Magnet
Status Report

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Detector Support Group

DSG STAFF

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- Control, Monitoring, and Interlock Systems
  - —Cryogenics Distribution Box
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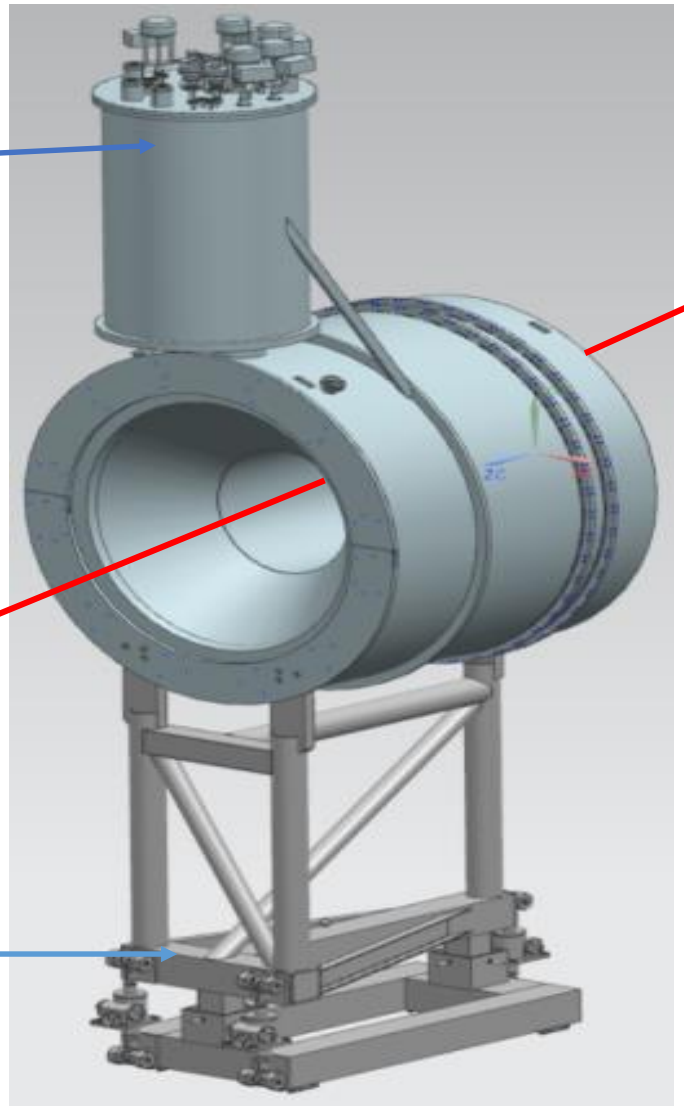
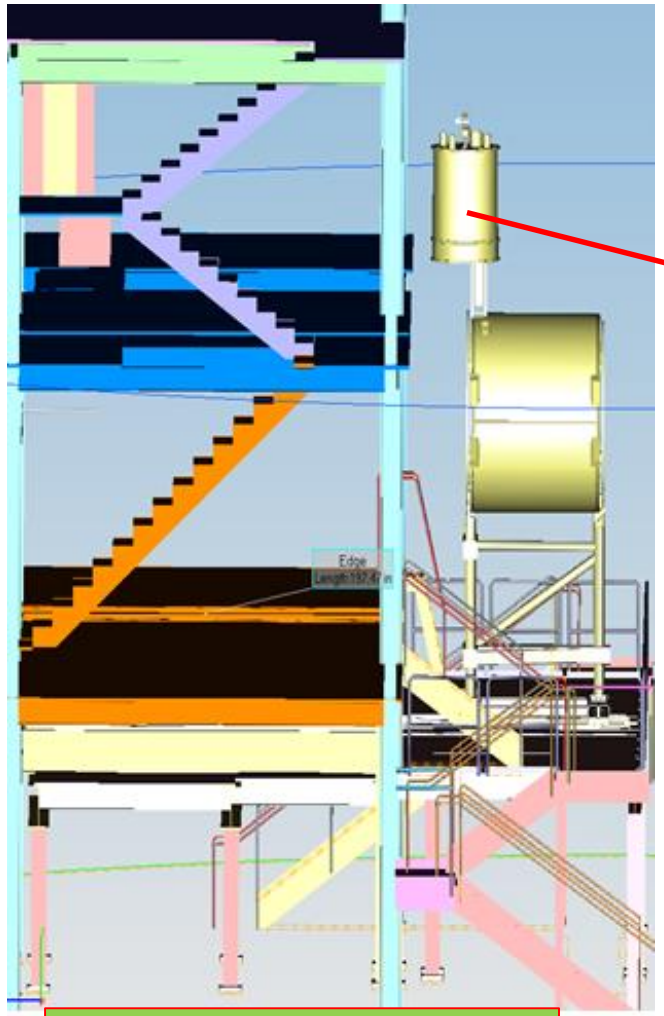
- Conclusion

Solenoid

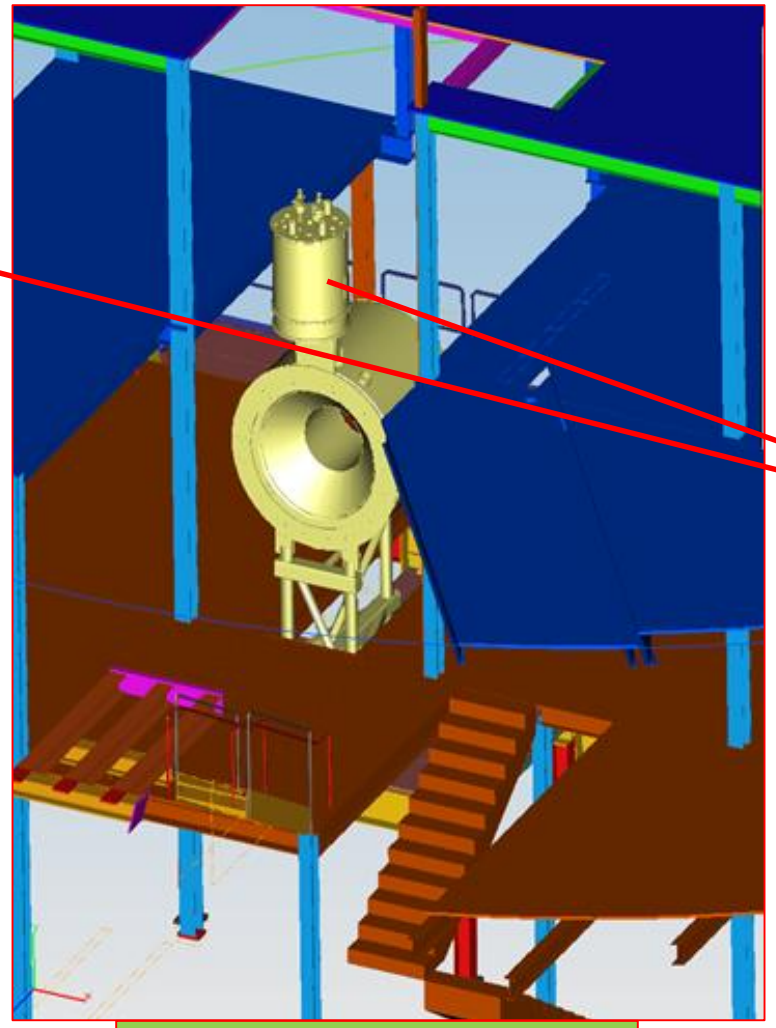


- Nominal current 2416 A
- Central field 5 T
  - Uniform field $\Delta B/B < 10^{-4}$
- Temperature 4.2 K

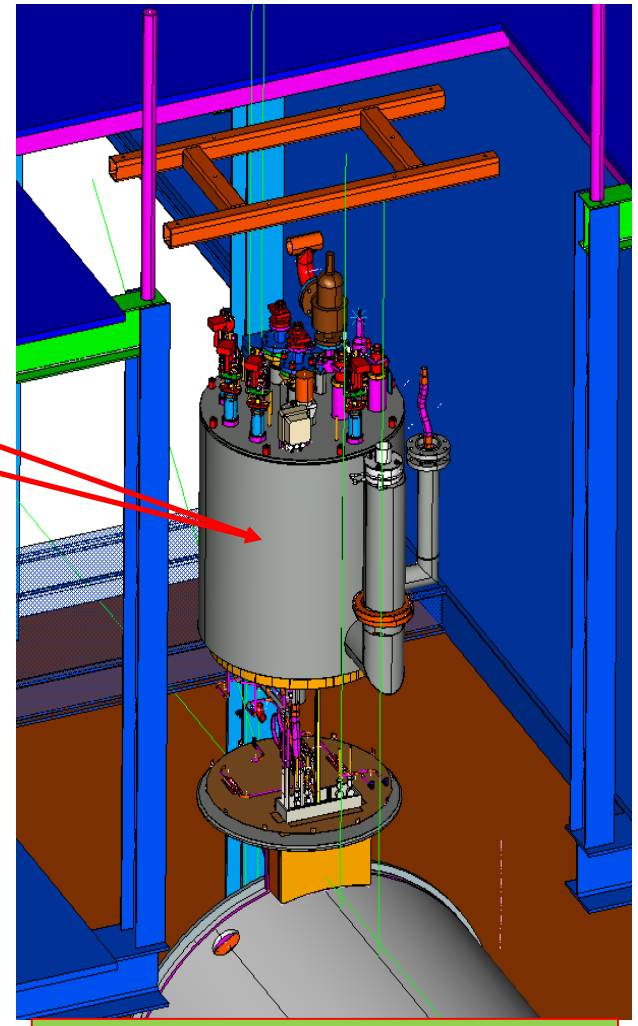
Solenoid Location in Hall B: Space Frame Level I



Solenoid Side View



Solenoid Isometric View



Solenoid Service Tower

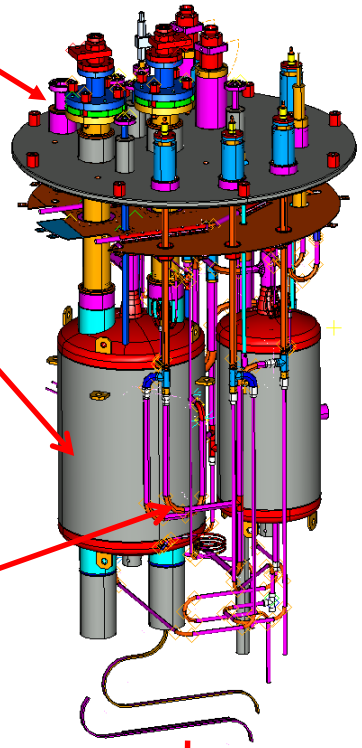
Solenoid Service Tower (SST)

