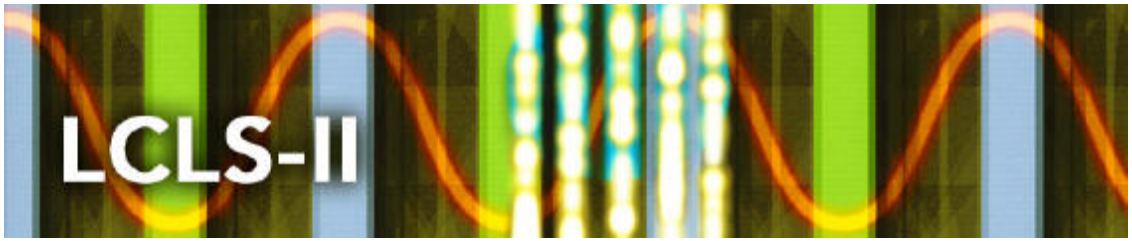


Status of the Low Energy Recirculation Facility (LERF) for LCLS-II CM Test Facility

K. Jordan, C. Hovater, J, Gubeli, W. Moore, J. Henry + team

20-OCT-2017

SLAC NATIONAL ACCELERATOR LABORATORY
BERKELEY LAB Lawrence Berkeley National Laboratory
Argonne NATIONAL LABORATORY
CORNELL UNIVERSITY FOUNDED A.D. 1865
Fermilab
Jefferson Lab

U.S. DEPARTMENT OF ENERGY
Office of Science

Outline

- FEL/LERF History
- Scope of effort
- Cryomodule connections
- Gallery / SSA Connections
- Computer & network infrastructure
- Summary

FEL/LERF History

Realization: the CEBAF CW SRF linac was a game-changer, not only for particle physics but for all high power applications (e.g., FELs, neutron sources)

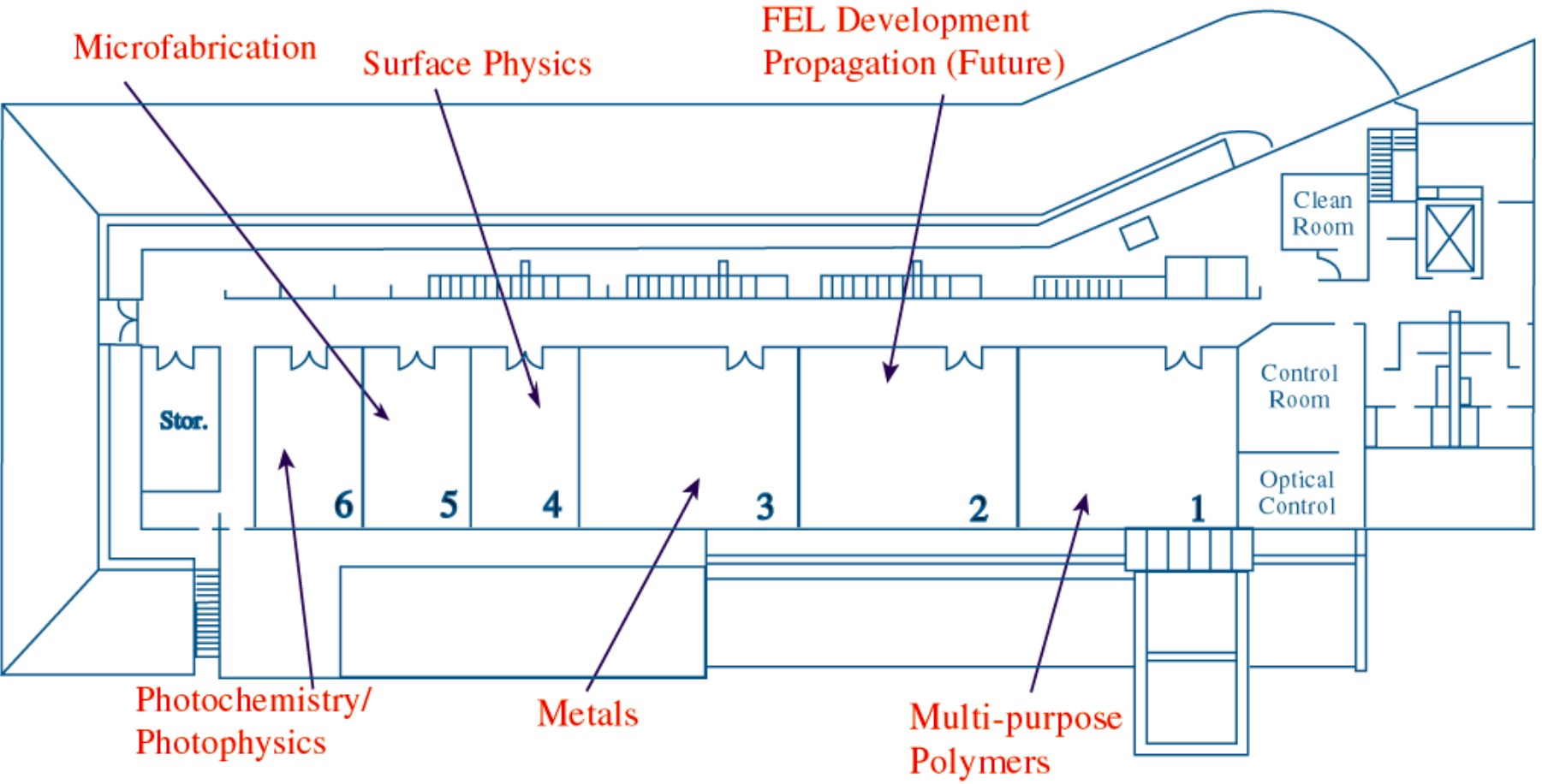
1990: "Applied Research and Technology " grant from VA's CIT
1991: First Design for standalone kilowatt class IR-UV FEL
1994: Reference Design completed for expanded collaboration:
"The Laser Processing Consortium"
1994: Submitted to DOE/DOC for $25m with $10m of partner $
(didn't make the cut ~ 0.1% of proposals funded)
1995: Project reviewed by NASA for DOE
Sec. O'Leary: "*great project, a model for the nation*"
"…good luck in finding the money"…
1995: With help from NPS and VA Congressional delegation,
$10M in FY 96 appropriation to Navy Research

IR FEL Demo Project Launched (1996)

- 1 kW IR FEL using spare cryomodule parts donated by DOE-NP
- Multipurpose FEL Facility and User Labs built with VA funds
- Cliffhanger: delayed federal funds due to FY96 shut-down; federal funds arrived shortly before VA funds disappeared
- Construction project compressed to 18 months (including 14 reviews)

FEL Team celebrating the "kilowatt prize"

