



# Advanced Light Source Upgrade Project – Accelerator Controls System Status Report

**Jeong Han Lee, Dr.rer.nat**

ALS-U Controls System Technical Lead

Staff Scientist / Engineer / Engineering Division, Physical Sciences

# Brief LBNL Intro

## Radiation Lab is the beginning of the Lawrence Berkeley National Laboratory (LBNL, LBL, Berkeley Lab)

Established in **1931** by the University of California (UC), the laboratory is sponsored by the United States Department of Energy and administered by the UC system. Ernest Lawrence, who won the Nobel prize for inventing the cyclotron, founded the Lab and served as its Director until his death in 1958. (Wikipedia, access 2024-04)

## Oppenheimer (Courtesy of WB)

These pictures will be removed after this (offline) presentation

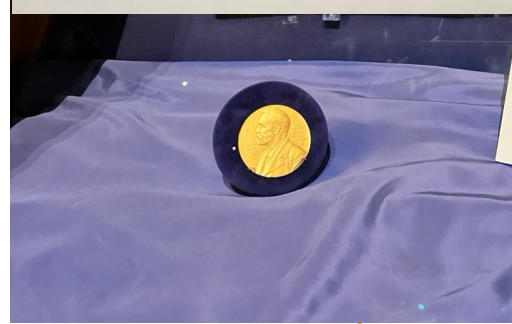
...ence were small, bench-top  
 ...ment or large investments in  
 ...er World War II, it was a  
 ...y directing an experiment  
 ...the Berkeley campus in 1931, the  
 ...of science, technology,  
 ...modern era of multidisciplinary  
 ...s from physics, chemistry,  
 ...ing teamwork would be critical to  
 ...awrence's brother John would go  
 ...nt cancer and other diseases.  
 ...his could choose to collaborate,  
 ...d also become the first lab in  
 ...ments with scientists. Lawrence  
 ...rivers or coalitions of scientists.  
 ...his next "machine."



**NOBEL LAUREATES**  
 A photograph of the Nobel Laureates...  
 ...the first to be awarded the Nobel Prize in Physics...  
 ...for his discovery of the positron...  
 ...and for his discovery of the meson...  
 ...and for his discovery of the muon...  
 ...and for his discovery of the tau lepton...  
 ...and for his discovery of the charm quark...  
 ...and for his discovery of the bottom quark...  
 ...and for his discovery of the top quark...  
 ...and for his discovery of the Higgs boson...  
 ...and for his discovery of the graviton...  
 ...and for his discovery of the photon...  
 ...and for his discovery of the gluon...  
 ...and for his discovery of the neutrino...  
 ...and for his discovery of the electron...  
 ...and for his discovery of the proton...  
 ...and for his discovery of the neutron...  
 ...and for his discovery of the deuteron...  
 ...and for his discovery of the triton...  
 ...and for his discovery of the alpha particle...  
 ...and for his discovery of the beta particle...  
 ...and for his discovery of the gamma ray...  
 ...and for his discovery of the X-ray...  
 ...and for his discovery of the ultraviolet...  
 ...and for his discovery of the infrared...  
 ...and for his discovery of the visible light...  
 ...and for his discovery of the ultraviolet...  
 ...and for his discovery of the infrared...  
 ...and for his discovery of the visible light...



**LAWRENCE ACCEPTS THE NOBEL PRIZE**  
 The greatest personal triumph for Ernest Lawrence  
 and his team was receiving the 1938 Nobel Prize in  
 Physics for the invention of the cyclotron.  
 The citation, "for his discovery of the positron,  
 the Ernest Orlando Lawrence for the invention,  
 and development of the cyclotron and especially  
 for his results obtained by means of this device in  
 the production of artificial radioactive elements."  
 Because of war restrictions and lab demands, Law-  
 rence was unable to travel to Sweden to receive the  
 prize in the Royal Auditorium on the 10th Berkeley  
 campus on February 29, 1940. It was UC Berkeley's  
 first Nobel Prize.



# Brief Speaker Intro

**Jeong Han Lee, Dr.rer.nat.**

**ALS-U Job: Technical Lead for Controls (~ 13 FTE)**

Institution: LBNL

Staff Scientist and Engineer



## Experience

- 22+ years of international accelerator facilities work experience (MAMI-Germany, RISP-South Korea, ESS-Sweden, and Jefferson Lab & LBNL - the United States)
- Experimental Nuclear Physics – Parity Violation for the Data Acquisition and Detector System, SW Data Analysis Framework based on ROOT, and Compton Backscattering Polarimeter Chicane Design and Construction.
- 8+ years Accelerator Controls Group Leader at RISP and LBNL
- 4+ years Hardware Integration Work Package Lead at ESS (Realtime and Embedded Linux, DAQ, MTCA, Timing, Network, EPICS SW architecture, E3 architect)
- 13+ years EPICS Collaboration Works and Contributions
- Published 2 Nature, 12 PRL, 10+ JACoW, and other international journal and conference papers and serves as a peer reviewer of NIM A.

# Brief Speaker Intro

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Old Man

# Advanced Light Source Upgrade Project

ALS-U will deliver a world-leading light source on schedule and budget that provides users with bright, high-coherent-flux soft x-rays unmatched by any other facility

## High-level goals:

- Achieve an increase in brightness and coherent flux of soft x-rays (@1 keV) of at least 2 orders of magnitude beyond today's ALS capabilities
- Develop a set of world-class experimental capabilities that will push the frontiers in soft x-ray science and maintain ALS leadership in this area
- Provide infrared and hard x-ray capabilities comparable to present-day ALS

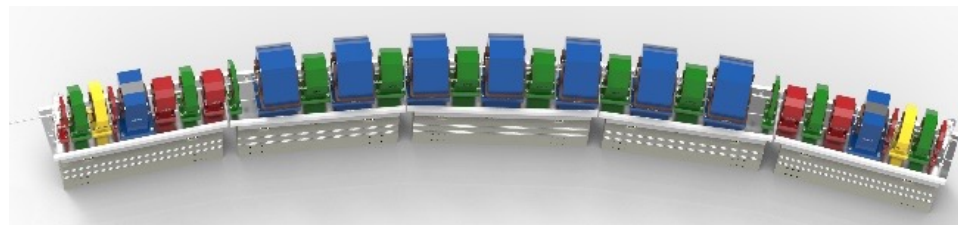
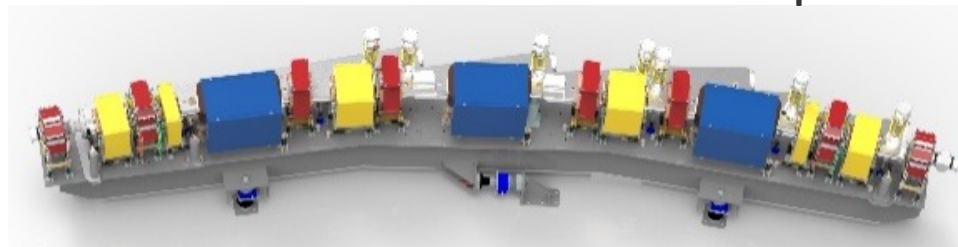
### Today's ALS

- 30 years, 40+ beamlines
- 2100+ users/year
- 16,000+ publications

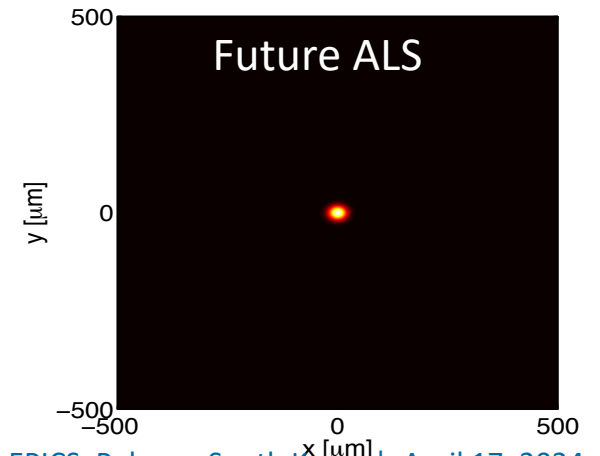
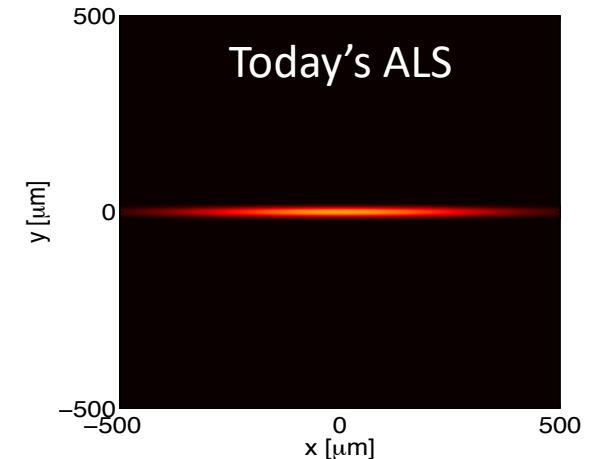
### Future ALS (aka ALS-U)

- next 25 years

## A SR Sector Arc Area Comparison



## Electron Beam Profiles



# ALS-U Project Scope

## Major items:

- New 2-GeV, high-brightness storage ring fed by a new full-energy accumulator ring and transfer lines in the existing ALS storage-ring tunnel
- 6 high-field bends and realignment of bend-magnet beamlines
- Adding a suite of 2 feature world-leading undulator beamlines
- Seismic/ALARA shielding upgrade: to improve seismic safety and minimize dose rates

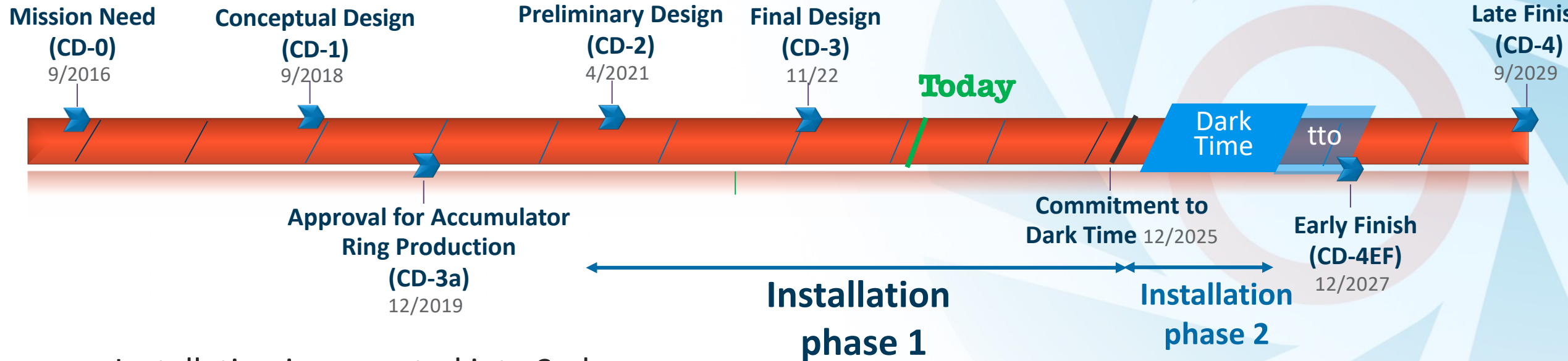
# ALS-U Key Performance Parameters (KPPs)

