LCLS-II Controls & Safety Systems Status

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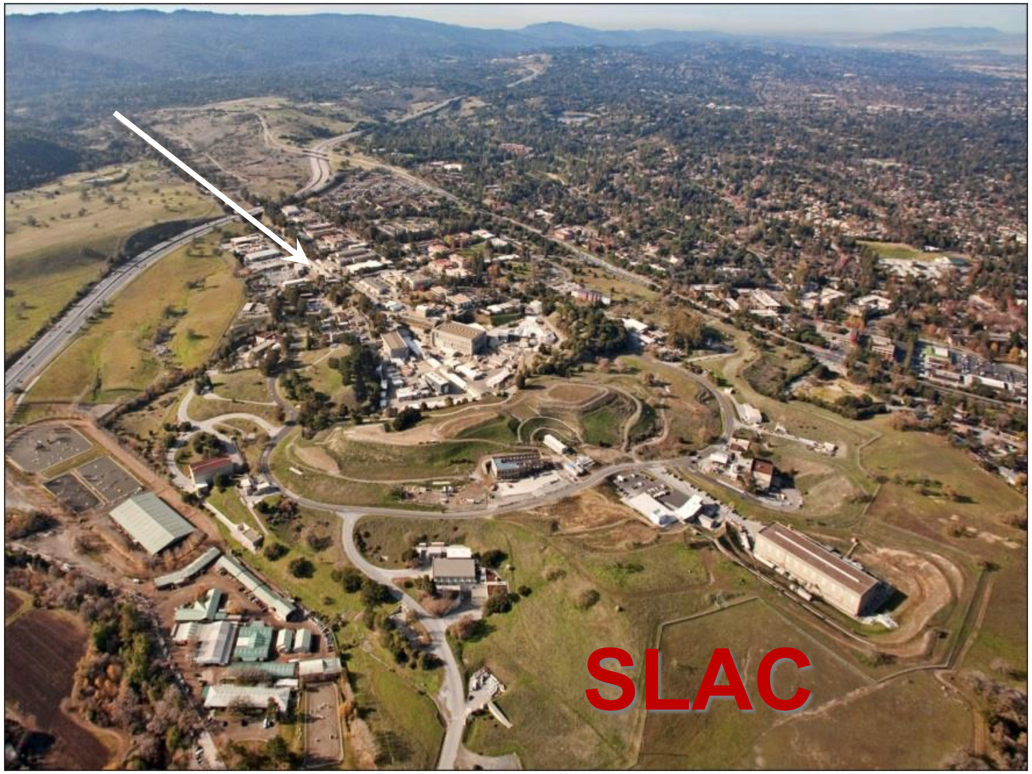
Outline

- 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

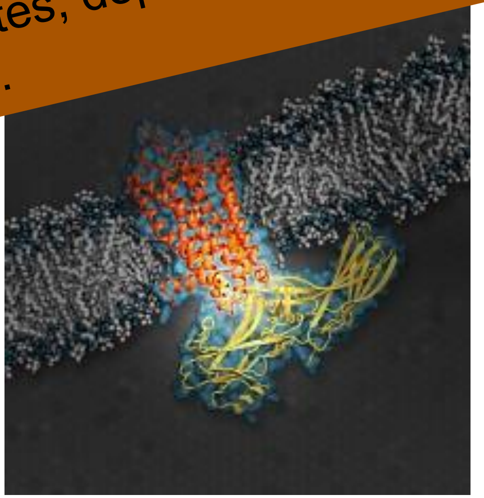
- Delivering science since 2009
- A billion times brighter than previous sources
- Study of ultra-fast and ultra-small phenomena
- Can capture images of atoms & molecules in motion
- Delivers to ~600 scientists/year (1300 user visits)
- ~25% of proposals are allotted time



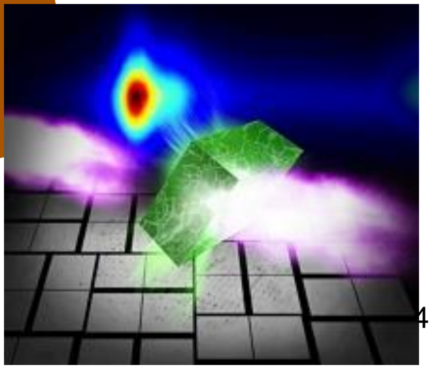
Recent Science Highlights

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.

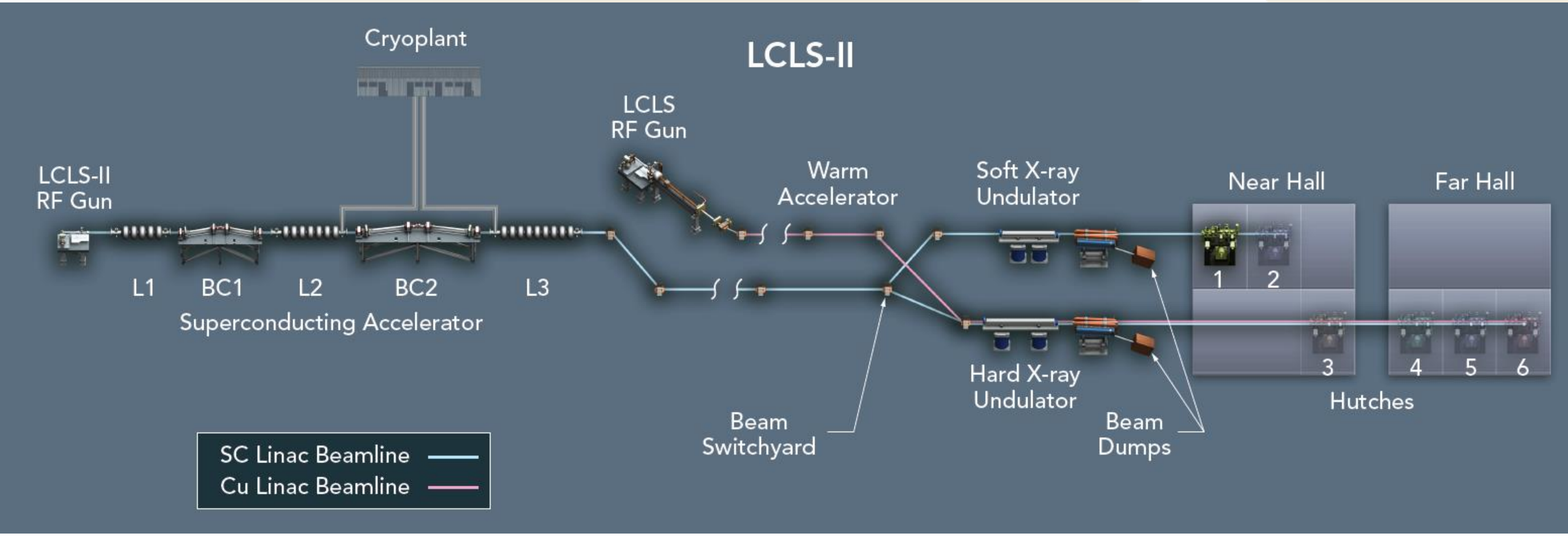


Now that's green…"All life that depends on oxygen is dependent on photosynthesis"; by studying how nature does it, one can apply the design principles to artificial systems, such as the creation of renewable energy sources.

