

LCLS-II Helium Refrigeration System:

A comprehensive overview of the project

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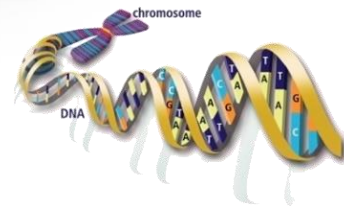
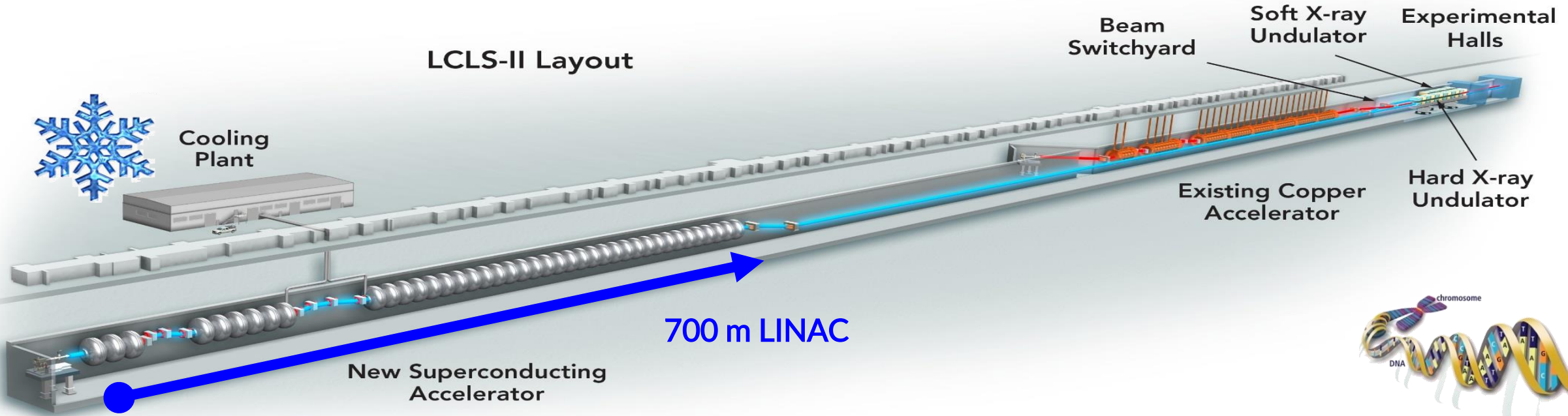
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LCLS-II Cryogenics Division Deputy Director

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- LCLS-II Overview
- Organization
- Staffing
- Schedule
- Budget
- Procurement
- Summary