Helium from Distribution Box

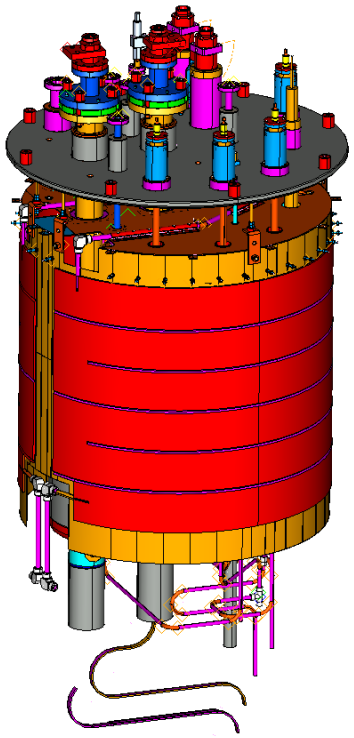
Valves

Helium Reservoir

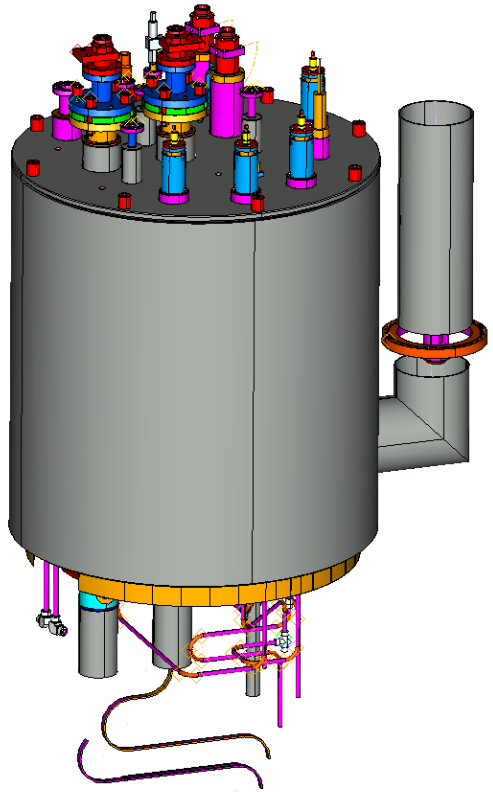
Inner Piping



To Magnet

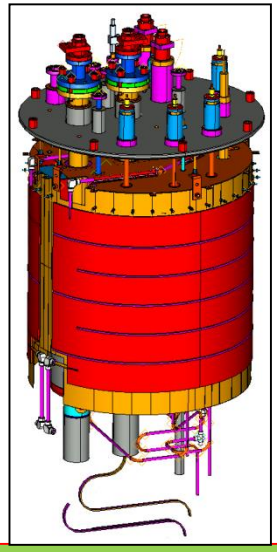


SST with outer shield



SST with vacuum jacket

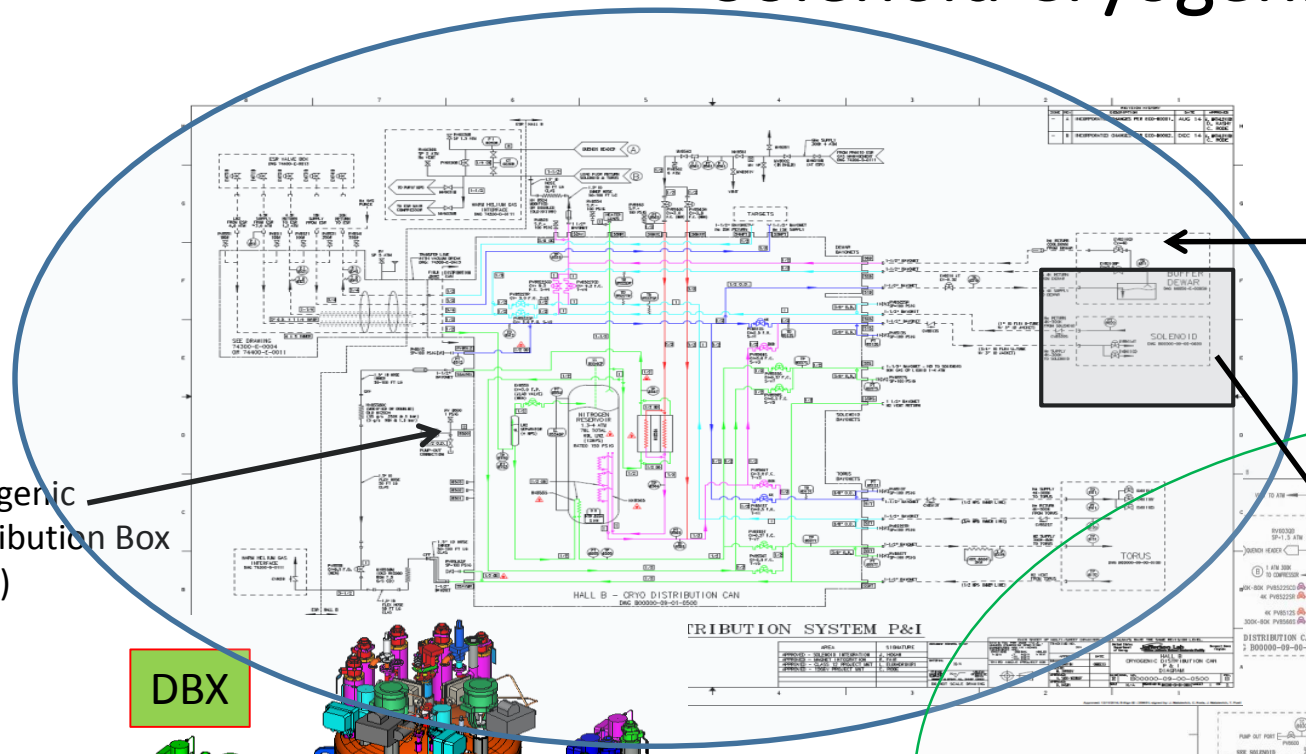
Piping & Instrumentation Diagram
Solenoid Cryogenic System



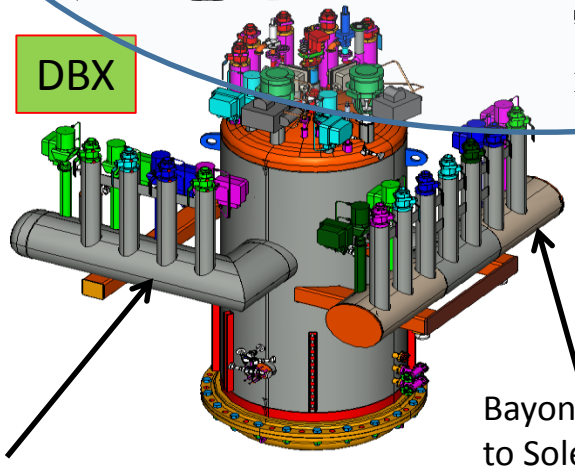
Buffer Dewar

Solenoid Service Tower

Cryogenic Distribution Box (DBX)

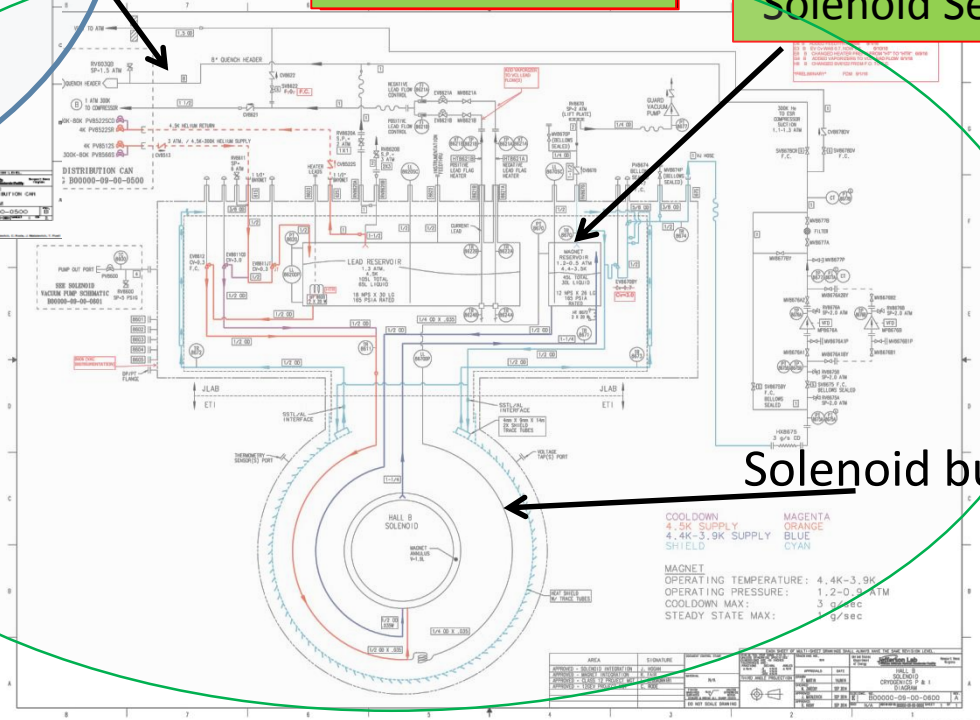


DBX



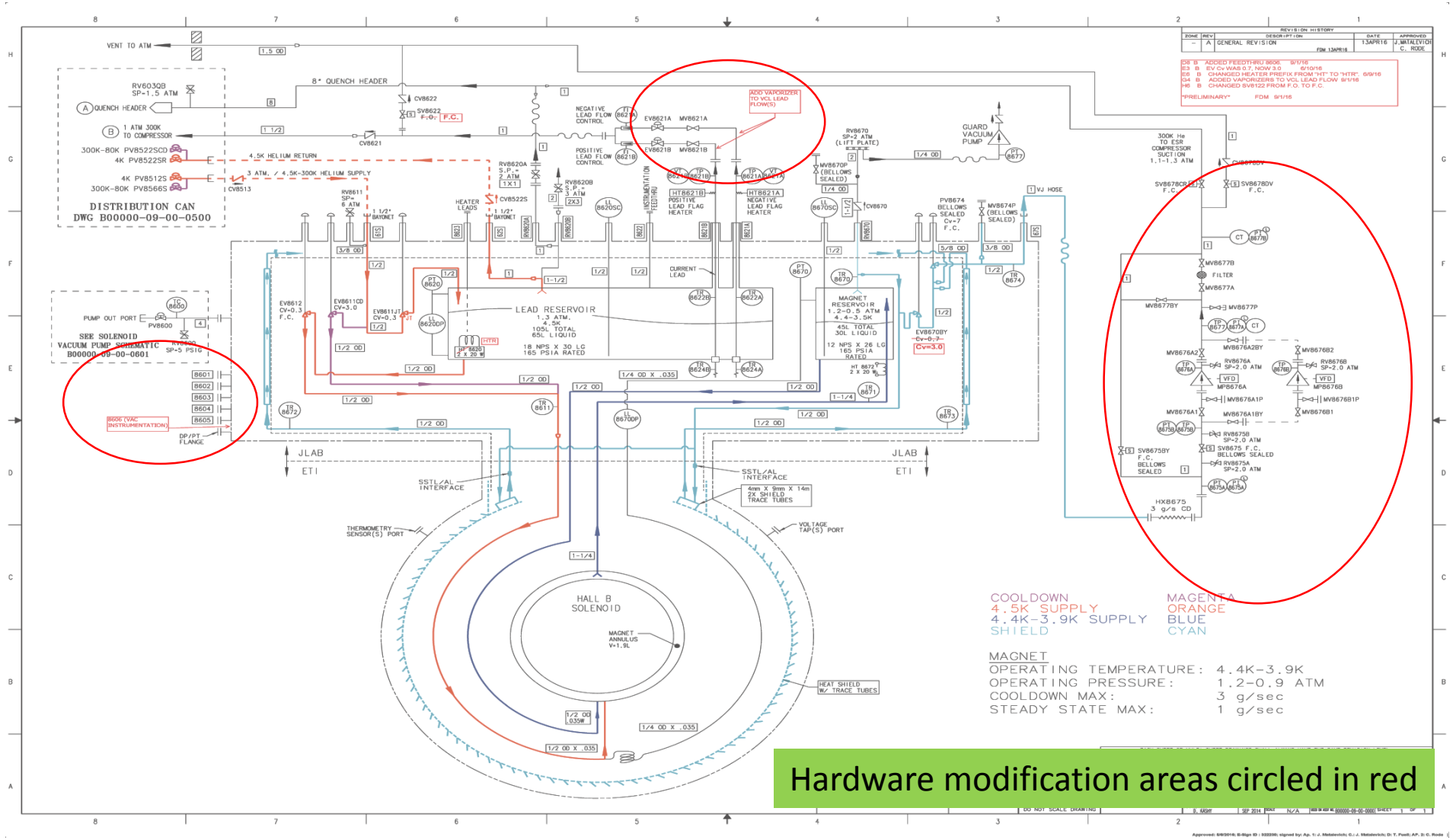
Bayonet Connections to Torus Service Tower

