The LCLS-II Experiment Control System

ICALEPCS CAPE TOWN SOUTH AFRICA 2023

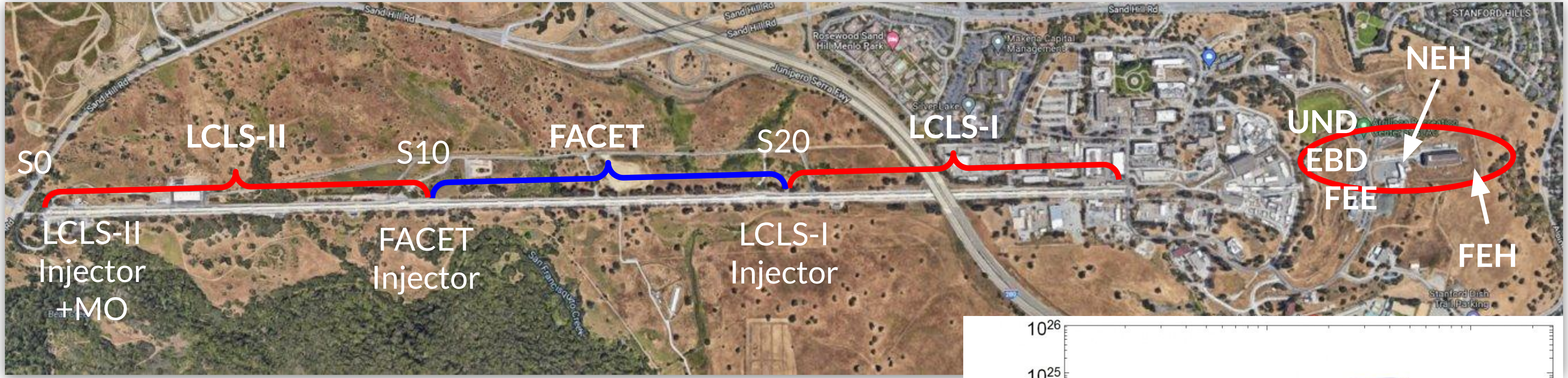
TH2BCO03

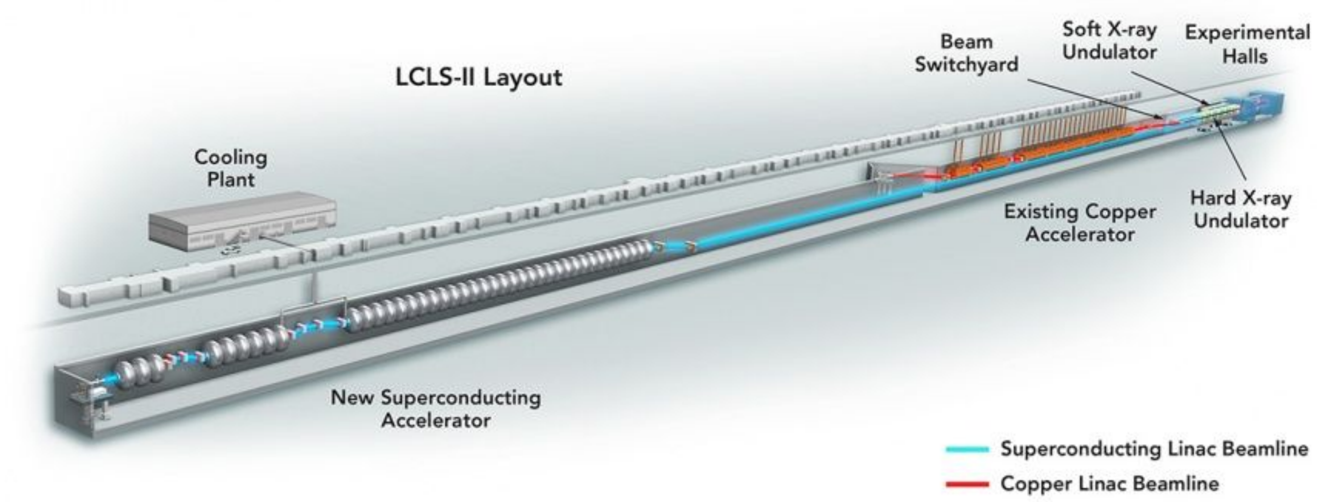
Daniel Flath, Margaret Ghaly, Tyler Johnson, Kenneth Lauer, Zachary Lentz, Márcio Paduan Donadio, Alex Wallace, Jing Yin