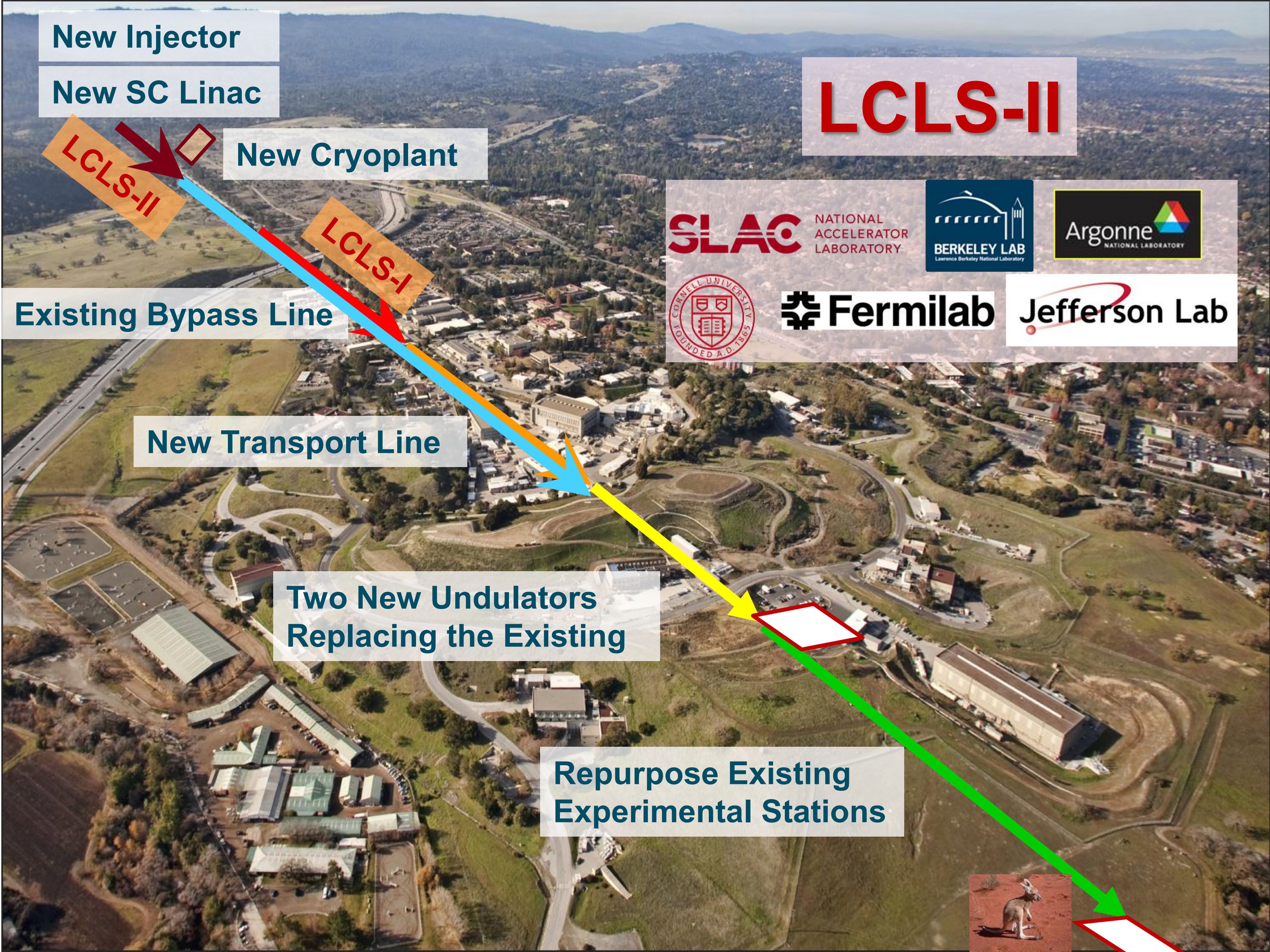


What's Next?   Next Generation LCLS-II…..