Bayonet Connections to Solenoid Service Tower



Solenoid built by ITE

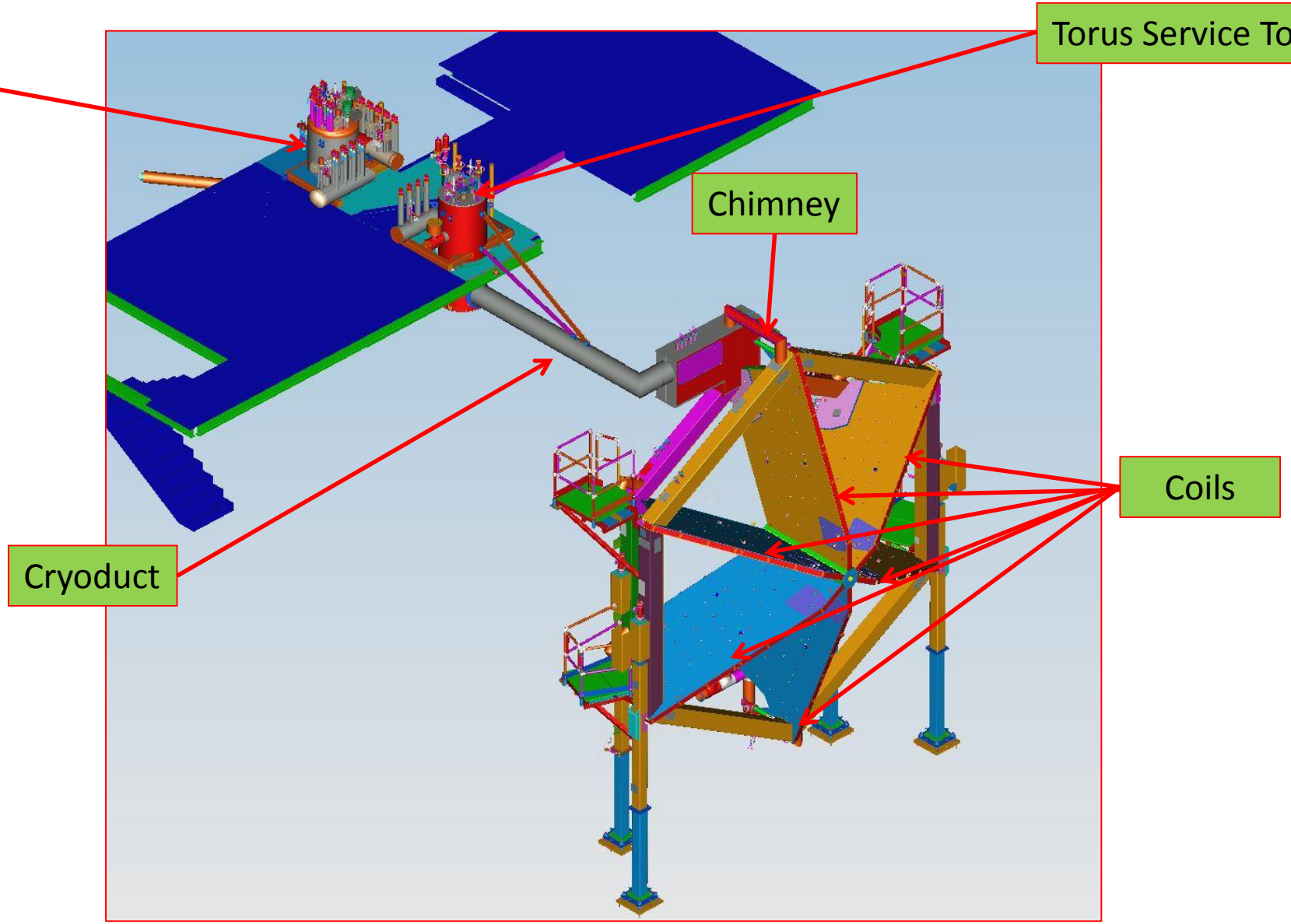
Piping & Instrumentation Diagram
Solenoid: Cryogenic System



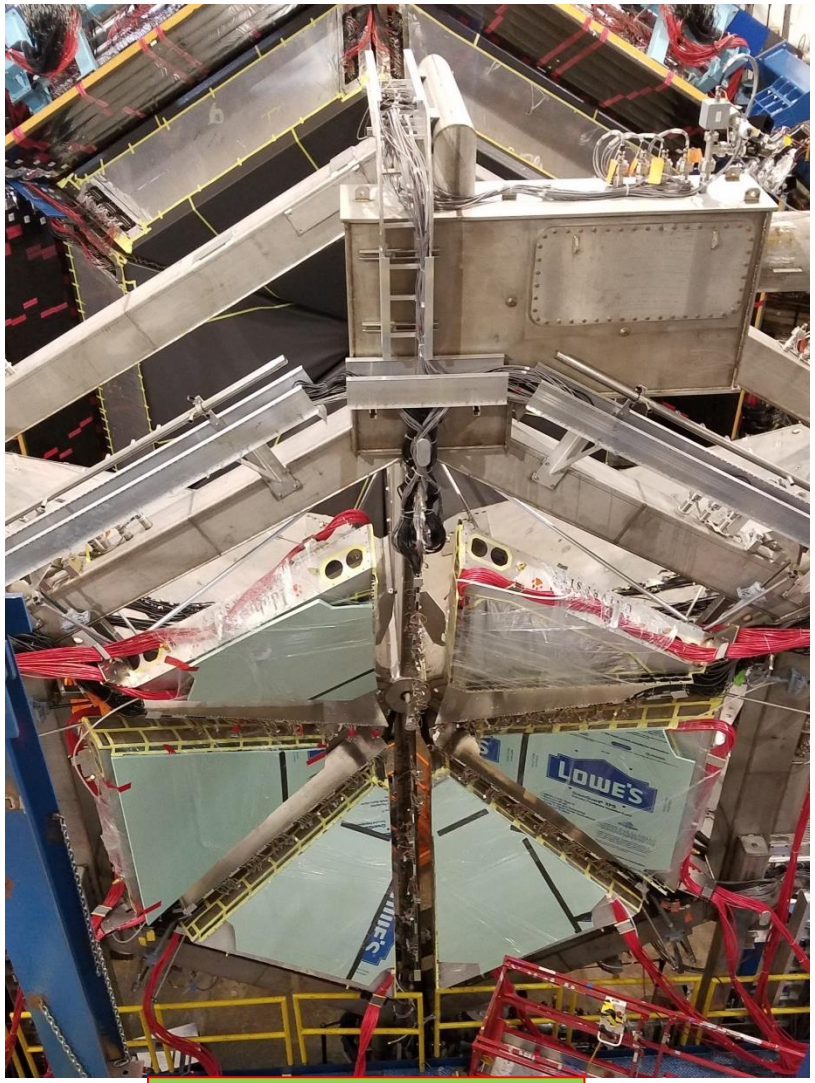
Hardware modification areas circled in red

Torus

- Nominal current 3770 A
- Central field 3.58 T
- Temperature 4.6 K



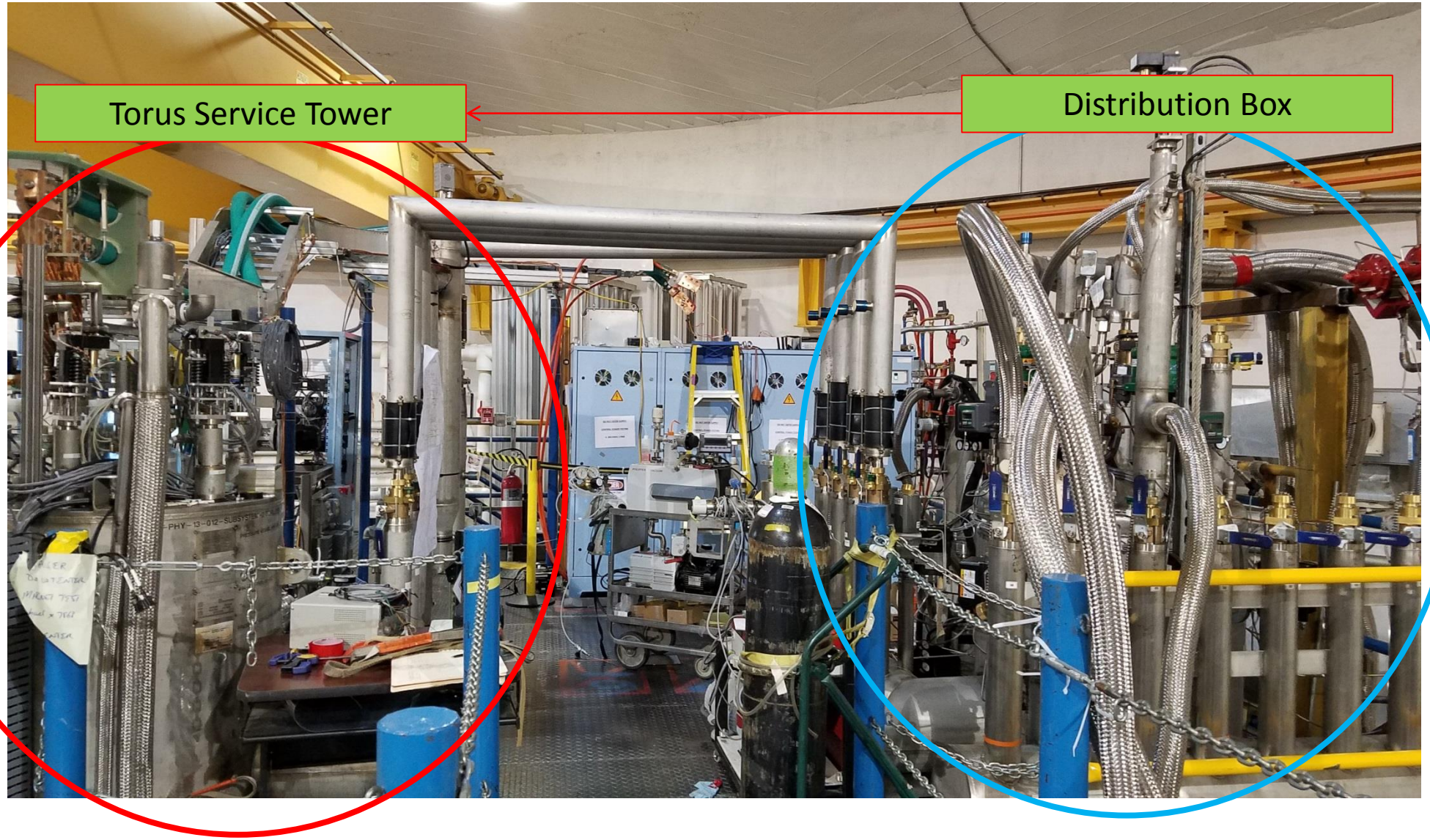
Torus in Hall B



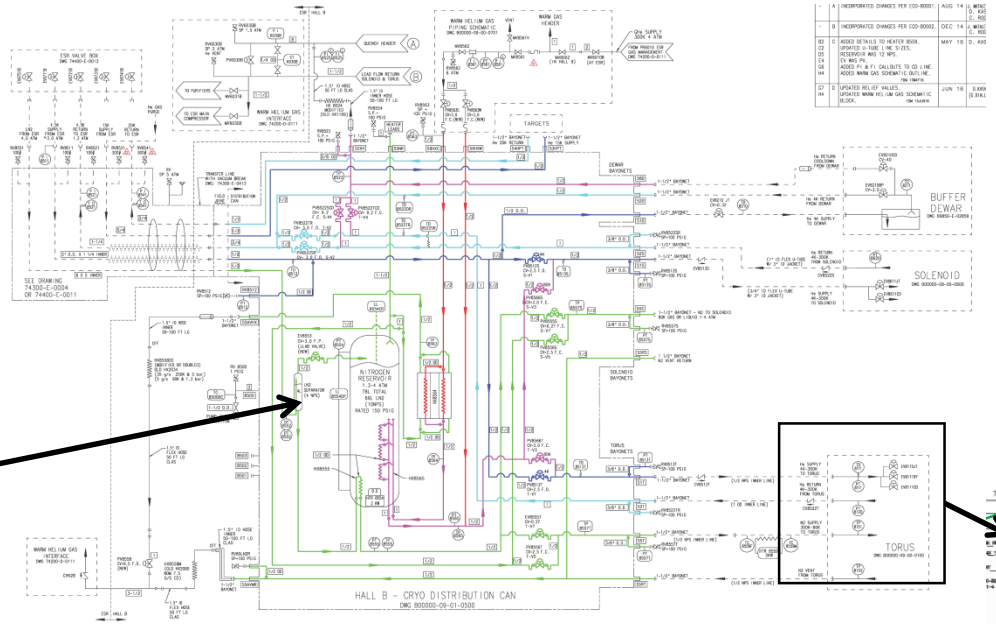
Torus Front View

Torus Side View

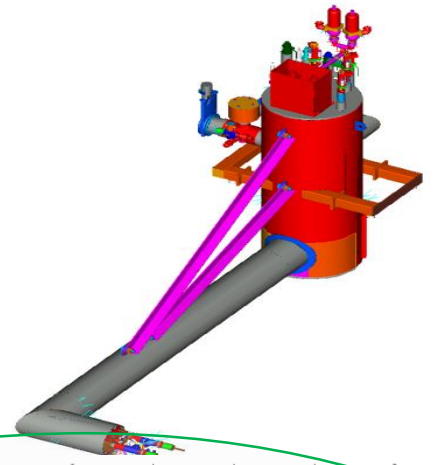
Hall B Torus Cryogenic System Located on Space Frame Level III