LCLS-II Overview

LCLS-II Layout

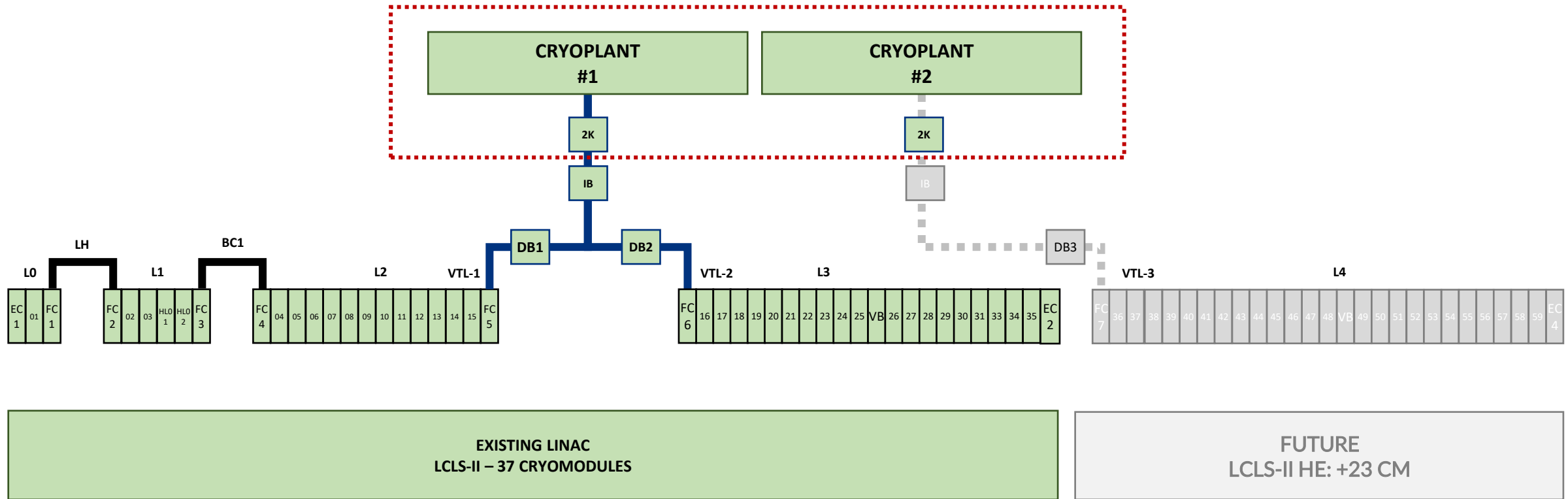


LCLS-II ELECTRON ACCELERATOR



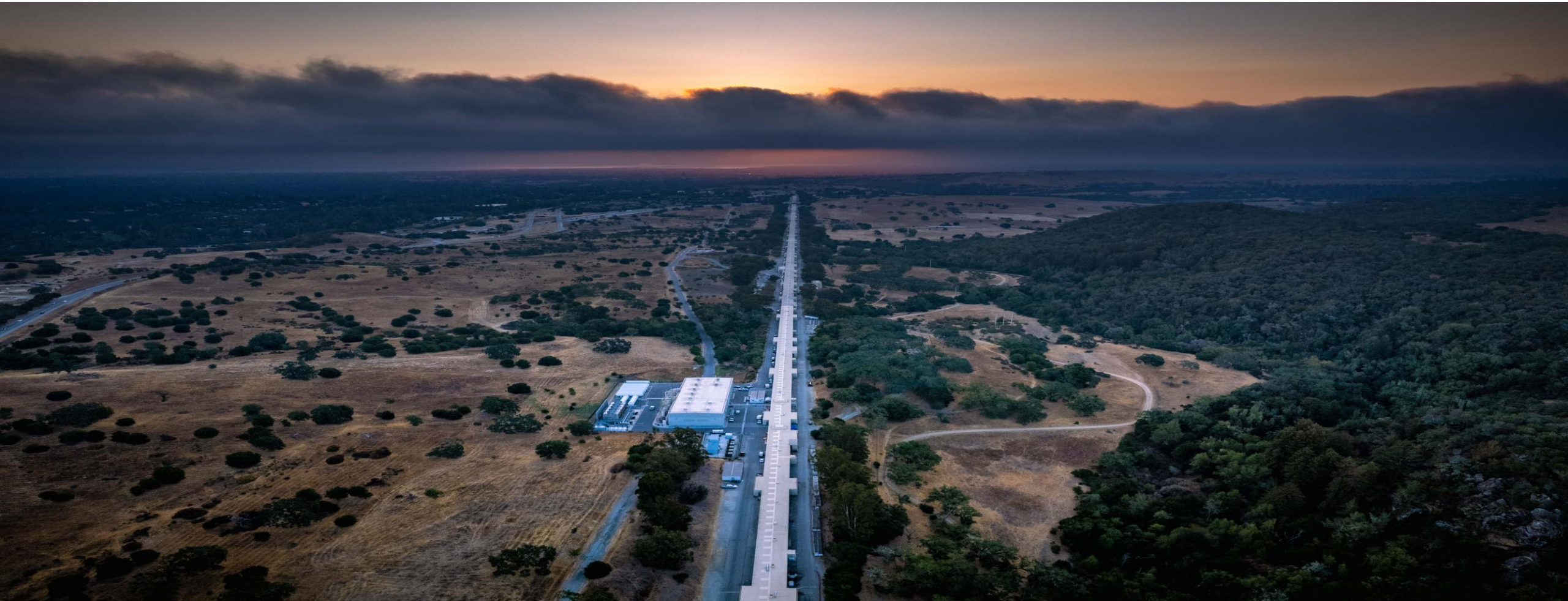
Science

LCLS-II Overview: Cryogenic System



CRYOPLANT STATUS: All Components have been fully tested, CP1 to serve LCLS-II and CP2 to serve LCLS-II HE.

