Facility for Rare Isotope Beam (FRIB) PLC Control Systems Introduction

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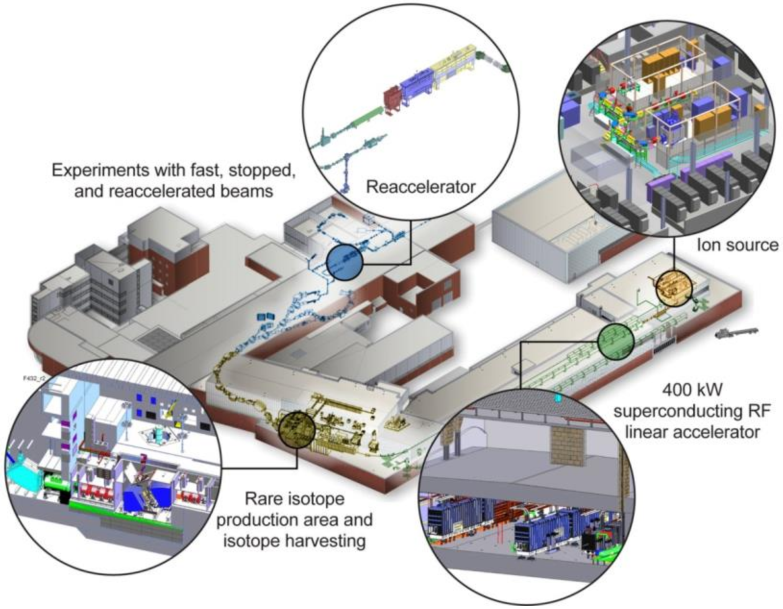
Outline

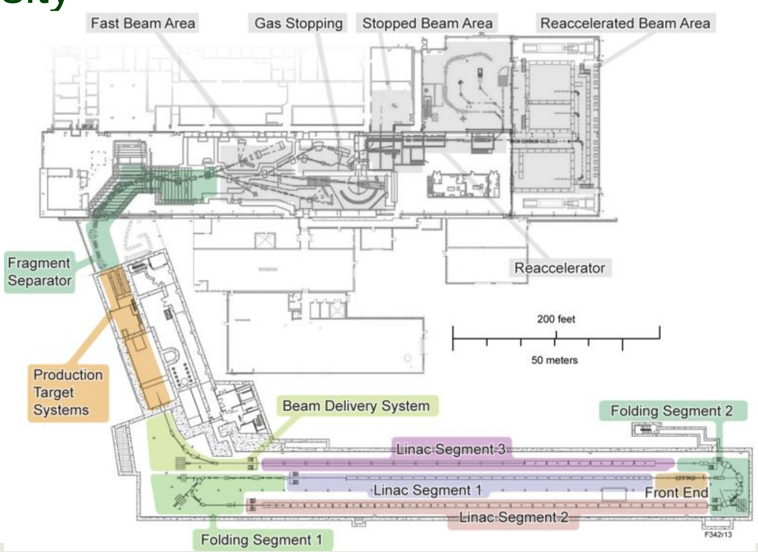
- FRIB project introduced
- PLC scope and application defined
- PLC Architecture defined
- Control Engineering Process defined
- Management of change workflow defined