Performance Measure	Threshold	Objective
Storage ring energy	$\geq 1.9$ GeV	2.0 GeV
Beam current	$> 25$ mA	500 mA
Horizontal emittance	$< 150$ pm rad	$< 85$ pm rad
Calculated brightness at 1 keV	$> 2.0 \times 10^{19}$	$2.0 \times 10^{21}$
Number of feature MBA beamlines installed	2	$\geq 2$

- The threshold KPPs are the minimum parameters against which the project's performance is measured at completion (CD-4)
- The objective KPPs describe the technical goals of the project

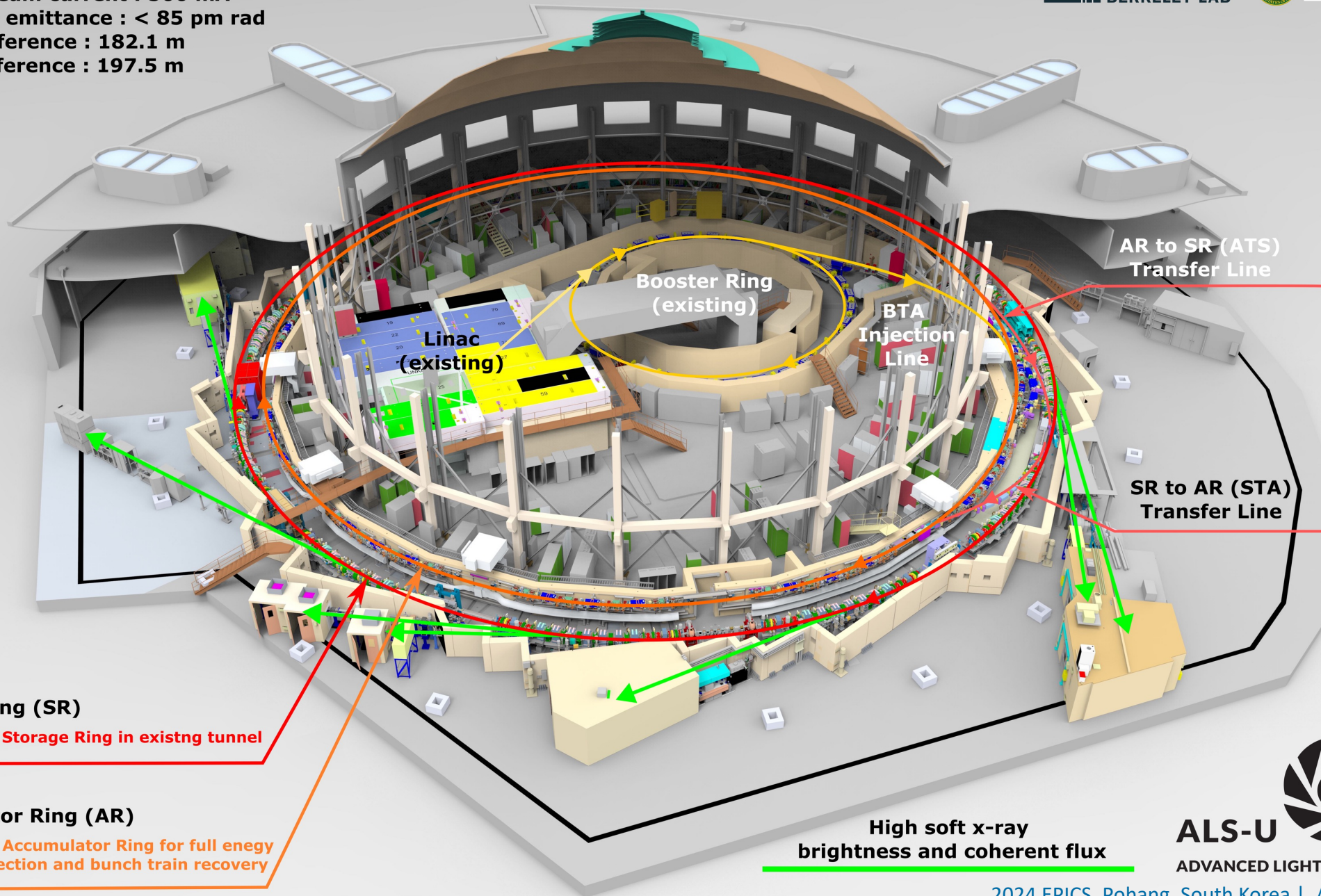


# ALS-U Project Timeline



- Installation is separated into 2 phases
  - Tunnel prep and accumulator ring installation and testing conducted during planned summer and winter ALS shutdowns that began in winter 2021
- Dark Time is scheduled to be one year in duration starting in June 2026 followed by a 6-month transition to operations (tto) where beamlines are brought online
- Commitment to Dark Time – at least 6 months prior to the start of dark time
- Postponed early finish by ~9 months since CD-3 to from April 2027 to Dec 2027
  - 20 months of schedule contingency remain, which is sufficient

Storage ring energy : 2.0 GeV  
Electron beam current : 500 mA  
Horizontal emittance : < 85 pm rad  
AR circumference : 182.1 m  
SR circumference : 197.5 m



**Storage Ring (SR)**

New 2.0 GeV Storage Ring in existng tunnel

**Accumulator Ring (AR)**

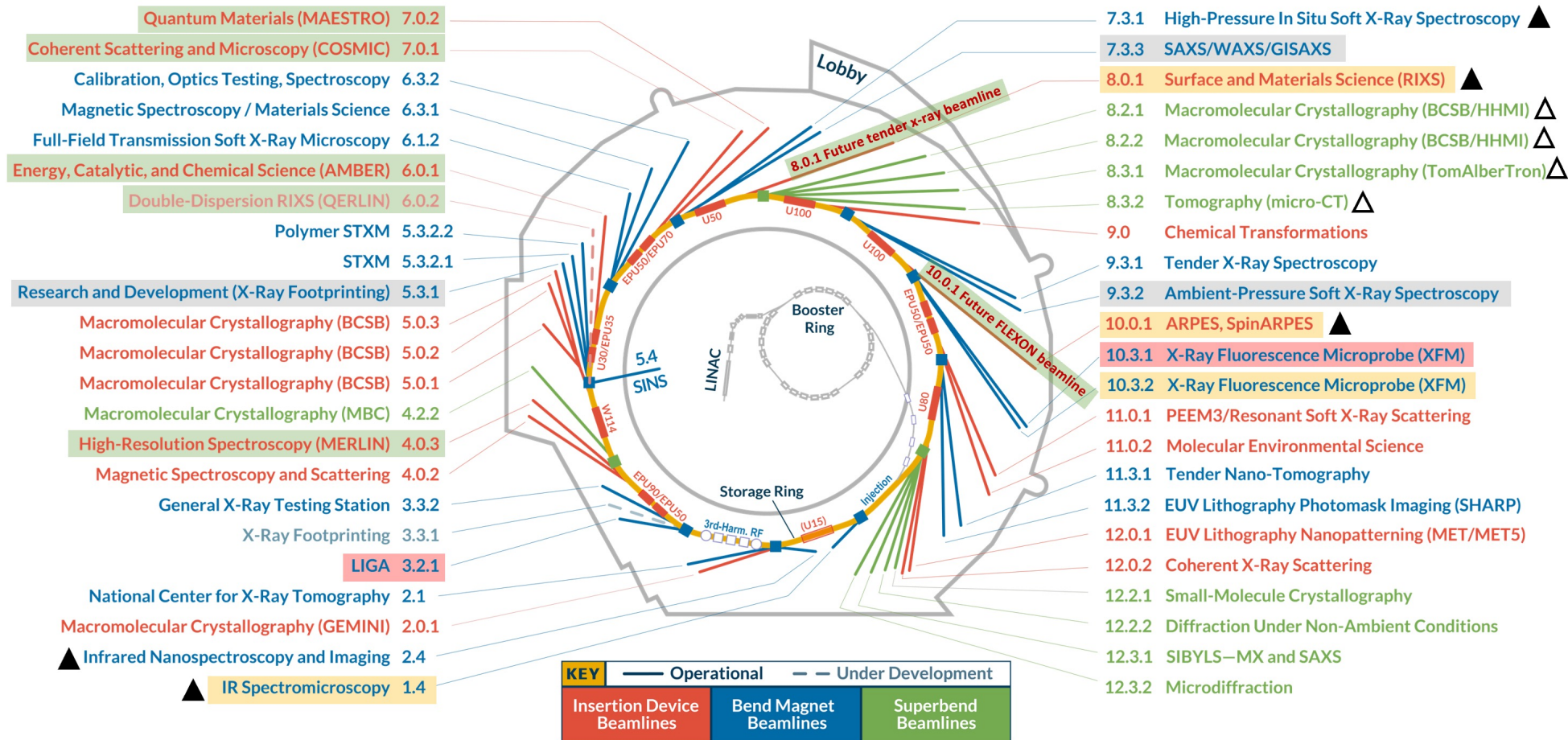
New 2.0 GeV Accumulator Ring for full enegy swap-out injection and bunch train recovery

High soft x-ray  
brightness and coherent flux

ALS-U  
ADVANCED LIGHT SOURCE

# ALS/ALS-U Beam Lines

<https://als.lbl.gov/als-u/als-u-beamline-impacts/>



Post-ALS-U operational status legend

Beamline upgrade/expanded capabilities

Beamline closed; capabilities will be migrated/expanded elsewhere

Beamline closed

Beamline closed; under consideration for post-ALS-U reopening/upgrade

▲ Beamline will turn off before the dark time

△ Beamline may turn off before the dark time

# A Typical Controls System Scope

## What

Carry / take all monitor, control, accelerator model-based calculated signals (data) from one place to another through network environment

## Where

All accelerator subsystems and operations subsystems. In addition, partially experiment, safety, and conventional facility

## How

Achieve a rock-solid control, interactive / non-interactive automation, and user-friendly operation environment

# ALS-U Controls scope

## Machine Protection System

- PLC-based Slow Interlock (ms)

Global Controls

## Motion Control

- Servo / Stepper Motion (Omron – Delta-Tau server, EtherCAT clients)