LCLS-II Overview: Cryogenic System



LCLS-II Overview: Cryogenic System



Linear Accelerator:

- 35x 1.3 MHz Cryomodules
- 2x 3.9 MHz Cryomodules

Distribution System:

- Interface Boxes
- Distribution Boxes
- Transfer Lines
 - Surface
 - Vertical
 - Tunnel
- Linac Components:
 - 6x Feed Caps
 - 2x End Caps

NOT COVERED



Infrastructure:

- Building
- Electrical
- Cooling Water

Cryoplant:

- 2x 4K Plant + 2K Plants
Providing ~ 2x 4.0 kW @ 2.0 K.

Auxiliaries:

- Recovery System
- He & N2 Storage

Controls

LCLS-II Overview: Cryogenic Plant



Cryoplant Building

~1900 m², L= 75m, W= 25m, H= 11m

Cooling Water

~10 MW, 1,000 m³/h
4 Towers + 1 Spare, 2 Pumps + 1 Spare

Electrical

2x 15 kV Feeders (Redundant)
4x 4.16 kV, 10 MVA Transformers (Redundant)
MCC with Soft Starters

LCLS-II Overview: Cryogenic Plant



Storages shared between the two Cryoplants:

- LN2 2x 80 m3 → Covers > 6 days of Operation.
- GHe 6x 110 m3
- LHe 2x 10 m3

LCLS-II Overview: Cryogenic Plant



Two Cryoplants, each equipped with HOWDEN 321-193 Screw Compressors:

- LP Compressors: 3x 600 kW
- MP Compressor: 1x 800 kW
- HP Compressor: 1x 1,800 kW
- Swing Compressor: 1x 1,800 kW [Stand-by]

Total Installed: 6,200 kW / Cryoplant
Nominal Consumption: 3,600 kW / Cryoplant

LCLS-II Overview: Cryogenic Plant



Two Cryoplants, each equipped with 4.5 K Cold Box and 2.0 K Cold Box:

- 4.5 K Cold Box: LN2 Pre-Cooled: ~ 18 kW eq. @ 4.5 K / each.
- 2.0 K Cold Box with 5 Cold Compressors: ~ 4.0 kW @ 2.0K, 230 g/s / each.

LCLS-II Overview: Cryogenic Plant



Purification System shared between the two Cryoplants:

- Recovery Compressors: 2x 20 g/s
- Purifier: 1x 40 g/s with dual beds.

Project Organization



LCLS-II Cryoplant Project Organization



DESIGN

- **Basic Design**, used for few design and build components [4K Cold Box]
- **Detailed Design**, used for numerous built to print components [compressors, oil removal, 2K Cold Boxes, etc.]

EQUIPMENT PROCUREMENT

- JLAB managed equipment procurements from contract award to delivery at SLAC



INFRASTRUCTURE:

- **Building**: including HVAC, overhead cranes, etc.
- **Utilities**: electrical switchyard and cooling water towers

INSTALLATION:

- **General Contractor** to execute the installation of all interconnecting piping, tubing and wiring
- **Lifting and Rigging** to receive store and set-in place components before General Contractor onboarded