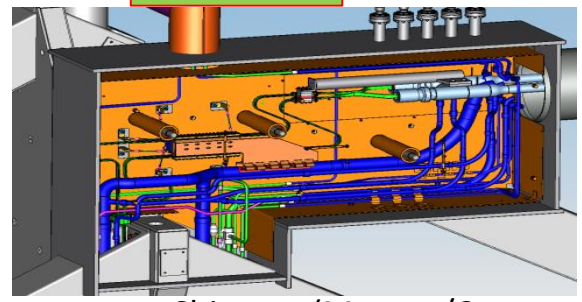
Torus Cryogenic System



Cryogenic Distribution Box

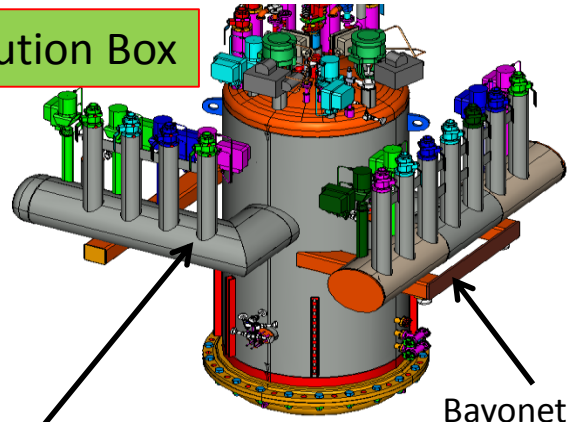


Chimney



Chimney (Magnet/Cryo Interface)

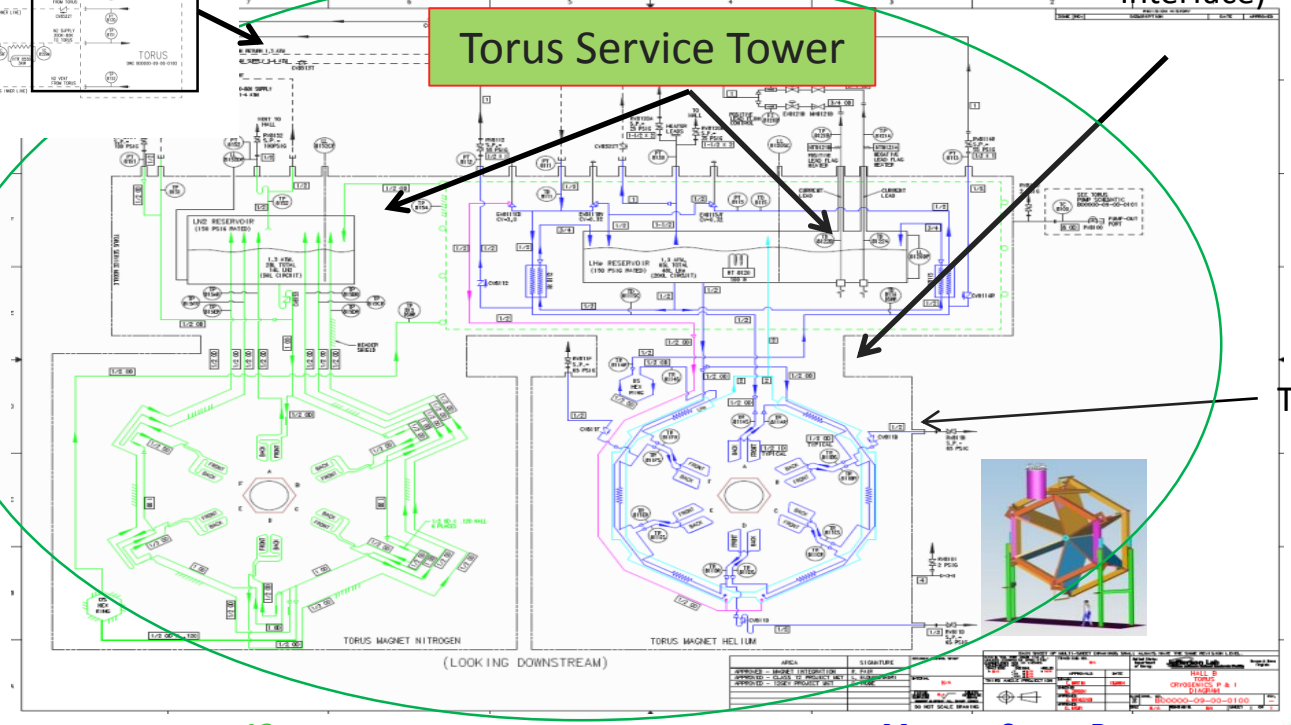
Distribution Box



Bayonet Connections to Torus Service Tower

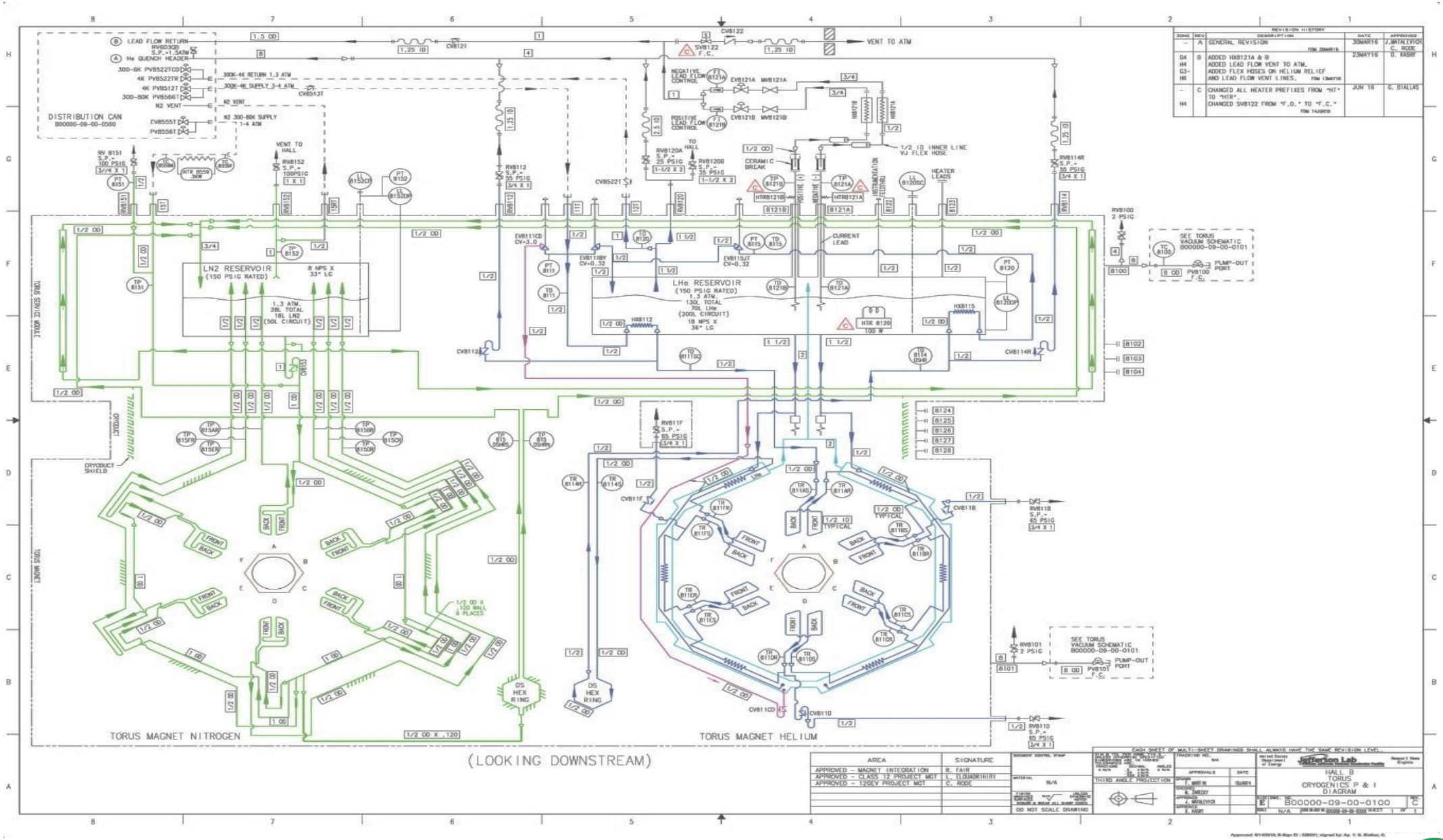
Bayonet Connections to Solenoid Service Tower