## Software High Level and Data Acquisition (DAQ) System

## Software and middleware services (EPICS)

## Infrastructure

- Controls Network – aka Operational Technology Network
- Rack - Rack temperature controller, water leak and smoke detection system
- Temperature monitoring system (TC and PRTD)
- Asset Management System (AMS) : QR Label, Scanner, Web, RESTful API

## Vacuum System

## Power Supply System

## Magnet System

## Beam Diagnostic System

## Facility/Radiation Safety System

## Radio Frequency System

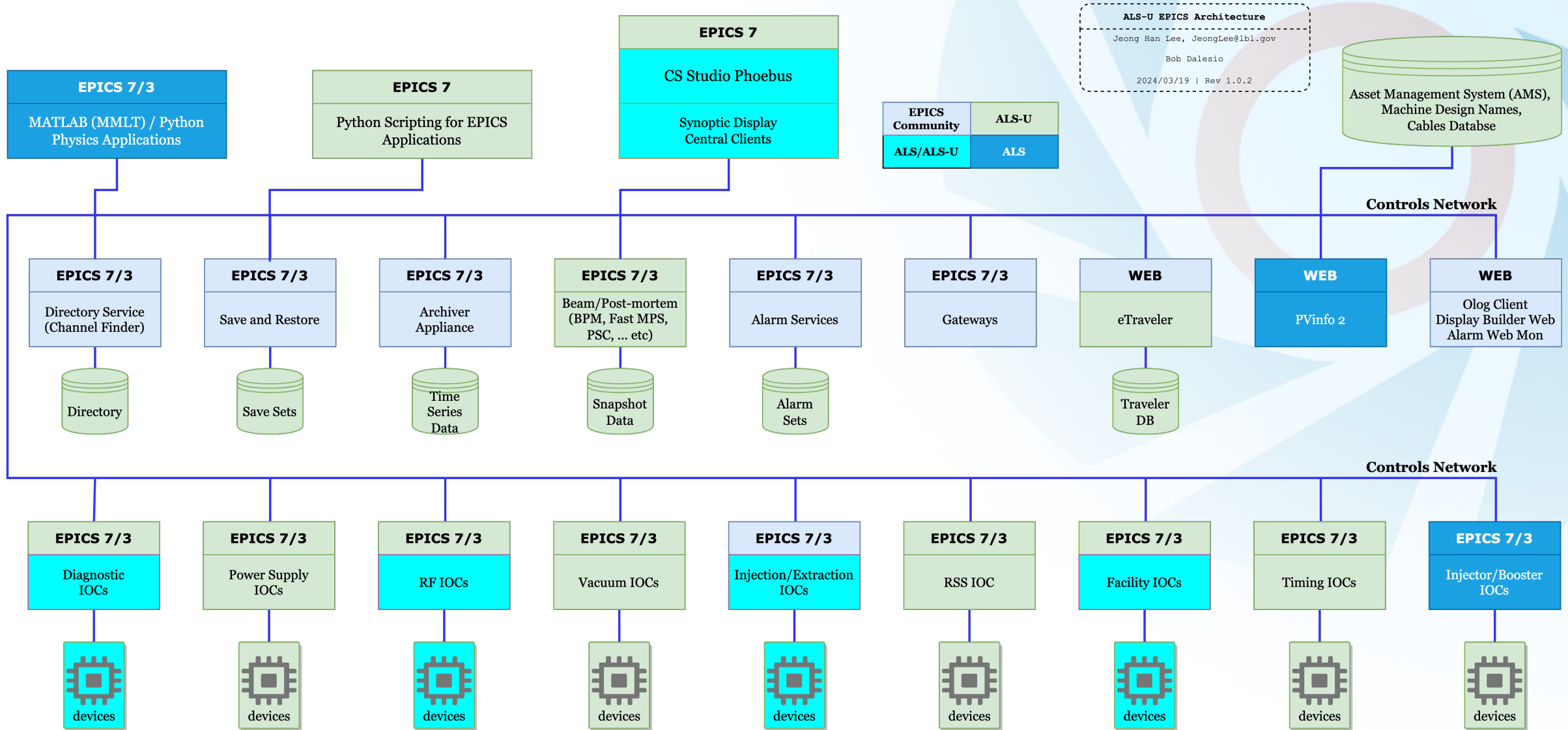
## Injection/Extraction System

## Quality Assurance

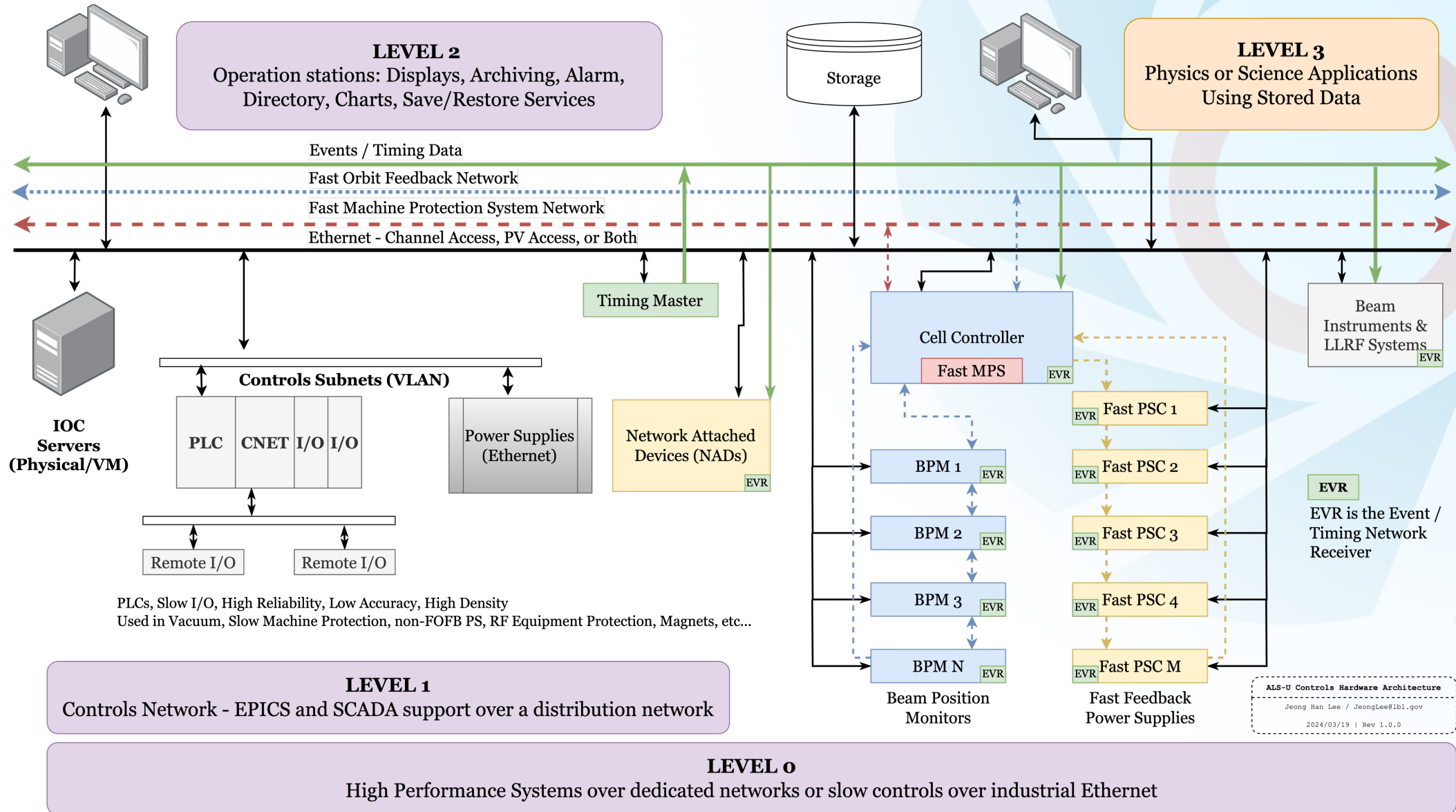
## Operation

Subsystem Controls

# Controls Software Architecture



# Controls Hardware Architecture



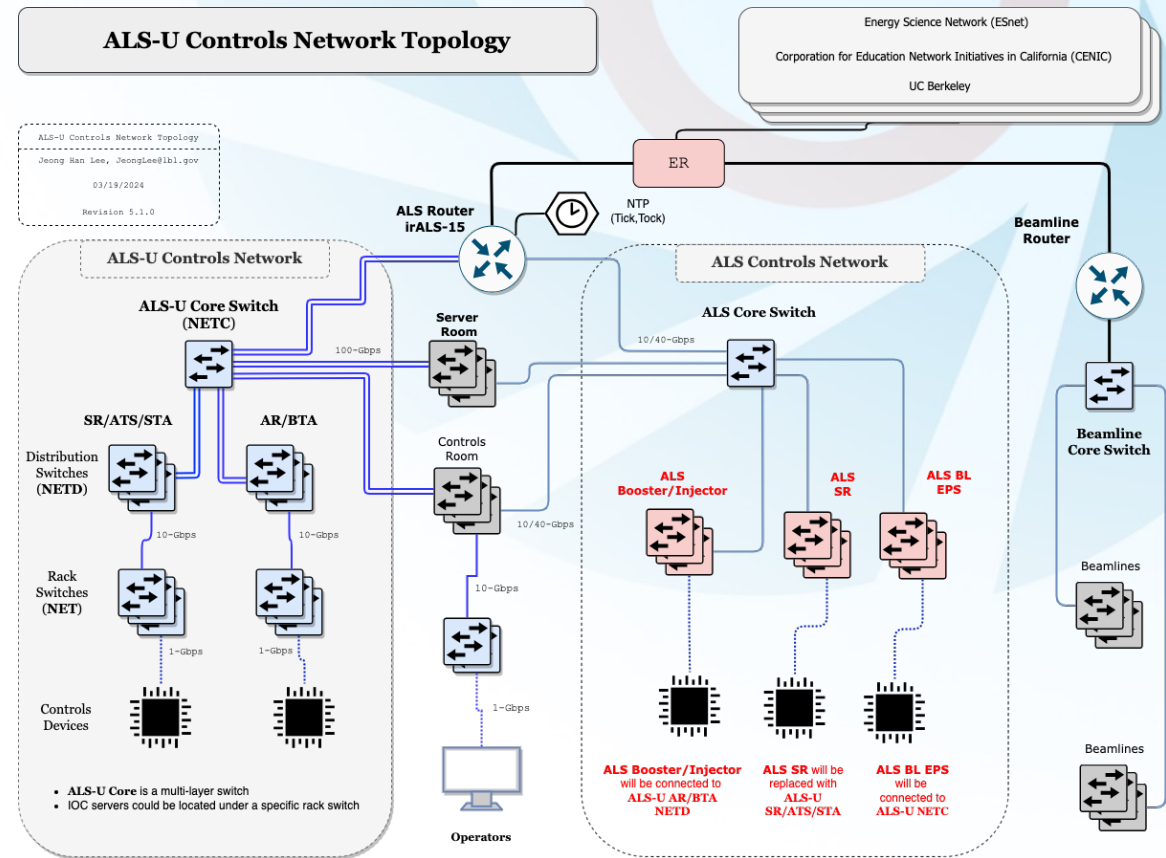
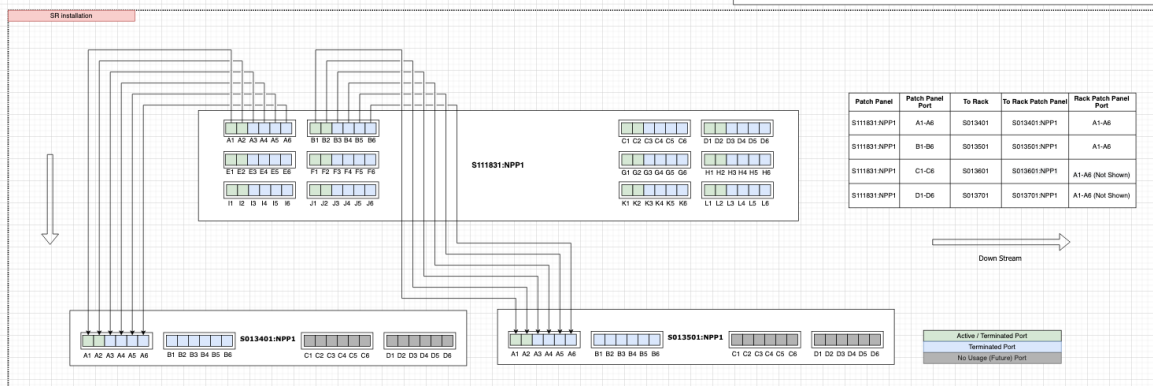
# Controls Network