FEL Facility User Lab



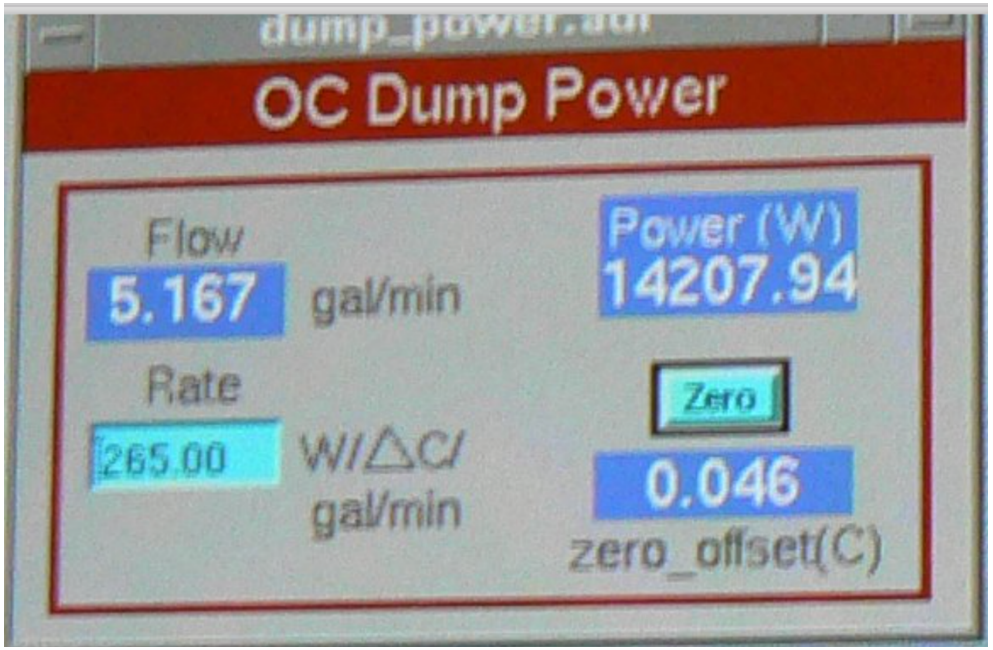
6600 ft^2 User Labs
40'x240' FEL Vault

On to the IR Upgrade

2001 - 2006

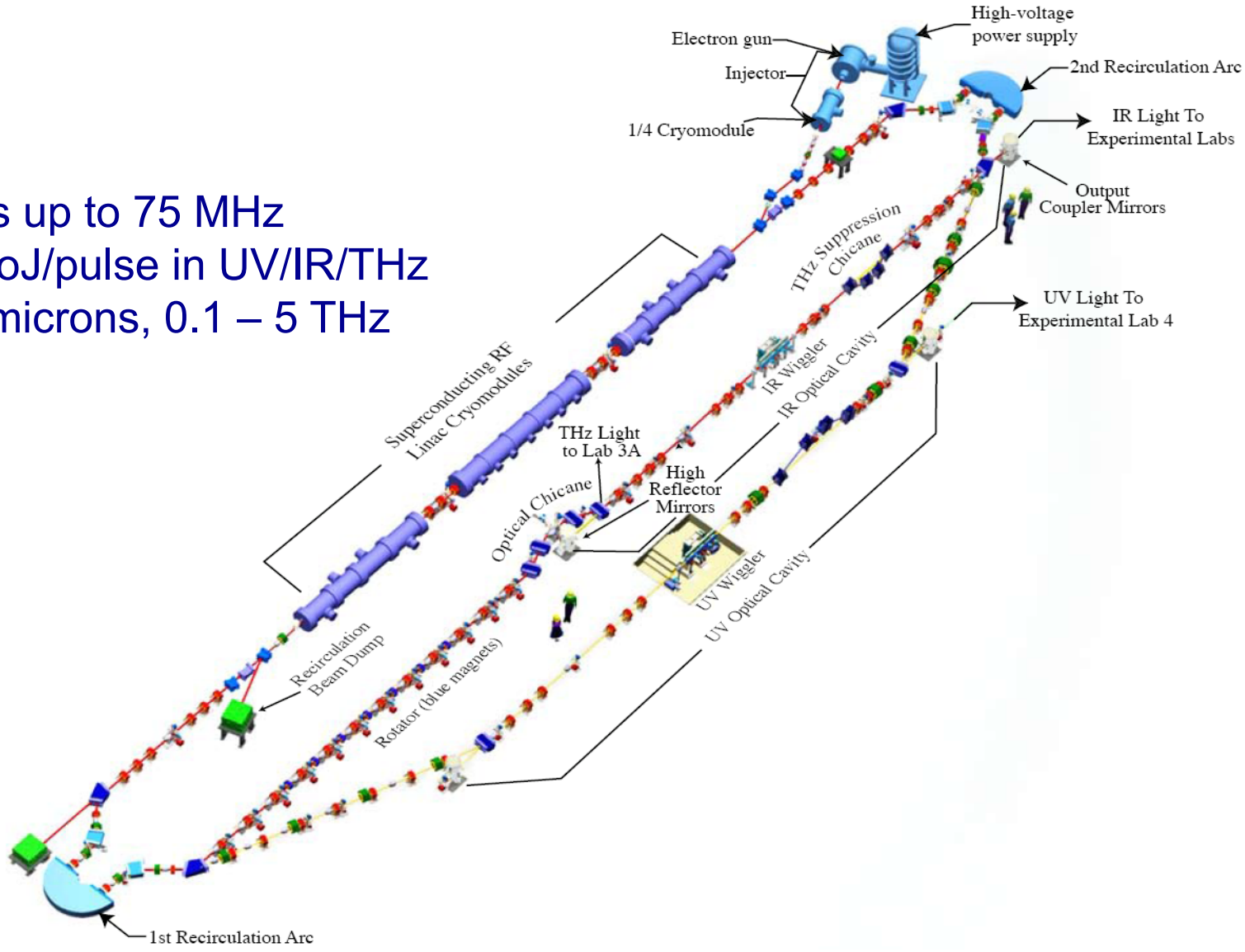
- Navy provides significant funding for upgrade of FEL to 10kW
- VA and collaborators continue to support FEL user operations
- ARO provides support for THz
- AFOSR provides support for UV Demo

The Power Record (still holds)



Jlab IR/UV ERL FEL

E = 120 MeV
135 pC pulses up to 75 MHz
20/120/1 microJ/pulse in UV/IR/THz
250 nm – 14 microns, 0.1 – 5 THz

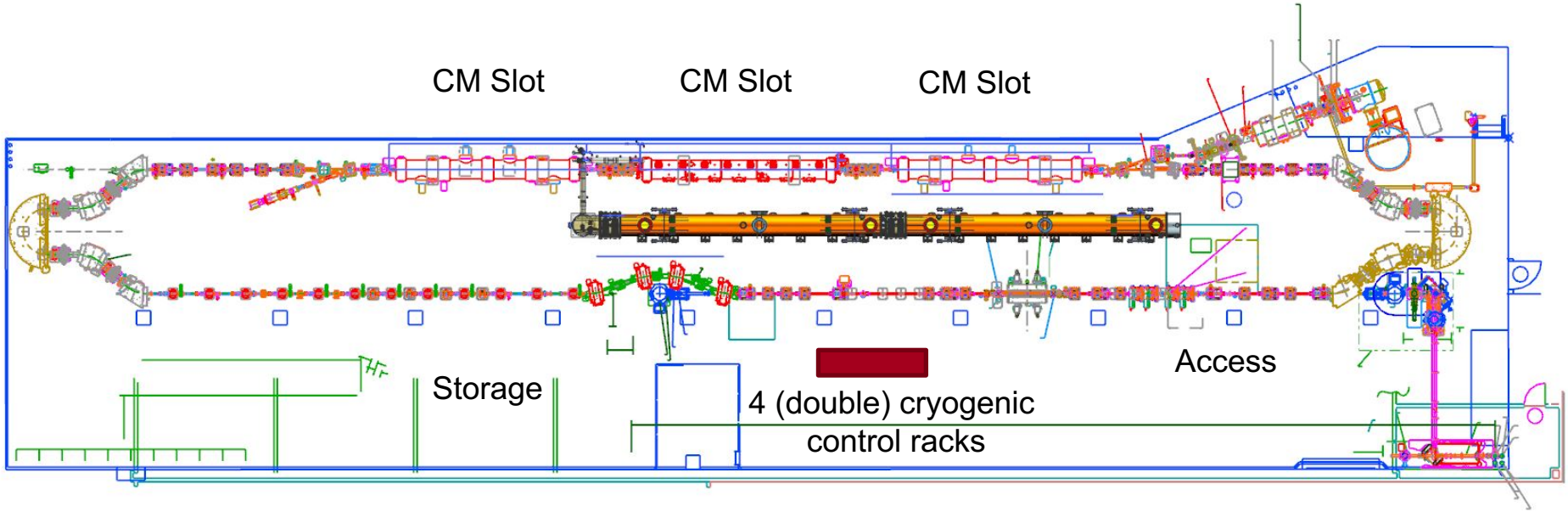


K. Jordan

Scope

- **Removal:**
  - Remove existing waveguide tophats and circulators from gallery
  - Remove 4 quad girders from FEL back leg for access to center of ring
  - Remove 2 existing CMs & store in back of LERF vault
  - Remove and store Darklight solenoid & baseplate in LERF vault
- **Install:**
  - 16 SSAs & LLRF in LERF Gallery
  - Connect to SSAs to existing waveguide that routes to tunnel
  - Install new cables in existing penetrations
  - Duplicate and install (2) AC distribution/PSS/VVU from Test Lab facility
  - Design & build new supply/return 'U-Tubes' for both 2K & shield
  - Develop EPICS based CM testing & commissioning tools
  - Install & commission 16 sets of LCLS LLRF hardware & software
  - Install & commission LCLS based cryo, vacuum & interlock systems
- **Test**
  - Remove shield blocks, roll in 2 modules, reinstall shield blocks
  - Connect 2 CMs together, tie into cryo, hookup tunnel waveguide
  - Cooldown & test
  - Repeat…
- **Restore LERF once CM commissioning is complete**

LCLS-II CM Layout in LERF – Testing 2 CMs per Cycle



- Current machine contains slots for 3 full CMs and 1 Injector CM
- Shielded vault
- Existing PSS including radiation and ODH monitoring
- Utilities include cryogenics, LCW water, N_2 gas, Instrument air, AC power
- Test 2 cryomodules installed in middle of FEL machine