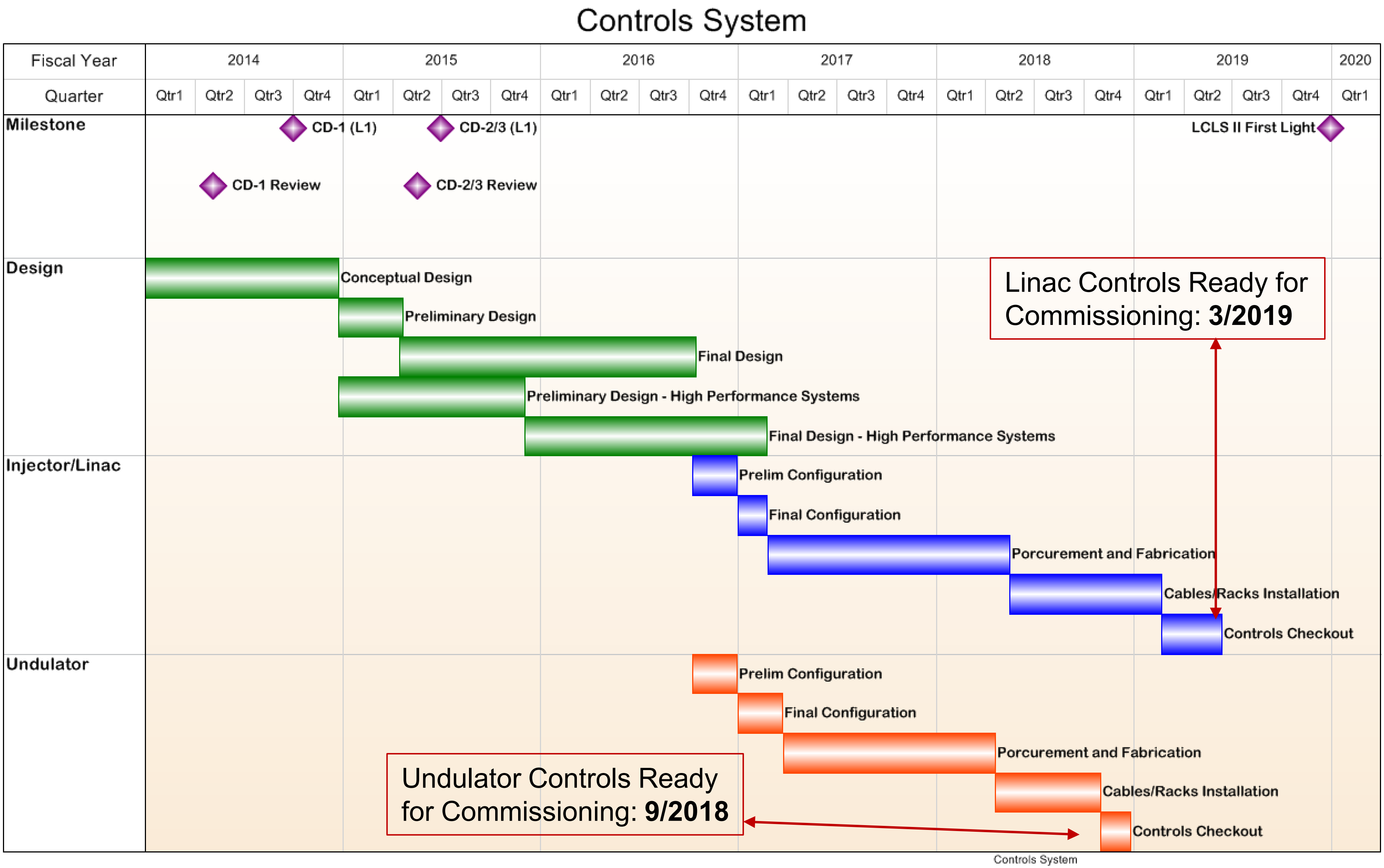
LCLS-II Layout - Project scope



- 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)


LCLS-II
New Injector
New SC Linac
New Cryoplant
LCLS-II
LCLS-I
Existing Bypass Line
New Transport Line
Two New Undulators
Replacing the Existing
Repurpose Existing
Experimental Stations
SLAC NATIONAL ACCELERATOR LABORATORY
BERKELEY LAB
Argonne NATIONAL LABORATORY
Fermilab
Jefferson Lab

Controls System High Level Schedule



Advancing Controls for LCLS-II

Mature Subsystems:

PPS, BCS*, Drive Laser,
Vacuum, Temperature,
Magnet Power Supply,
Undulator Motion, Fast Wire Scanner,
Profile Monitors,
Network & Computing,
Physics High Level Applications,
Operational Software

★ Highly Leverage LCLS Designs

✓ PDR Complete

FDR Fall '16

* Except for fast shutoff electronics

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

★ New Requirements due to higher beam power rep rate

PDR Spring '16

FDR Winter '16

Brand New Subsystems

SCRF, ODH, Cryo I/Fs

★ Partner Lab Involvement

PDR Spring '16

FDR Winter '16

PDR = Preliminary Design Review

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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

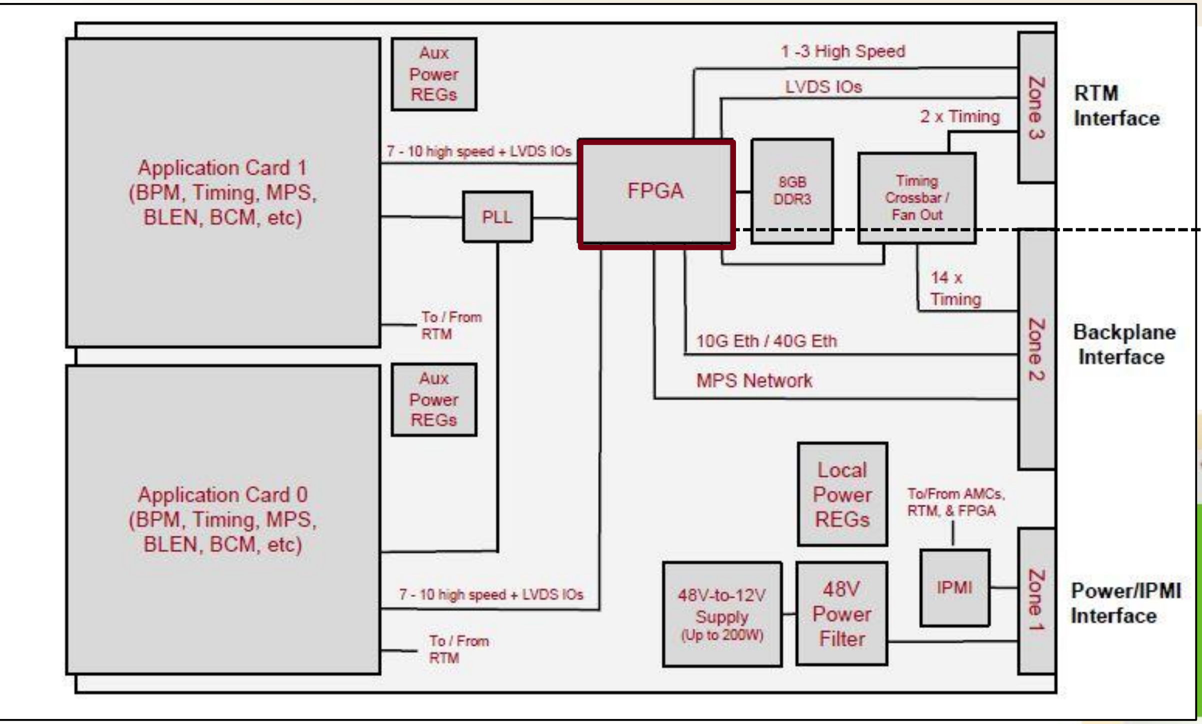
Common Platform & Architecture

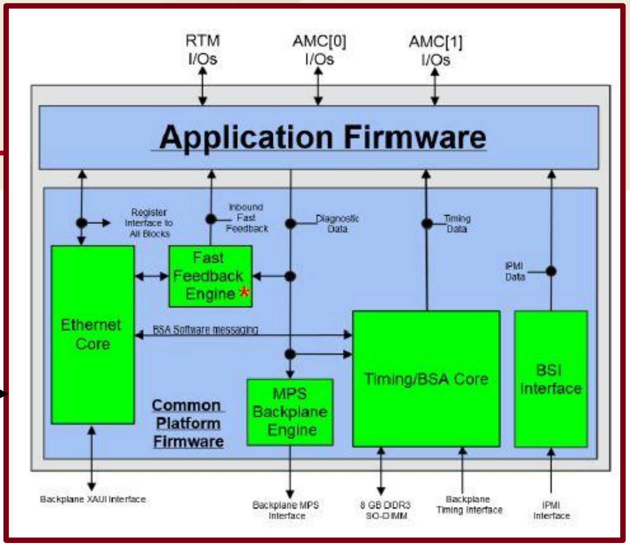
- Standard ADC + FPGA Electronics
- 4-10 channels of 120-250 MHz >11 effective bit ADC's.
- FPGA containing common platform FW plus applications for daughter cards
- Memory to buffer several million consecutive readings.
- Computer interface for setup/read-back.