FRIB Introduction



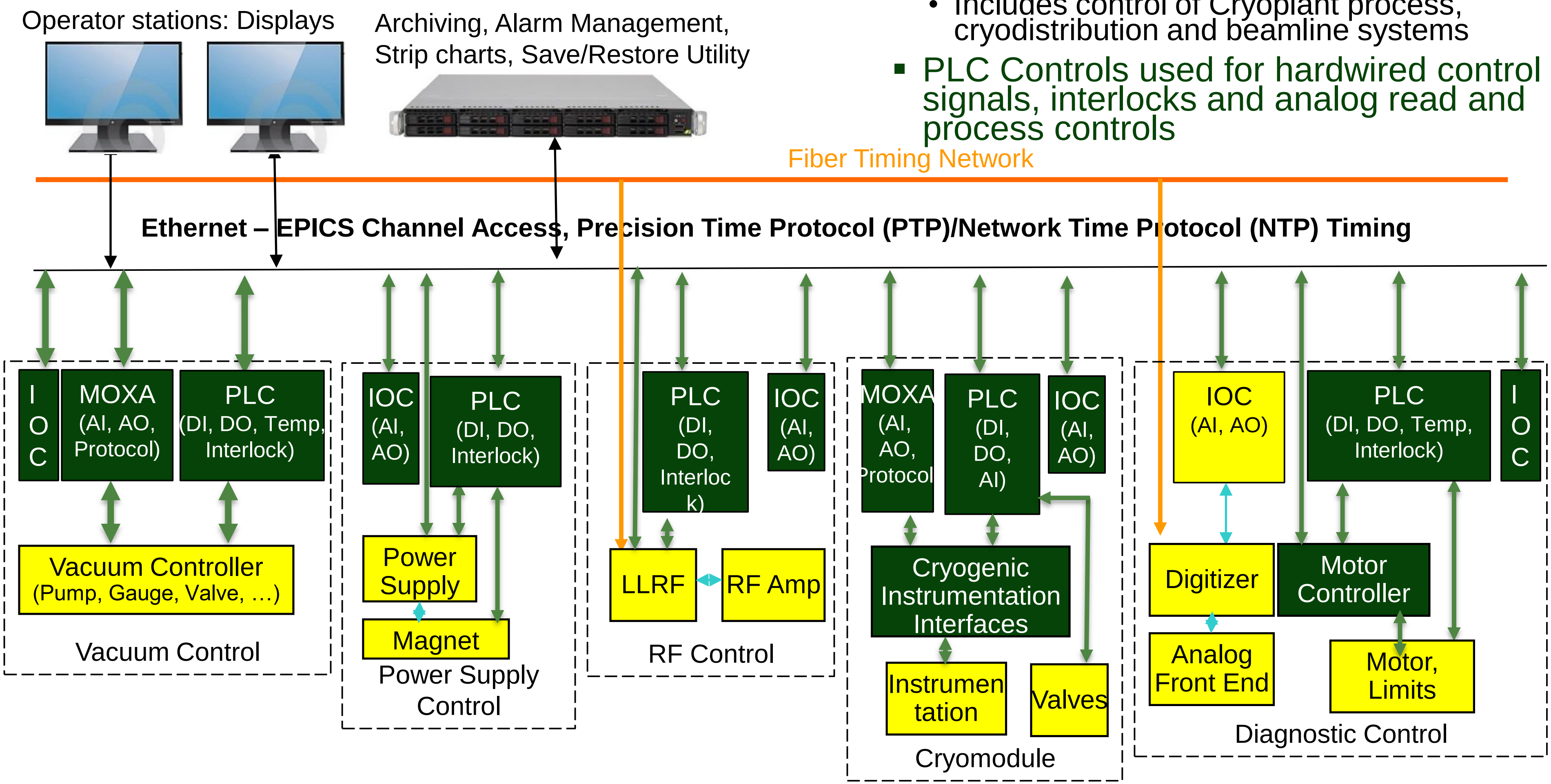
- The FRIB, is a new heavy ion accelerator facility currently under construction at Michigan State University
  - Replaces existing coupled cyclotrons in the National Superconducting Cyclotron Lab
- It is being built to provide intense beams of rare isotopes
- Funded by DOE–SC Office of Nuclear Physics with contributions and cost share from Michigan State University

- Serving over 1,400 users
- Key feature is 400 kW beam power for all ions, from H to ^{238}U with energies of no less than 200 MeV/u
- Provides separation of rare isotopes in-flight
  - Supplying fast, stopped, and reaccelerated beams to experimenters
- Scheduled completion, 2022



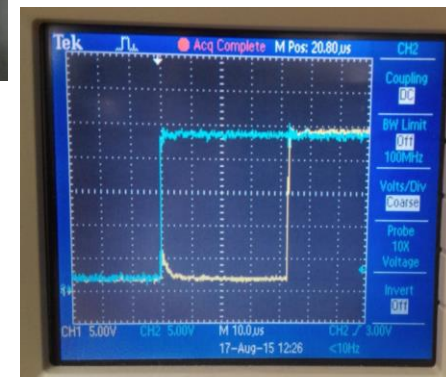
FRIB Low Level Controls Scope and Application

- Based on EPICS and industrial PLC control systems
  - (Items in green are within the scope of Low Level Controls)
- FRIB will have ~50 ControlLogix PLCs
  - NSCL has a similar number with ~12K I/O points
  - Includes control of Cryoplant process, cryodistribution and beamline systems
- PLC Controls used for hardwired control signals, interlocks and analog read and process controls



FRIB PLC Architecture Defined [1]