- Decouple from the ALS network / Move the new ALS-U network after Darktime
- Network device port counts 2000+, Single Mode Fiber Distribution
- Estimated Overall Data Traffic: NETC (56+ Gbps), NETD (43+ Gbps), NET (5+ Gbps)
- For the network design and security models, we follow the NIST Special Publication (NIST SP 800-82) such as the Guide to Industrial Control Systems Security (Rev 2) and Guide to Operational Technology Security (Rev 3) since 2021

SR	S111716:NPP1	C3/D3	S111824:NETD3	u1/u2	S111824:NETD3	d37	S111845:NPP8:A1	ATS120101:NPP1:A1	ATS120103:NET1	u1	PS rack
SR	S111716:NPP1	C4/D4	S111826:NETD4	u1/u2	S111826:NETD4	d37	S111845:NPP8:A2	ATS120101:NPP1:A2	ATS120103:NET1	u2	
SR							S111845:NPP8:A3	ATS120101:NPP1:A3			
SR							S111845:NPP8:A4	ATS120101:NPP1:A4			
SR							S111845:NPP8:A5	ATS120101:NPP1:A5			
SR							S111845:NPP8:A6	ATS120101:NPP1:A6			
SR	S111716:NPP1	C3/D3	S111824:NETD3	u1/u2	S111824:NETD3	d38	S111845:NPP8:B1	ATS120401:NPP1:A1	ATS120403:NET1	u1	C&I rack
SR	S111716:NPP1	C4/D4	S111826:NETD4	u1/u2	S111826:NETD4	d38	S111845:NPP8:B2	ATS120401:NPP1:A2	ATS120403:NET1	u2	
SR							S111845:NPP8:B3	ATS120401:NPP1:A3			
SR							S111845:NPP8:B4	ATS120401:NPP1:A4			
SR							S111845:NPP8:B5	ATS120401:NPP1:A5			
SR							S111845:NPP8:B6	ATS120401:NPP1:A6			
SR	S111716:NPP1	C3/D3	S111824:NETD3	u1/u2	S111824:NETD3	d39	S111845:NPP8:C1	ATS120501:NPP1:A1	ATS120503:NET1	u1	Vac rack
SR	S111716:NPP1	C4/D4	S111826:NETD4	u1/u2	S111826:NETD4	d39	S111845:NPP8:C1	ATS120501:NPP1:A2	ATS120503:NET1	u2	
SR							S111845:NPP8:C3	ATS120501:NPP1:A3			
SR							S111845:NPP8:C4	ATS120501:NPP1:A4			
SR							S111845:NPP8:C5	ATS120501:NPP1:A5			
SR							S111845:NPP8:C6	ATS120501:NPP1:A6			
SR	S111716:NPP1	C3/D3	S111824:NETD3	u1/u2	S111824:NETD3	d40	S111845:NPP8:D1				

ALS-U Network Distribution Level 3 (NPP,NPP)

S1117 and S1118 Rack location number follows the ALS standard rack number convention. It start 9 from the top  
 XXXXX rack location number follows the ALS-U standard rack number convention. It starts 1 from the top.

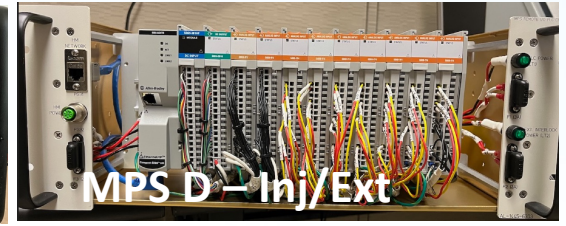
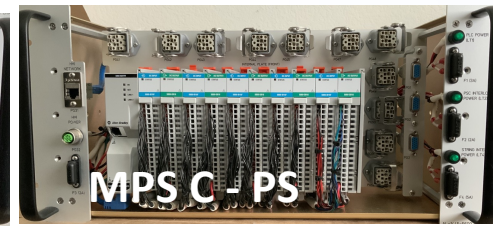
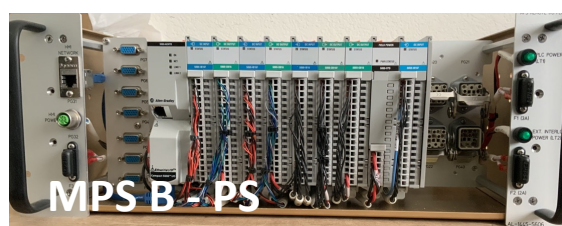
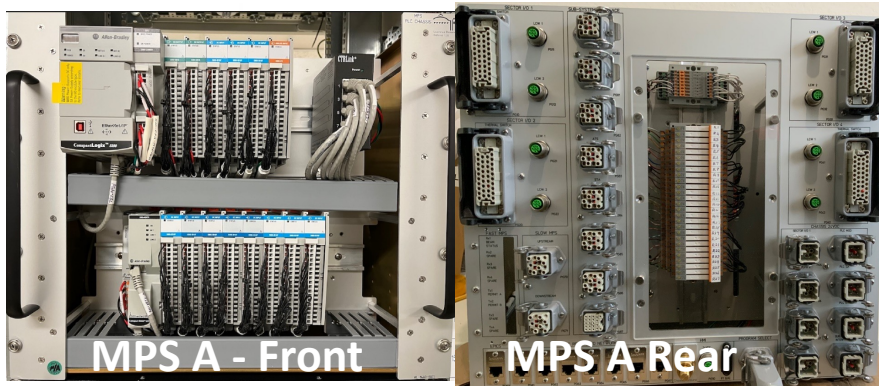
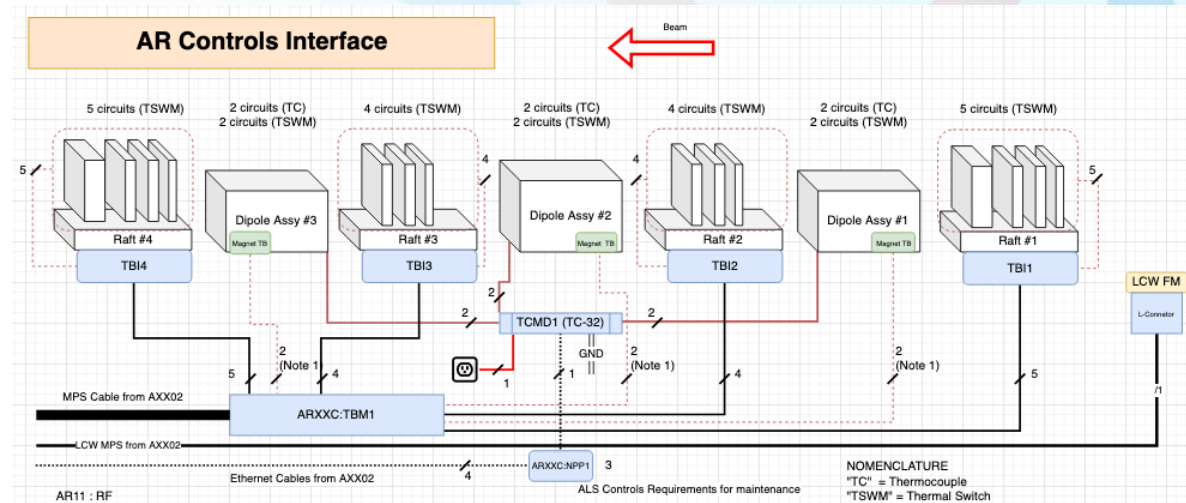
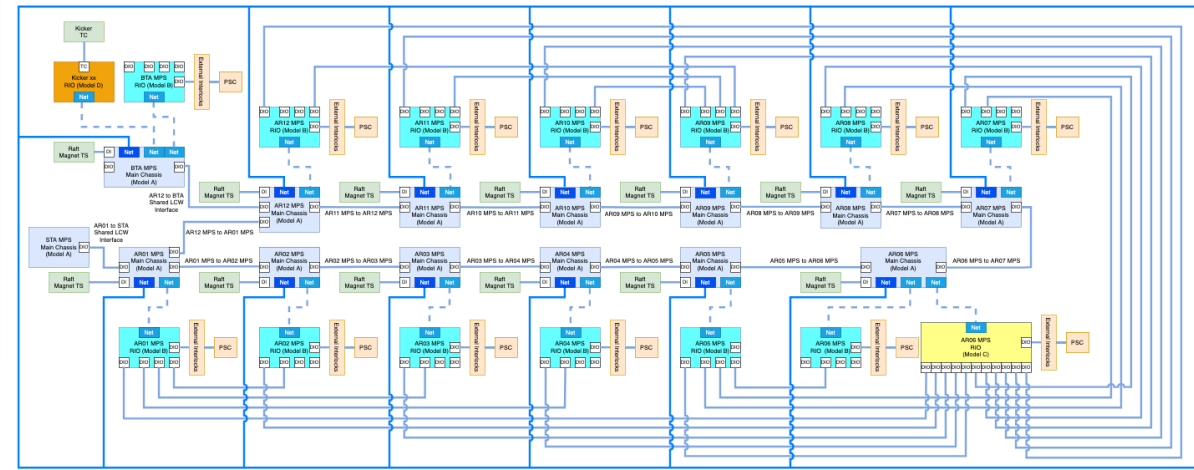