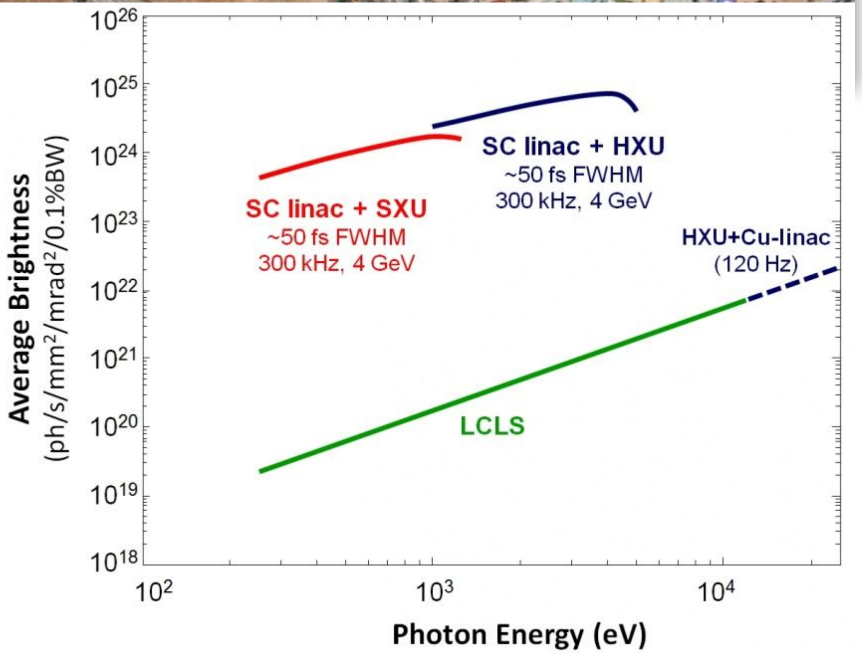
SLAC NATIONAL ACCELERATOR LABORATORY

Stanford University | U.S. DEPARTMENT OF ENERGY

LCLS-II Overview







LCLS-II TTO KPP Progress, Sept 23, 2023

(TTO KPP = Transition To Operations, Key Performance Parameters)

Performance Measure	Threshold (5 kW beam)	Objective (120 kW beam)	Measurements
Variable gap undulators	2 (soft and hard x-ray)	2 (soft and hard x-ray)	
Superconducting linac-based FEL system			
Superconducting linac electron beam energy	3.5 GeV ✓	≥ 4 GeV	Spectrometer bend (magnet strength, screen)
Electron bunch repetition rate	93 kHz ✓	929 kHz	BPM's, laser rate
Superconducting linac charge per bunch	0.02 nC ✓	0.1 nC ✓	Toroid, Faraday cup
Photon beam energy range	250–3,800 eV ✓	200–5,000 eV	Absorption edges, spectrometer
High repetition rate capable end stations	≥ 1 ✓	≥ 2 ✓	N/A
FEL photon quantity (10^{-3} BW) per bunch	5×10^{8} (10x spontaneous) @2,500 eV ✓	> 10^{11} @ 3,800 eV	Gas energy monitor, GMD, Spectrometer
Normal conducting linac-based system			
Normal conducting linac electron beam energy	13.6 GeV ✓	15 GeV ✓	Spectrometer bend (magnet strength, screen)
Electron bunch repetition rate	120 Hz ✓	120 Hz ✓	BPM's, laser rate
Normal conducting linac charge per bunch	0.1 nC ✓	0.25 nC ✓	Toroid, Faraday cup
Photon beam energy range	1–15 keV ✓	1–25k eV ✓	Absorption edges, spectrometer
Low repetition rate capable end stations	≥ 2 ✓	≥ 3 ✓	N/A
FEL photon quantity (10^{-3} BW[a]) per bunch	10^{10} (lasing @ 15 keV) ✓	> 10^{12} @ 15 keV	Gas energy monitor, GMD, Spectrometer

ECS Team

Delivery
19 (+3s +1m)
- HW & SW Deployment
- User and Experiment Support
- Data Analysis
- Instrumentation Expertise