- Allen Bradley (AB) ControlLogix PLC
  - Large installed base in local industry
  - Already deployed and established as standard for NSCL projects since 2004
  - Used at several other National labs
  - Existing in-house expertise
  - Excellent local support from manufacturer
- Provides the direct interface to the process devices via modular I/O
  - Interfaces with discrete logic signals via 24 VDC
  - Interfaces with analog signals via 4..20 mA current loops or +/- 10 VDC
  - Other signaling levels can be translated through appropriate signal conditioning
- Remote I/O
  - Ethernet connected chassis house I/O modules for host controllers
  - Use of off-chassis I/O transparent to the programmer
  - Programmable failure modes for loss-of-communication faults
- Use AB AssetCentre for version control
  - Nightly compares verifies no unauthorized changes



- Baseline I/O Modules
  - Analog Input – 1756-IF16
  - Analog Output – 1756-OF8
  - Digital Input – 1756-IB16IF
  - Digital Output – 1756-OB16IEF
  - RTD Input – 1756-IRT8I
- Using High Speed Digital I/O modules
  - Lower Cost than diagnostic modules
  - Modules can place timestamps on data
  - Ability for higher speed reaction to inputs with bypassing CPU (<= 150 μ S, Tested at 40-60 μS)

PLC Architecture Defined [2]

- Interface Modules (IFMs) will be used as the connection point between the 1756 ControlLogix PLC Input and Output modules and signals from devices in the field
  - Designed to interface with specific Allen Bradley I/O modules and pre-wired terminal blocks
    - » Reduces cabinet installation time from ~40 hours to 10 hours
    - » Reduces wiring errors
    - » Reduces cost vs commercial option
    - » Provides 24 V or Com for every signal (Module Type Dependent)
    - » Provides extra 24 V, Com Connections
  - One module for each IO type
    - » Analog Input
    - » Analog Output
    - » Digital Input
    - » Digital Output
  - Uniform design across PLC systems for simplified spare inventory
  - Uses commercial pre-wired cables from I/O module to terminal blocks

FRIB Controls Engineering Workflow, SOP

Initiation (ECO/New)

- ☐ Requirement Development
- ☐ Supporting Analysis
- ☐ Risk Analysis
- ☺ **Approved Subsystem Requirement Specification (SubSyRS)**
- ☺ **Interface Document**
- ☺ **Signal List**
- **Preliminary Project Plan (P6)**
- ♡ **Gate review report (doable or not)**

Elaboration

- ☐ Engineering evaluation
- ☐ Detail planning
- ☐ Architectural Design/Key technology selection
- **Approved Project Plan (P6)**
- ☺ **SubSystem Design Description**
- ☼ **ACL Documents**
- ♡ **Gate review (ready to implement?)**

Implementation

- ☐ Detail Engineering Design/Implementation
- ☐ Unit/Component/Bench Test
- ☐ Installation
- ☐ **Schematic Package in Adept**
- ☐ **Installation Test**
- ☐ **Component/Connection Testing (verify interlocks, setpoints and control interface w/ other groups)**
- ☐ **Integration test and verification**
- ☺ **Engineering Design Description (EDD)**
- ☺ **SOW Documents**
- ☺ **User manual**
- ☼ **Test and Verification report**
- ♡ **Gate Review report (ready for production?)**

Production/Maintenance

- ☐ Manufacturing and Acceptance Test (HW)
- ☐ Deployment
- ☐ User Training
- ☼ **Acceptance Test Report (ARR, documented in Global Database)**
- ☺ **Installation and service manual (if applicable, may be same as EDD)**
- ☺ **Gate Review Report (Project Complete?)**

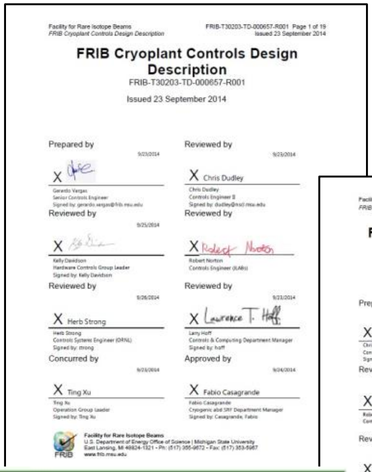
Hardware and big project will have longer Initiation/Elaboration phases.
Software (quick evolving) project will have short first two phases to form a baseline.
ECO process covered by FRIB Document

Legend

- **Living document**
- ☺ **Engineering Document**
- ☼ **Q/A document**
- ♡ **Gate review**

