PIP-II Installation and Commissioning

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Outline

• Scope of I&C
• PIP2IT Test Infrastructure
• PIP-II Building Infrastructure
• PIP-II Linac Installation
• Summary
Scope of I&C

• The PIP-II Installation and Commissioning (I&C) WBS includes:
  – 121.04.01 Project Management (PM)
  – 121.04.02 Warm Front End (WFE)
  – 121.04.03 Test Infrastructure (TI)
  – 121.04.04 Building Infrastructure (BI)
  – 121.04.05 Linac Installation (LI)
  – 121.04.06 Beam Commissioning (COM)
  – 121.04.07 Accelerator Physics (AP)

- See PIP2IT talk (Pozdeyev)
- Will be discussed in this talk
- See PIP2IT talk (Pozdeyev)
**PIP-II Injector Test (PIP2IT)**

- The PIP2IT accelerator is a testbed for the PIP-II WFE, HWR and SSR1
  - Testing of an integrated system with beam
  - Verification of key PIP-II components and technologies
- The PIP2IT facility will be converted to a test stand for PIP-II’s cryomodules
PIP2IT Status/Accomplishments

- I&C responsibilities for PIP2IT:
  - Construction and installation of test cave, infrastructure and utilities ✔
  - Installation of accelerator components ✔
  - Beam commissioning (see Pozdeyev PIP2IT talk) ✔
  - Disassembly/removal of PIP2IT accelerator components & storage of equipment
  - Conversion of PIP2IT into cryomodule test stands (for no-beam cold RF testing)
PIP2IT Test Infrastructure (TI) Scope and Status Summary

• Installation of and operations support for the PIP2IT accelerator facility
  – Mission completed with the beam test program, April 2021
• Design of PIP2IT fluids and electrical systems
  – Developed an implemented solutions that will be carried forward into PIP-II
• (PIP2IT Disassembly)
  – Different WBS, same team
  – Removal of accelerator equipment to storage, ongoing now
• 650MHz Test Stand Modifications
  – Preparing for installation start in June (following HWR systems removal)
PIP2IT Test Infrastructure

• Construction of PIP2IT’s infrastructure from 2013-2021 provided opportunities to develop
  – Design practices
  – Work planning
  – Team coordination
PIP2IT Test Infrastructure – Building Infrastructure Experience

• Successful features carried forward to PIP-II Building Infrastructure Design
  – RFQ cooling system (water-based tuning and resonance control)
  – Coupler air cooling
  – Ion Source chiller
  – Dissolved oxygen removal technology
  – Cable database implementation

RFQ cooling system
The Linac Installation team coordinated PIP2IT installation
- Team was onboarded early to take advantage of opportunity to gain experience
- Experience and lessons learned carried forward to PIP-II installation planning
- Especially relevant to PIP-II acceptance, verification/validation and traveler plans
**PIP2IT Disassembly**

- PIP2IT is being disassembled and stored, in preparation for reinstallation in PIP-II
  - Another opportunity to optimize our PIP-II processes and documentation
650 Test Stand Modifications

• PIP2IT is being turned into a test stand for PIP-II cryomodules
  – Accommodates 1 SSR module + 1 650MHz module
  – Capability to test modules independently, simultaneously
  – 2K operation with RF

• Test Infrastructure Responsibilities
  – Electrical and mechanical infrastructure & utility modifications
  – Integration and installation support for all sub-systems
  – Cryogenic Transfer Line
    • Adapts existing HWR bayonet interfaces to standard 650MHz cryomodule interfaces

3-D Model of 650 MHz and SSR cryomodule test stands
650 Test Stand Overview 3D Models

- 650MHz amplifier systems
- 650MHz test stand (HB650 shown)
- SSR test stand (SSR2 shown)

New cryogenic transferline

Facility layout

CMTS1: LCLS2-HE Test Stand
Building Infrastructure (BI) – Scope and Status Summary - Electrical

• Design of Electrical distribution from CF interface point to system equipment
  – Power distribution and grounding
  – Cable, connectors, and tray routing, overall cable plant management
  – Similar scope successfully managed and completed for PIP2IT
  – PIP-II preliminary design is complete, preparing final design
  – BI team actively supporting PIP-II CF design

• Design of PIP-II cable database
  – Cable database prototype has been created
  – Testing of database and implementation currently underway using PIP2IT 650 MHz test stand reconfiguration