- ALS-U Core is a multi-layer switch
- IOC servers could be located under a specific rack switch



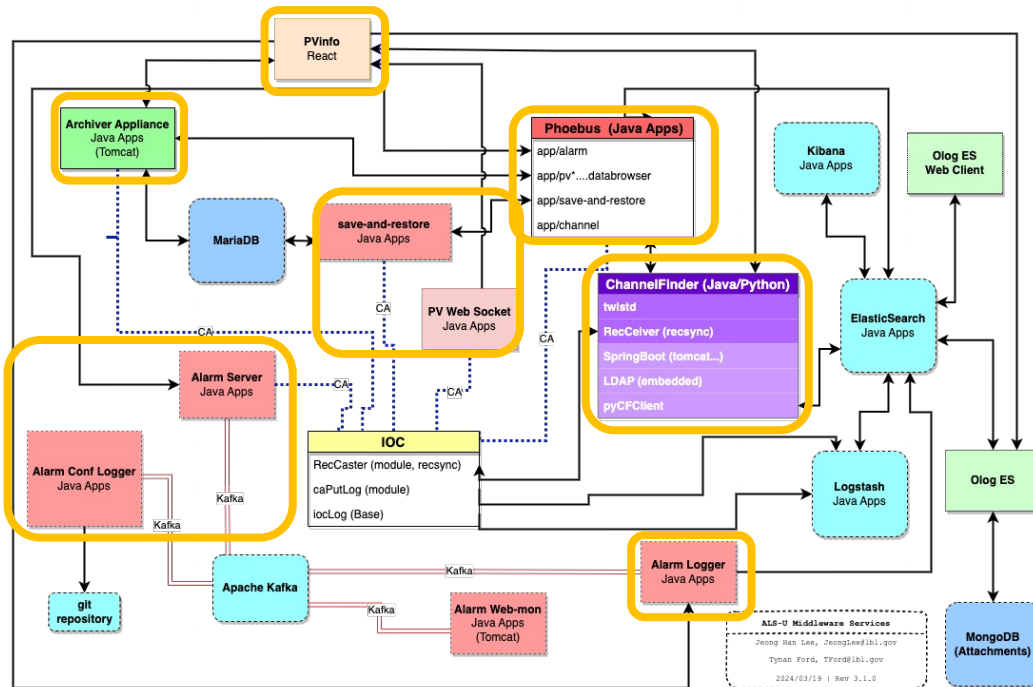
# Slow MPS

- Allen-Bradley PLC L320ER family with the latest RS Studio version
- Main PLC (MPS A) and Remote IO Chassis Topology to cover AR/BTA requirements across subsystems (Magnet, Pre-staging, Inj/Ext, Power Supply)
- AR MPS Design will cover the SR Slow MPS also with an additional RIO (MPS E)
- Various level diagrams for plug-to-plug cable mapping and detailed I/O mapping between PLC IO and a physical signal
- Terminal blocks for AR magnet thermal sensor interfaces



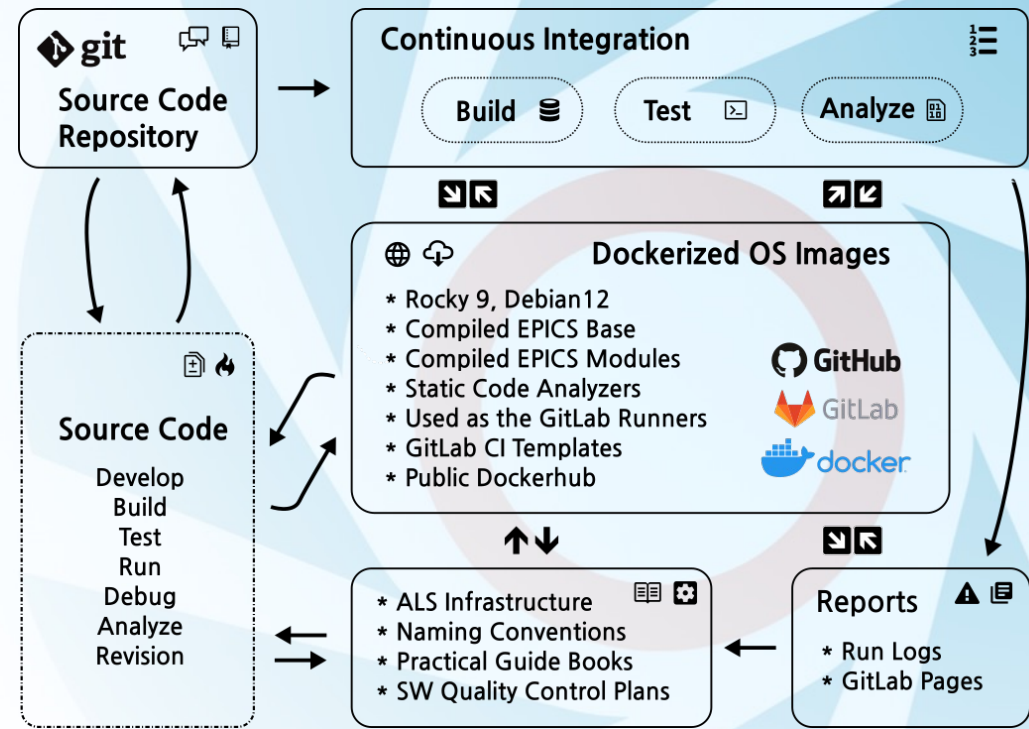
# Controls Software

- Released ALS-U EPICS environment 1.0.0 for the AR production
  - Rocky 9.2 and Debian 12 are official supported Linux
  - Include various SW quality checkers (shellcheck, splint, cppcheck, gcovr, flawfinder, static code analyzer pmd) in Docker images for Continuous Integration
- ALS GitLab is the source code repository and a central place where we work. We work very closely together to build this environment.
- The entire workflow at <https://git.als.lbl.gov/> is running since 2021!



### Key Middleware Services

- Phoebus
- ChannelFinder
- Archiver Appliance
- Alarm Services
- Save-and-Restore
- PV Web Socket
- PVInfo

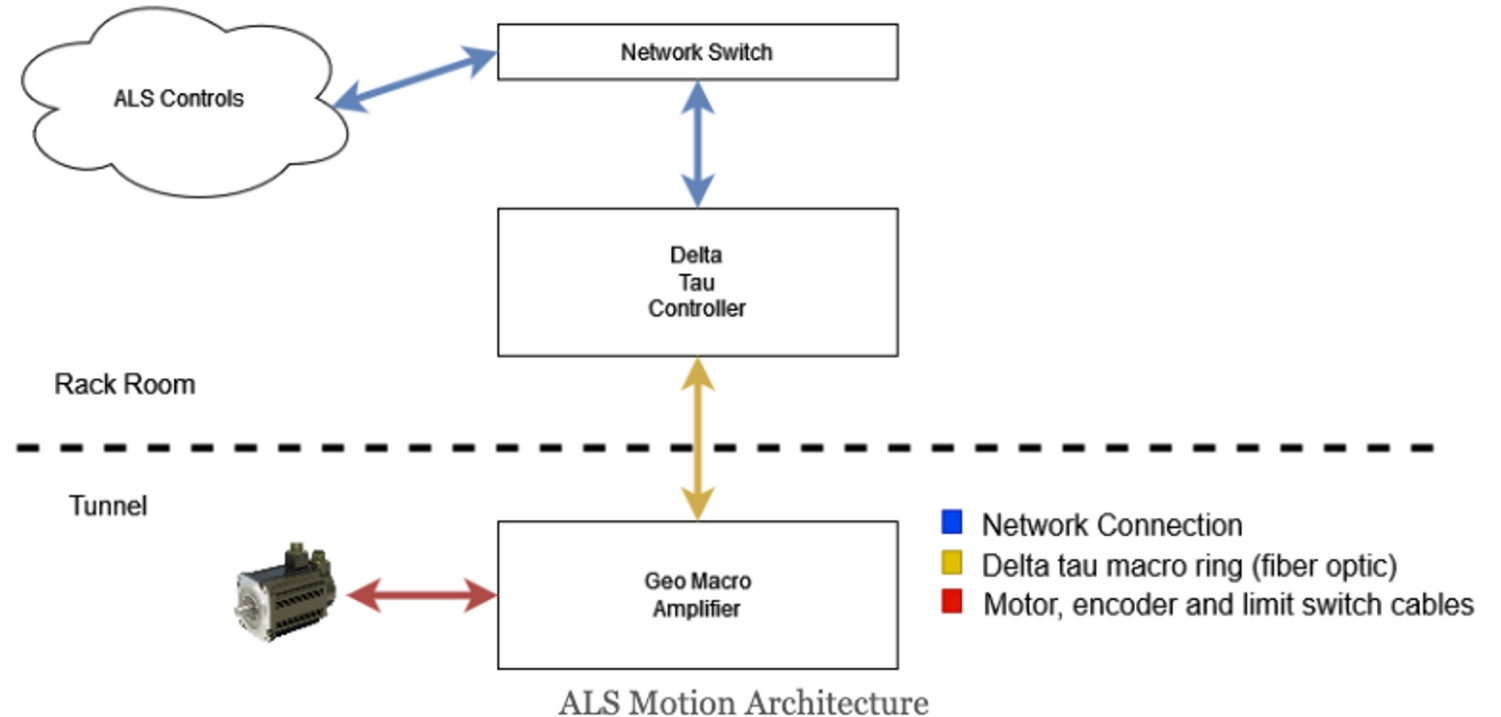


- EPICS Community Middleware Services
- Collaboration with the ALS Controls team to use the same environment
- Phoebus, ChannelFinder, and Archiver Appliance are ready for the AR production
- Alarm Services and Save-and-Restore configuration and study in progress
- Work with the EPICS collaborators intensively

# ALS-U Motion

- *Stepper Motion Control Supports (no resources from ALS, end of life hardware, and so on), work with Osprey to find a feasible solution studies during 1.5 years*
- **After 1.5 year study, we finalized the ALS-U Motion Architecture to compatible with ALS motion and EPICS SW architectures.**

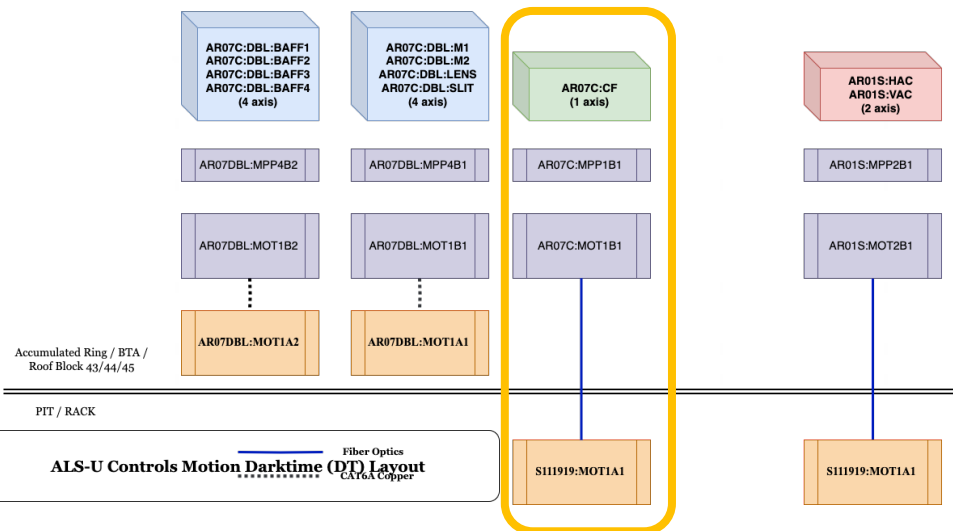
The following figure shows the current ALS motion architecture.