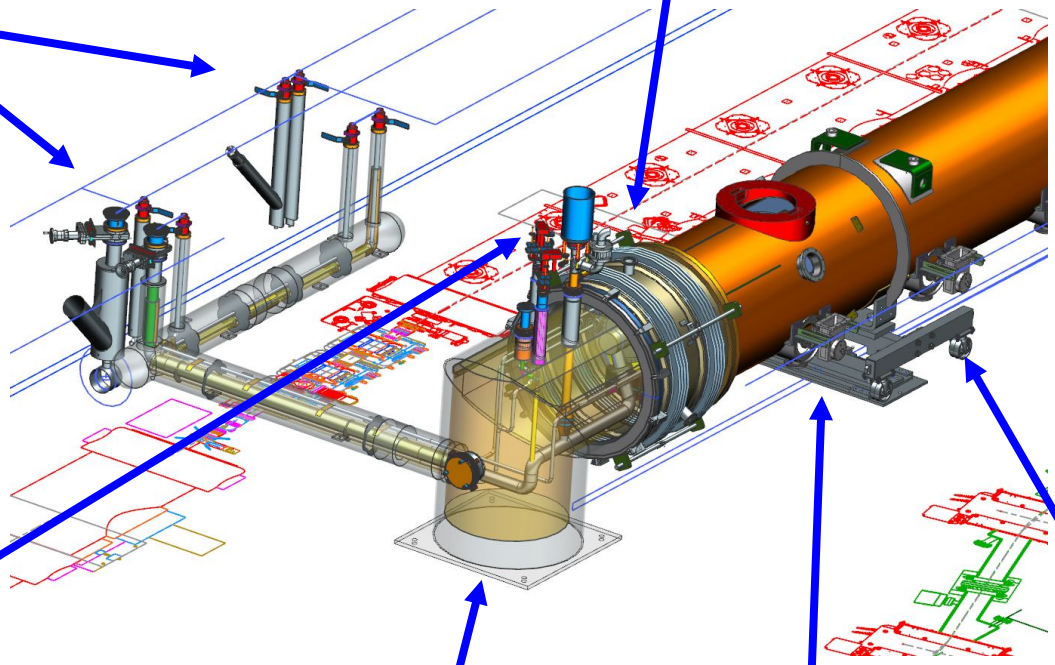
Existing Cryomodule Vacuum being secured

- Clean hoods in place for securing existing beam line vacuum
- First two cryomodule will be removed and third will be relocated to the first position & reconnected as buffer tank for LHe

CEBAF Style Cryomodule as a Test Bed for Q_0 Studies

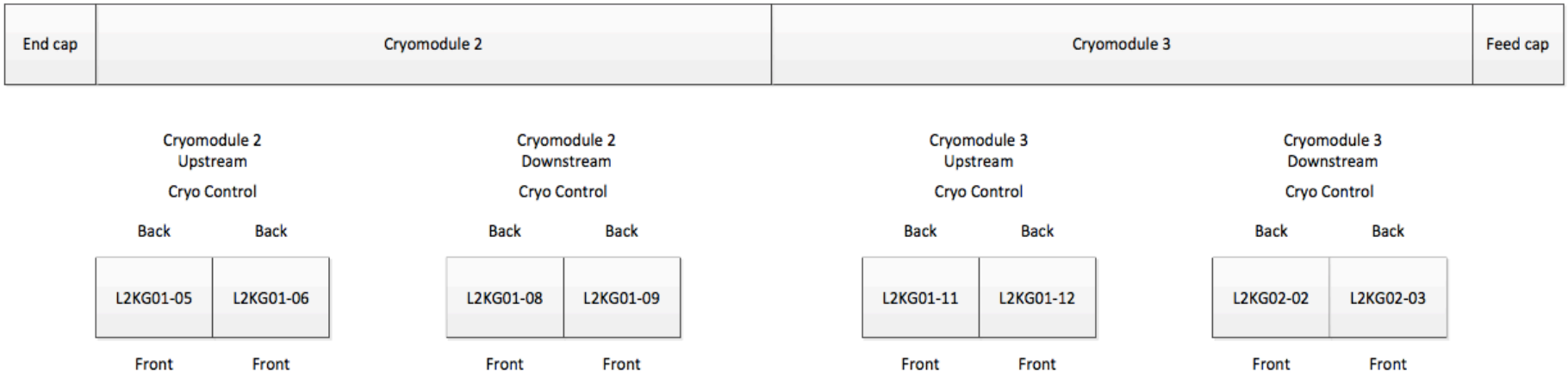
- "Opportunistic" testing of the first CM will be done
  - Baseline Q_0, Degaussed Q_0, Magnetized Q_0, …

End Can & U-tubes – Evolving Design



Instrumentation in Cryogenic Control Racks

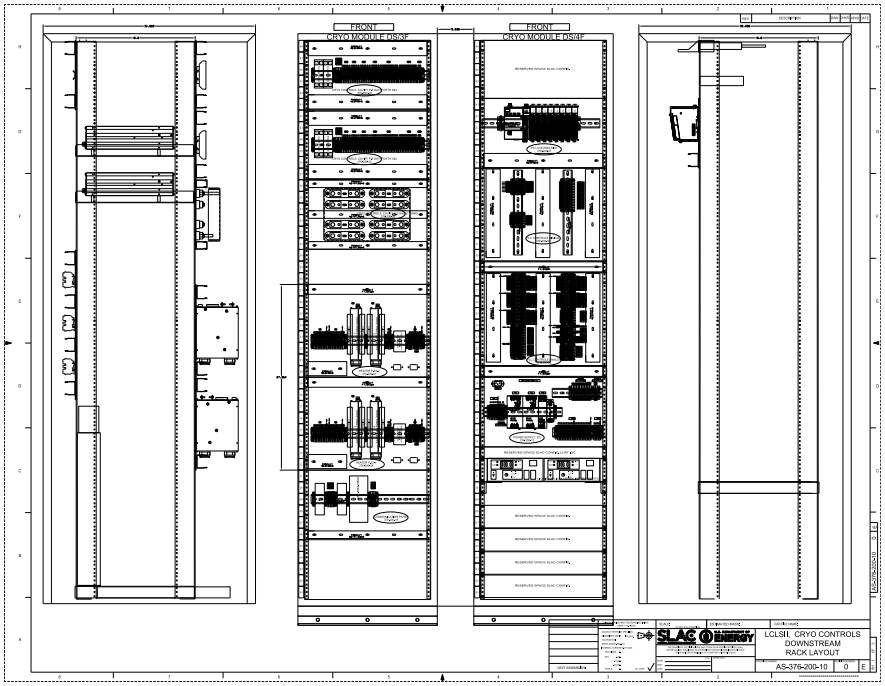
- Temperature, pressure, heater control, liquid level, & valve control…
- End can controls are being addressed
  - 2 x JT controllers, 6 (X2) diodes in supply cap, 2 (X2) diodes in return cap and mass flow for Q_0 measurements

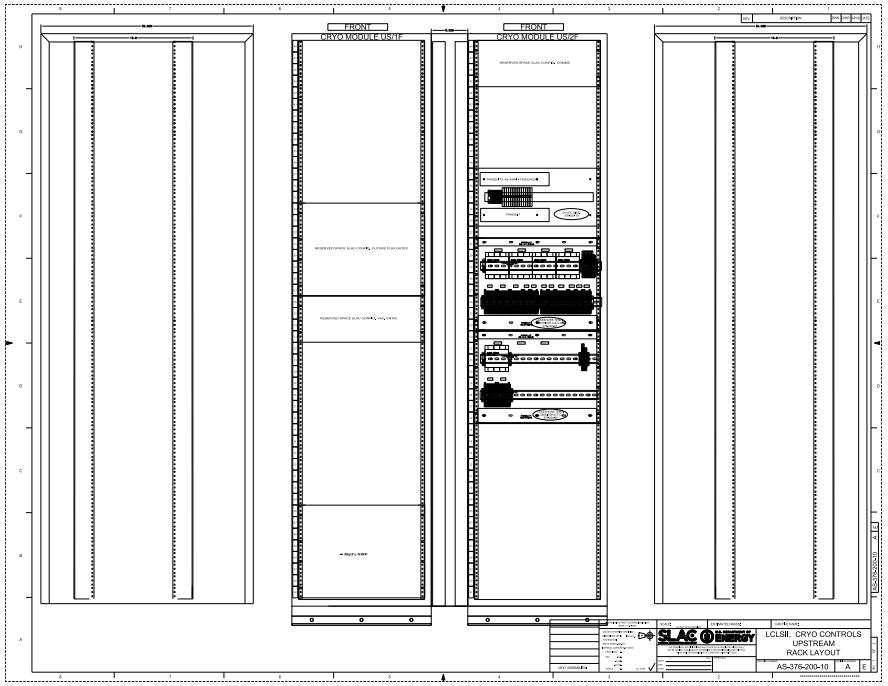


One set of cryogenic control racks

Location for Cryogenic Control Racks

- There are 2 double racks per cryomodule each 48” wide
  - The space in the gallery is “tight”
  - These racks will be located in the vault (next slide)
  - Reduces cable length and installation expense