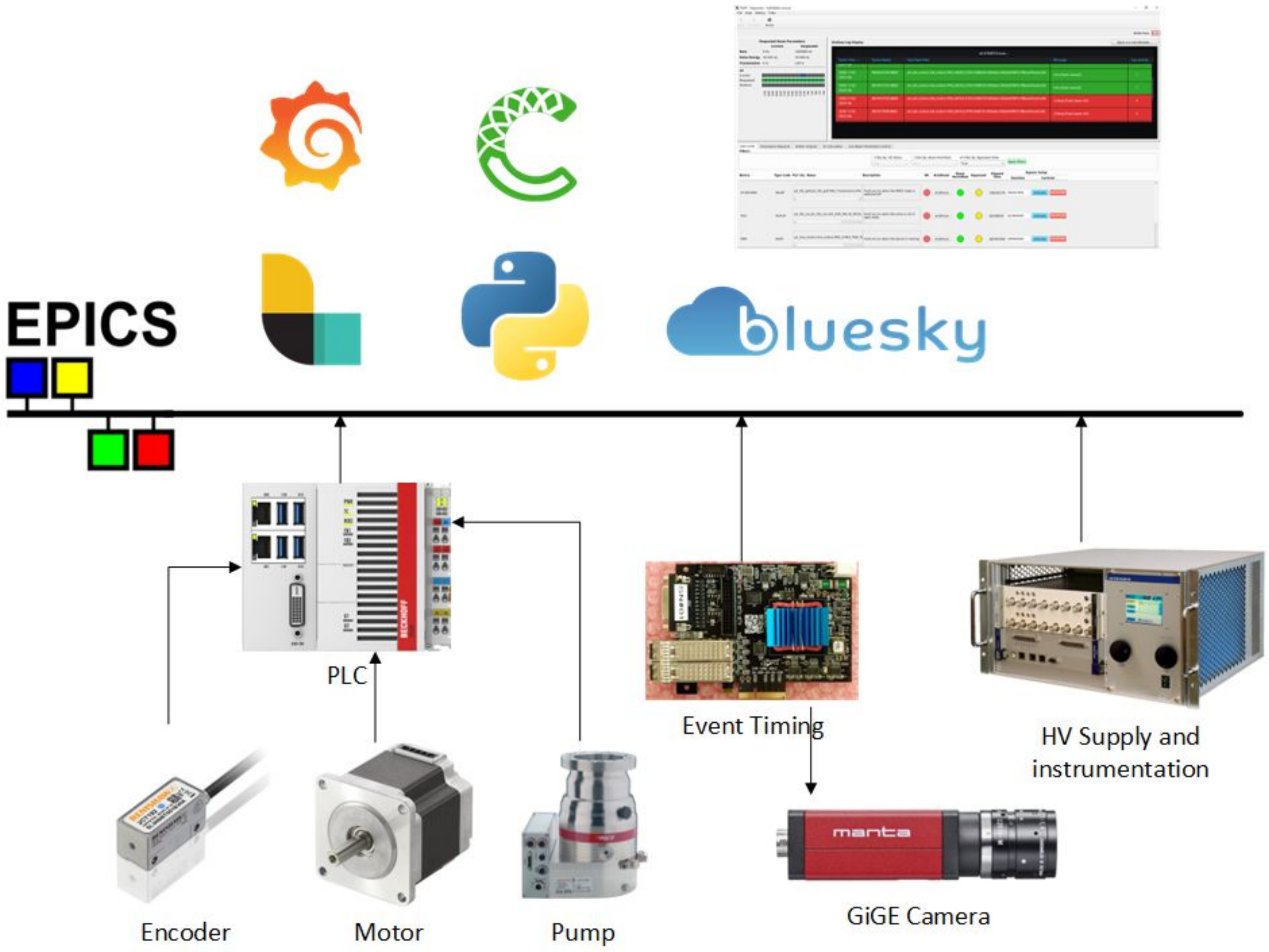
Platform Dev
12 (+2m)
- Core Hardware and Software Development
- Expert Support
- Project Management

IT Systems
(1m)
- Core IT Development
- Deployment
- Expert Support

- 3 complimentary teams
- ~3 dozen personnel
  - Staff / Students
  - Matrixed Staff
  - Contractors