Torus Service Tower

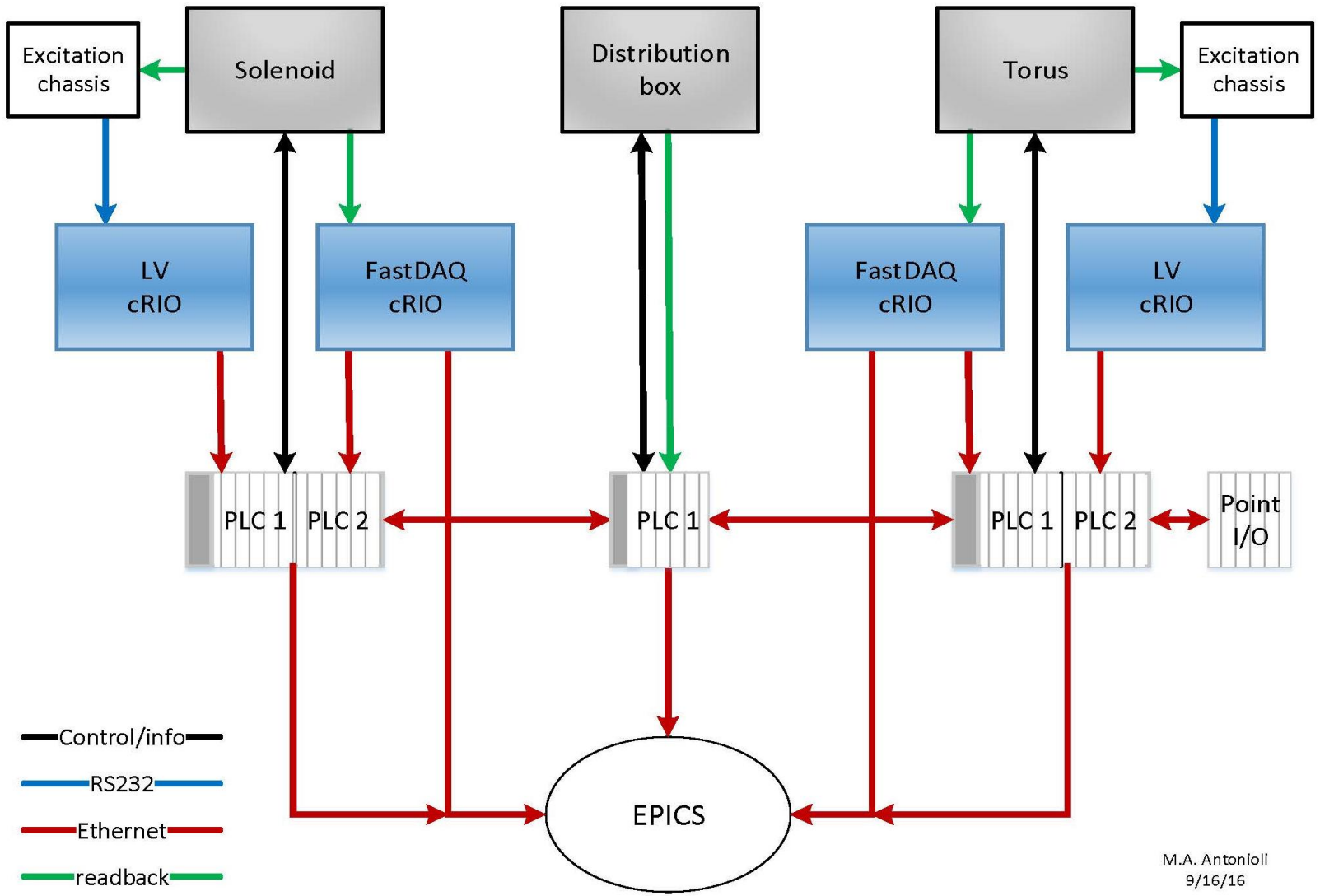


Torus Magnet

Piping & Instrumentation Diagram: Torus Cryogenic System

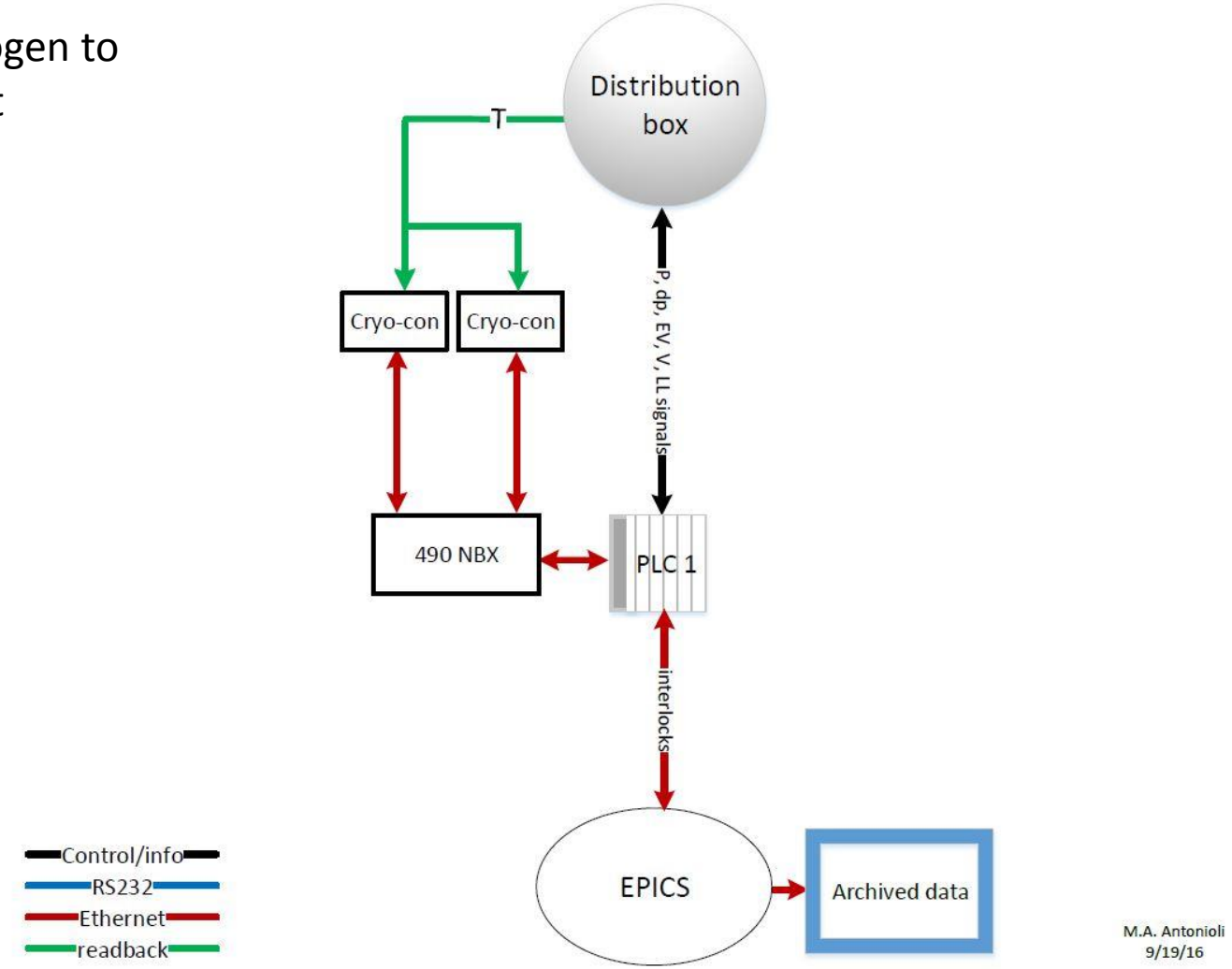


Controls, Monitoring, and Interlock System Flowchart

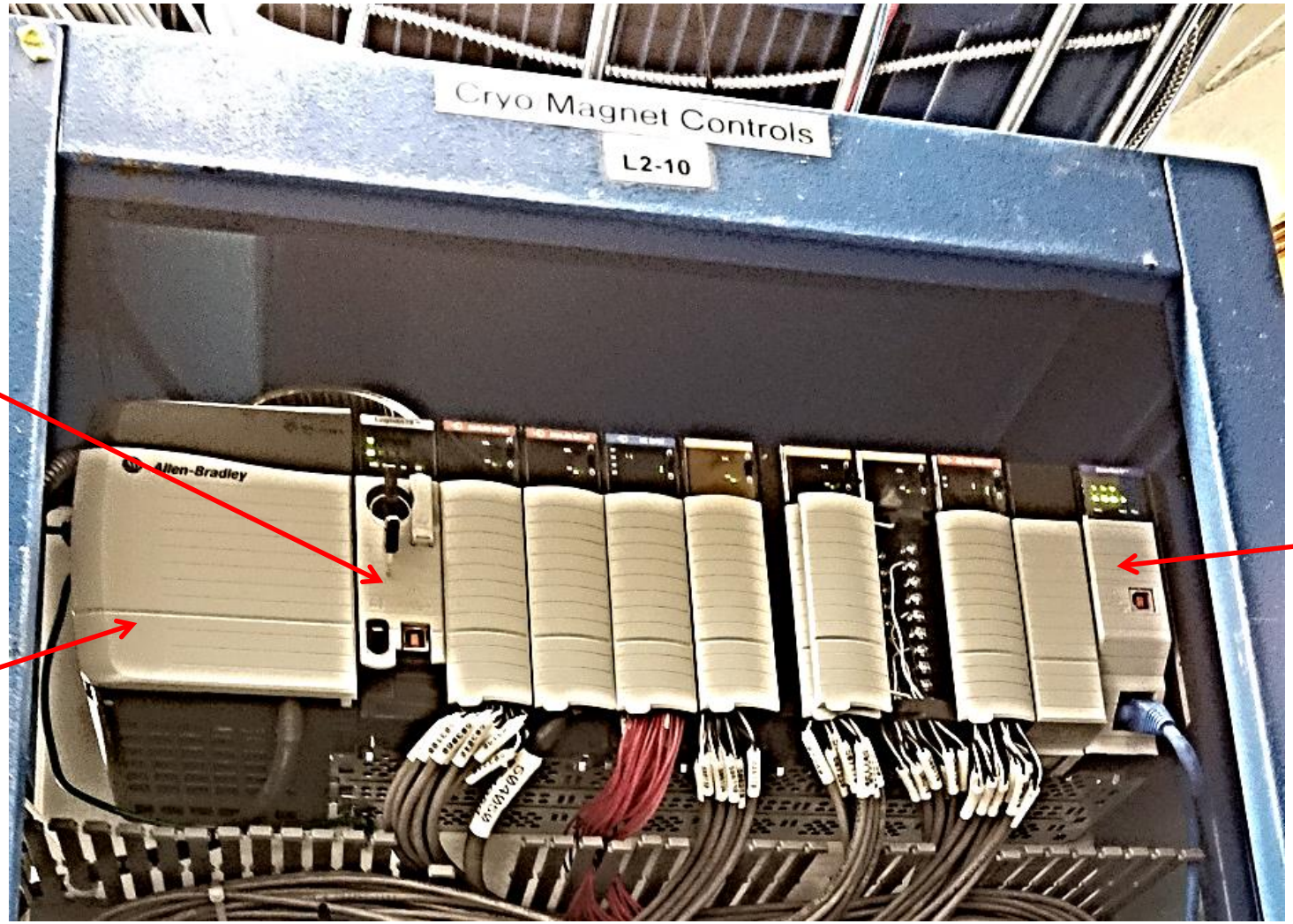


Controls, Monitoring, and Interlock System Flowchart: Cryogenics Distribution Box

Distribution box distributes cryogen to Solenoid, Torus, and Cryo-target



Controls, Monitoring, and Interlock System
Cryogenics Distribution Box: PLC Chassis

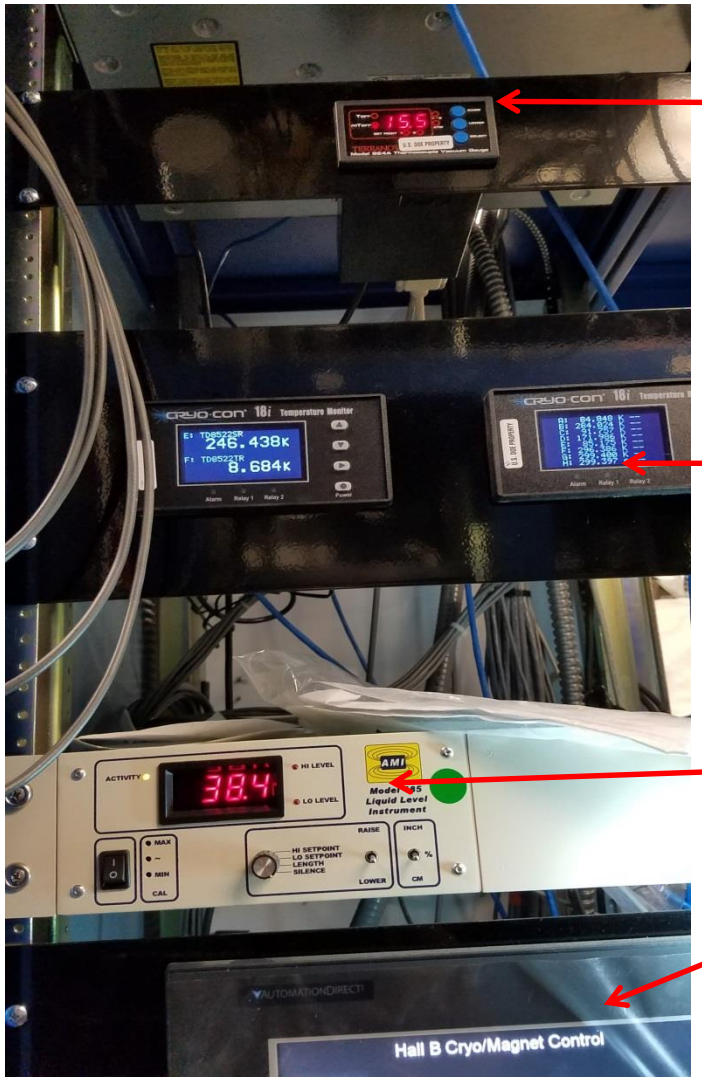


AB 1756-L72 Control Logix Controller

AB 1756-PA72 Power Supply

AB 1756-EN2T Ethernet Module

Controls, Monitoring, and Interlock System
Cryogenics Distribution Box: Instrumentation



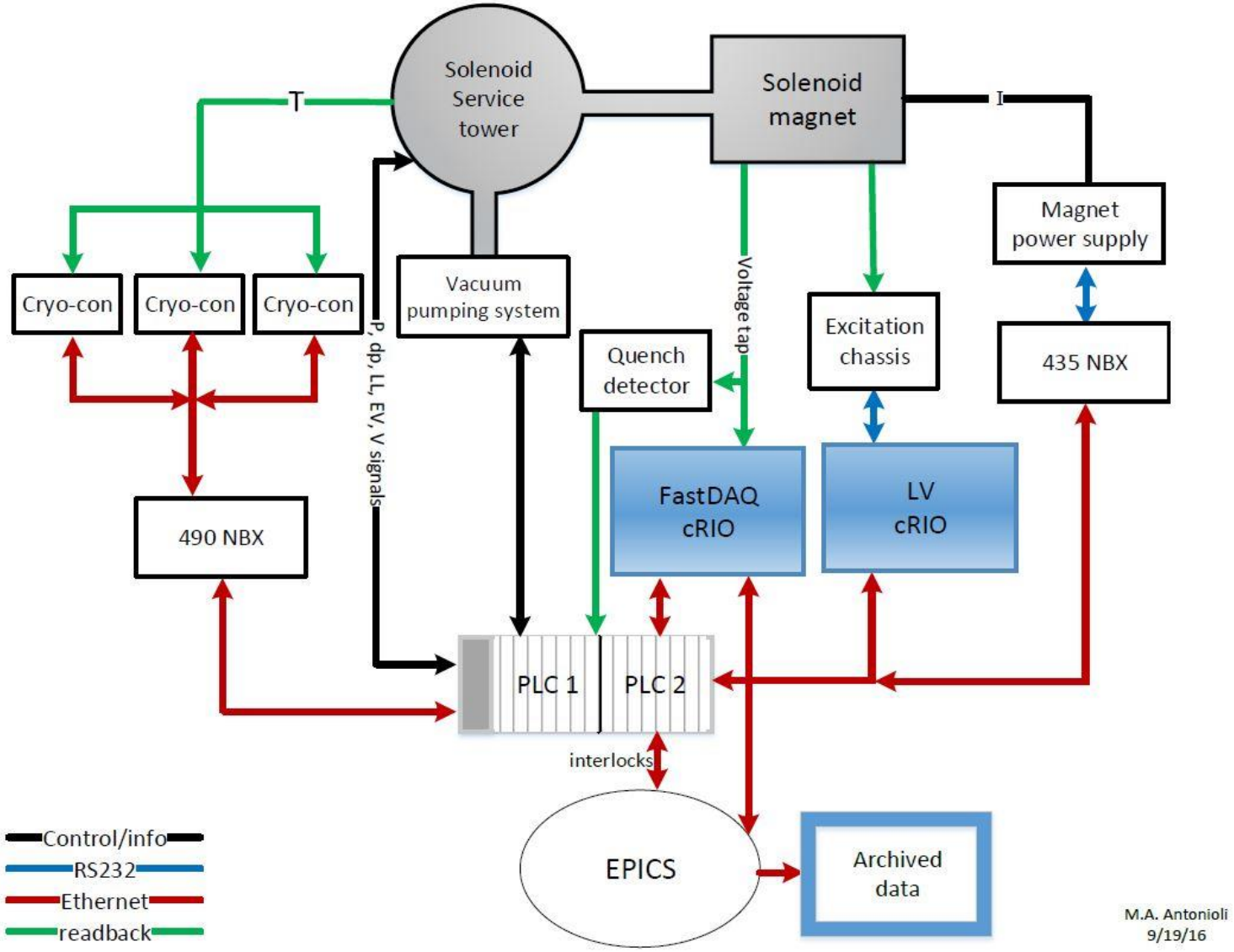
Terranova 924 A Thermocouple Vacuum Gauge
Magnet operating pressure = 1.2—0.9 ATM