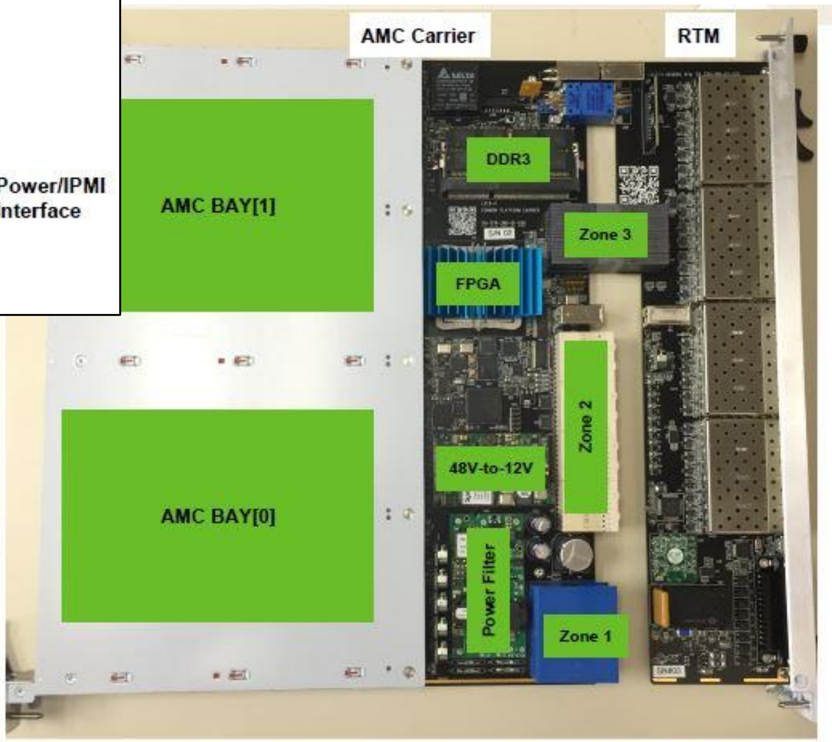
Prototyping in progress with ATCA (not mTCA) and NADs

- 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



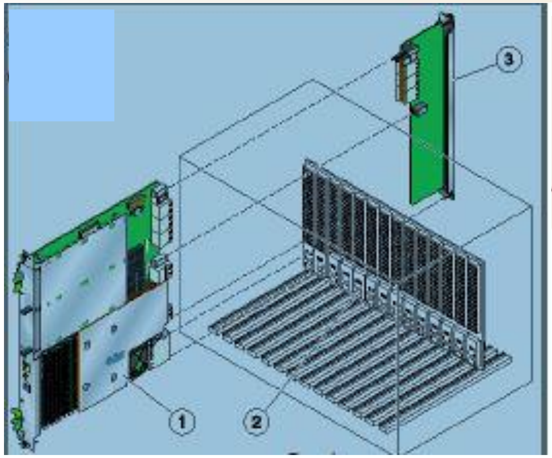


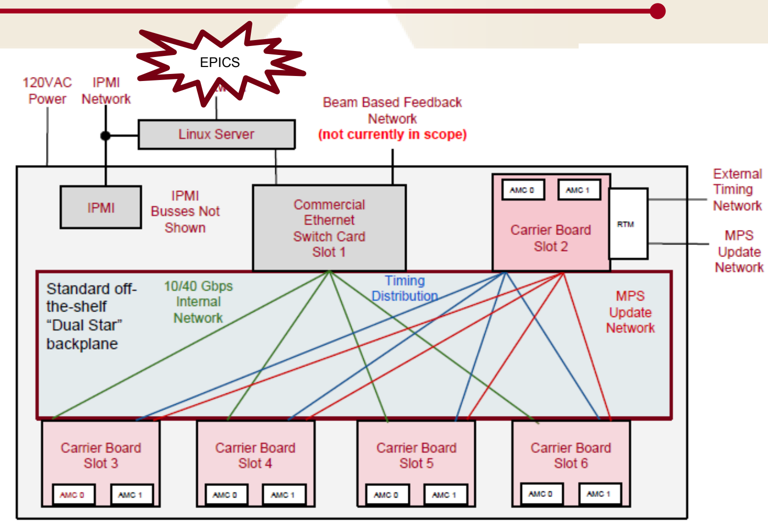


Carrier Board (AMC)