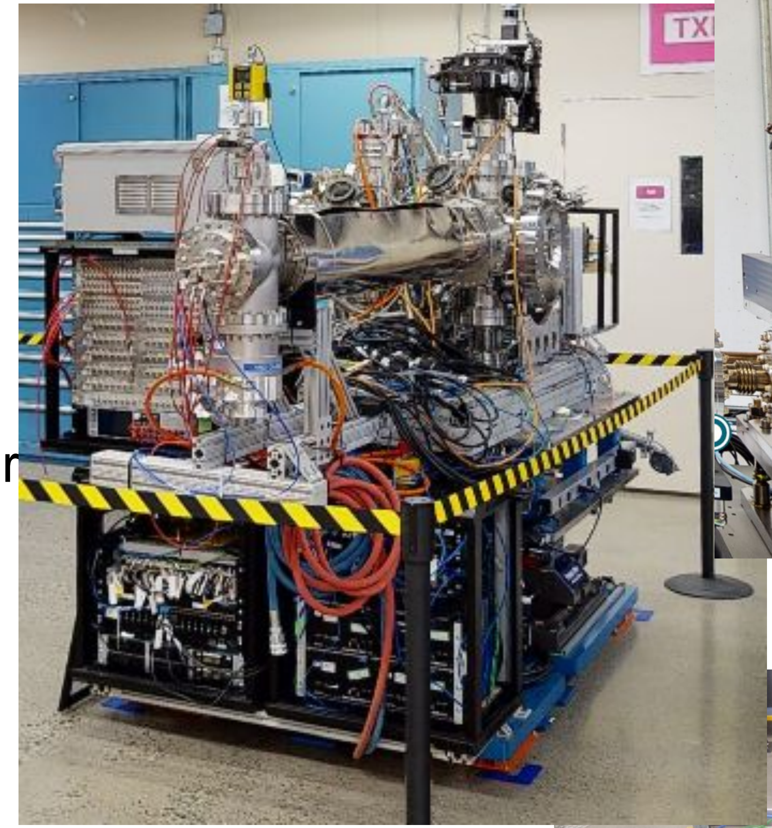
LCLS-II ECS Overview

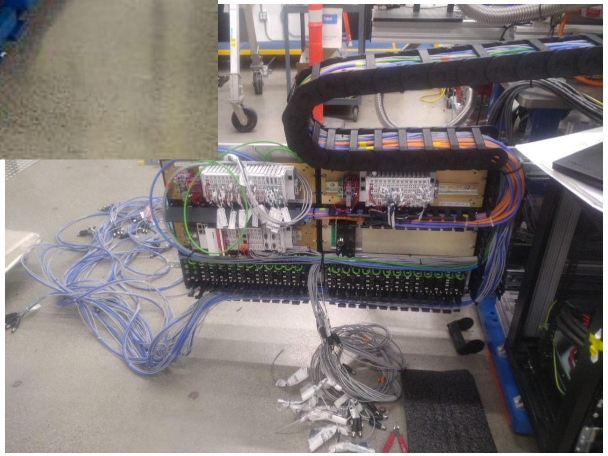
- The controls core system has been redesigned for the LCLS-II beam under XTES and L2S-I projects. Performance verified:
  - EBD, FEE
  - TMO
  - RIX.
- Controls system and subsystems
  - Preemptive Machine Protection
  - Motion
  - Vacuum
  - Lasers
  - Sensors
  - EPICS
  - Logging and Alerts
  - User Interfaces



