procserv
  - Interruptions are brief and self-healing
- **IOC configurations simplified, generated by build scripts**
  - Specify device, PV, address/channel, boilerplate generated by script
  - Less time and errors in the IOC setup process
- **Parameter Database for Motors**
  - Reduces errors and time spent configuring motors
  - Can share motors around facility much more easily and efficiently
  - Will be expanded to additional devices

Past Improvements (2)

- **ipython-based beamline control**
  - Provides efficient command-line based beamline control
  - Allows for routine tasks to be quickly automated in code
  - Code can be reused in other applications
  - Beamline scientist love it
- **Migrate cameras to AreaDetector**
  - Consistent set of PVs for client tools, users
  - Fewer software packages to maintain

Linac Coherent Light Source II (LCLS-II)



	Now	HXU - Cu	HXU - SC	SXU - SC	SXU – Cu
Photon Energy Range (keV)	0.25 -12.8	1 - 25	1 - 5	0.25 - 1.6	0.25 - 6
Repetition Rate (Hz)	120	120	929,000	929,000	120
Per Pulse Energy (mJ)	~ 4	~ 4	~ 0.2	~ 1	~ 8
Photons/Second	~ 10^{14}	~ 10^{14}	~ 10^{16}	~ 10^{17}	~ 10^{14}

LCLS Electron Accelerator Comparison

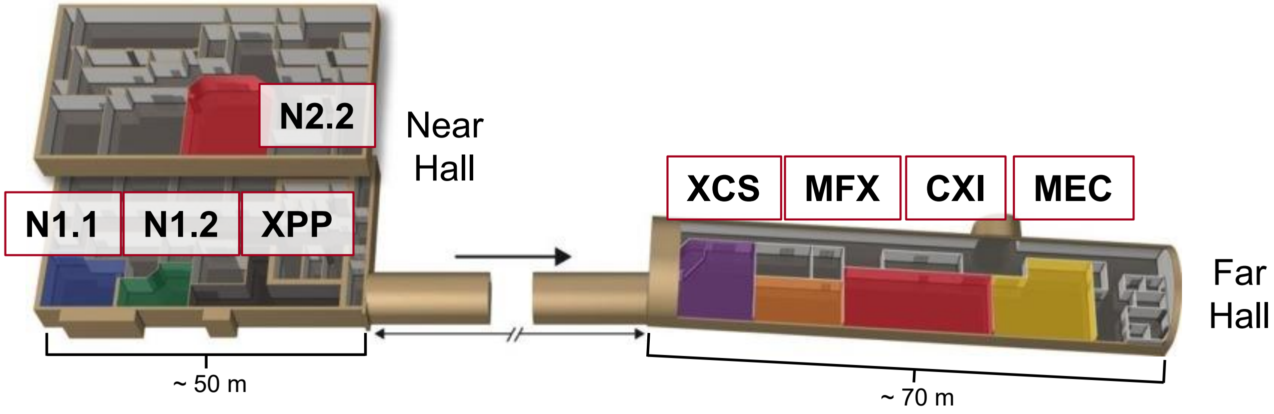
SLAC

	LCLS-I	LCLS-II
Accelerator technology	Normal conducting or "warm" 	Superconducting or "cold" 
RF frequency	2.8 GHz	1.3 GHz
Ave. RF gradient	~ 25 MV / m	~ 16 MV / m
Electron energy	15 GeV	4 GeV
Cavity Q	$\sim 10^4$	$\sim 10^{10}$
RF "pulse" duration	~ 1 μs	CW
Bunch repetition rate	120 Hz	930,000 Hz

X-ray instrument plans for LCLS-II

SLAC

- 7 instruments fed by a single undulator at present
- 8 instruments available for LCLS-II (new soft & tender instruments)