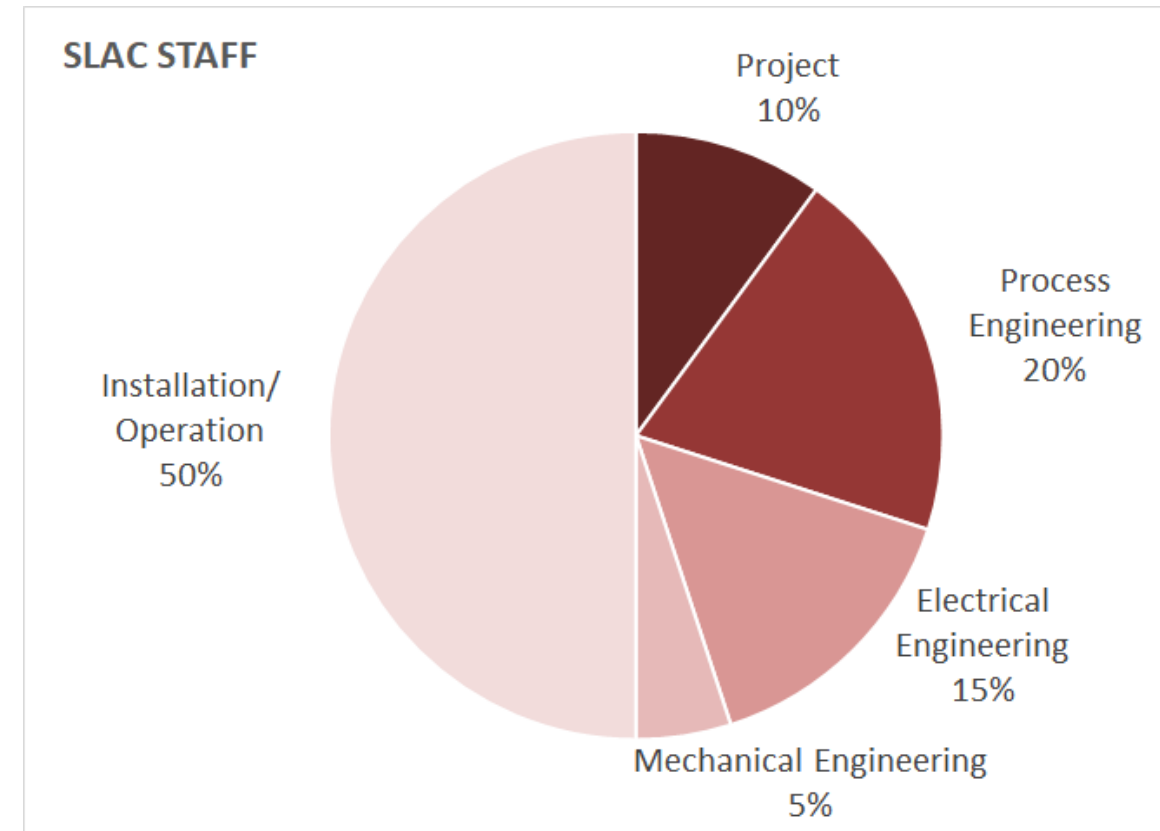
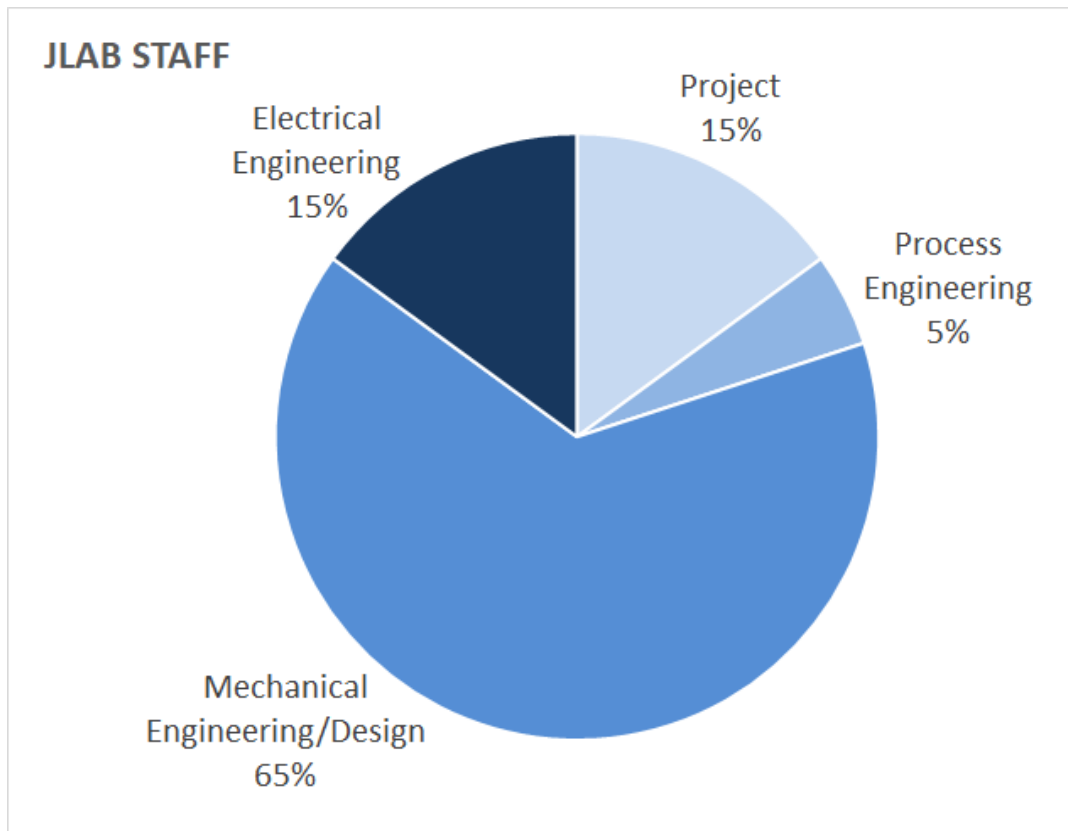
PROCESS CONTROL:

- Process Controls, Functional Analysis and PLC Code
- Human Machine Interface, EPICS Based

COMMISSIONING :

- Some Vendor's onsite support
- Jefferson Lab remote support

LCLS-II Cryoplant Organization: Staffing



JLAB: Design & Procurement: 2015~2019

- Basic Design ~ 5
- Average ~ 15
- Detail Design ~ 55 at peak

~140,000 h

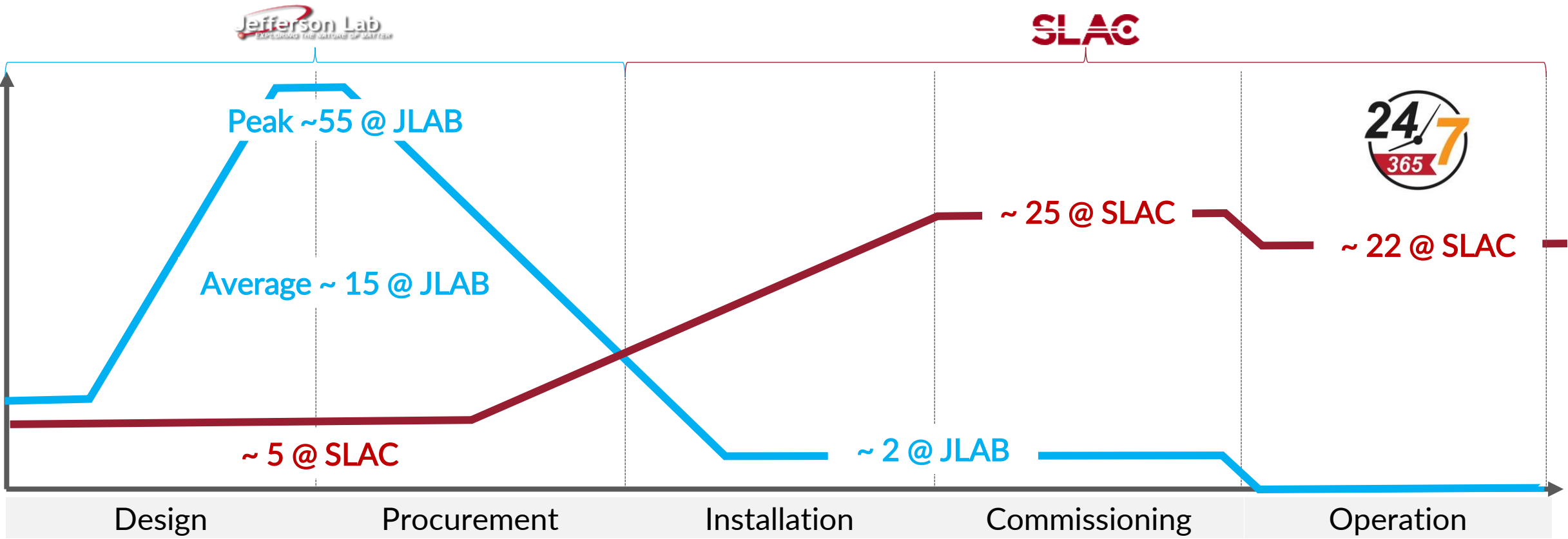


SLAC: Installation & Commissioning

- Average ~ 5 during Design 2015~2018
- Average ~ 15 during Instal. & Comm. 2019~2023

~140,000 h

LCLS-II Cryoplant Staffing Profile



- Design & Procurement: Led by Partner Laboratory.
- Installation & Commissioning: Led by Host Laboratory.

→ Built integrated Project Team whenever possible to ensure a smooth transition.
 5 SLAC Staff were positioned at JLAB during the design phase.

MULTI LABORATORY PROJECTS:

- Pros: Leverage talent and expertise across multiple institutions.
- Cons: Challenges in project management, resources are not centrally controlled.

These Multi Laboratories Collaborations are essential to Multi-Billion Dollar Projects,
But they bring by design complexity to project management that should not be underestimated.