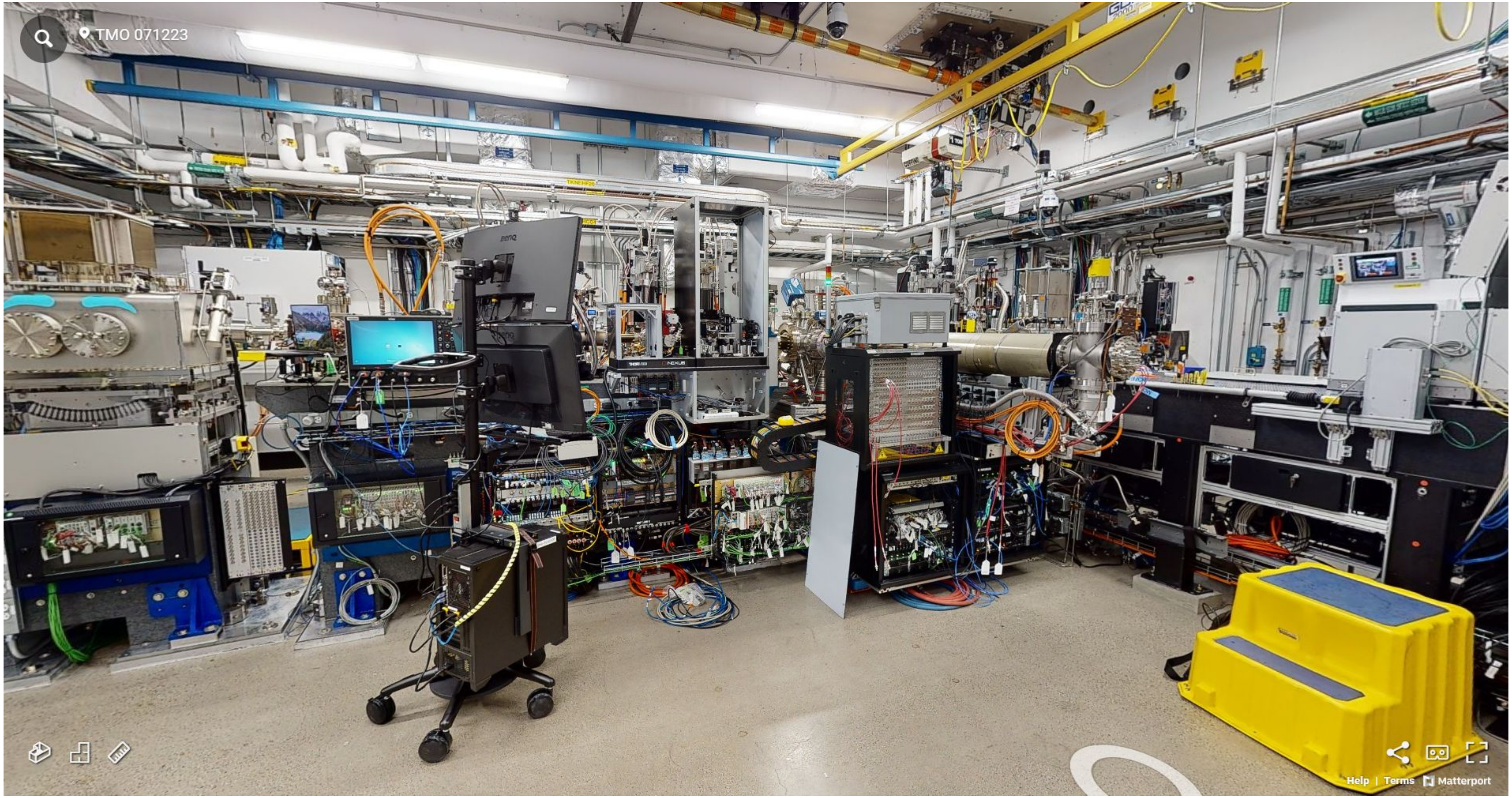
LCLS-II ECS Platform - Hardware

- Controls are mounted on DIN rails on the device.
  - Motion terminals
  - IO Terminals
  - Power distribution
    - 24V, 48V from DCT
    - DIN rail DC-DC converters modules for other voltage requirements.
- Control interface connection
  - Power (24V, 48V)
  - EtherCAT
- EtherCAT distribution junction
  - Connects all components to Motion PLC
  - Star topology
- Fully integrated into PMPS.