• Design and layout of relay racks for PIP-II
  – Prototype racks have been purchased and set up for users inspection/feedback
Building Infrastructure – Electrical Lessons Learned from PIP2IT

• Design
  – It’s helpful if rack layouts are finalized early
  – Include overhead in cabling plans to accommodate late changes
  – Enforce standardized cables

• Cable Database
  – Database, sequence of work, must be constantly monitored and maintained
  – Fully define cable routes
  – Track special cable considerations in Database prior to pull

• Installation
  – Be flexible with cable pulls when necessary
  – Protect cable after installation to avoid damage
  – Have a central cable store, with an adequate staging area for electricians
  – Enforce labeling before installation
Building Infrastructure – Cable Database
Building Infrastructure – Prototype Relay Racks

• Prototype relay racks purchased
  – Standardized, configurable options
  – Handling and ergonomics considered
  – Available for team design
• Design of distribution process fluid piping system utilities (PCW, LCW, compressed air, utility Nitrogen) in the Linac High Bay Building and Gallery, Linac tunnel, and Beam Transfer Line
  – Includes
    • PCW pump room in the Utility Plant at the Cryoplant Building.
    • LCW pump room in the F37 Service Building.
    • Special application skids, chillers in warm front end and BTL absorber.
    • Layout planning of piping/hose connection assemblies, valve, and instrumentation
  – Management of CF interface and envelopes with process fluid systems are well understood and stable
  – Preliminary design is complete, implementing PDR recommendations.
• Procurement and installation
  – Installation of primary distribution piping is part of CF construction
  – PCW and LCW pump room system procurement and installation performed by BI
  – Linac/Gallery instrumentation and connecting hardware procured by BI, installed by Linac Installation team
  – Planning and communication with CF and LI is underway and well understood.
Building Infrastructure Scope – Process Water Cooling

- Process Clean Water (PCW) System
- Low Conductivity Water (LCW) System
- RFQ Intermediate Cooling Skid
- RFQ Vane Cooling Skid
- RFQ Wall Cooling Skid
- RFQ Circulator Chiller
- Ion Source Chiller
- Absorber RAW Skid
Building Infrastructure Scope – Compressed Gas

- Compressed Air System
- Utility Nitrogen Gas Piping System
Process Clean Water (PCW) System

• Provides process clean cooling water to the SRF power amplifier equipment
  – Low conductivity is not a cooling water requirement for this equipment in LINAC gallery
  – As a result, a separate, smaller LCW system created for LINAC/BTL enclosures

• PCW Pump Room located in the Utility Plant

• Preliminary design is complete, implementing PDR recommendations.
Low Conductivity Water (LCW) System

• Provides low conductivity cooling water to accelerator magnets, power supplies, and other beamline components
• LCW Pump Room located in the Utility Plant
• The preliminary design is complete
PCW/LCW - Piping and Instrumentation Diagram (P&ID)

- P&ID completed for pump rooms, skids, chillers, compressed gas systems

- Currently working on complete P&ID for entire PIP-II PCW and LCW systems
PCW/LCW - System Flow Analysis

- Comprehensive analysis of PCW and LCW systems completed
- AFT Fathom - Fluid dynamic simulation software
- Calculates pressure drop and pipe flow distribution in piping fluid systems
- Confirmed equipment selection and sizing satisfies system requirements
AFT Fathom Example – PCW to amplifiers

PCW System Pump Room at Utility Plant

LB650

SSR1

RFQ Amplifiers

SSR2

MEBT Amplifiers

HB650

HWR Amplifiers
RFQ LCW Cooling System and Ion Source Chiller

- RFQ uses three skids (Vane, Wall, Intermediate) working together as one system
  - Recirculates LCW through vane and wall sections of the RFQ
  - Cooled via intermediate skid using facility chilled water (CHW)
- Ion Source Chiller, Self-contained, Air-cooled, LCW
- Both systems successfully tested during PIP2IT operations
- Systems will be reused for PIP-II
BTL Beam Absorber RAW Skid

- Radioactive Water system
- Cools the Beam Absorber located in the Beam Transfer Line (BTL)
- The preliminary design is complete, final design in process
- Similar Absorber RAW Skid design successfully in operation at NML
Air and Nitrogen