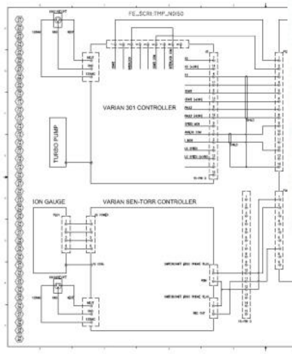
Controls Engineering Deliverables

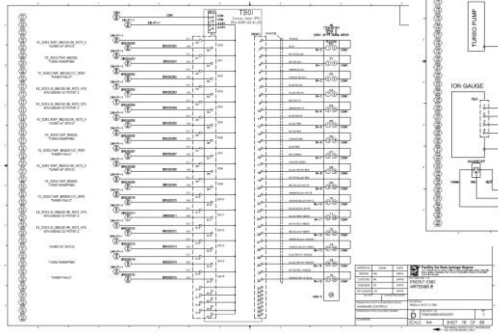
- Final designs include:
  - Interface, requirements, design description documents
  - Signal lists, interlock, and testing validation documents, support manual
  - Unique schematics
  - BOM
  - Rack layouts

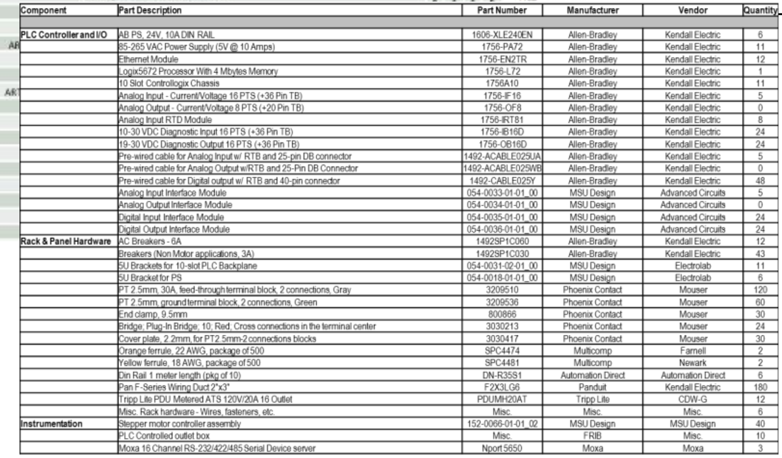


ARTEMIS Ion Source and High Voltage Platform Signal List

P &ID Ref.#	FRIB Name	Device Description	Device Type	AI	AO	DI	DO
		ARTEMIS High Voltage (Earth Ground)					
	FE_SCR1:EL_N0000	Platform HV	P100kV/20mA	2	1	1	2
		ARTEMIS High Voltage (100kV Platform)					
1	FE_SCR1:EL_N0100	High voltage power supply	P40kV/15mA Glassman - EW40P15	2	1	1	2
2	FE_SCR1:EL_N0300	Puller Power Supply	N10kV/10mA Glassman - FC10N12	2	1	1	2
	FE_SRC1:PSX_N0001	Inductive oven power supply					
	FE_SRC1:RFA_N0001	14 GHz Klystron Amplifier					
3	FE_SRC1:SOLP_N0300	Extraction coils of ARTEMIS ion source					
4	FE_SRC1:SOLP_N0100	Injection coils of ARTEMIS ion source					
5	FE_SCR1:IGC_N0150	Injection Ion Gauge					
6	FE_SCR1:IGC_N0150	Injection Ion Gauge Controller					
7	FE_SCR1:IGC_N0250	Middle Ion Gauge					
8	FE_SCR1:IGC_N0250	Middle Ion Gauge Controller					
33	FE_SCR1:TMPC_N0150	Injection Turbo Pump Controller					
34	FE_SCR1:TMP_N0250	Middle Turbo Pump					
35	FE_SCR1:TMPC_N0250	Middle Turbo Pump Controller					
36	FE_SCR1:TMP_N0350	Extraction Turbo Pump					
37	FE_SCR1:TMPC_N0350	Extraction Turbo Pump Controller					