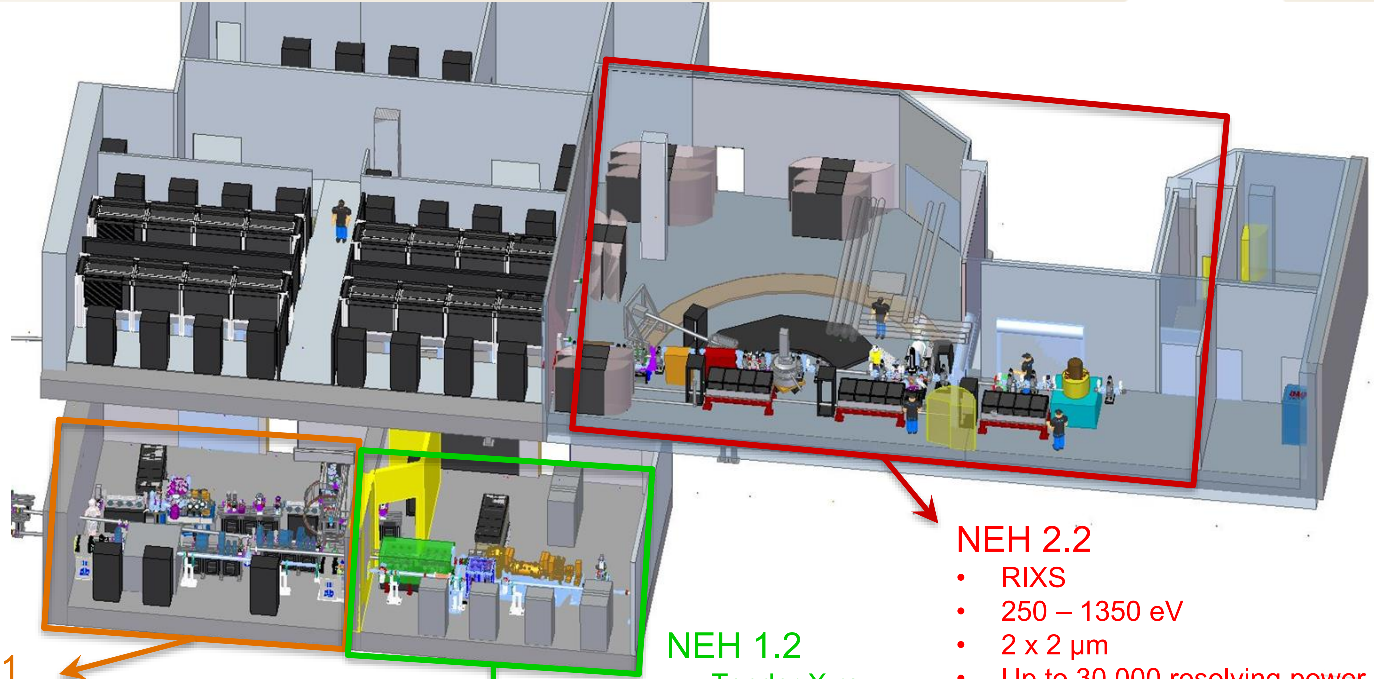


SXU

HXU

NEH 1.1:	Atomic, Molecular and Optical	2 Soft X-ray
NEH 2.2:	Soft X-ray Research	
NEH 1.2:	Tender X-ray Instrument	1.5 “tender” x-ray
XPP:	X-ray Pump Probe	4.5 Hard X-ray
XCS:	X-ray Correlation Spectroscopy	
MFX:	Macromolecular Femtosecond Crystallography	
CXI:	Coherent X-ray Imaging	
MEC:	Matter in Extreme Conditions	

Experimental layout for LCLS-II consolidates functionality into 3 new instruments (5+1 endstations)



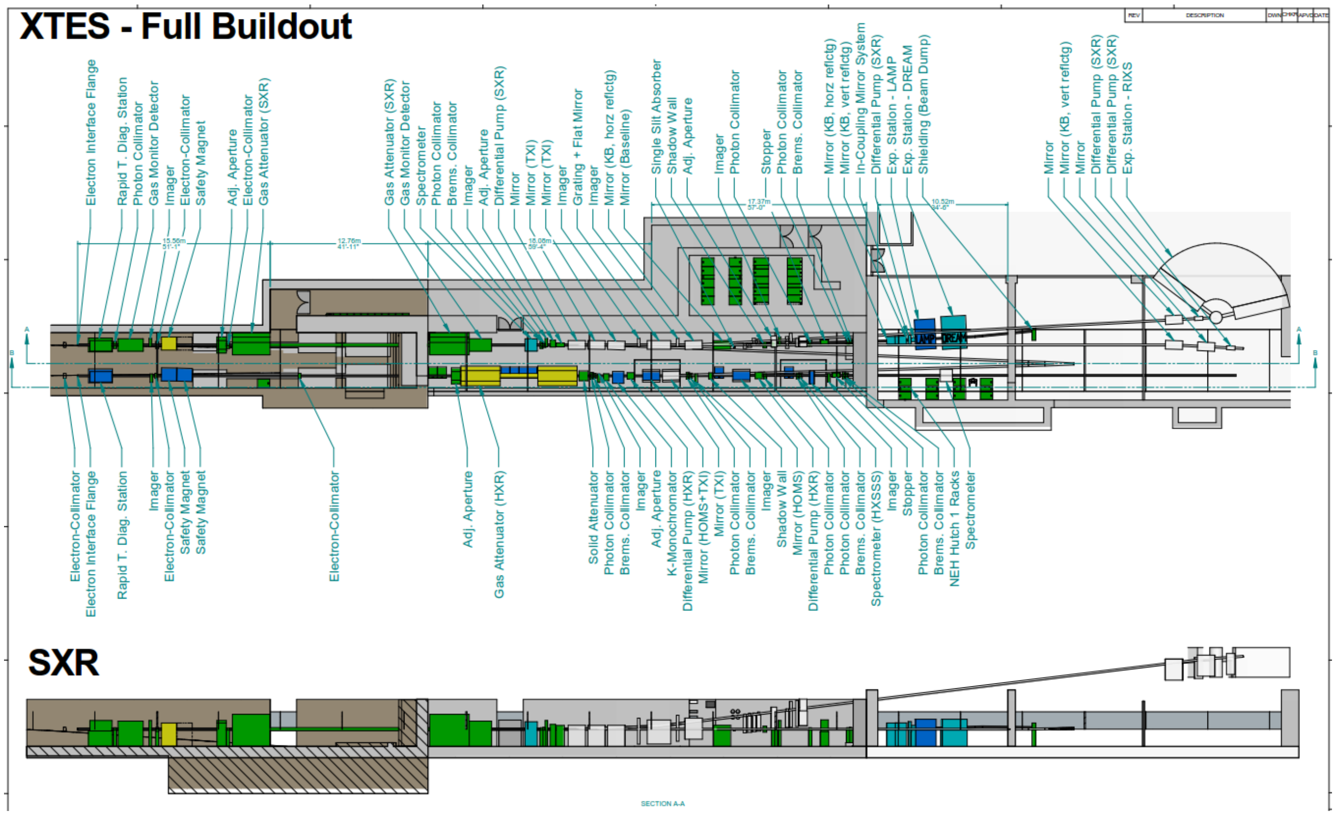
NEH 1.1
- High Flux Soft X-ray
- 250 – 2000 eV
- 1 µm / 0.3 µm
- Minimal Optics

