LCLS-II Helium Refrigeration System:

A comprehensive overview of the project

Author: Eric Fauve
LCLS-II Cryogenics Division Director

Presenter: Dirk Pflueckhahn
LCLS-II Cryogenics Division Deputy Director

CEC-ICMC 23
Outline

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

**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

**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

**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
Storages shared between the two Cryoplants:

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

**SLAC: Installation & Commissioning**
- Average ~5 during Design 2015~2018
- Average ~15 during Instal. & Comm. 2019~2023

~140,000 h
• 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

9 Years from Inception to End of Commissioning

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

- **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

<table>
<thead>
<tr>
<th>COMPRESSORS</th>
<th>4K COLD BOX</th>
<th>2K COLD BOX</th>
<th>AUXILIARIES</th>
<th>STORAGES</th>
<th>CONTROLS/UTILITIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor Skids</td>
<td>Oil Removal</td>
<td>Valve Panels</td>
<td>Oil Processor</td>
<td>4K Cold Boxes</td>
<td>Atmospheric Heaters</td>
</tr>
<tr>
<td>2K Cold Box #1 Vendor A</td>
<td>2K Cold Box #2 Vendor B</td>
<td>2K Cold Compressors</td>
<td>4K Cold Boxes</td>
<td>Helium Purifier</td>
<td>Secondary Water</td>
</tr>
<tr>
<td>Recovery Compressors</td>
<td>Liquid He Storage</td>
<td>Liquid N2 Storage</td>
<td>Gas He Storage</td>
<td>Electrical Cabinets</td>
<td>Instrument Air Compressors</td>
</tr>
</tbody>
</table>

### PROCUREMENTS [Summary, over 50 separate procurements]

- **Build to Spec.**
- **Build to Print.**
LCLS-II Cryoplant Procurement

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!