Component	Part Description	Part Number	Manufacturer	Vendor	Quantity
PLC Controller and I/O	AB PS, 24V, 10A DIN RAIL	1606-XLE240EN	Allen-Bradley	Kendall Electric	6
	85-265 VAC Power Supply (5V @ 10 Amps)	1756-PA72	Allen-Bradley	Kendall Electric	11
	Ethernet Module	1756-EN2TR	Allen-Bradley	Kendall Electric	12
	Logix5672 Processor With 4 Mbytes Memory	1756-L72	Allen-Bradley	Kendall Electric	1
	10 Slot Controllogix Chassis	1756A10	Allen-Bradley	Kendall Electric	11
	Analog Input - Current/Voltage 16 PTS (+36 Pin TB)	1756-IF16	Allen-Bradley	Kendall Electric	5
	Analog Output - Current/Voltage 8 PTS (+20 Pin TB)	1756-OF8	Allen-Bradley	Kendall Electric	0
	Analog Input RTD Module	1756-IRT8I	Allen-Bradley	Kendall Electric	8
	10-30 VDC Diagnostic Input 16 PTS (+36 Pin TB)	1756-IB16D	Allen-Bradley	Kendall Electric	24
	19-30 VDC Diagnostic Output 16 PTS (+36 Pin TB)	1756-OB16D	Allen-Bradley	Kendall Electric	24
	Pre-wired cable for Analog Input w/ RTB and 25-pin DB connector	1492-ACABLE025UA	Allen-Bradley	Kendall Electric	5
	Pre-wired cable for Analog Output w/RTB and 25-Pin DB Connector	1492-ACABLE025WB	Allen-Bradley	Kendall Electric	0
	Pre-wired cable for Digital output w/ RTB and 40-pin connector	1492-CABLE025Y	Allen-Bradley	Kendall Electric	48
	Analog Input Interface Module	054-0033-01-01_00	MSU Design	Advanced Circuits	5
	Analog Output Interface Module	054-0034-01-01_00	MSU Design	Advanced Circuits	0
	Digital Input Interface Module	054-0035-01-01_00	MSU Design	Advanced Circuits	24
	Digital Output Interface Module	054-0036-01-01_00	MSU Design	Advanced Circuits	24
Rack & Panel Hardware	AC Breakers - 6A	1492SP1C060	Allen-Bradley	Kendall Electric	12
	Breakers (Non Motor applications, 3A)	1492SP1C030	Allen-Bradley	Kendall Electric	43
	5U Brackets for 10-slot PLC Backplane	054-0031-02-01_00	MSU Design	Electrolab	11
	5U Bracket for PS	054-0018-01-01_00	MSU Design	Electrolab	6
	PT 2.5mm, 30A, feed-through terminal block, 2 connections, Gray	3209510	Phoenix Contact	Mouser	120
	PT 2.5mm, ground terminal block, 2 connections, Green	3209536	Phoenix Contact	Mouser	60
	End clamp, 9.5mm	800866	Phoenix Contact	Mouser	30
	Bridge; Plug-In Bridge; 10; Red; Cross connections in the terminal center	3030213	Phoenix Contact	Mouser	24
	Cover plate, 2.2mm, for PT2.5mm-2 connections blocks	3030417	Phoenix Contact	Mouser	30
	Orange ferrule, 22 AWG, package of 500	SPC4474	Multicomp	Farnell	2
	Yellow ferrule, 18 AWG, package of 500	SPC4481	Multicomp	Newark	2
	Din Rail 1 meter length (pkg of 10)	DN-R35S1	Automation Direct	Automation Direct	6
	Pan F-Series Wiring Duct 2"x3"	F2X3LG6	Panduit	Kendall Electric	180
	Tripp Lite PDU Metered ATS 120V/20A 16 Outlet	PDUMH20AT	Tripp Lite	CDW-G	12
	Misc. Rack hardware - Wires, fasteners, etc.	Misc.	Misc.	Misc.	6
Instrumentation	Stepper motor controller assembly	152-0066-01-01_02	MSU Design	MSU Design	40
	PLC Controlled outlet box	Misc.	FRIB	Misc.	10
	Moxa 16 Channel RS-232/422/485 Serial Device server	Nport 5650	Moxa	Moxa	3

FRIB Work Control Procedures

- Work control procedures for control changes are documented
  - Changes are to follow both software configuration management plan, or Engineering Change order process, FRIB/NSCL PLC Change Control Procedure and work control plan
  - Communication with System Owner defined and required
    - » Role of System Owner defined
    - » Area Manager identifies System Owner for the work
    - » Discussion on the risk with System Owner required
    - » Ownership handover procedure with System Owner defined
  - Peer review required before installation
  - Adequate validation after the work
- Developing online change control request system to get system/area managers approval ahead of work planning
- Access restrictions at various level are in place
  - Physical access granted only to those with appropriate site training
  - Work after hours/weekends on FRIB site must be pre-approved
  - Access to FRIB Controls and Test Network limited to personnel with business need and appropriate qualifications
  - Access to PLC and GIT repositories are also restricted to appropriate personnel

Summary

- PLCs have a large scope and application within FRIB
- PLC Architecture has been determined, made use of time saving designs and has been a very stable platform
- Control Engineering Process defined
- Management of change workflow is defined and undergoing improvements

Backup Slides