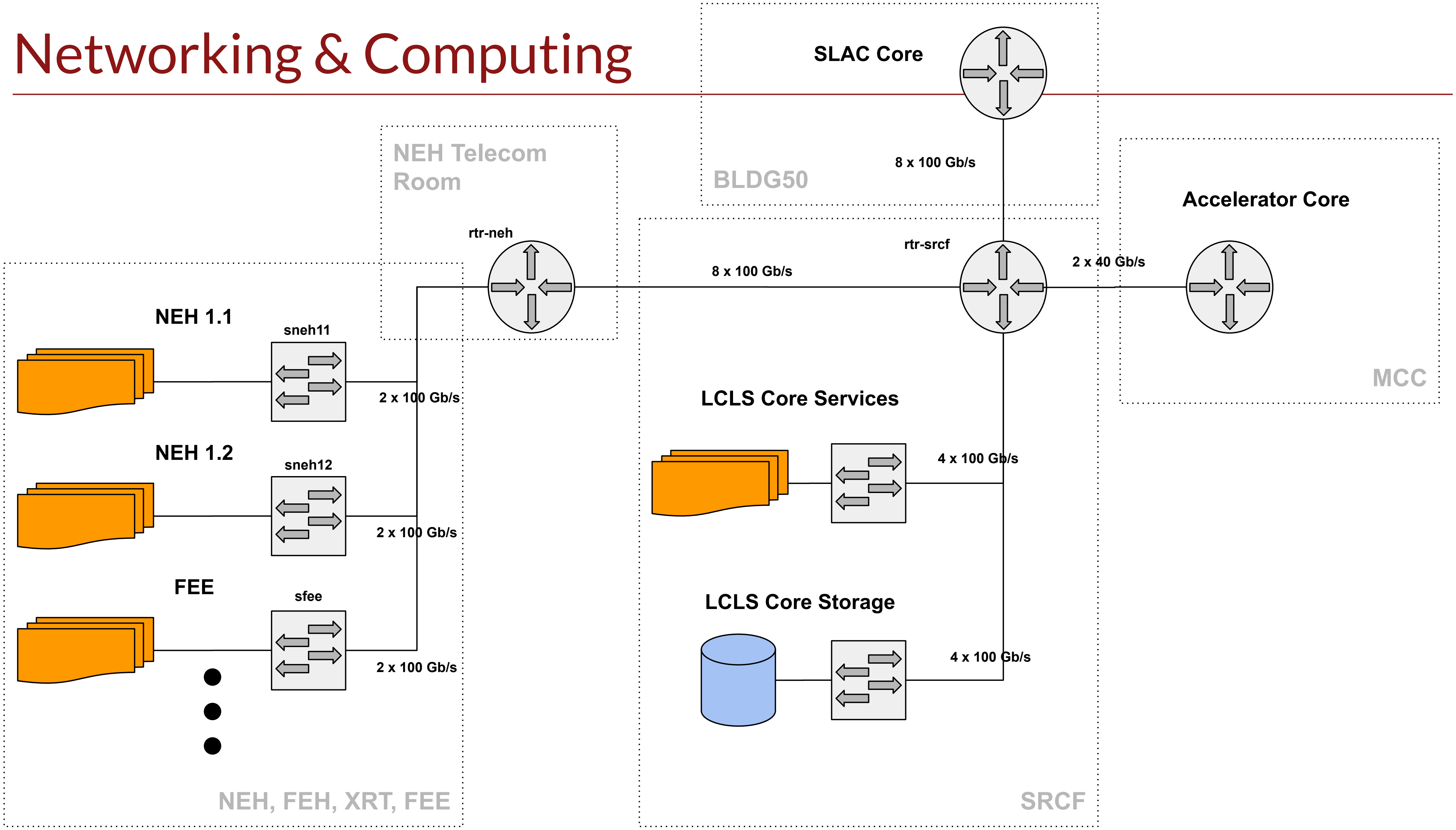




LCLS-II ECS - Example Installation - TMO

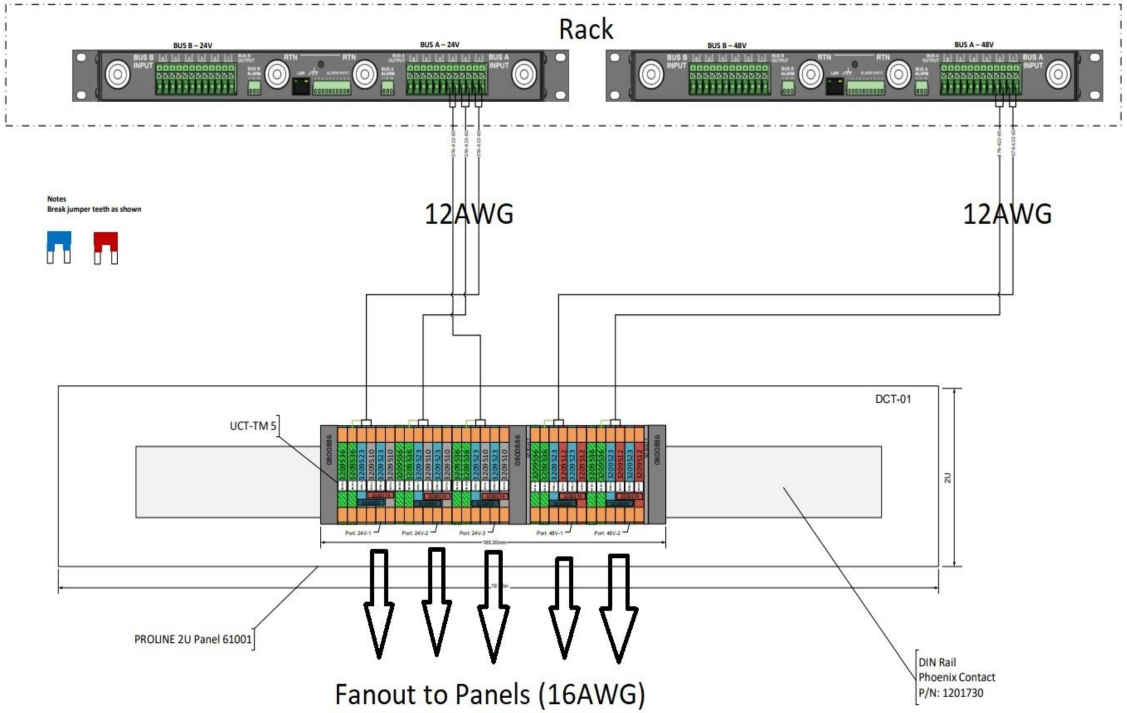


Networking & Computing



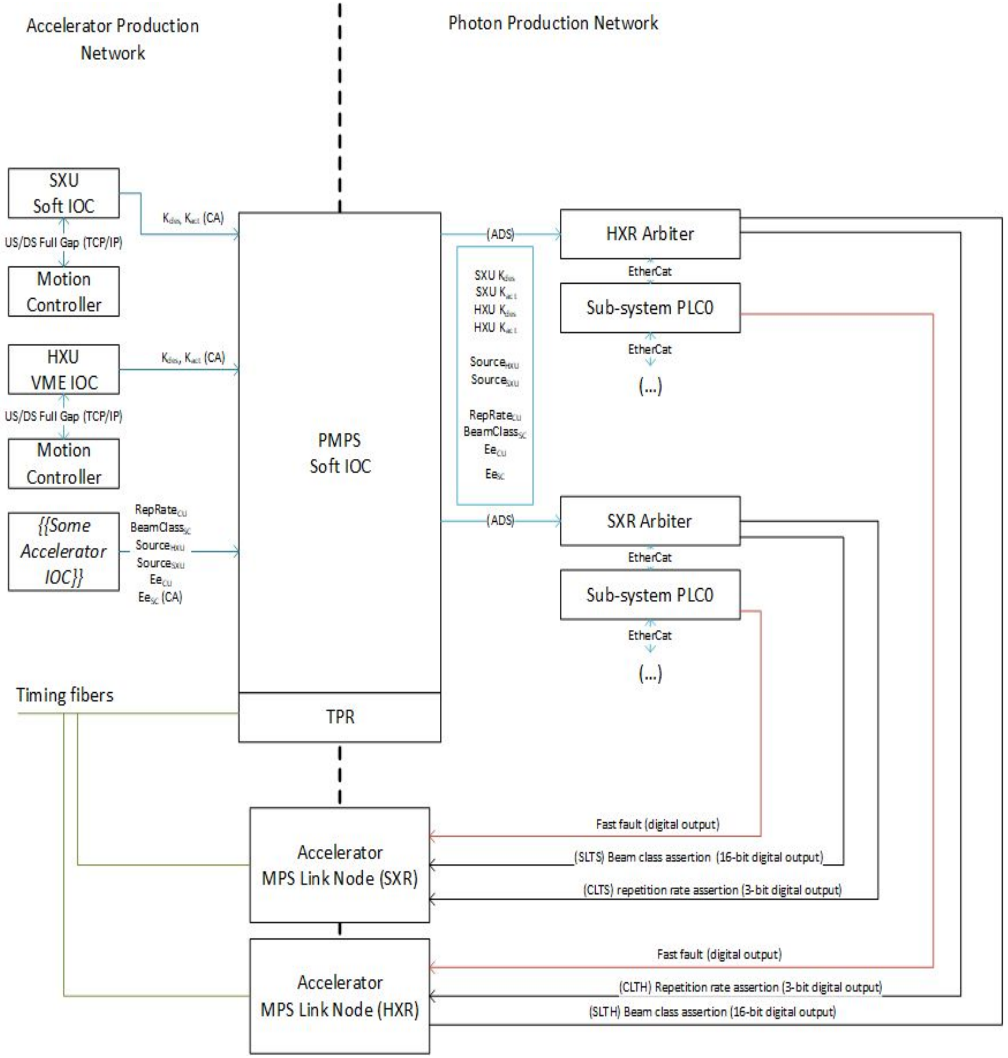
Low-voltage DC Power System

- Provides a distributed low voltage power delivery system for controls
- Using high current AC-DC rectifiers to convert to 24VDC or 48VDC, easy to swap.
- Distribute 24VDC and 48VDC using ICT distribution unit
- 15A DC channels are individually controlled and monitored remotely



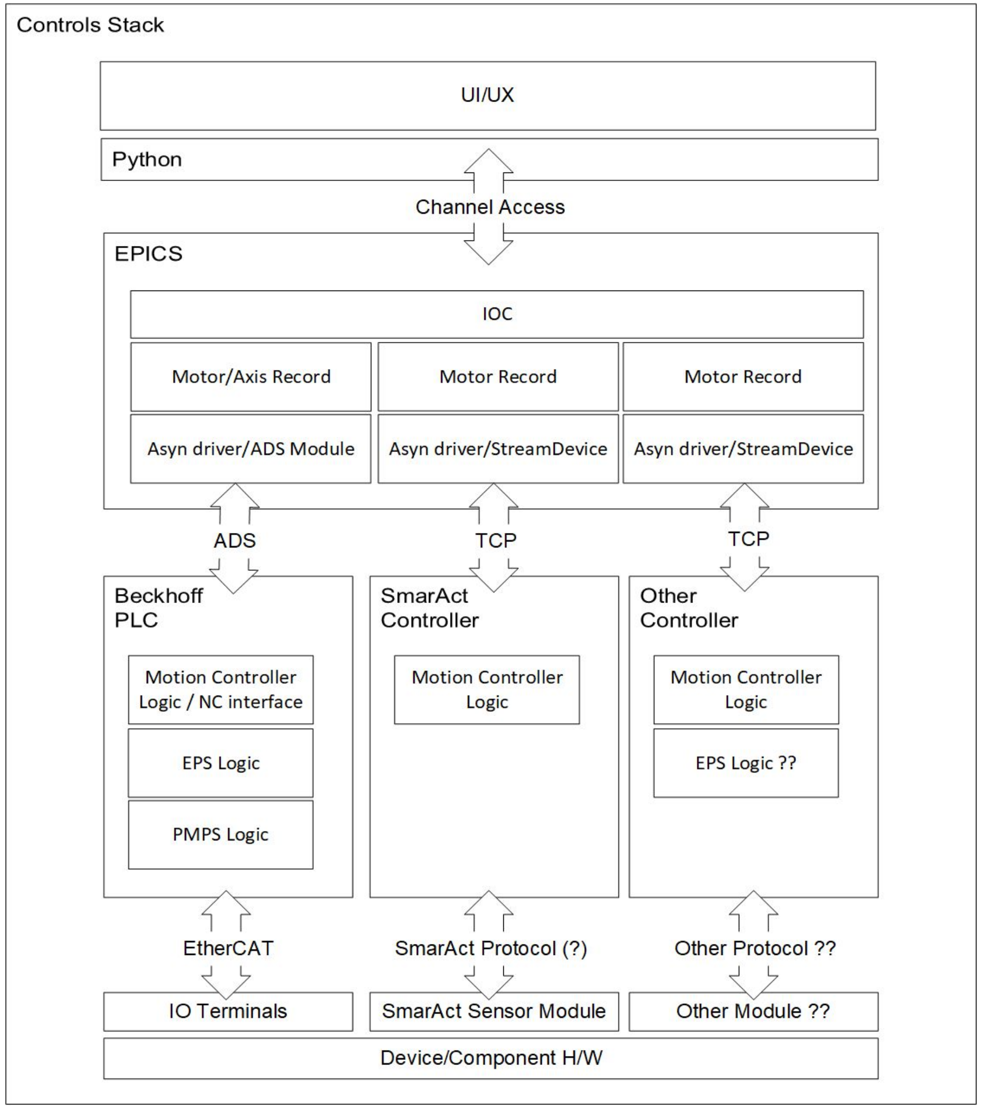
Pre-emptive Machine Protection System

- PMPS utilizes PLC controllers integrating various actuators, vacuum transducers, absolute encoders, dry-contact switches, flowmeters, and temperature sensors to control and monitor device states and beam parameters through the EtherCAT bus.
- Preemptive and reactive elements are kept separate.
- PLC code framework for implementing new devices, interlocks and transition manager.
- Dedicated EPICS IOC for relaying undulator K, electron energy, and active beamclass to the PMPS