LCLS-II is 100% funded by the US Department of Energy [DOE]
Host laboratory controls the funds and partner laboratories are reimbursed for all costs.

LCLS-II Cryoplant Schedule



2016 – Green Field



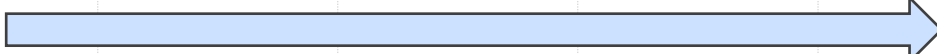
2023 - End of Commissioning

LCLS-II Cryoplant Schedule

Design: 4 Years



Procurement: 4 Years



Building Construction: 1.5 Years



Installation: 2.5 Years



Commissioning: 3.5 Years



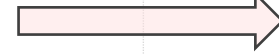
Auxiliaries: 1.5 Year



CP#1: 1.0 Year



LINAC: 0.5 Year



CP#2: 0.5 Year



Jefferson Lab
EXPLORING THE NATURE OF MATTER

SLAC

JLAB Led

SLAC Led



9 Years from Inception to End of Commissioning

LCLS-II Cryoplant Schedule: 9 Years End to End

- **Basic Design** ~ 2.0 years
Maturity was sufficient for Long Lead Procurements and Building Construction.
- **Detail Design** ~ 2.0 years
Started after Basic Design, in parallel with Building Construction and Long Lead Items procurements.
- **Procurements** ~ 4.0 Years
Started after Basic Design, Many significant delays from Vendors with significant impact on schedule.
- **Building Construction** ~ 1.5 years
Started in parallel with Procurement, some foundations details were required to complete execution.
- **Installation** ~ 2.5 years
Started after Detailed Design and after Building completion, but in parallel with procurement, Synchronization of Installation and Logistics [Storage, Deliveries] is essential.
- **Commissioning** ~3.5 years
Started in parallel with Installation - introducing complexity and risks, careful synchronization was required.
 - Utilities & Auxiliaries: Water, Elec., Storages, Purifier, Recovery ~ 1.5 year
 - Cryoplant #1: Compressors, Oil Removal, 4K Cold Box ~ 1.0 year
 - LINAC: Conditioning, Cool-Down to 4K, Pump-Down to 2K ~ 0.5 year
 - Cryoplant #2: Compressors, Oil Removal, 4K Cold Box ~ 0.5 year

LCLS-II Cryoplant Procurement



SCOPE



PROCUREMENTS [Summary, over 50 separate procurements]