Cryocon-18i Temperature Monitors
Magnet operating temp = 4.4—3.9 K

185- Liquid Level Instrument
Normal nitrogen liquid level = 69%

AutomationDirect Touch Panel
Used for manual operation

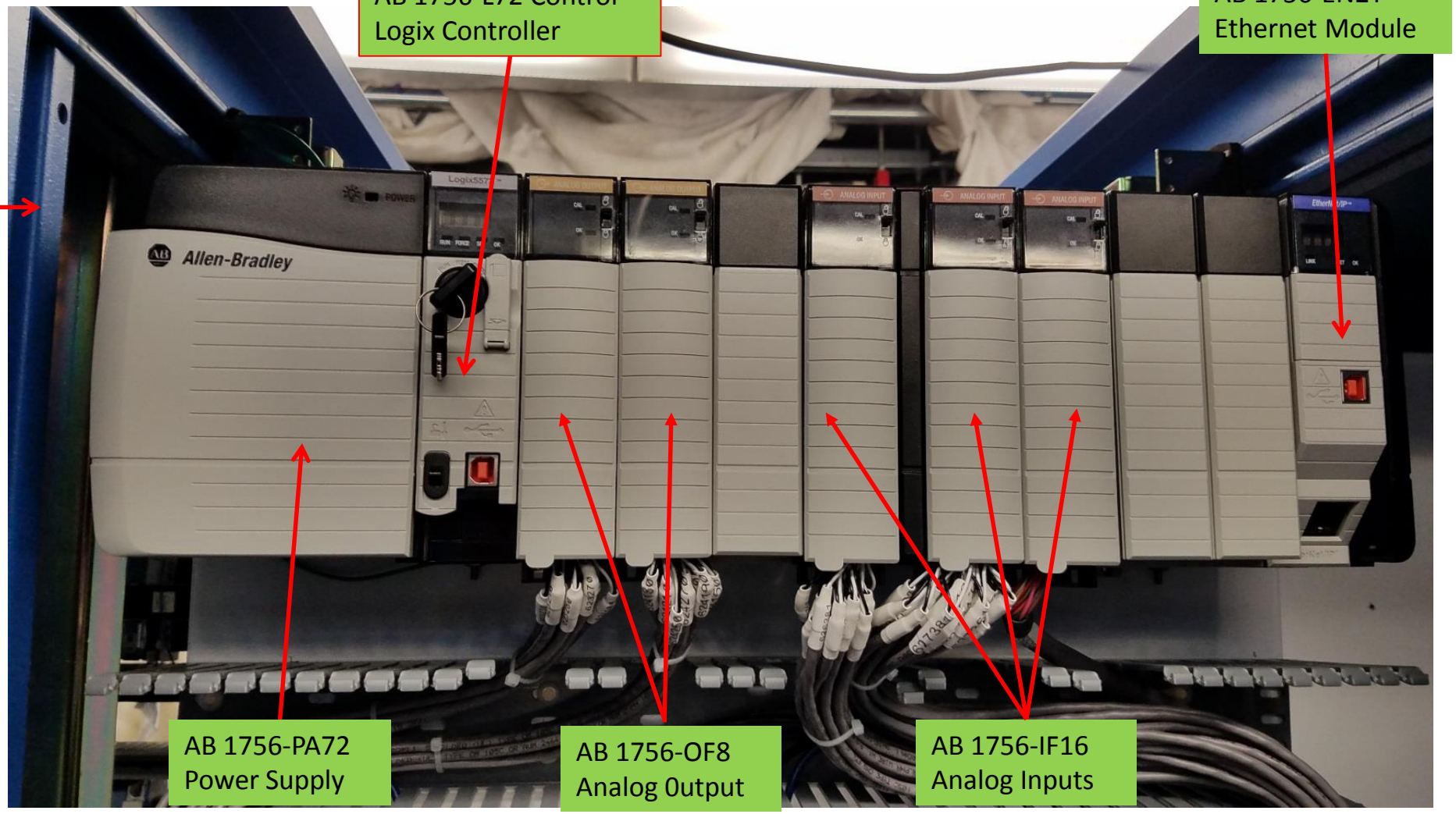
Controls, Monitoring, and Interlock System Solenoid



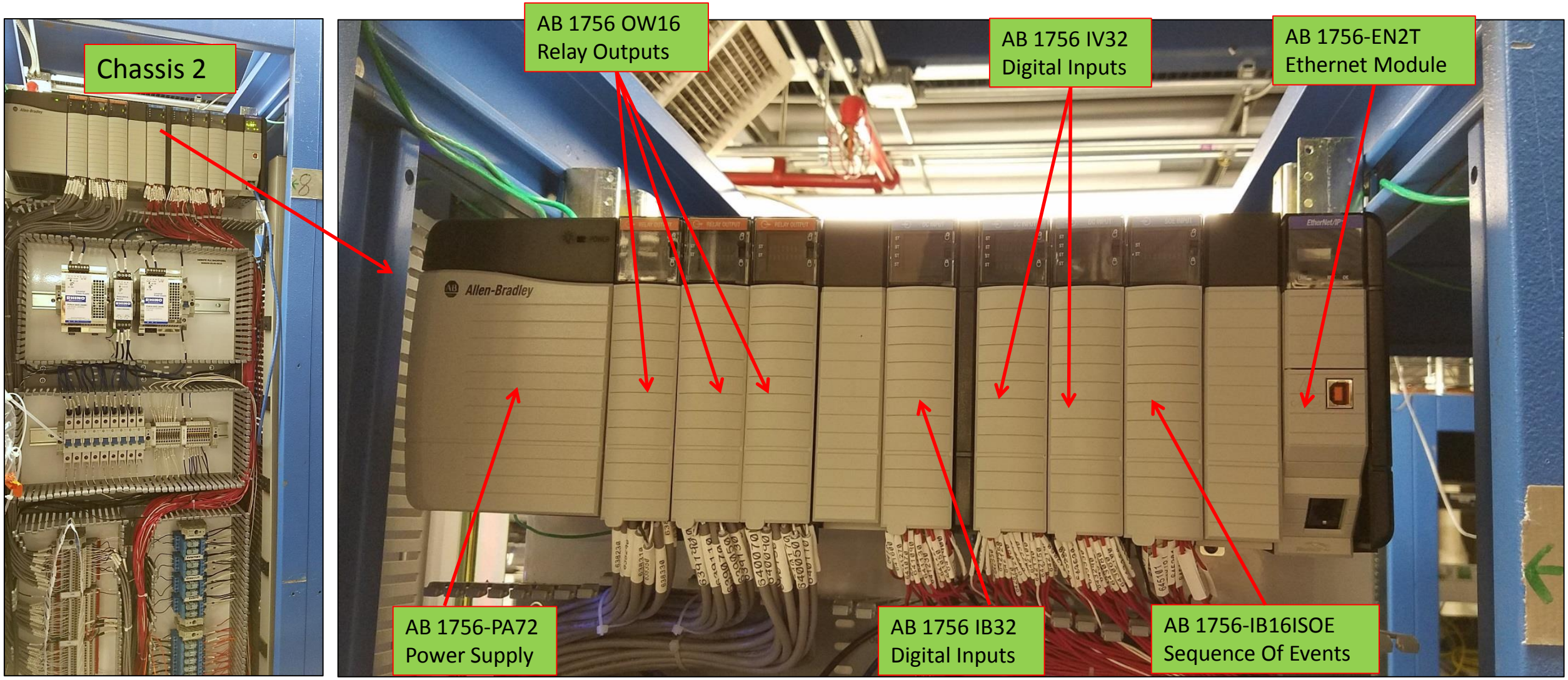
Control, Monitoring, and Interlock System Solenoid: PLC System Components

- AB 1756 L72 Contro-logix Allen Bradley
- I/O digital and analog modules
- Relay and sequence of events (SOE) modules
- Cryocon 18i temperature monitors
- 435 and 490 NBX modules
- Remote control power supply
- Touch panel monitors