One set of cryogenic control racks

Location for Cryogenic Control Racks

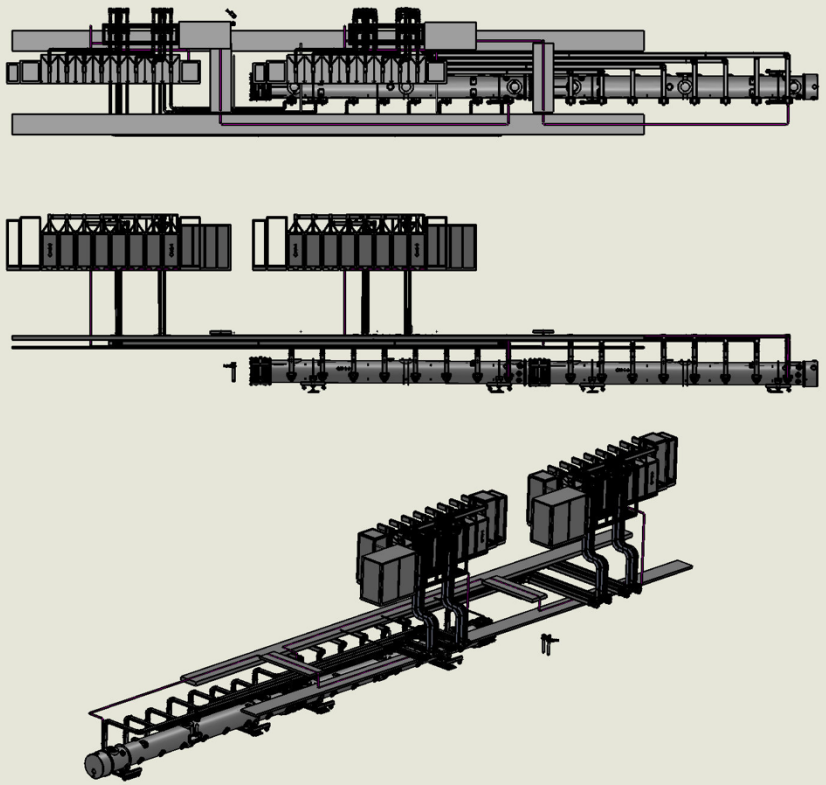
- ‘Nice’ location for cryogenic control racks
  - Wiggler is on wheels; easily moved, need to move addition girder
- Access for 48” x 36” x 8’ racks is no problem

Location for Cryogenic Control Racks

- 5’ clearance in back, 7’ clearance in front
- Portable lead ‘shadow shields for radiation protection

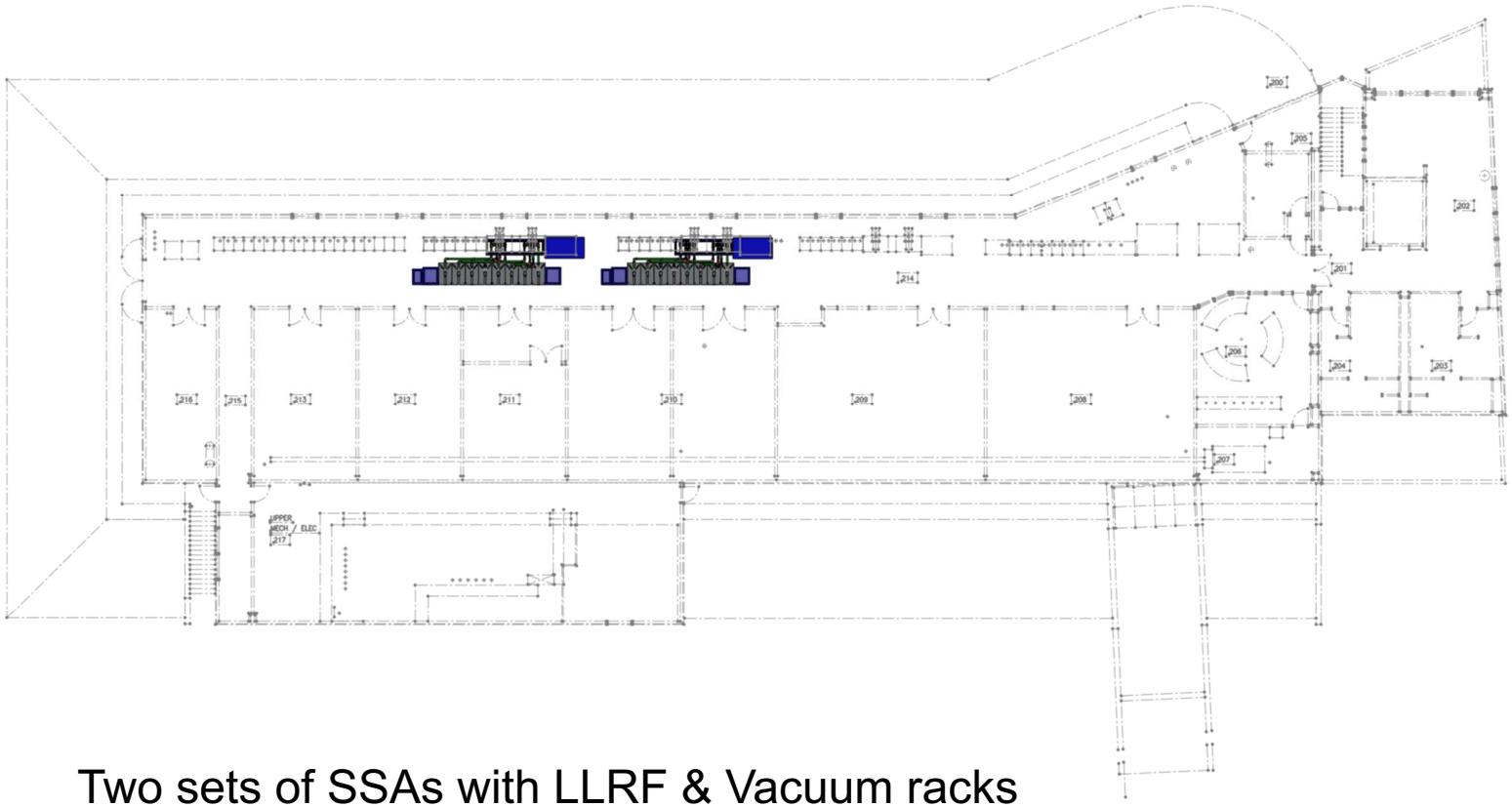
High Power RF – SSA & Waveguide

- Waveguide design complete
  - Design review held 11-Oct-2017, https://wiki.jlab.org/lerf/index.php/Reviews
  - Purchase requisition submitted & signed 16-Oct-2017
  - Will work with vendor to prioritize module # 2 first (up & down)



Item	Length
CM1-1	81'-8.5"
CM1-2	82'-3"
CM1-3	81'-7.5"
CM1-4	87'-4"
CM1-5	89'-9.5"
CM1-6	90'-2"
CM1-7	89'-10.5"
CM1-8	95'-10"
CM2-1	61'-1"
CM2-2	65'-8.5"
CM2-3	73'-10.5"
CM2-4	85'-5.5"
CM2-5	93'-6"
CM2-6	98'-2.5"
CM2-7	106'-6"
CM2-8	118'-1.5"
RF Cable CM1	120'-3"
RF Cable CM2	117'-4"