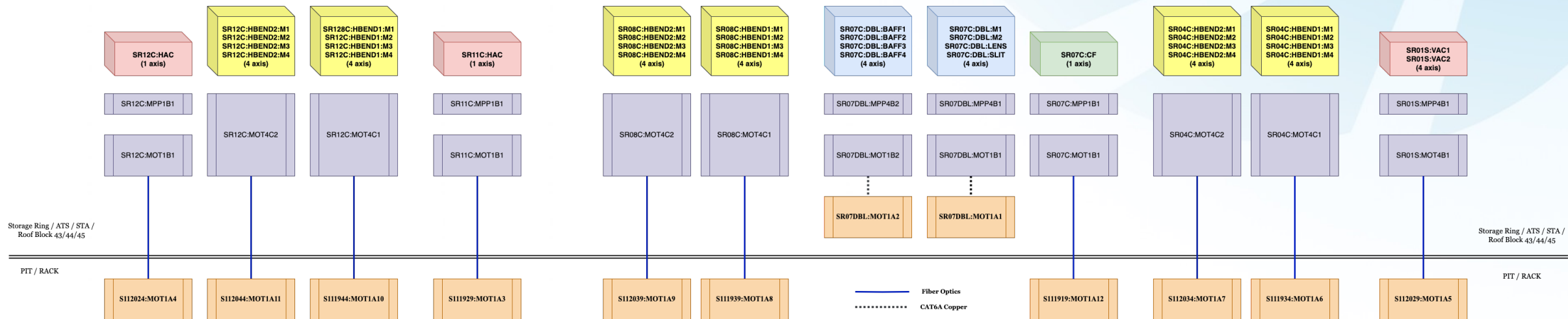
We focus on finding feasible solutions to meet the ALS-U motion requirements and keeping the ALS architecture as close as possible to market available protocol, which is reliable and sustainable for the next two decades. Moreover, we aim to make a modularized solution per each axis, so we can scale up that module to cover potential multi-axis requirements without losing the design strategy.

# ALS-U Motion Racks (Pit / DBL)

ALS-U Controls Motion Pre-Darktime Layout

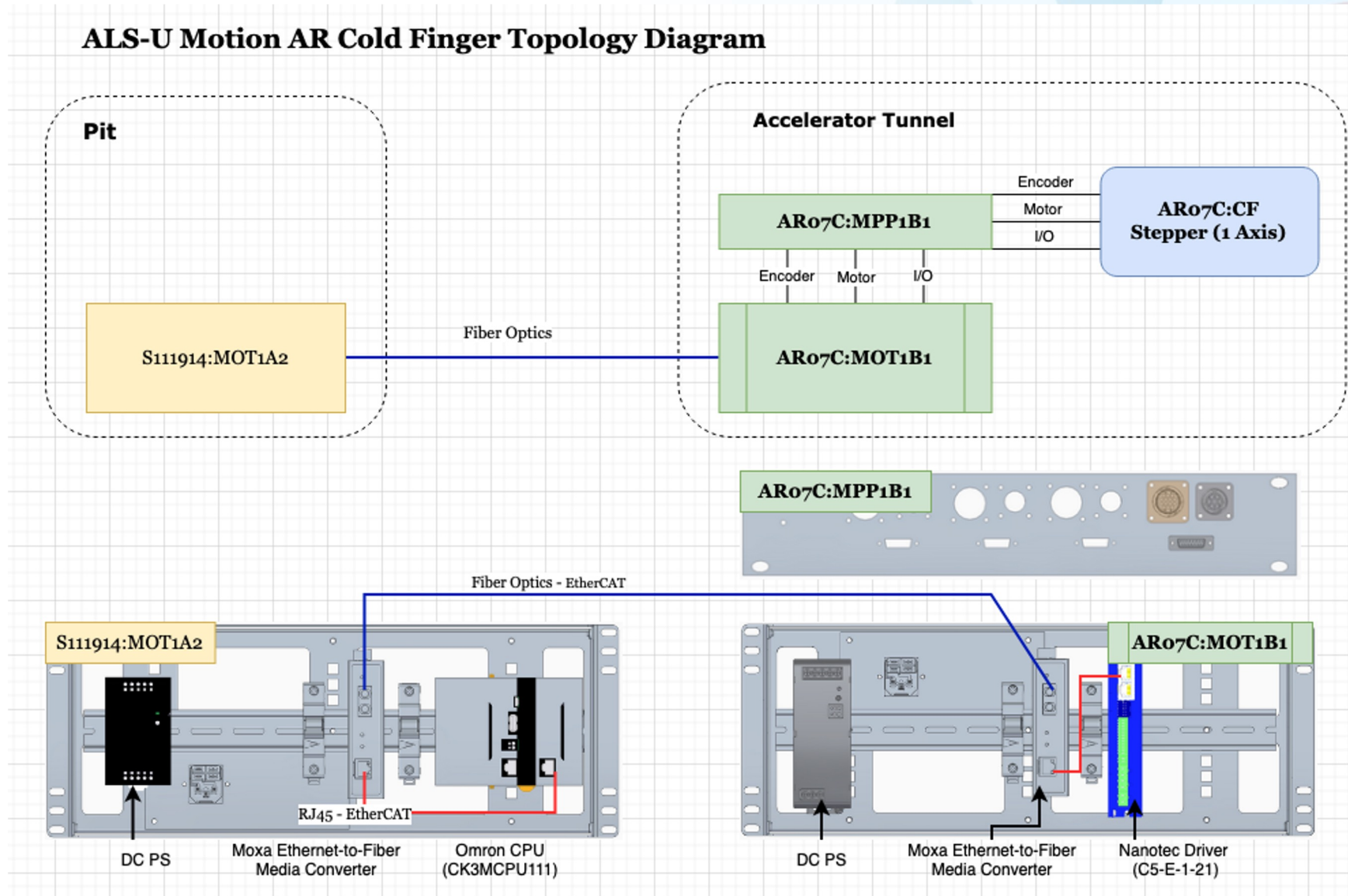


AR Cold Finger



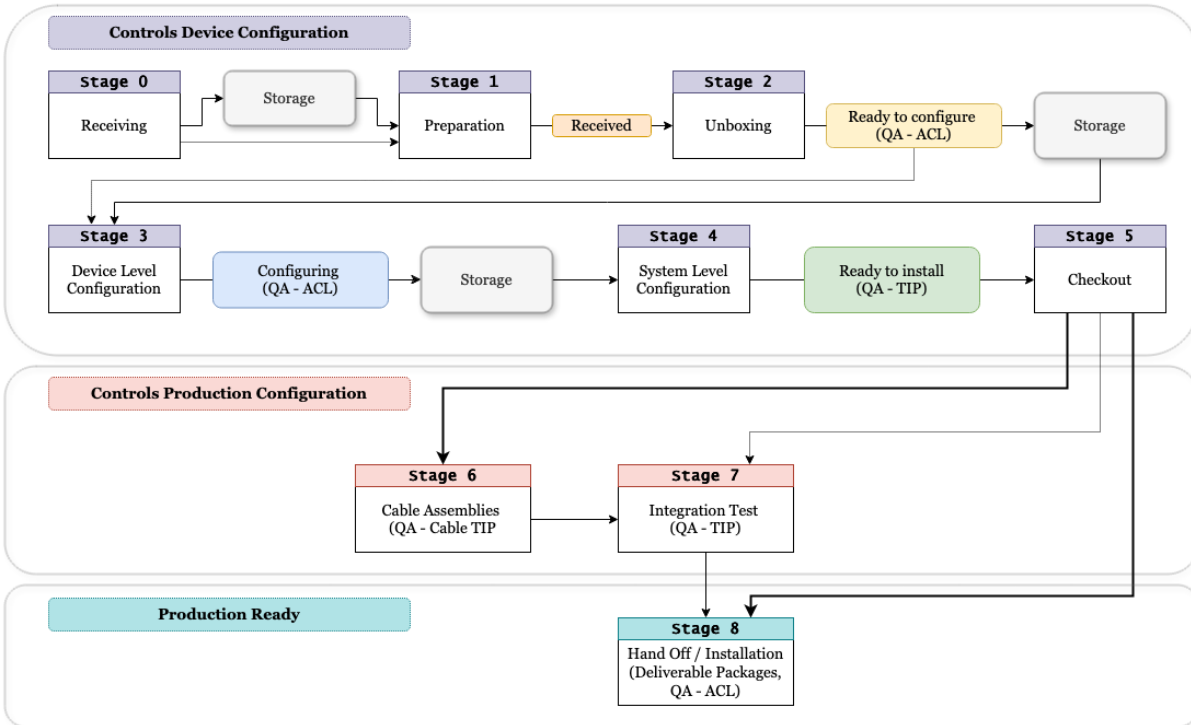
# ALS-U Motion : AR CF Topology (An example)

ALS-U Motion AR Cold Finger Topology Diagram



# Asset Management System (AMS)

## ALS-U Controls Configuration and Installation Workflow : Device / Rack



Controls Asset Management Status

Received

Ready to configure

Configuring

Ready to install

**Dashboard**

1,000 assets | 2 licenses | 0 accessories | 0 consumables | 16 components | 18 people