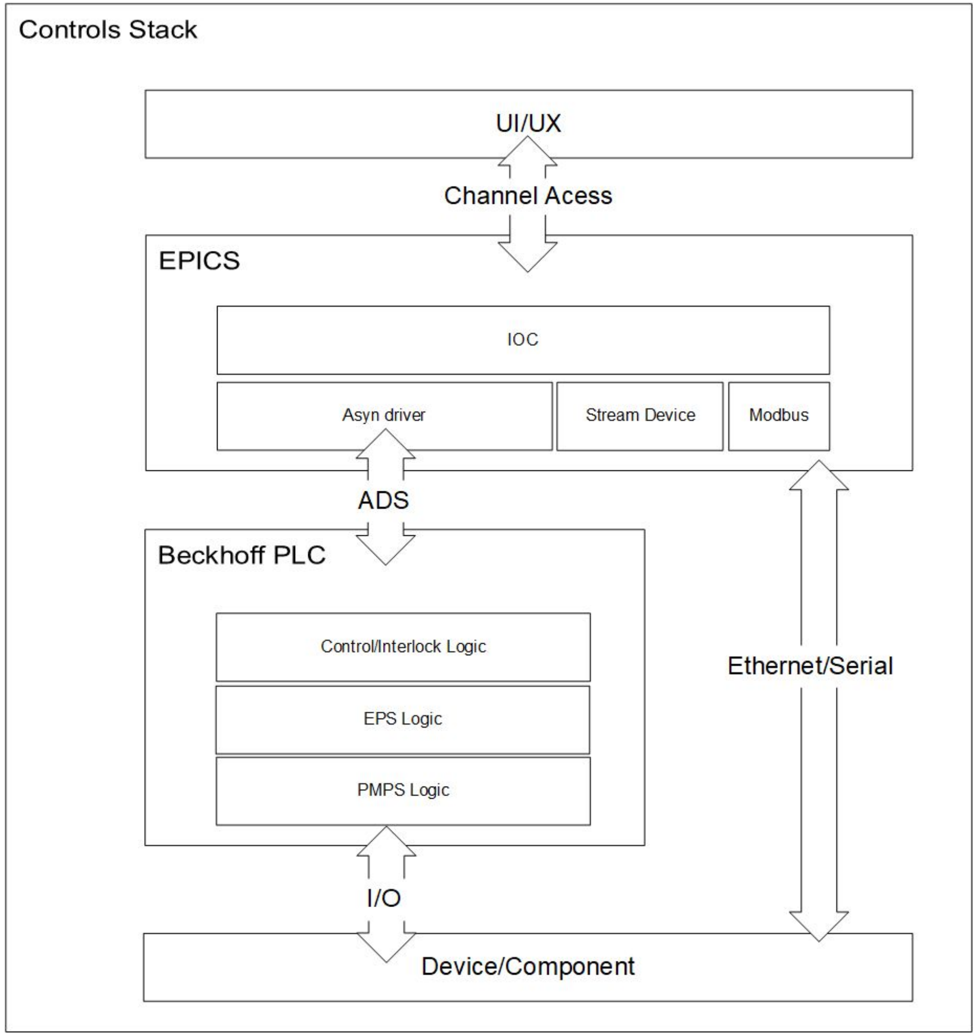
Motion System

- Axis coordination and basic automation
- EPS - Equipment Protection System
  - Prevent crashes, collisions, damage
- PMPS Interface
  - Provide timely readbacks to PMPS via Beckhoff EtherCAT interface
    - State Mover
      - Prevent unsafe states preemptively
    - BPTM
      - Ensures safe beam condition before transitions.
  - MPS reactive fault via digital output



Vacuum System

- Integration of all vacuum devices all the way to EPICS and PyDM.
- Vacuum supported devices
  - Gauges: hot cathodes, cold cathodes, pirani, combo gauges, rad hard gauges.
  - Pumps: Ion pumps (gamma and nextorr), Turbo pumps (Pfieffer, Leybold, Ebara, Agilent), Roughing pumps.
  - Valves: Various pneumatic valves, Pfeiffer EVR116, MKS 248 variable valve, Motorized valves.



Thank You

Thank You!

- ECS and LCLS teams
- SLAC (esp. AD/TID/LCLS2), and the DOE Office of Science
- Collaborators, especially at NSLSII and the ESS
- Many people in this room or their colleagues who have participated in our many reviews and given invaluable insight and encouragement

See for more detailed content:
WE1BCO04, WE1BCO07, MO4BCO06, TUPDP129