- Compressed air system supports multiple end uses, including significant coupler cooling loads
- Nitrogen supports skid blankets, vacuum needs
- Preliminary design is complete, implementing PDR recommendations.
Linac Installation (LI) Scope and Status Summary

- **PIP-II Integrated CAD Model**
  - Mechanical model, incorporates solid models developed by PIP-II system teams
  - Model is in place and growing

- **Designs for...**
  - Alignment network (In design)
  - Cryomodule stands and mover (stand prototypes in use at PIP2IT)
  - Warm unit structures (PDR June 2021)

- **PIP-II WFE+SCL Installation**
  - Planning and execution
  - Incremental handoff to Commissioning

_Cryomodule modular stand with HWR_
Integrated CAD Model

- LI maintains the top-level PIP-II CAD model
  - Lessons learned from the PIP2IT model have been employed
  - Techniques for geometry simplification, assembly structure management and 3D scan have been incorporated
  - Robust data exchange with CF team
Cryomodules – selectable level of visual simplification managed in NX Arrangements

LB650 Section
Integrated CAD Model – Existing Booster

3D scan of existing booster tunnel and equipment in PIP-II injection region
Integrated CAD Model – Integration with Conventional Facility

- Design is coordinated with the CF team
  - 2-way data exchange to allow parallel design with CF’s A&E
  - Linac Complex CF design is complete as of April 2021

Lattice-based penetration locations coordinated with CF structure

Alignment network sight risers (line-of-sight to surface of shielding berm)
Existing external survey monuments: Incorporated in CF, CAD and alignment network designs
Alignment Network Design

- Surface network designed to allow for line-of-sight and GPS survey techniques
- Underground network designed for laser tracker survey
Modular cryomodule stands accommodate all cryomodule styles

Modular warm unit structures accommodate varying instrumentation suite
Linac Installation Process Design – Current Focus

- Hardware Acceptance Framework
  - Installation Readiness Review (IRR) – gate at hardware delivery

- Sequencing
  - Visual storyboarding being used to define overall installation sequence
  - System design teams are developing installation plans for their specific designs, presented (at a minimum) at reviews

- Traveler Framework
  - Working to identify travelers to describe the full scope of work between IRR and handoff to beam commissioning

- Verification and Validation (V&V) Framework
  - Building a plan for system validation at each level of integration
**PIP-II Installation Readiness Reviews**

- **Partner or vendor delivery**
- **L3 Testing and QC**
- **L3 acceptance of partner/vendor deliverable per Acceptance Criteria Document and List**
- **L3-managed documentation stored in Fermilab systems (procedures, drawings, travelers, QC data, etc.)**
- **Partner/Vendor Documentation (procedures, drawings, travelers, QC data, etc.)**
- **Installation Deliverable List Document**
- **Hardware gets configured by L3 as agreed per Installation Deliverable List**
- **Handoff to installation WBS**

**Installation Readiness Review, administered by Tech. Integration**

- *Pass*
- *Fail*

**Responsibility**

- **Partner**
- **L3**
- **Tech. Int.**
- **Installation**

**LI team input: tensioned process**
Sequencing and Storyboarding

Example – Detail storyboard frames for 650MHz Warm Unit Installation
Traveler Framework

• Developing a hierarchical list of the travelers to be developed
  – Utilizing a “traveler tree” framework

• Goals
  – Identify the work and guide traveler writing
  – Identify dependencies between systems
  – Identify small-scale milestones
    • e.g. subsystem Operational Readiness Clearance reviews
    • Coordinate tree structure with these milestones
  – Facilitate Verification and Validation efforts
Traveler Framework

Example – traveler identification by system

Hierarchical traveler tree
Verification and Validation (V&V)

- Verification is the confirmation that specified requirements have been fulfilled.
- Validation is the confirmation that the intended use has been fulfilled.
  - In most cases, large-scale system function and performance.
- Steps defined and data captured within the traveler framework.
- Verification and Validation scope:
  - Oversee the implementation of the quality plan.
  - Confirm functionality of integrated systems.
  - Make sure the machine works!
  - Bridge between installation and beam commissioning teams and efforts.
I&C Summary

- PIP2IT Accelerator construction and operation was a key training ground for the I&C Team
- Lessons learned are being carried forward into 650 Test Stand and PIP-II designs and plans
- Hardware and process designs for PIP-II are advancing