NEH 1.2
- Tender X-ray Instrument
- 400 – 7000 eV
- 1 µm
- 2x XFELs

NEH 2.2
- RIXS
- 250 – 1350 eV
- 2 x 2 µm
- Up to 30,000 resolving power

XPP will be modified for high rep rate tender X-ray operations

Electron Beam Dump & Front End Enclosure



New LCLS-II

Upgraded by LCLS-II

Existing LCLS

Upgraded by LCLS

New L2S-I

High repetition rate instruments early science timeline

Inst.	Commissioning	Early Science (LCLS + users)	Normal Operation (via PRP)
NEH 1.1 (DREAM)	**1/2020**	**4/2020**	**7/2020**
NEH 1.1 (LAMP)	**1/2020**	**4/2020**	**7/2020**
Tender XPP	**1/2020**	**4/2020**	**7/2020**
NEH 2.2 (LJE)	**6/2020**	**9/2020**	**12/2020**
NEH 2.2 (RIXS)	**1/2022**	**4/2022**	**7/2022**
NEH 1.2	**1/2023**	**4/2023**	**7/2023**

Near Experimental Hall

Item on LCLS-II "Scope Add List"

- Phased delivery over FY20-FY23, dependent on resources

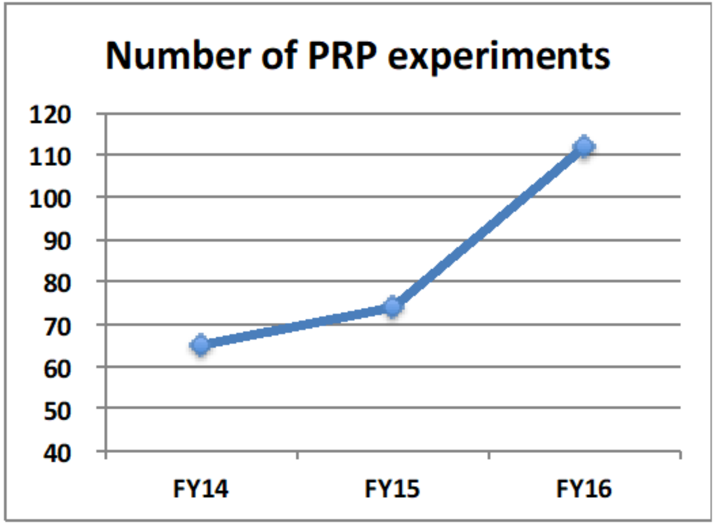
L2S-I Requirements & Challenges

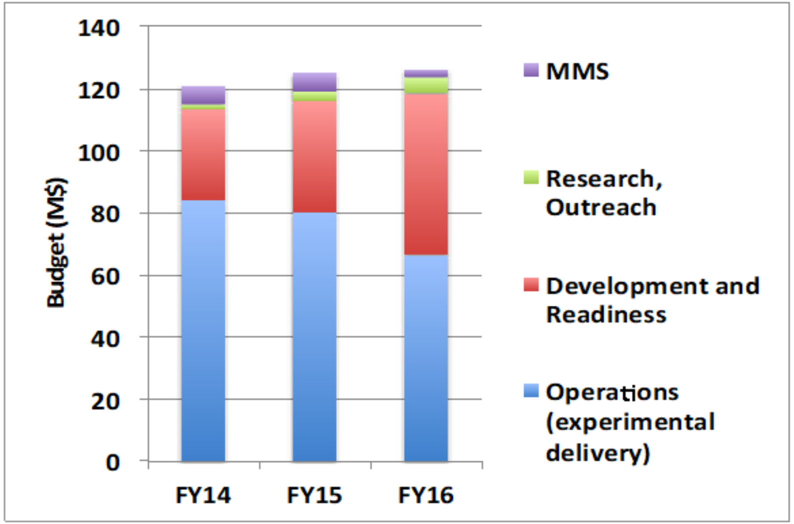
- **Automation**
  - X-ray Beam Delivery – optics alignment & focus, to sample
  - Pump-Laser Delivery – alignment to X-ray beam and sample
  - Pump-Laser Timing – drift control from ATM feedback

- **Intuitive User Interfaces**
  - Reduce need for expert scientific staff to operate experiments
  - Guide users through experiment setup and execution
  - Security & Access-control

- **Robustness**
  - Enhanced focus on reliability, delivery
  - Configuration control
  - Security & Access-controls

Operational Efficiency Improvements





From 2014 to 2016:

- **72% increase in user experiments**
- **21% reduction in cost of operations, releasing funds for the ongoing development of LCLS**
- **Operations reduced from 17.2 to 11.8 FTE in Controls & Data Systems (target is 9.5 in 2018)**

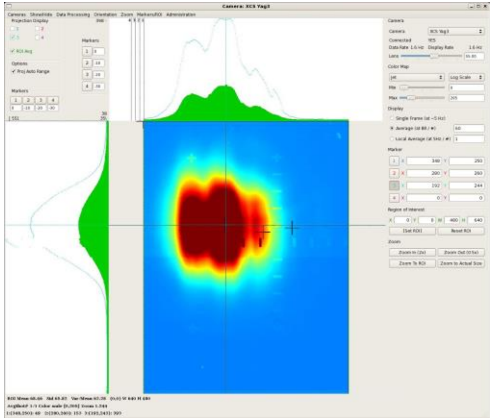
Current & Future Improvements

- **Platforms**
  - RHEL 5 → RHEL 7
  - cPCI / VME → SLAC Common Platform