- 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 IOC in linux host

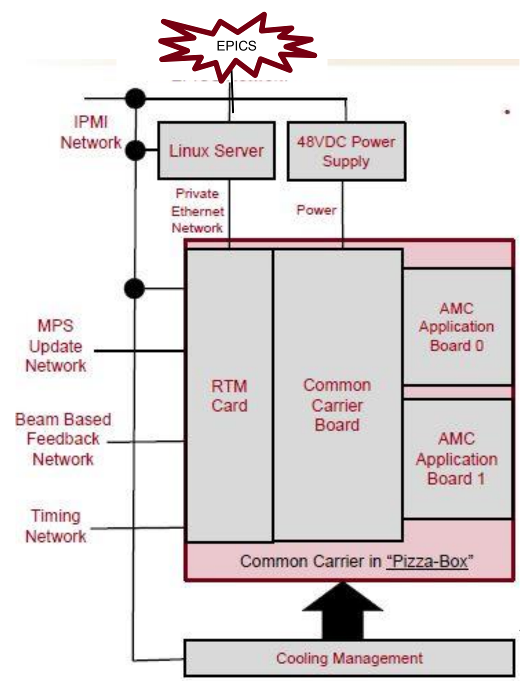
Platform Packaging





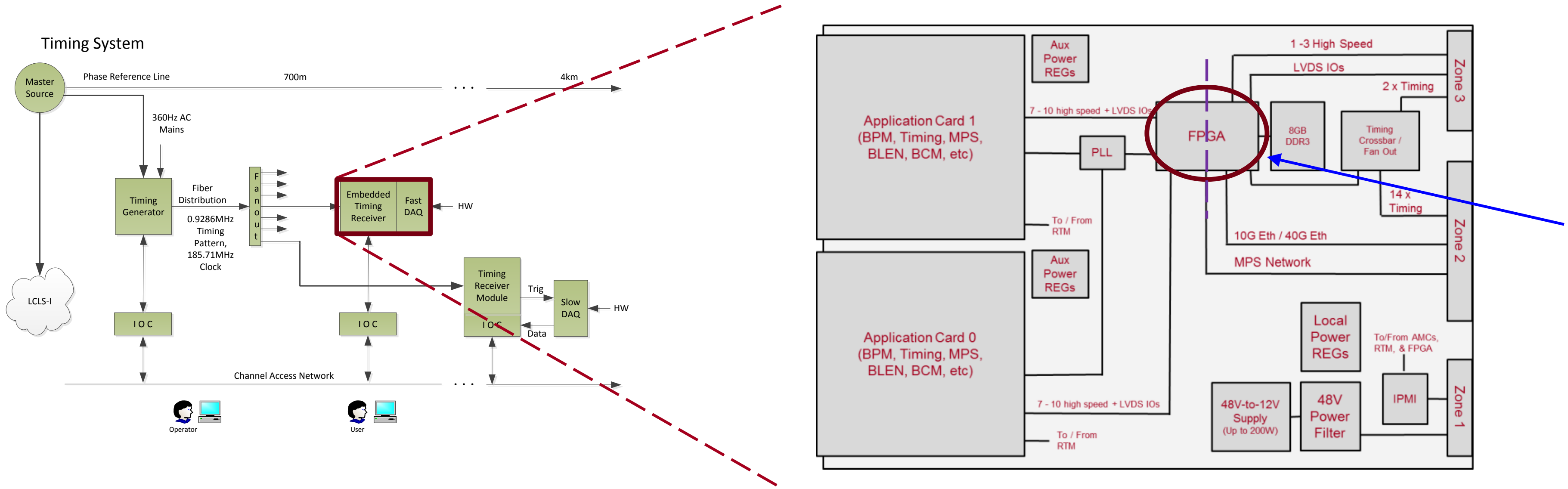
Common ATCA module can be mounted in multi-slot crate (only 1 RTM required for Timing/MPS)