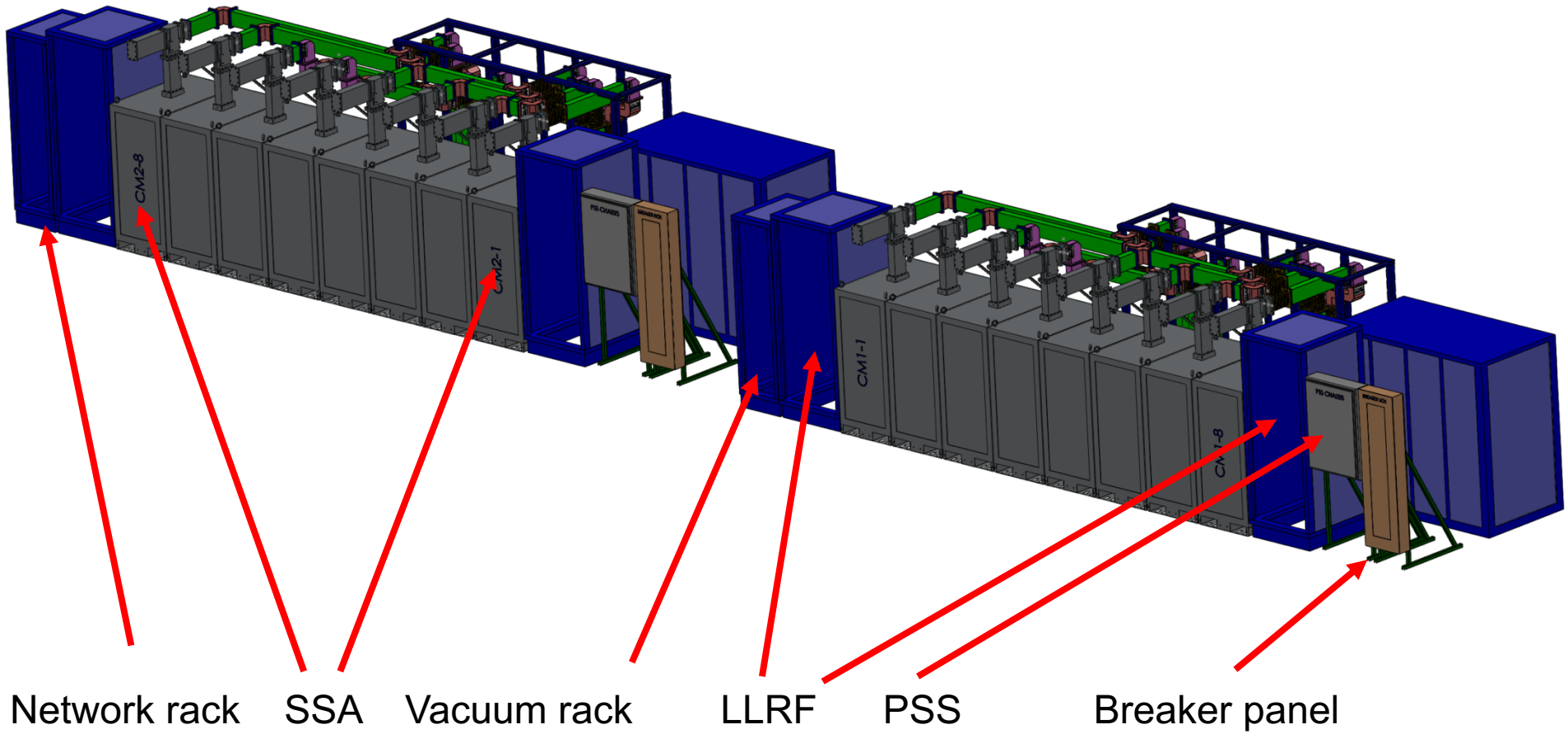
SSA Layout in Gallery



Two sets of SSAs with LLRF & Vacuum racks

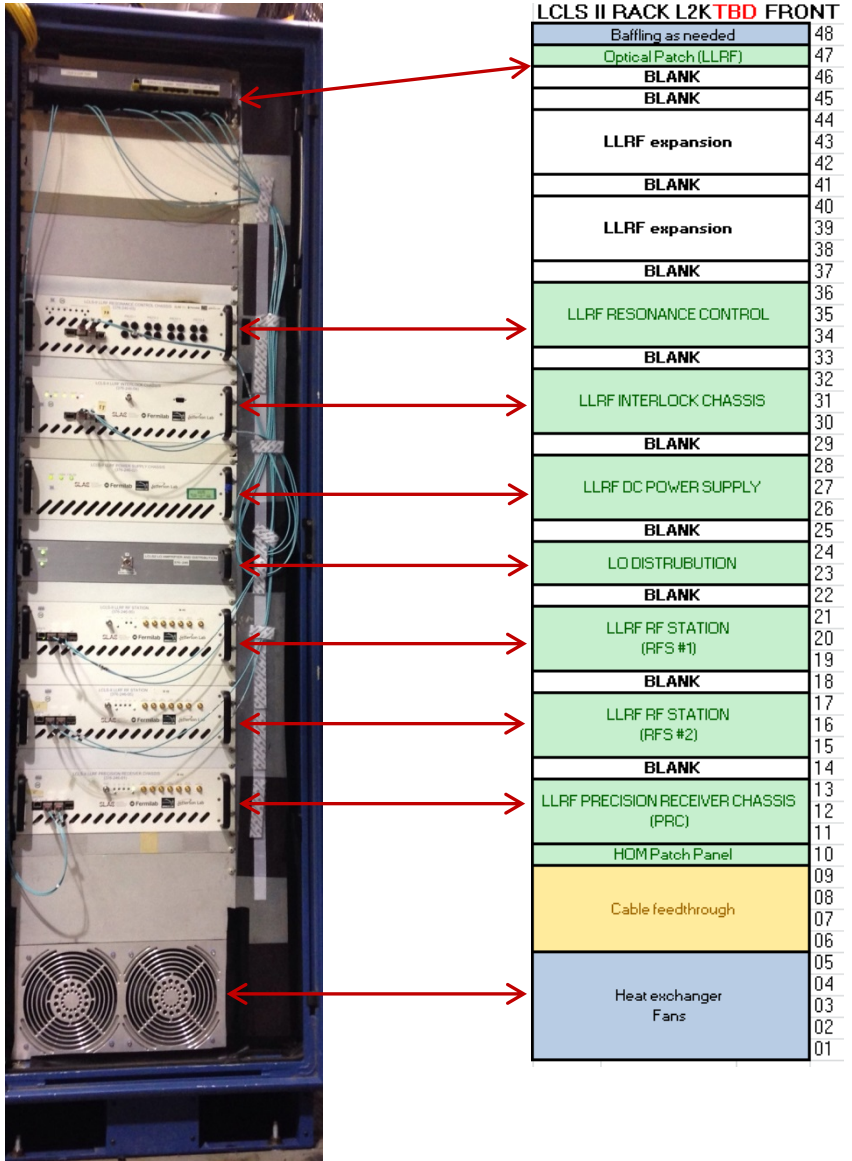
SSA Layout in Gallery

Two sets of SSAs with LLRF & Network & Vacuum racks



LLRF Rack layout

- We will receive complete LLRF Racks from SLAC
- LLRF CAPTAR (cable plant will guide what cables to purchase and install)
- One IOC controls eight cavities
- UDP is used to communicate from the IOC to multiple chassis (FPGAs)



RF Controls Notes from Sonya

RF Controls Meeting Notes – 18 October 2017[edit]

Architecture[edit]

Each cryomodule requires 2 racks of RF equipment. Each cryomodule rack pair interfaces to EPICS via a single CPU. Each rack pair utilizes a local private network for internal communication between the RF CPU, the RF electronics chassis, and the Cryo system PLC network. A single terminal server will be used for console access to the 2 RF CPUs.

Each rack contains 4 electronics chassis, each of which requires a network connection to the new LERF VLAN for purposes of firmware management.

Each CPU requires a single connection. Each SSA (one per cavity) requires a single connection.

CPU connections: 1 per CPU 1 x 2 2

Electronics connections: 4 per rack 4 x 4 16 SSA connections: 1 per cavity 1 x 16 16

Total: 34 Ethernet connections

Figure 1: RF connections to LERF VLAN

To be determined:

- Locations of RF CPUs
- Routing of Cryo PLC connections to CPUs
- Location of terminal server

Software[edit]

The RF CPUs run the LinuxRT operating system and host many EPICS IOCs. These IOCs interface to the RF rack electronics via the local private network. Most of the RF software functionality resides in these IOCs. The SSAs are controlled by IOCs running on the LERF application server.

To be determined: ==

- List of applications and functionality still to be ported from external scripts, etc. to EPICS
- Software development scheme between LERF and CEBAF
- IOC-to-SSA ratio

Responsibilities[edit]

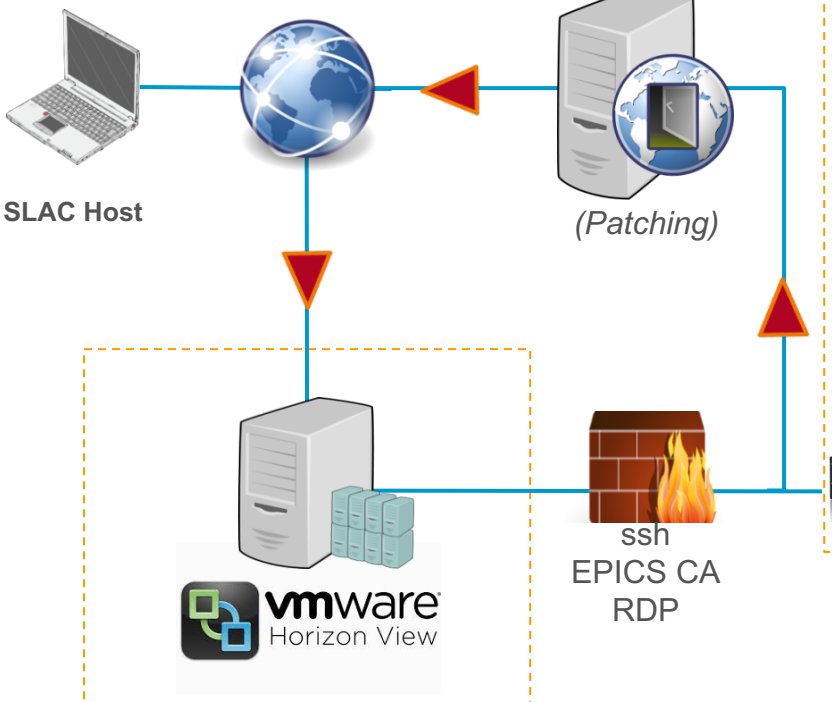
SLAC Provides[edit]

- 2 network switches for the RF local private networks
- Fully configured LinuxRT CPUs

JLab Provides[edit]

- Terminal server for console access to the two RF CPUs

Network & Computer Architecture (Draft from W. Moore)



LCLS-II ACCESS VLAN

*VDI VMs**
(RHEL6, 2-Factor)

LCLS-II VLAN

RHEL6 IOC/Application Server
RHEL6 Development/Backup Server

RHEL6 Workstations
WIN7 - Rockwell SW (x1)

redhat. LINUX

Windows

CRYO PLCs (x2) + Vacuum

LLRF Chassis (x16)