Solenoid Control, Monitoring, and Interlock System
Chassis 1 PLC components



Solenoid Control, Monitoring, and Interlock System
Chassis 2 PLC components

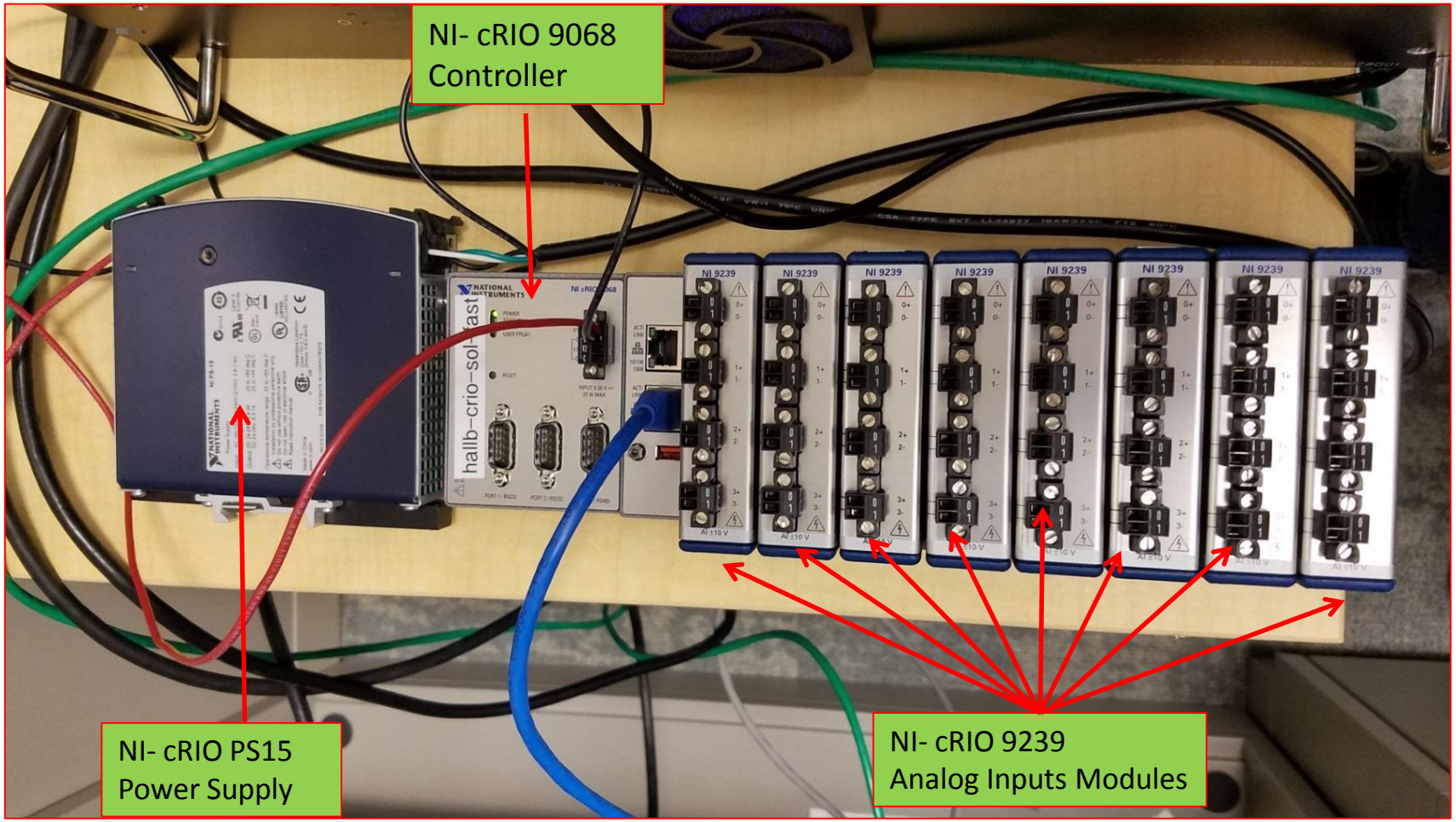


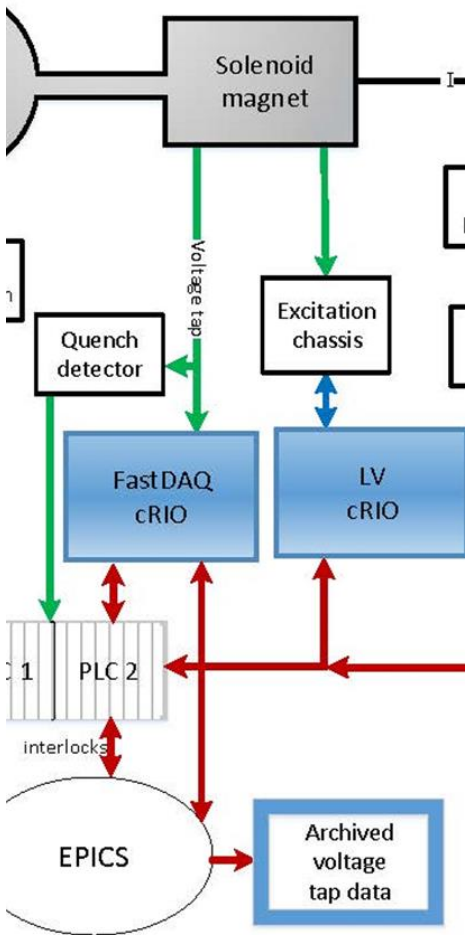
Control, Monitoring, and Interlock System
Solenoid: cRIO Components

- 9068 NI cRIO and 9030 cRIO NI controllers
- (1) NI 9870 cRIO RS-232 modules
- (8) NI 9239 Analog Input modules
- Low voltage excitation readback chassis
- Temperature, voltage, strain, and hall sensors

Control, Monitoring, and Interlock System
Solenoid: Fast_DAQ cRIO components

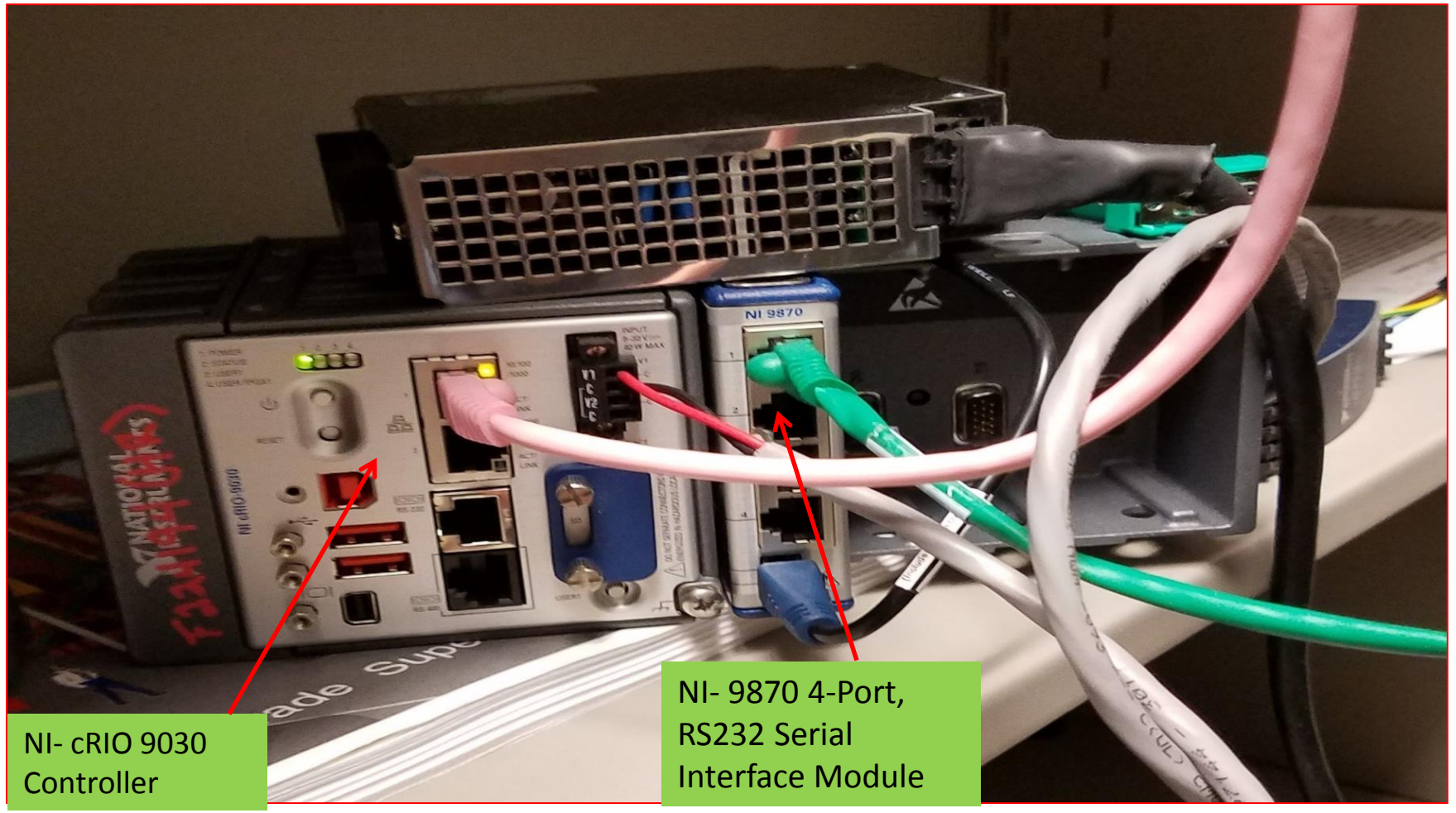
- Fast_DAQ cRIO processes data from voltage taps on Solenoid

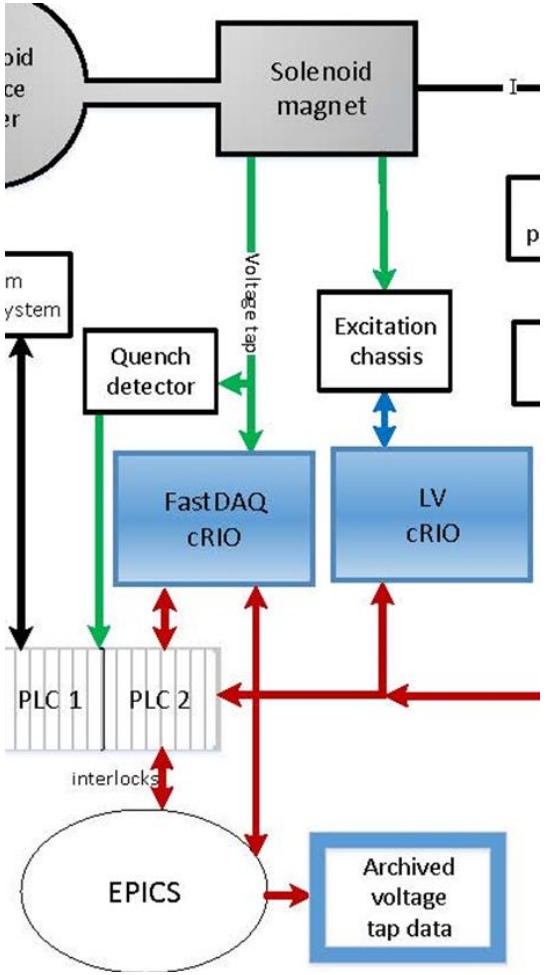




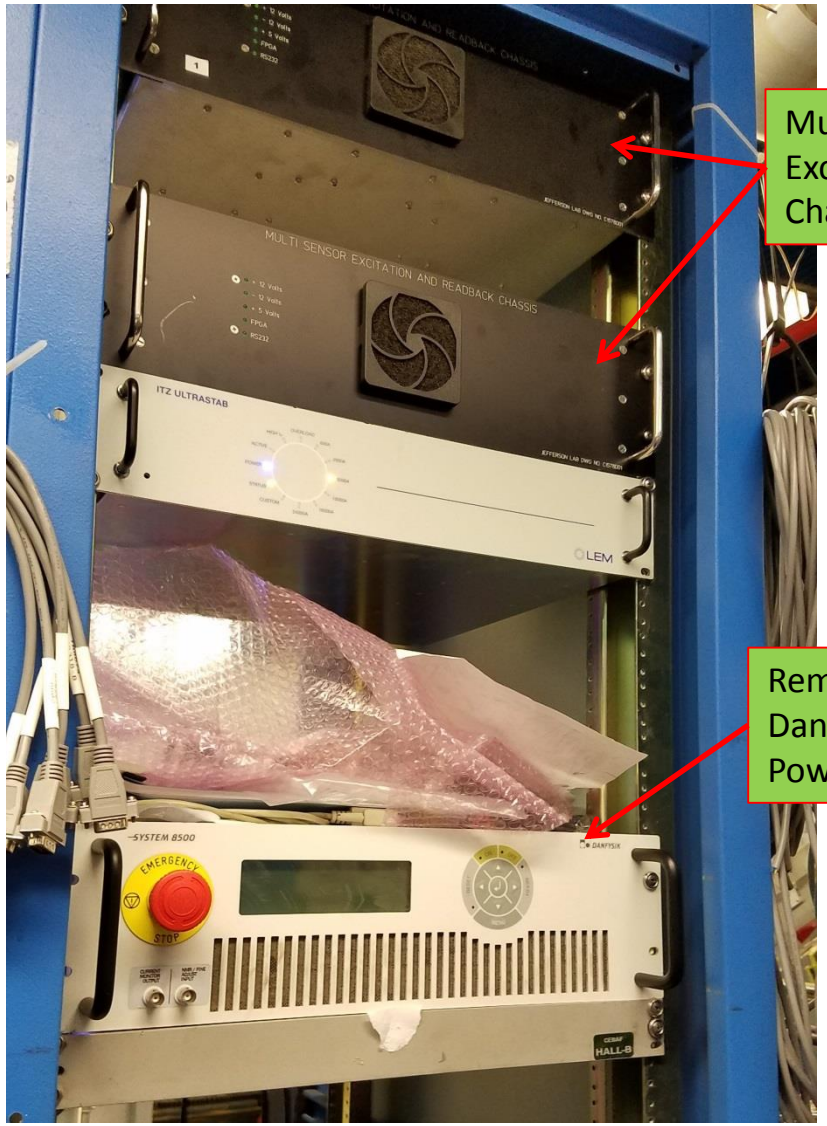
Control, Monitoring, and Interlock System
Solenoid: cRIO Control Components

"Low Voltage (LV)" cRIO processes data signals from sensors connected to Excitation chassis