OR single slot pizza-box



Timing Receiver: Common Platform Design

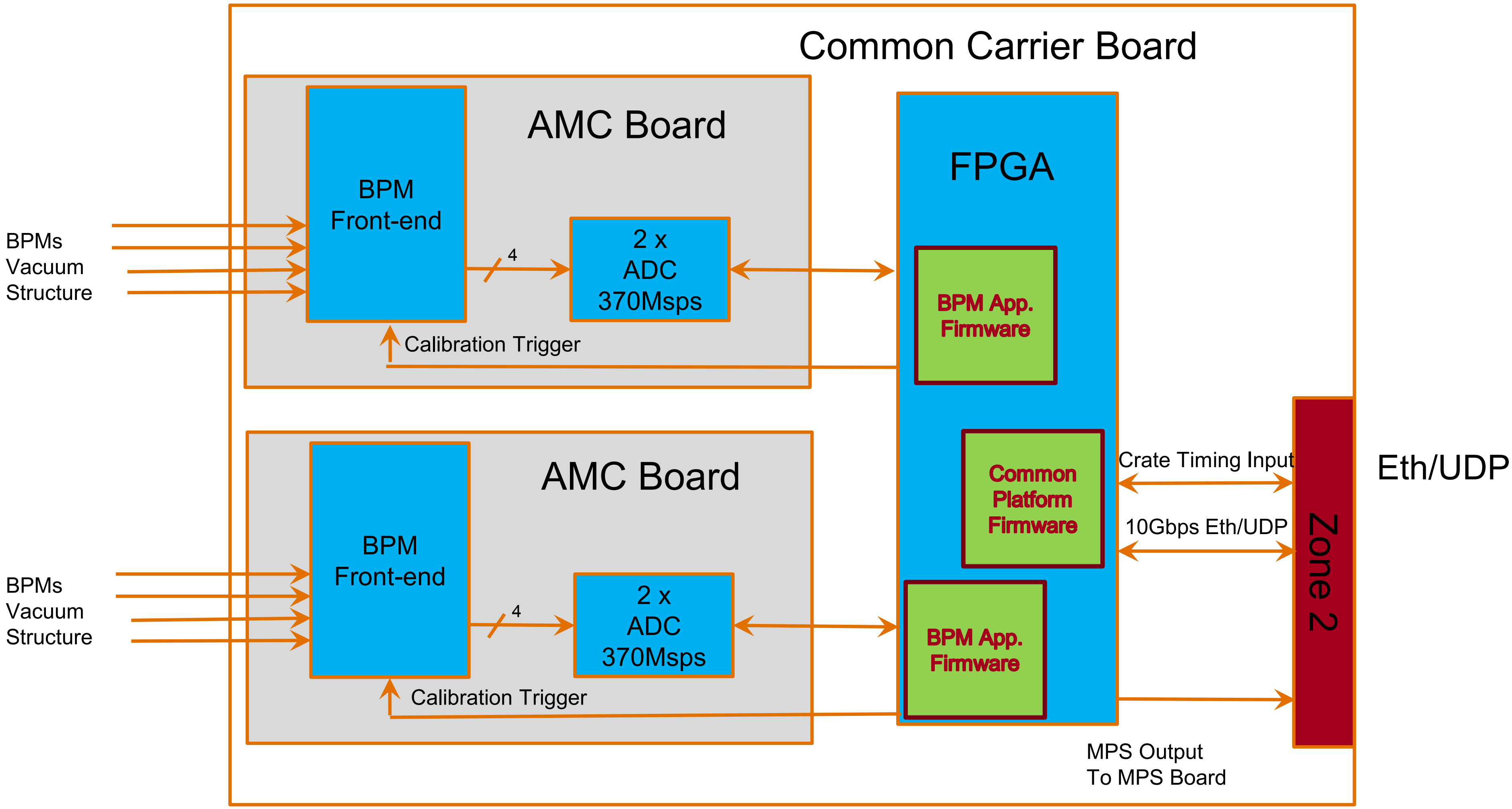
Common Platform Carrier Card



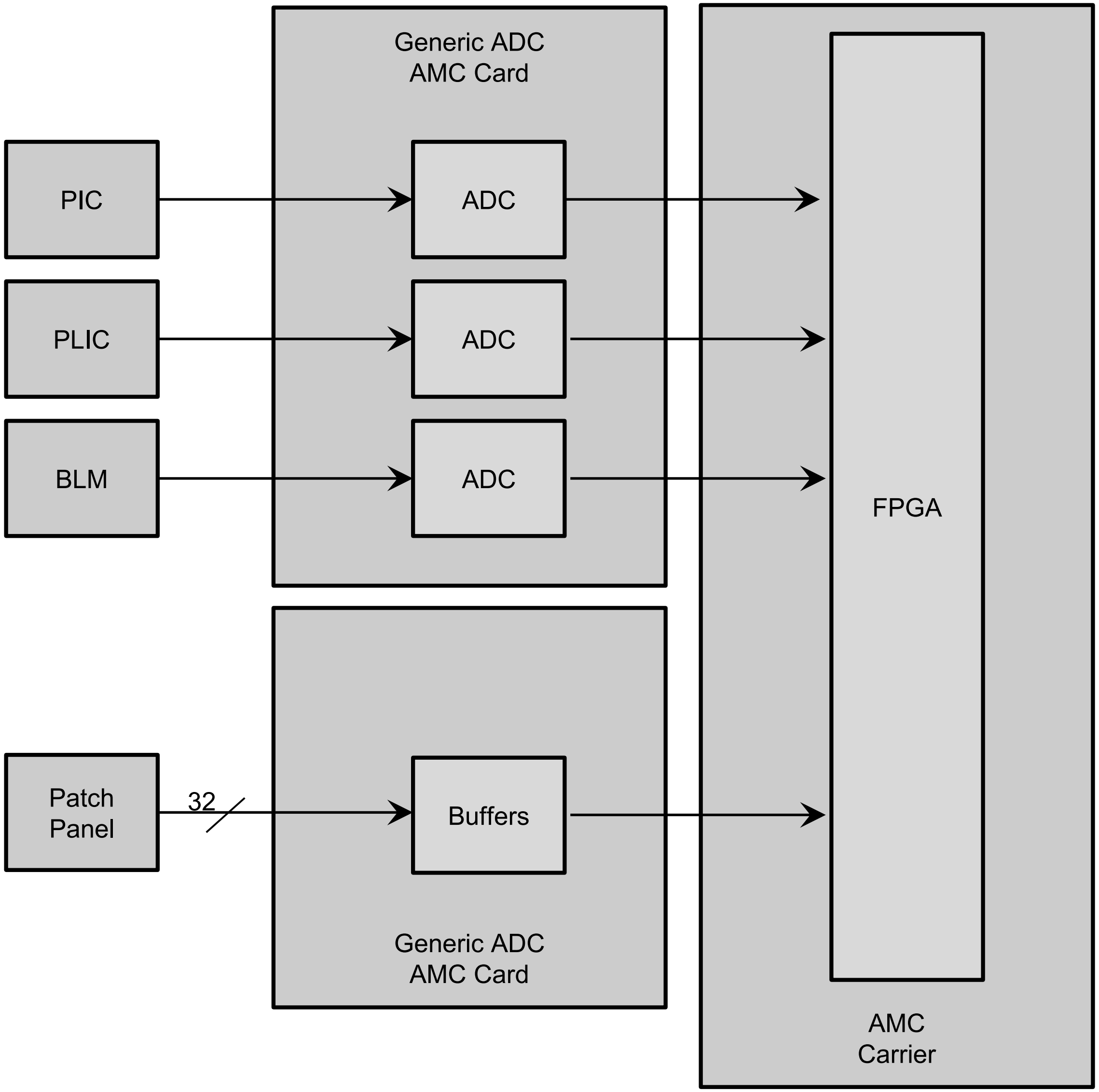
Interface to the common platform is the embedded timing receiver firmware and software to execute common acquisition functions.

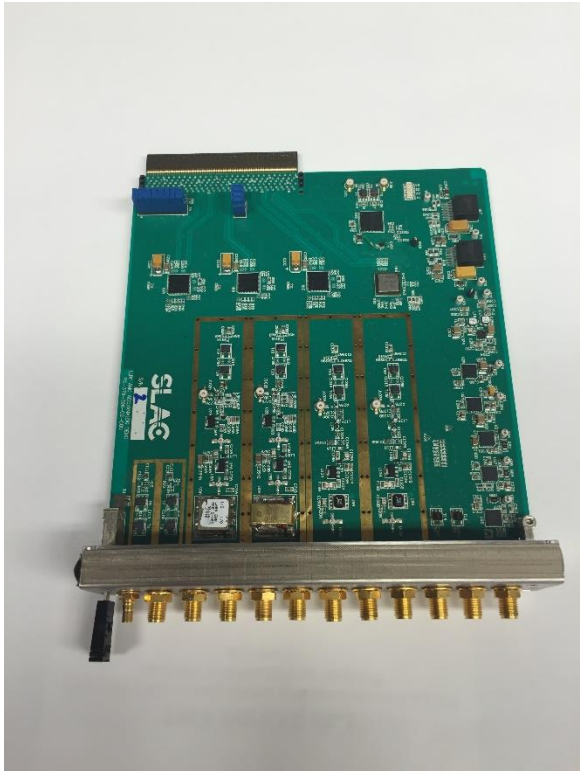
Stripline and Cold Button BPM: Common Platform Design