Managed Switch (48 port)

Digi PortServer

CEBAF/OPS VLAN

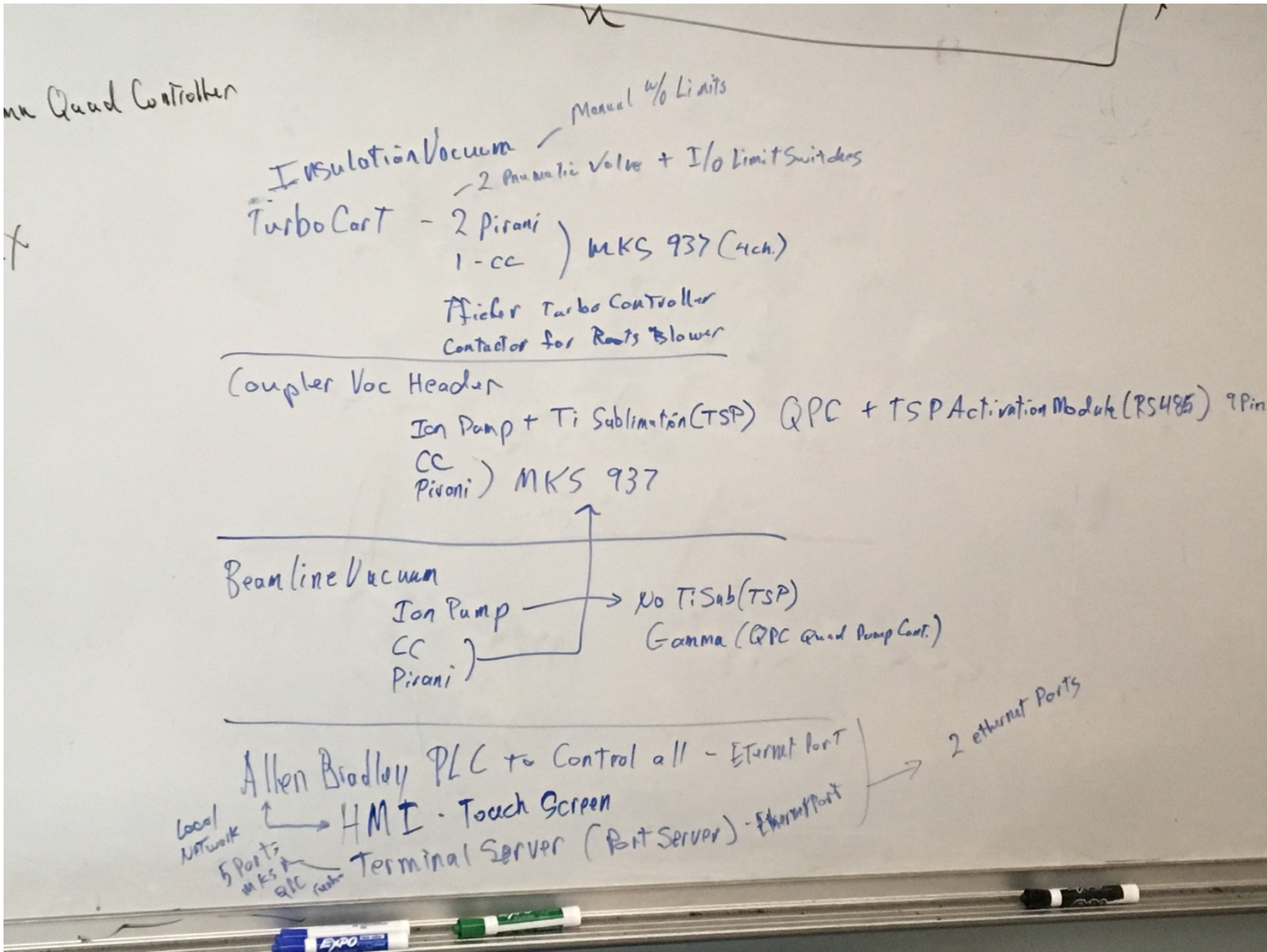
MYA Archiver
MCC Operations Staff

LERF/OPS VLAN

LERF Operations Staff
LERF Control Room Workstations

Vacuum Controls

- Vacuum rack will be in the gallery



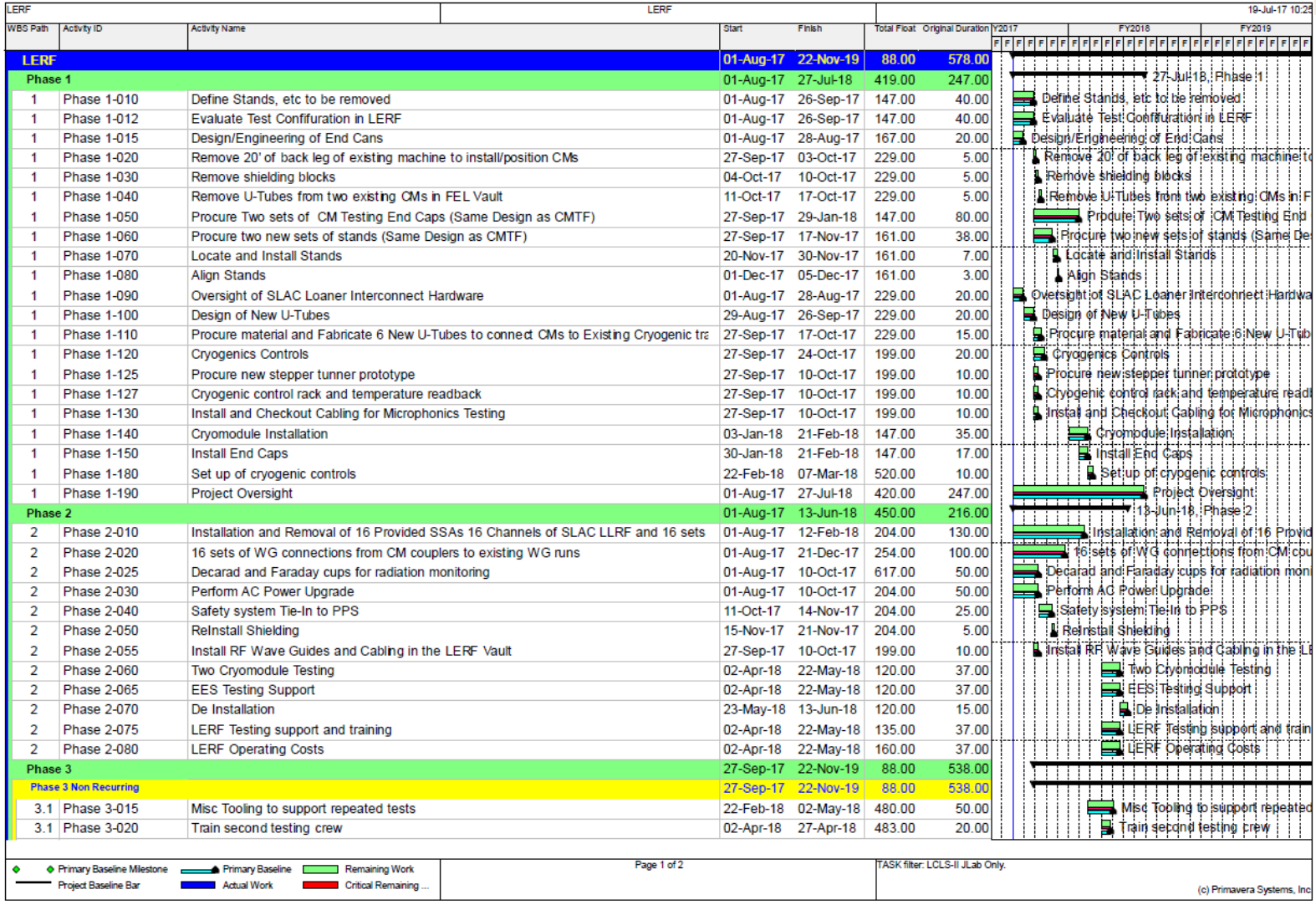
Plan of Attack!