**Recent Activity**

Date	Admin	Action	Item	Target
2024-04-11 10:09AM	Najm Us Saqib	checkin from	000577 - Monitor	Joseph Link
2024-04-09 02:59PM	Joseph Link	checkout	000577 - Monitor	Joseph Link
2024-04-09 02:57PM	Najm Us Saqib	checkin from	000577 - Monitor	001182 - ALS-U Rack
2024-04-09 02:30PM	Najm Us Saqib	checkout	000577 - Monitor	001182 - ALS-U Rack
2024-04-09 02:30PM	Najm Us Saqib	checkout	001207 - DUMMY ASSET	001182 - ALS-U Rack
2024-04-09 02:30PM	Najm Us Saqib	checkout	001208 - DUMMY ASSET	001182 - ALS-U Rack
2024-04-09 02:04PM	Najm Us Saqib	checkin from	001208 - DUMMY ASSET	001182 - ALS-U Rack
2024-04-09 02:04PM	Najm Us Saqib	checkin from	000577 - Monitor	001182 - ALS-U Rack
2024-04-09 02:04PM	Najm Us Saqib	checkin from	001207 - DUMMY ASSET	001182 - ALS-U Rack

**Assets by Status**

- Ordered (1)
- Ready to Install (156)
- Obsolete (16)
- Received (21)
- Ready to Configure (47)
- Configuring (707)
- N/A (Test Equipment) (68)

# Asset Management System (AMS)

Asset Tag	Serial	Model	Category	Status	Checked Out To	Location
000267	1182	E2D	Monitoring	Configuring <span>Deployed</span>	(000553) - ALS-U Rack	A0802
000388	5A2043E05879	AP8932-NMC2	PDU	Configuring <span>Deployed</span>	(000553) - ALS-U Rack	A0802
000553	A0802	ALS-U Rack	Installation	Configuring <span>Deployed</span>	A0802	A0802
000768	6754	RTC	DAQ	Configuring <span>Deployed</span>	(000553) - ALS-U Rack	A0802

## View Asset 000553

Info
Licenses
Components
Assets 3
History
Maintenances
Files 3
Additional Files
Upload

**Status** ● Configuring Deployed → A0802

**Company** AR Production

**Serial** A0802

**Manufacturer** Schrott

**Category** Installation

**Model** ALS-U Rack

**Model No.** 850

**BYOD** ✗ No

**Subsystem** ALS-U Controls System, ALS-U Instrumentation System, Electrical Cable and Integration

**DOE Number**

**eTraveler URL**

**Notes**

**Location** A0802

**Default Location** AR Sector, ALS-U

Checkin Asset

Edit Asset

Clone Asset

Audit


Delete

**Checked Out To**

A0802

A0802

📅 Checkout Date: 2024-03-28



## View Asset 000553

Info Licenses Components **Assets 3** History Maintenances Files 3 Additional Files

Edit Go

Search

Showing 1 to 3 of 3 rows

Asset Name	Device Image	Asset Tag	Serial	Model	Category	Status	Checked Out To
		000267	1182	E2D	Monitoring	Configuring <span>Deployed</span>	(000553) - ALS-U Rack
		000388	5A2043E05879	AP8932-NMC2	PDU	Configuring <span>Deployed</span>	(000553) - ALS-U Rack
		000768	6754	RTC	DAQ	Configuring <span>Deployed</span>	(000553) - ALS-U Rack

Showing 1 to 3 of 3 rows



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Asset Tag	Serial	Model	Category	Status	Checked Out To	Location
000267	1182	E2D	Monitoring	Configuring <span>Deployed</span>	(000553) - ALS-U Rack	A0802
000388	5A2043E05879	AP8932-NMC2	PDU	Configuring <span>Deployed</span>	(000553) - ALS-U Rack	A0802
000553	A0802	ALS-U Rack	Installation	Configuring <span>Deployed</span>	A0802	A0802
000768	6754	RTC	DAQ	Configuring <span>Deployed</span>	(000553) - ALS-U Rack	A0802

## View Asset 000553

Info
Licenses
Components
Assets 3
History
Maintenances
Files 3
Additional Files
Upload

**Status** ● Configuring Deployed → A0802

**Company** AR Production

**Serial** A0802

**Manufacturer** Schrott

**Category** Installation

**Model** ALS-U Rack

**Model No.** 850

**BYOD** ✗ No

**Subsystem** ALS-U Controls System, ALS-U Instrumentation System, Electrical Cable and Integration

**DOE Number**

**eTraveler URL**

**Notes**

**Location** A0802

**Default Location** AR Sector, ALS-U

Checkin Asset

Edit Asset

Clone Asset

Audit


Delete

**Checked Out To**

A0802

A0802

📅 Checkout Date: 2024-03-28



## View Asset 000553

Info Licenses Components **Assets 3** History Maintenances Files 3 Additional Files

Edit Go

Search

Showing 1 to 3 of 3 rows

Asset Name	Device Image	Asset Tag	Serial	Model	Category	Status	Checked Out To
		000267	1182	E2D	Monitoring	Configuring <span>Deployed</span>	(000553) - ALS-U Rack
		000388	5A2043E05879	AP8932-NMC2	PDU	Configuring <span>Deployed</span>	(000553) - ALS-U Rack
		000768	6754	RTC	DAQ	Configuring <span>Deployed</span>	(000553) - ALS-U Rack

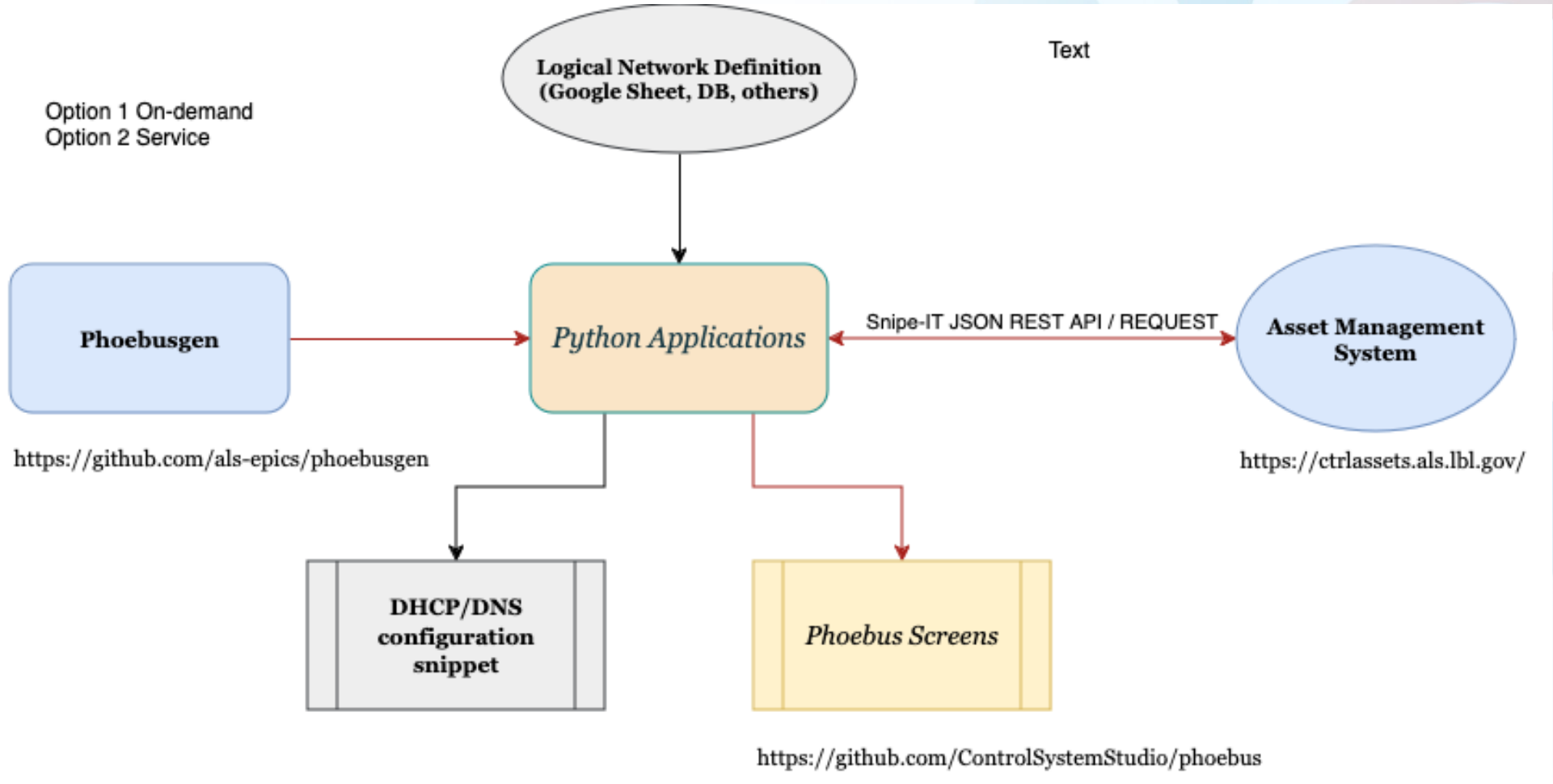
Showing 1 to 3 of 3 rows



# Asset Management System (AMS)



# Asset Management System (AMS)



# Asset Management System (AMS)

Phoebus Screen 1

AR SR

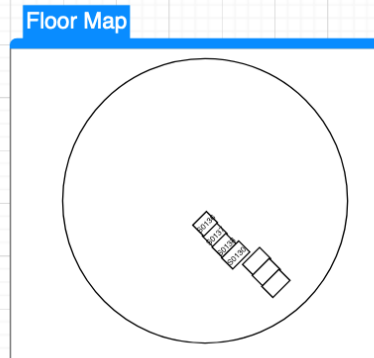
A0101	A0102	A0102	A0103	
A1201	A1202			

Phoebus Screen 2

Controls Instr. RF

A0102	A0202	A0302
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Phoebus Screen 3