Two BPMs serviced by a single Common Carrier Board

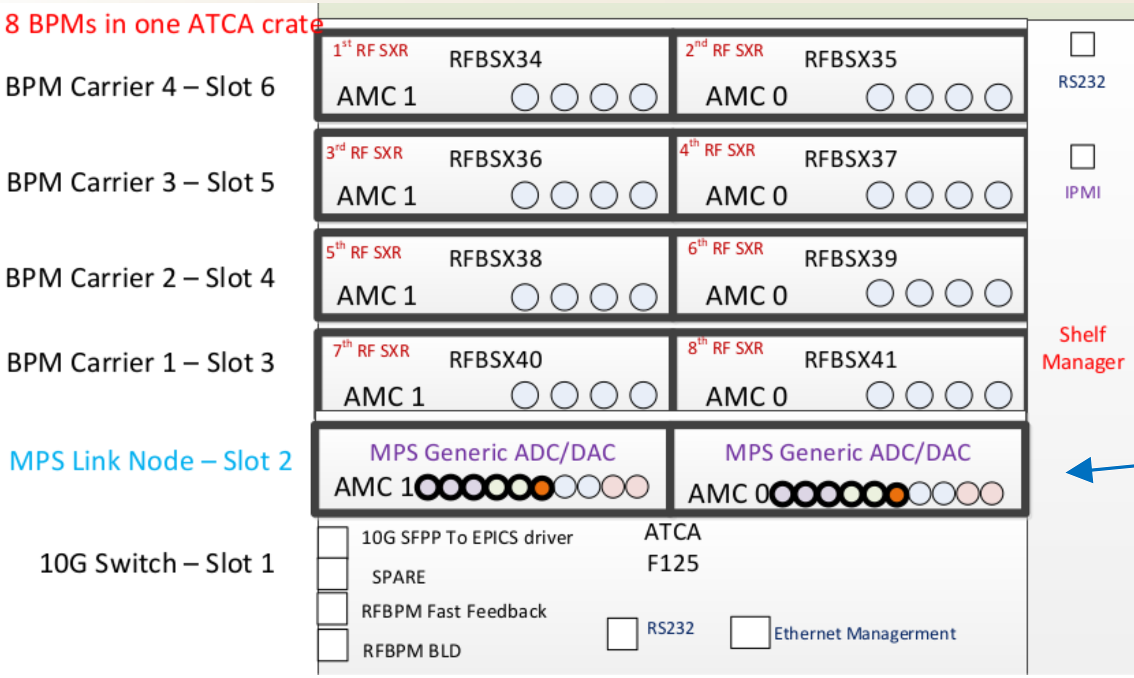


MPS Input Processing: Common Platform





MPS Chassis Example



Example deployment with 8 BPMs and 6 MPS beam loss monitors

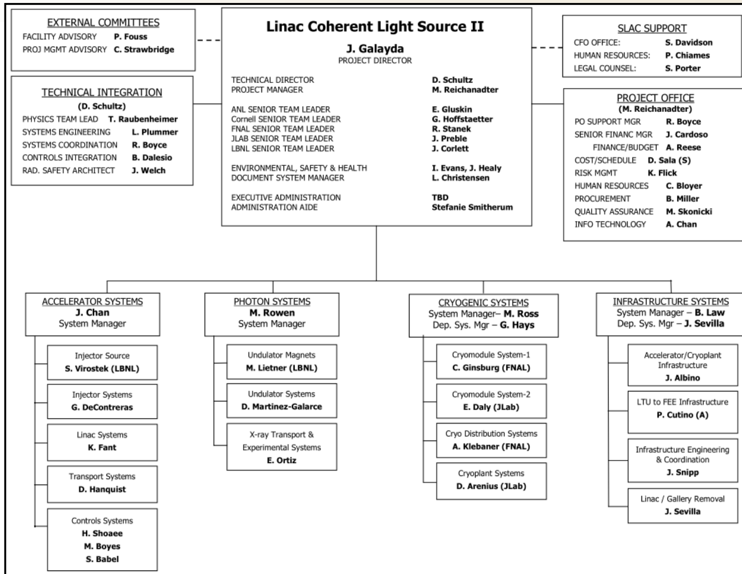
MPS link node card with BLMs

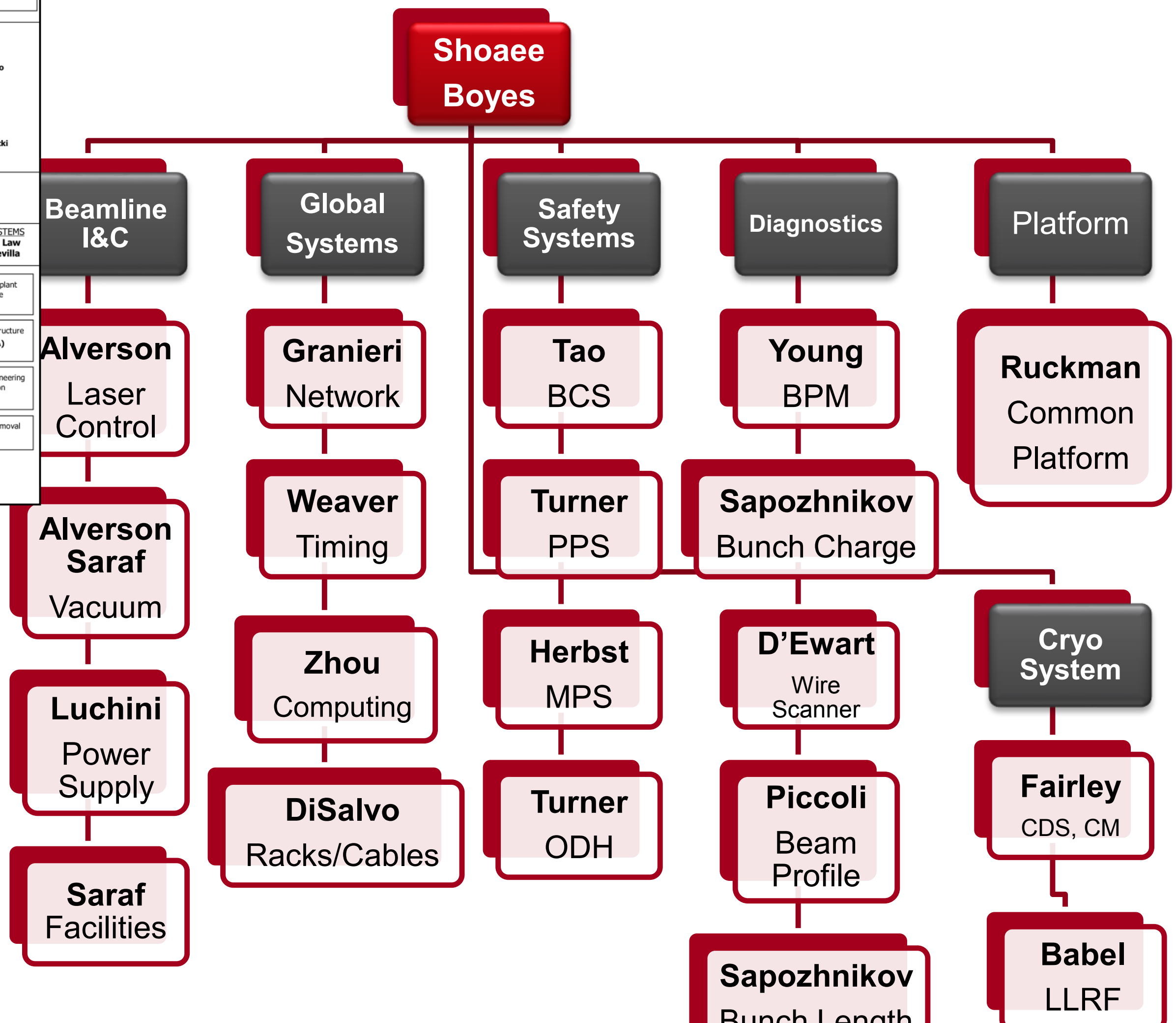
ASIS 7 slot ATCA crate
Possible to support 10 BPMs plus MPS link node in 6U