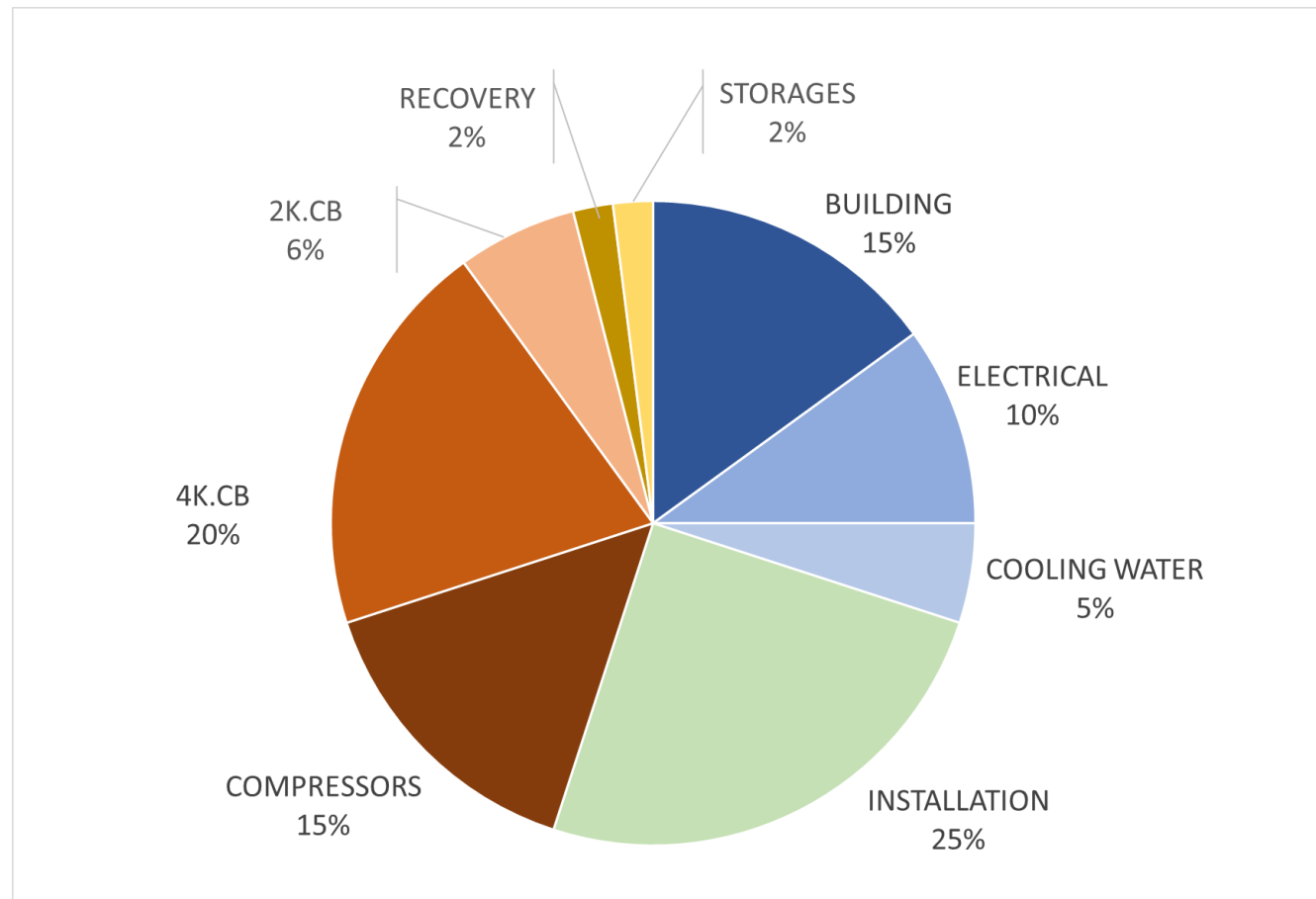
COMPRESSORS	Compressor Skids	Oil Removal	Valve Panels	Oil Processor
4K COLD BOX	4K Cold Boxes	Atmospheric Heaters	Conditioning System	Test Bench
2K COLD BOX	2K Cold Box #1 Vendor A	2K Cold Box #2 Vendor B	2K Cold Compressors	Vacuum Groups
AUXILIARIES	Recovery Compressors	Helium Purifier	Secondary Water	Vacuum Guard
STORAGES	Liquid He Storage	Liquid N2 Storage	Gas He Storage	Cryogenic Lines
CONTROLS/UTILITIES	Electrical Cabinets	Instrument Air Compressors	Instrument Air Storage	

Build to Spec.	-
Build to Print.	-

DESIGN & PROCUREMENT STRATEGY

- Cryoplant design based on existing facility (JLAB – CHL-2 12 GeV)
 - Based most procurements on Build-To-Print principle.
 - Did award the Cryoplant contracts to multiple vendors.
- **PROS**
 - Maintain and develop cryogenic expertise within the DOE complex.
 - Lower procurements costs.
 - Limit vendors risk exposure and design efforts.
 - **CONS**
 - Significant number of Interfaces to be managed.
 - Significant integration, engineering and design costs.
 - Significant procurement and contract management effort.

LCLS-II Cryoplant Budget



For the two CRYOPLANTS:

- Costs ~ 110 M\$ for Materials and Services
- Labor ~ 280,000 hrs SLAC & JLAB not included in above cost.

LCLS-II Cryoplant Project Summary

ORGANIZATION:

- Multi DOE Laboratories Project; Essential to build integrated project teams
- Funded by DOE only; No in-kind procurement

BUDGET:

- ~ 280,000 hrs of SLAC & JLAB Labor for Design, Installation and Commissioning Efforts
- ~ 110 M\$ of Procurement Costs for 2 Cryoplants
- ~ 60% of Procurement Costs for Infrastructure and Installation

STAFFING:

- Design & Procurement: ~20 with average / ~60 during detailed design peak.
- Commissioning & Operation: ~22 with 24/7 Operation.

SCHEDULE:

- 2014-2016: Basic Design
- 2016-2018: Detailed Design
- 2016-2020: Procurement
- 2018-2020: Installation
- 2019-2023: Commissioning

PROCUREMENT:

- No single contractor: design, installation, controls and commissioning by JLAB and SLAC
- Large number of contracts: compressors, oil removal system , 4K boxes, 2K boxes...



Thank you

... and a special thanks to all team members
who made this project a success!