- First get the network & software infrastructure operational
  - My hope is to have two-factor access to a machine on the new network BEFORE Thanksgiving – “Hello World”
  - From there able to get remote PLC programing operational both for vacuum & cryo controls
    - Before Christmas!
- Focus on getting the connections from SSAs to CM in the position #2 (next to cyro-can)
  - Waveguide procurement, LLRF, Cryo Control
  - Plan “B” is that first test is a single cryomodule
    - Incase of delays in *anything* waveguide, SSA, Isolators…

Documentation & Status Updates

- WIKI has been created as a repository for status & documentation
  - https://wiki.jlab.org/lerf/index.php
  - Notes from SLAC visit Oct. 18-19:
    - https://wiki.jlab.org/lerf/index.php/Oct_19_2017

P6 Schedule (1/2)

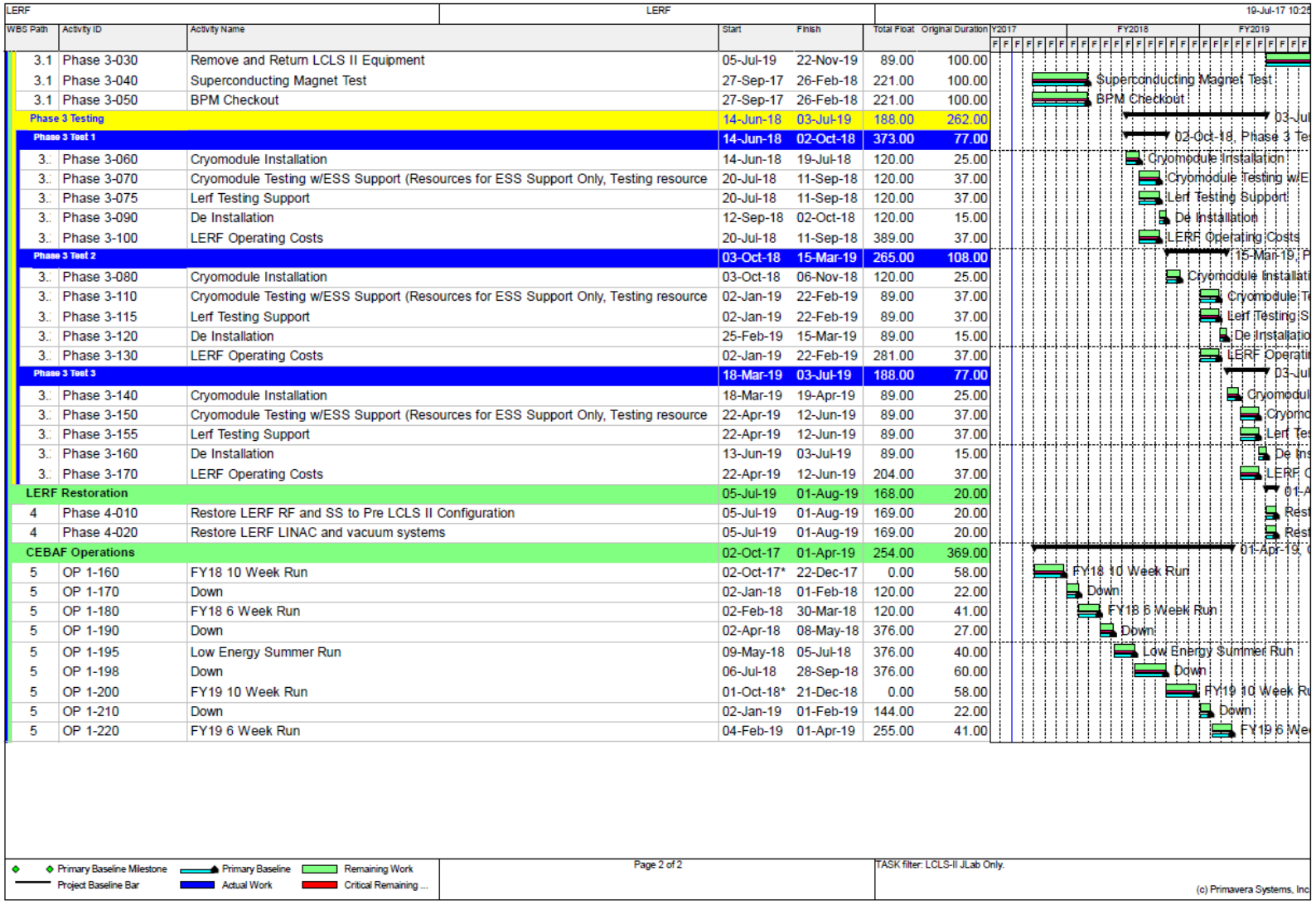


LERF — LERF — 19-Jul-17 10:25

WBS Path	Activity ID	Activity Name	Start	Finish	Total Float	Original Duration
LERF			01-Aug-17	22-Nov-19	88.00	578.00
Phase 1			01-Aug-17	27-Jul-18	419.00	247.00
1	Phase 1-010	Define Stands, etc to be removed	01-Aug-17	26-Sep-17	147.00	40.00
1	Phase 1-012	Evaluate Test Confifuration in LERF	01-Aug-17	26-Sep-17	147.00	40.00
1	Phase 1-015	Design/Engineering of End Cans	01-Aug-17	28-Aug-17	167.00	20.00
1	Phase 1-020	Remove 20' of back leg of existing machine to install/position CMs	27-Sep-17	03-Oct-17	229.00	5.00
1	Phase 1-030	Remove shielding blocks	04-Oct-17	10-Oct-17	229.00	5.00
1	Phase 1-040	Remove U-Tubes from two existing CMs in FEL Vault	11-Oct-17	17-Oct-17	229.00	5.00
1	Phase 1-050	Procure Two sets of CM Testing End Caps (Same Design as CMTF)	27-Sep-17	29-Jan-18	147.00	80.00
1	Phase 1-060	Procure two new sets of stands (Same Design as CMTF)	27-Sep-17	17-Nov-17	161.00	38.00
1	Phase 1-070	Locate and Install Stands	20-Nov-17	30-Nov-17	161.00	7.00
1	Phase 1-080	Align Stands	01-Dec-17	05-Dec-17	161.00	3.00
1	Phase 1-090	Oversight of SLAC Loaner Interconnect Hardware	01-Aug-17	28-Aug-17	229.00	20.00
1	Phase 1-100	Design of New U-Tubes	29-Aug-17	26-Sep-17	229.00	20.00
1	Phase 1-110	Procure material and Fabricate 6 New U-Tubes to connect CMs to Existing Cryogenic tra	27-Sep-17	17-Oct-17	229.00	15.00
1	Phase 1-120	Cryogenics Controls	27-Sep-17	24-Oct-17	199.00	20.00
1	Phase 1-125	Procure new stepper tunner prototype	27-Sep-17	10-Oct-17	199.00	10.00
1	Phase 1-127	Cryogenic control rack and temperature readback	27-Sep-17	10-Oct-17	199.00	10.00
1	Phase 1-130	Install and Checkout Cabling for Microphonics Testing	27-Sep-17	10-Oct-17	199.00	10.00
1	Phase 1-140	Cryomodule Installation	03-Jan-18	21-Feb-18	147.00	35.00
1	Phase 1-150	Install End Caps	30-Jan-18	21-Feb-18	147.00	17.00
1	Phase 1-180	Set up of cryogenic controls	22-Feb-18	07-Mar-18	520.00	10.00
1	Phase 1-190	Project Oversight	01-Aug-17	27-Jul-18	420.00	247.00
Phase 2			01-Aug-17	13-Jun-18	450.00	216.00
2	Phase 2-010	Installation and Removal of 16 Provided SSAs 16 Channels of SLAC LLRF and 16 sets	01-Aug-17	12-Feb-18	204.00	130.00
2	Phase 2-020	16 sets of WG connections from CM couplers to existing WG runs	01-Aug-17	21-Dec-17	254.00	100.00
2	Phase 2-025	Decarad and Faraday cups for radiation monitoring	01-Aug-17	10-Oct-17	617.00	50.00
2	Phase 2-030	Perform AC Power Upgrade	01-Aug-17	10-Oct-17	204.00	50.00
2	Phase 2-040	Safety system Tie-In to PPS	11-Oct-17	14-Nov-17	204.00	25.00
2	Phase 2-050	ReInstall Shielding	15-Nov-17	21-Nov-17	204.00	5.00
2	Phase 2-055	Install RF Wave Guides and Cabling in the LERF Vault	27-Sep-17	10-Oct-17	199.00	10.00
2	Phase 2-060	Two Cryomodule Testing	02-Apr-18	22-May-18	120.00	37.00
2	Phase 2-065	EES Testing Support	02-Apr-18	22-May-18	120.00	37.00
2	Phase 2-070	De Installation	23-May-18	13-Jun-18	120.00	15.00
2	Phase 2-075	LERF Testing support and training	02-Apr-18	22-May-18	135.00	37.00
2	Phase 2-080	LERF Operating Costs	02-Apr-18	22-May-18	160.00	37.00
Phase 3			27-Sep-17	22-Nov-19	88.00	538.00
Phase 3 Non Recurring			27-Sep-17	22-Nov-19	88.00	538.00
3.1	Phase 3-015	Misc Tooling to support repeated tests	22-Feb-18	02-May-18	480.00	50.00
3.1	Phase 3-020	Train second testing crew	02-Apr-18	27-Apr-18	483.00	20.00

REV -, 20-OCT-2017

P6 Schedule (2/2)