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

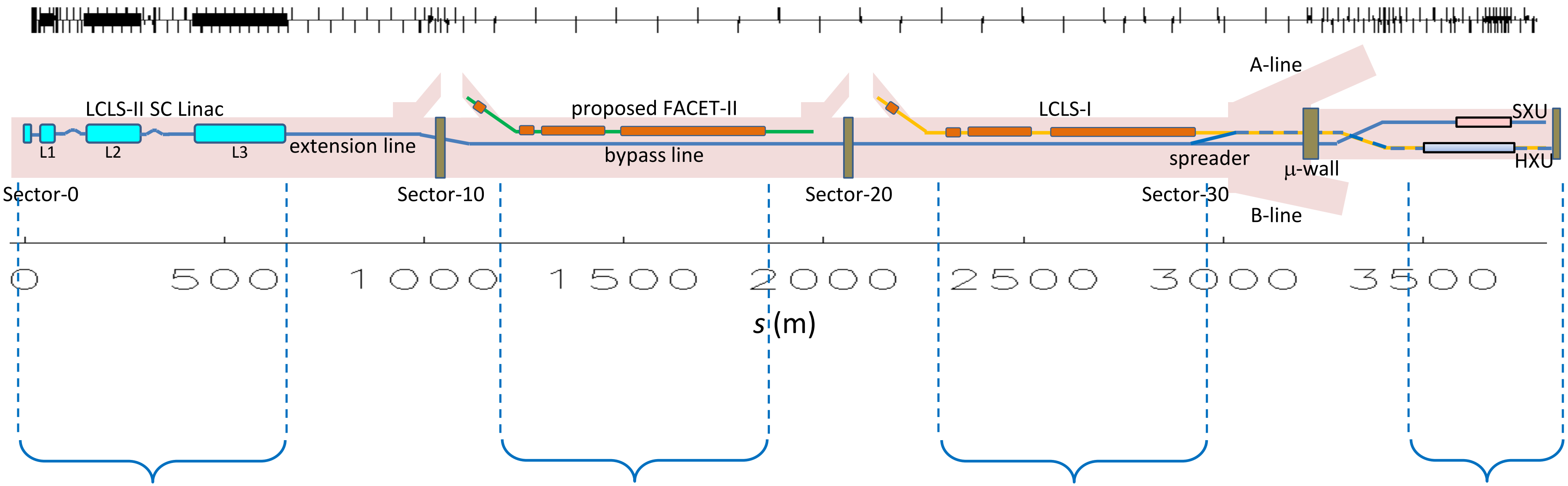




Backup Slides

LCLS-II Layout in SLAC Linac Tunnel

(only approximately to scale)



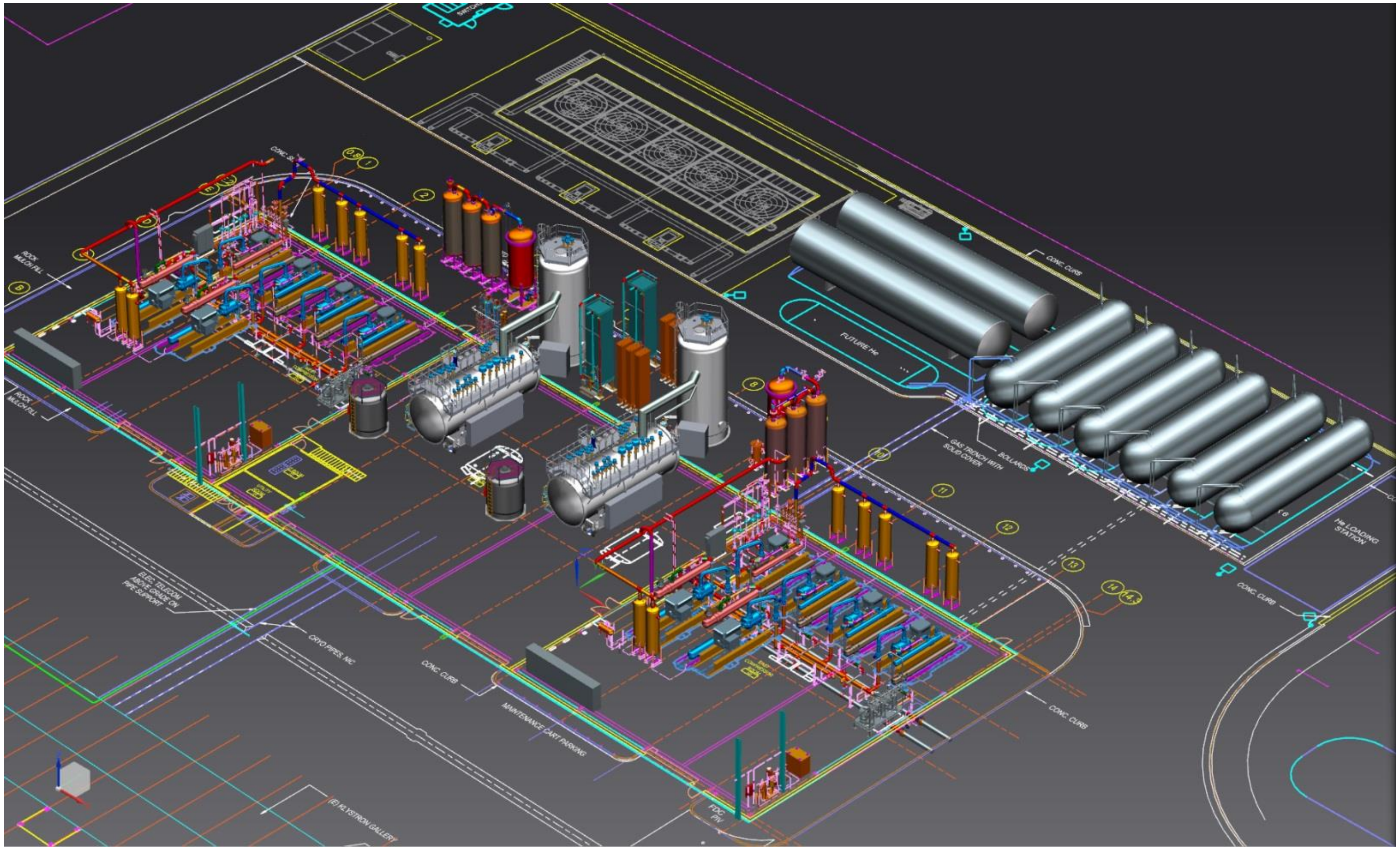
New SCRF Linac (4 GeV)

Proposed FACET-II and Bypass Line

Existing LCLS-I

Undulators (LCLS-I & -II)

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 — EXPLORING THE NATURE OF MATTER

- 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 — Founded A.D. 1865

- R&D planning, prototype support
- processing for high-Q (high Q gas doping)
- e^- gun option

Key Performance Parameters

Performance Measure	Threshold	Objective
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
Electron bunch repetition rate	93 kHz	929 kHz
Superconducting linac charge per bunch	0.02 nC	0.1 nC
Photon beam energy range	250–3,800 eV	200–5,000 eV
High repetition rate capable end stations	≥ 1	≥ 2
FEL photon quantity (10^{-3} BW)	$5x10^8$ (10x spontaneous @2,500 eV)	> 10^{11} @ 3,800 eV
Normal conducting linac-based system		
Normal conducting linac electron beam energy	13.6 GeV	15 GeV
Electron bunch repetition rate	120 Hz	120 Hz
Normal conducting linac charge per bunch	0.1 nC	0.25 nC
Photon beam energy range	1,000–15,000 eV	1,000–25,000 eV
Low repetition rate capable end stations	≥ 2	≥ 3
FEL photon quantity (10^{-3} BW[a])	10^{10} (lasing @ 15,000 eV)	> 10^{12} @ 15,000 eV

[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