  - EPICS 3.14 → 3.15 → 7
- **User Interfaces**
  - EDM → PyDM
  - Beamline Python → Bluesky/Ophyd (NSLS2)
- **Installation Density**
  - Vacuum - Gauges w/ Integrated Controllers
  - Vacuum, Motion, Temp, I/O – beamline mounted fieldbus solutions
  - DC power distribution, TBD
- **PLC System Simulation**
  - End-to-end testing of PLC code before installation
  - Large time savings in post-install testing

Collaborative Endeavors

- **Within SLAC**
  - Controls working group representing lab-wide stakeholders
  - Internal Controls Development Roadmap developed
    - Recent External Review highly supportive of the Roadmap

- **EPICS**
  - Renew engagement with collaboration to share development
- **Tools**
  - Bluesky / Ophyd https://nsls-ii.github.io/
    - Adopting for LCLS, actively working with NSLS-II staff
  - PyDM https://github.com/slaclab/pydm
    - Currently in use at: SLAC, LNLS, MPI-H Pentatrap Group
    - Under evaluation at: NSLS-II, APS, …



Related Presentations and Posters

Section	Title	Author
THSH102 Th. 17:45	PyDM: A Python-Based Framework for Control System Graphical User Interfaces	M.L. Gibbs
WEAPL06	Skywalker: Python Suite for Automated Photon Alignment at LCLS	T.F. Rendahl
THPHA129	X-Ray Split and Delay Automated Mirror Alignment	A.P. Rashed Ahmed
THPHA173	Vacuum System Simulation with EtherCAT Simulator	T.A. Wallace
THPHA007	Git Workflow for EPICS Collaboration	B.L. Hill
THPHA022	Roadmap for SLAC Epics-Based Software Toolkit for the LCLS-I/II Complex	D. Rogind

Career Opportunities

Beamline Operations Engineer:

https://chk.tbe.taleo.net/chk01/ats/careers/requisition.jsp?org=SLAC&cws=1&rid=2261

PLC & Automation Engineer:

https://chk.tbe.taleo.net/chk01/ats/careers/requisition.jsp?org=SLAC&cws=1&rid=2863

Laser Controls Engineer:

Stay tuned: https://careers.slac.stanford.edu/

Contact:

Daniel Flath - dflath@slac.stanford.edu