LERF | LERF | 19-Jul-17 10:25

WBS Path	Activity ID	Activity Name	Start	Finish	Total Float	Original Duration
3.1	Phase 3-030	Remove and Return LCLS II Equipment	05-Jul-19	22-Nov-19	89.00	100.00
3.1	Phase 3-040	Superconducting Magnet Test	27-Sep-17	26-Feb-18	221.00	100.00
3.1	Phase 3-050	BPM Checkout	27-Sep-17	26-Feb-18	221.00	100.00
Phase 3 Testing			14-Jun-18	03-Jul-19	188.00	262.00
Phase 3 Test 1			14-Jun-18	02-Oct-18	373.00	77.00
3..	Phase 3-060	Cryomodule Installation	14-Jun-18	19-Jul-18	120.00	25.00
3..	Phase 3-070	Cryomodule Testing w/ESS Support (Resources for ESS Support Only, Testing resource	20-Jul-18	11-Sep-18	120.00	37.00
3..	Phase 3-075	Lerf Testing Support	20-Jul-18	11-Sep-18	120.00	37.00
3..	Phase 3-090	De Installation	12-Sep-18	02-Oct-18	120.00	15.00
3..	Phase 3-100	LERF Operating Costs	20-Jul-18	11-Sep-18	389.00	37.00
Phase 3 Test 2			03-Oct-18	15-Mar-19	265.00	108.00
3..	Phase 3-080	Cryomodule Installation	03-Oct-18	06-Nov-18	120.00	25.00
3..	Phase 3-110	Cryomodule Testing w/ESS Support (Resources for ESS Support Only, Testing resource	02-Jan-19	22-Feb-19	89.00	37.00
3..	Phase 3-115	Lerf Testing Support	02-Jan-19	22-Feb-19	89.00	37.00
3..	Phase 3-120	De Installation	25-Feb-19	15-Mar-19	89.00	15.00
3..	Phase 3-130	LERF Operating Costs	02-Jan-19	22-Feb-19	281.00	37.00
Phase 3 Test 3			18-Mar-19	03-Jul-19	188.00	77.00
3..	Phase 3-140	Cryomodule Installation	18-Mar-19	19-Apr-19	89.00	25.00
3..	Phase 3-150	Cryomodule Testing w/ESS Support (Resources for ESS Support Only, Testing resource	22-Apr-19	12-Jun-19	89.00	37.00
3..	Phase 3-155	Lerf Testing Support	22-Apr-19	12-Jun-19	89.00	37.00
3..	Phase 3-160	De Installation	13-Jun-19	03-Jul-19	89.00	15.00
3..	Phase 3-170	LERF Operating Costs	22-Apr-19	12-Jun-19	204.00	37.00
LERF Restoration			05-Jul-19	01-Aug-19	168.00	20.00
4	Phase 4-010	Restore LERF RF and SS to Pre LCLS II Configuration	05-Jul-19	01-Aug-19	169.00	20.00
4	Phase 4-020	Restore LERF LINAC and vacuum systems	05-Jul-19	01-Aug-19	169.00	20.00
CEBAF Operations			02-Oct-17	01-Apr-19	254.00	369.00
5	OP 1-160	FY18 10 Week Run	02-Oct-17*	22-Dec-17	0.00	58.00
5	OP 1-170	Down	02-Jan-18	01-Feb-18	120.00	22.00
5	OP 1-180	FY18 6 Week Run	02-Feb-18	30-Mar-18	120.00	41.00
5	OP 1-190	Down	02-Apr-18	08-May-18	376.00	27.00
5	OP 1-195	Low Energy Summer Run	09-May-18	05-Jul-18	376.00	40.00
5	OP 1-198	Down	06-Jul-18	28-Sep-18	376.00	60.00
5	OP 1-200	FY19 10 Week Run	01-Oct-18*	21-Dec-18	0.00	58.00
5	OP 1-210	Down	02-Jan-19	01-Feb-19	144.00	22.00
5	OP 1-220	FY19 6 Week Run	04-Feb-19	01-Apr-19	255.00	41.00

FY2017 | FY2018 | FY2019

Primary Baseline Milestone | Primary Baseline | Remaining Work
Project Baseline Bar | Actual Work | Critical Remaining ...

Page 2 of 2

TASK filter: LCLS-II JLab Only.

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REV -, 20-OCT-2017

CEBAF Operations – Constraints on LERF Ops

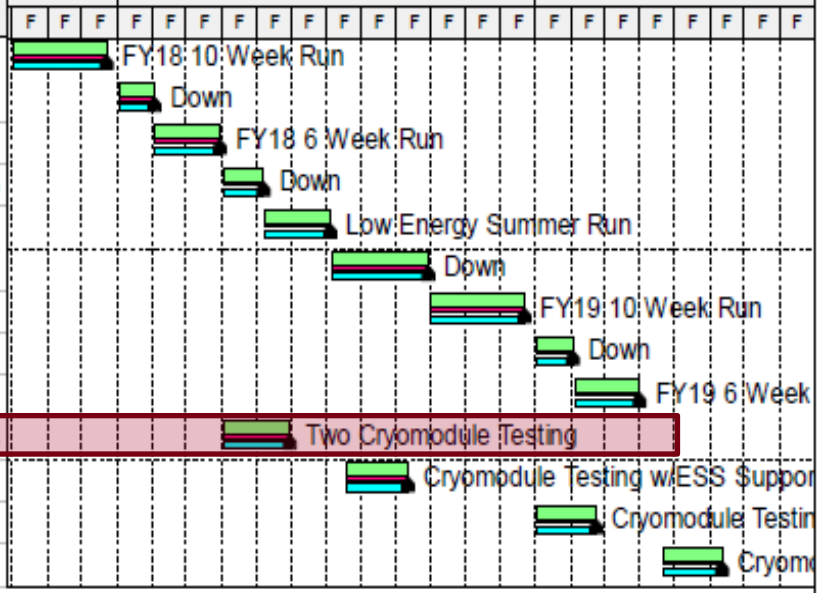
- CEBAF Operation Plan – working on nailing this down better!
  - FY18 Q1 – 10 wks (Oct/Nov/Dec) – Highly Likely
  - FY18 Q2 – 6 wks (Feb/Mar) – Highly Likely
  - FY18Q3 – 8 wks at 6 GeV - TBC
- CHL Configurations
  - FY18 Q1/Q2 – 2 x (CHL + Cold Boxes)
    - Transition by May 6th to 1 CHL
  - FY18 Q3/Q4 – 1 x (CHL + Cold Box) – Two week transition at 4K (cold down opportunity)
    - Transition by Nov 10th to 2 CHLs
- Cryogenics
  - U-tube ops required at 4K – hope to have design that eliminates this constraint!
  - Integrate with maintenance plans on SC1 (Ops on SC2 – FY18Q3)

Schedule Integrated with CEBAF Operations

- Testing cycles could occur three times per FY at the conclusion of planned CEBAF runs
- First testing cycle most likely in Jul-2018 contingent upon actual FY2018 run schedule and staffing availability

LERF perations 21-Jul-17 10:35

Activity ID	Activity Name	Start	Finish
OP 1-160	FY18 10 Week Run	02-Oct-17*	22-Dec-17
OP 1-170	Down	02-Jan-18	01-Feb-18
OP 1-180	FY18 6 Week Run	02-Feb-18	30-Mar-18
OP 1-190	Down	02-Apr-18	08-May-18
OP 1-195	Low Energy Summer Run	09-May-18	05-Jul-18
OP 1-198	Down	06-Jul-18	28-Sep-18
OP 1-200	FY19 10 Week Run	01-Oct-18*	21-Dec-18
OP 1-210	Down	02-Jan-19	01-Feb-19
OP 1-220	FY19 6 Week Run	04-Feb-19	01-Apr-19
Phase 2-060	Two Cryomodule Testing	02-Apr-18	30-May-18
Phase 3-070	Cryomodule Testing w/ESS Supl	20-Jul-18	11-Sep-18
Phase 3-110	Cryomodule Testing w/ESS Supl	02-Jan-19	22-Feb-19
Phase 3-150	Cryomodule Testing w/ESS Supl	22-Apr-19	12-Jun-19



REV3, 03-AUG-2017

Impacts & Risks

- Cryogenics: present 2K issues complicate near term scheduling. Contamination is a concern that could affect availability.
  - Can't stab U-tubes during CEBAF ops (need CEBAF @ 4K for 1 week)
  - Repeated stabbing adds potential contamination problems
  - Cooldown and warm-up : overall cryo load must be handled properly with controls.
- CEBAF Operations:
  - Phase I no impact.
  - Phase II & III requires PSS Control and interface. Cannot keep two of the FEL CMs cold as CEBAF spares. Coordination is required with other cryo activities.
  - Phase II & III need coordination with CEBAF 12 GeV operations.
- LERF Operations: Phase II and Phase III would eliminate all other LERF operations.
- Staffing: Initial plan utilizes combination of in-house staff and possibly term hires. Higher priority work might limit available staff.
- Schedule: Working towards July test cycle (April if all goes very well.)

Summary

- Waveguide design complete & out for procurement
- Gallery & tunnel layout works
- Computer architecture in draft
  - Ethernet switch on order – first test of SLAC to PC in weeks
  - Remote programing of PLC before Christmas
- End can cryogenic design evolving nicely - need to get PR

Questions?

Thanks for your attention!