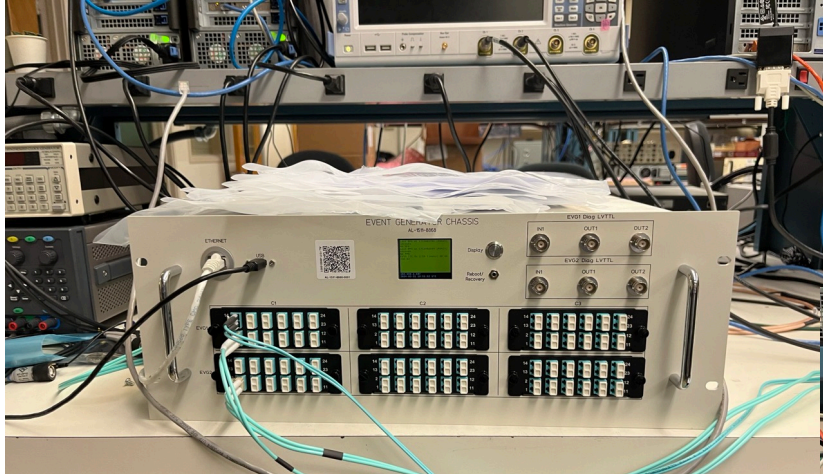


Ao8o2
NET : EX3400-24T
DCPS
MPSA
DCDS
EVR
BLM
NPCT
DMM
BCM
E2D
RTC
PDU

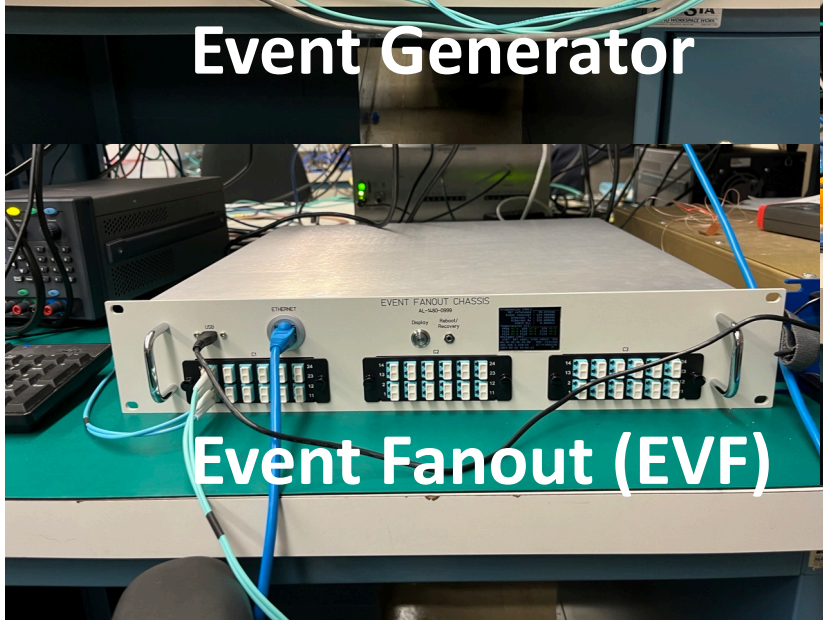
- Rack Name (Parent)
- NAME : DEVICE Model (dynamic\* PVs)
- Each unit (Child asset) has all static information and dynamic\* PVs from IOC if exists
- Asset Tag
- Serial Number
- Model
- Firmware
- IP address
- Subnet mask
- Gateway
- MAC Address

(dynamic\* PVs) : Future expansion

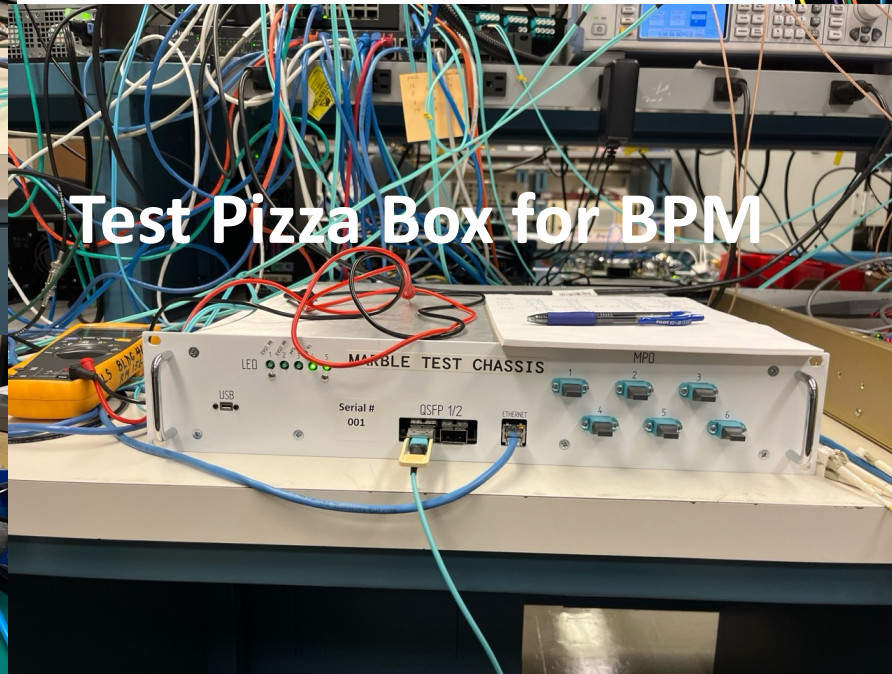
# ALS-U Hardware



Event Generator



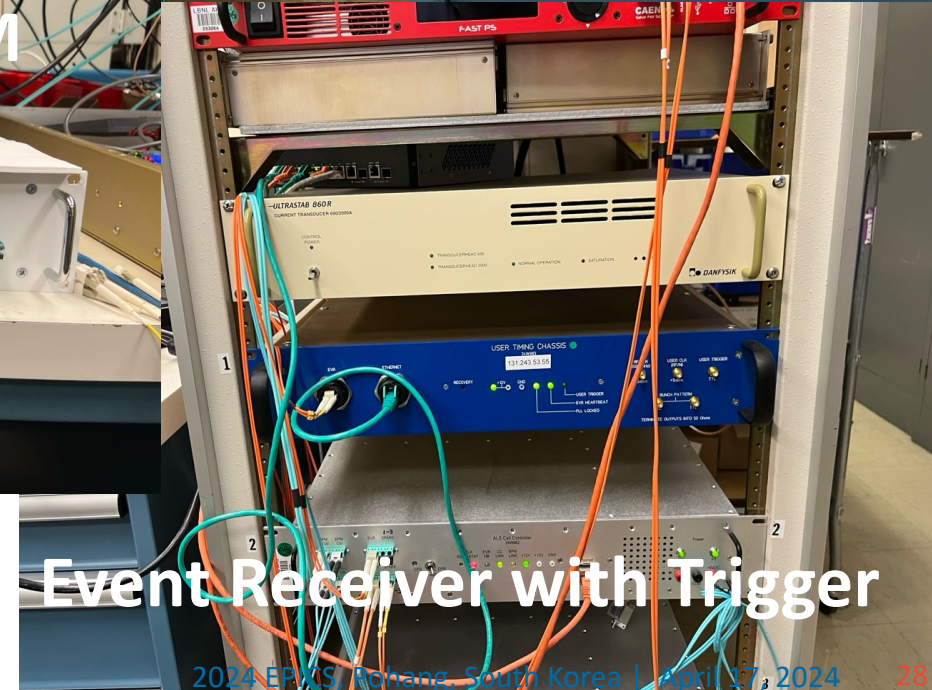
Event Fanout (EVF)



Test Pizza Box for BPM



High Speed Digitizer (HSD)



Event Receiver with Trigger

# ALS-U Hardware

Rack Temperature Controls  
Water Leak and Smoke Detection

Rack Heat Exchanger

TCMD : TC monitoring

DMM : Averaging  
Beam Current with  
NPCT

TBM : Magnet Coil  
Temperature Interlock

TCMD : TC monitoring

TBI

# ALS-U Hardware



# Lesson Learned?



We found we have zero clearance, and random orientation for the FM cable, so we had to find additional L-Shape cable adaptor. Please engage your design at early stage of the mechanical and plant design.

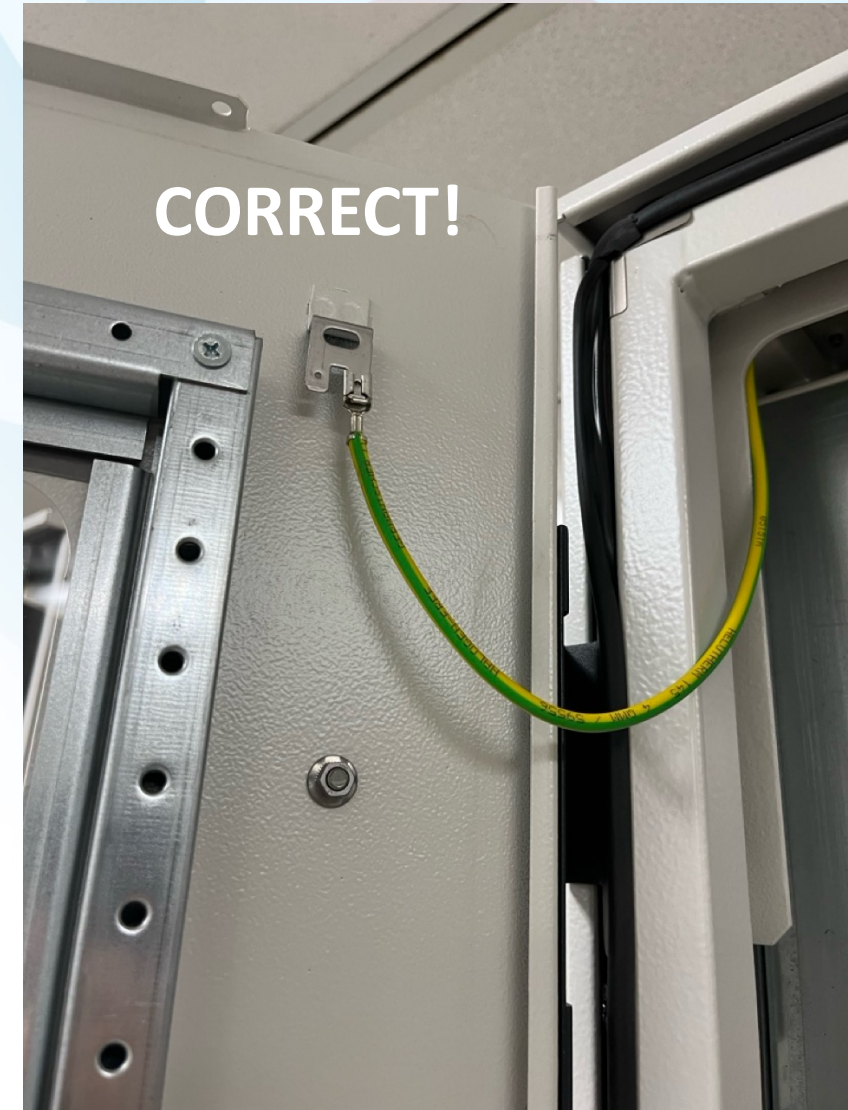
# Lesson Learned?



We received the vendor (Schroff/nVent) with the rack frame grounding on the left.

We fixed it rightly!

Be aware about the vendor QC/QA engineering





# Lesson Learned?

- Grounding on a painted surface (Schroff / nVent)
- not enough tolerance on mounting rails, so we cannot mount



Thank you!  
감사합니다!

Let the Light In ALS-U!