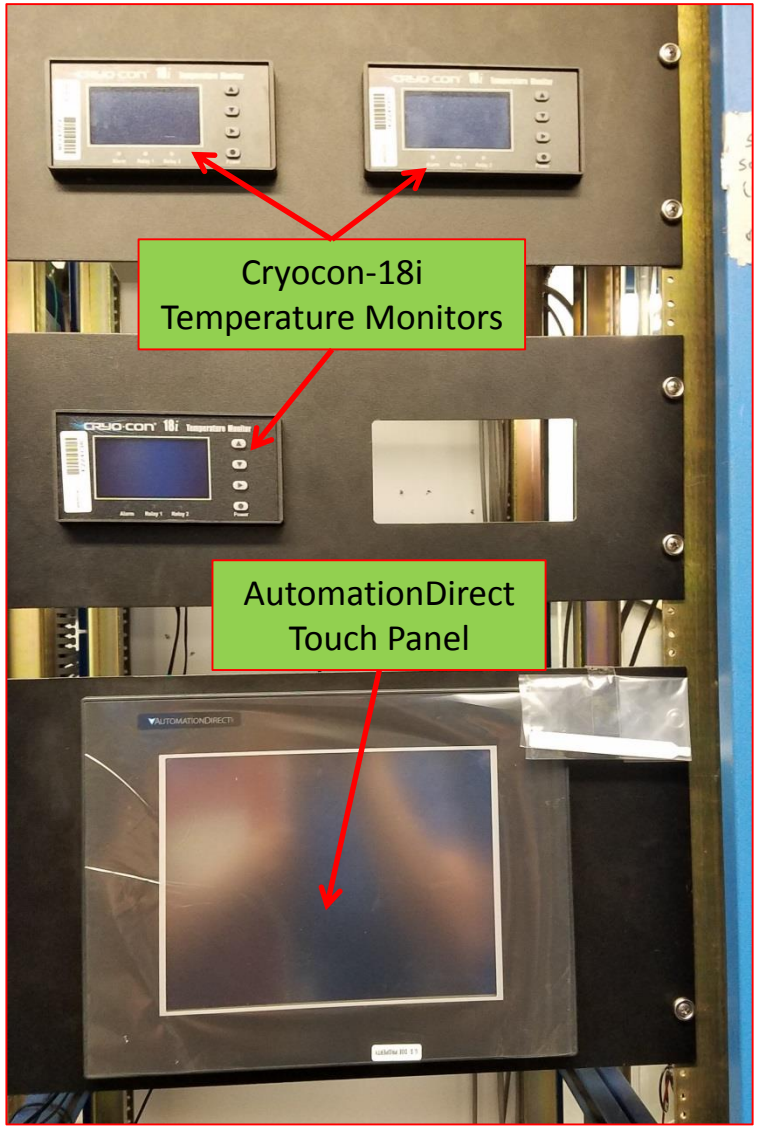


Control, Monitoring, and Interlock System
Solenoid: Instrumentation



Multi Sensor Excitation Readback Chassis

Remote Control Danfysik System 8500 Power Supply



Cryocon-18i Temperature Monitors

AutomationDirect Touch Panel

Control, Monitoring, and Interlock System
Solenoid: List of Control Signals

TEMPERATURE (CERNOX)

ID	Location	Type
TR8611	Cooldown Helium Supply Temp	Temperature (Cernox)
TR8622A	Lead A Top	Temperature (Cernox)
TR8622B	Lead B Top	Temperature (Cernox)
TR8624A	Lead A Bottom	Temperature (Cernox)
TR8624B	Lead B Bottom	Temperature (Cernox)
TR8670	Lhe Tank Vent (pre-valve)	Temperature (Cernox)
TR8671	Magnet Reservoir Return	Temperature (Cernox)
TR8672	Shield Supply	Temperature (Cernox)
TR8673	Shield Vent	Temperature (Cernox)
TR8674	Lhe Tank Vent	Temperature (Cernox)

TEMPERATURE (PT100)

ID	Location	Type
TP8621A	Lead A Warm End	PT100
TP8621B	Lead B Warm End	PT100
TP8675	LHE Return Line Temp (outside can)	PT100
TP8676A	LHE Return Line Temp (outside can)	PT100
TP8676B	LHE Return Line Temp (outside can)	PT100
TP8677	LHE Return Line (after pumps)	PT100

PRESSURE

ID	Location	Type
PT8620	Lead Reservoir Pressure	Pressure
PT8670	Magnet Reservoir Pressure	Pressure
PT8675A	LHE Return Line Press	Pressure
~~PT8675B~~	~~LHE Return Line Press Sub-ATM~~	~~Pressure~~
PT8677	Inlet to guard vacuum	Pressure
LL8620DP	Lead Reservoir dP LL	dP
LL8670DP	Magnet Reservoir dP LL	dP
TC8600	Vacuum	Vacuum TC

LIQUID LEVELS

ID	Location	Type
LL8620SC	Lead Reservoir LL	Superconducting Probe
LL8670SC	Magnet Reservoir LL	Superconducting Probe

VALVES

ID	Location	Type
EV8611CD	Cooldown Bottom Fill	EV
EV8670BY	Lhe Return Valve	EV
EV8611JT	Top Fill	EV
EV8612	Bottom Fill	EV
EV8611CD_LVDT	Cooldown Bottom Fill	EV
EV8670BY_LVDT	Lhe Return Valve	EV
EV8611JT_LVDT	Top Fill	EV
EV8612_LVDT	Bottom Fill	EV
PV8674	Warm Return Valve	PV
SV8622	Lead Flow Vent to Atmosphere	Solenoid
SV8677CR	Warm Return Valve	Solenoid
SV8622DV	Warm Return Vent to Atmosphere	Solenoid
FI/EV 8621A	Lead A Flow Control	Analog in/out
FI/EV 8621B	Lead B Flow Control	Analog in/out
PV8600	Vacuum Gate Valve	Solenoid Valve

HEATER

ID	Location	Type
HT8621A	Lead A flag heater	Heater
HT8621B	Lead B flag heater	Heater
HTR8620	Lead Reservoir (2 x 20 W)	Heater
HTR8672	Mag Reservoir Return (3 x 20 W)	Heater

PRESSURE INDICATOR

ID	Location	Type
PIXXXXX	Relief Valve Vacuum	????

SYSTEM HEALTH

ID	Location	Type
	24 VDC OK	Digital
	UPS Low Power	Digital
	UPS on Battery	Digital
	Vacuum pump 1 speed	Analog
	Vacuum pump 2 speed	Analog
	Vacuum pump 1 ON	Digital
	Vacuum pump 2 ON	Digital

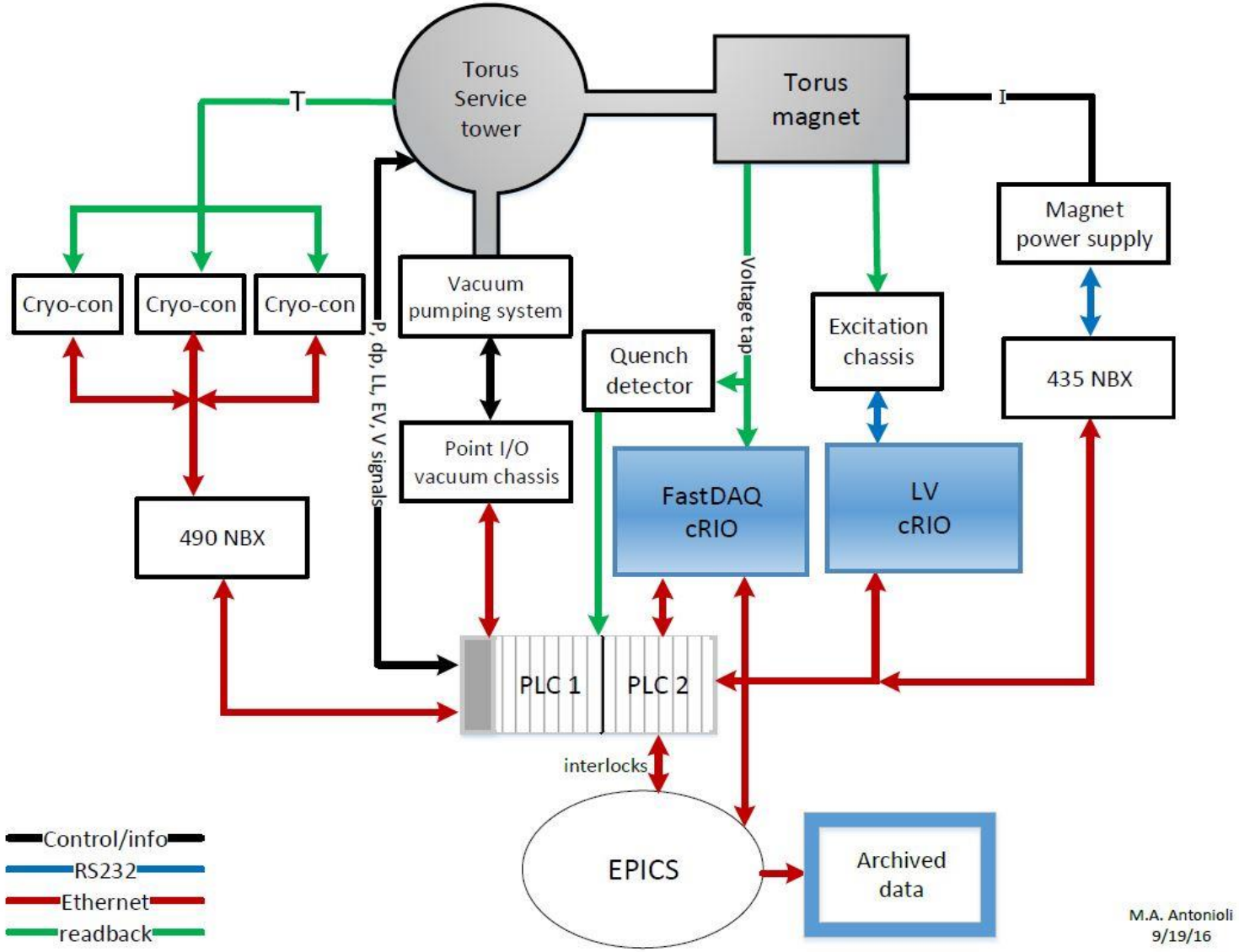
Magnet Monitoring/Control

ID	Location	Type
	Fast Dump	Digital
	Slow Dump	Digital
	Power Supply Communications	Digital
	Quench Detector Status	Digital
	Quench Detector Reset	Digital
	Power Supply Resets	Digital
	Watchdog/Keep Alive + Reset	Digital
	Power Supply Status	Digital

VFD's

ID	Location	Type
MP8676A	Helium vacuum pallet	Mix
MP8676B	Helium vacuum pallet	Mix

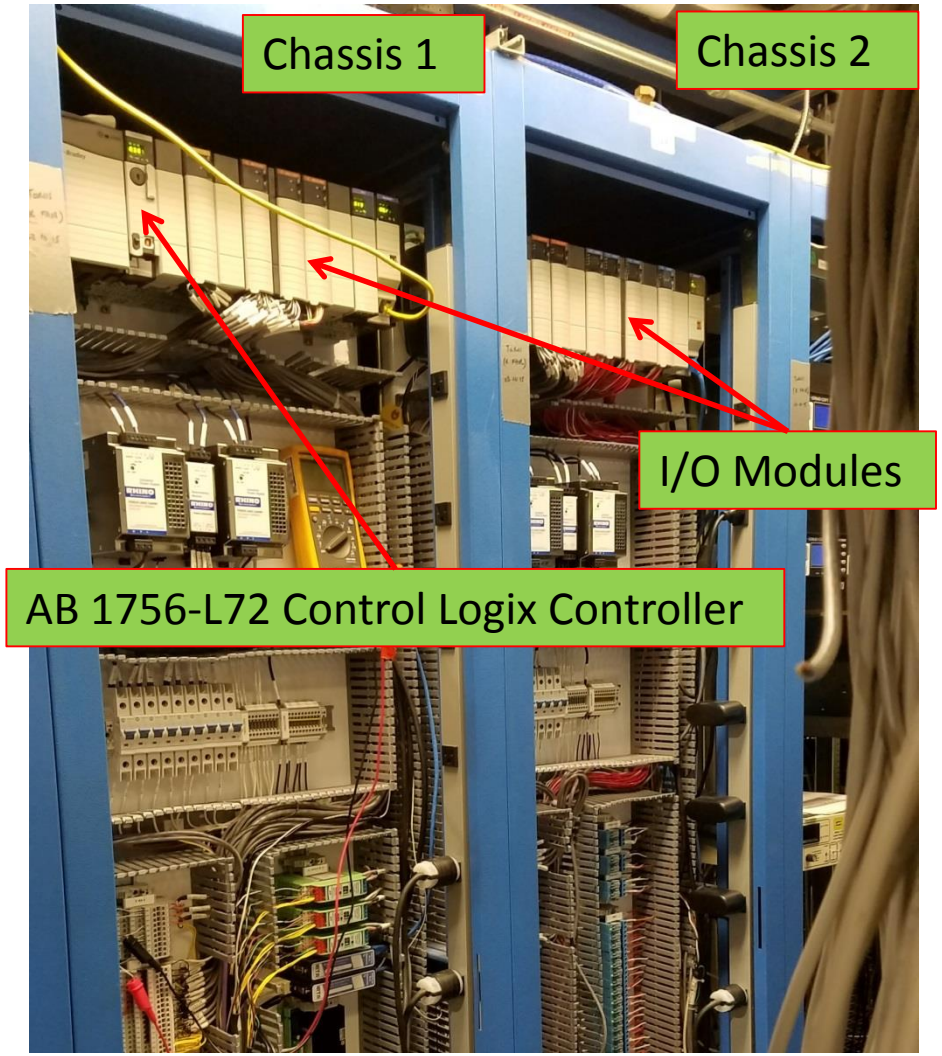
Control, Monitoring, and Interlock System
Torus

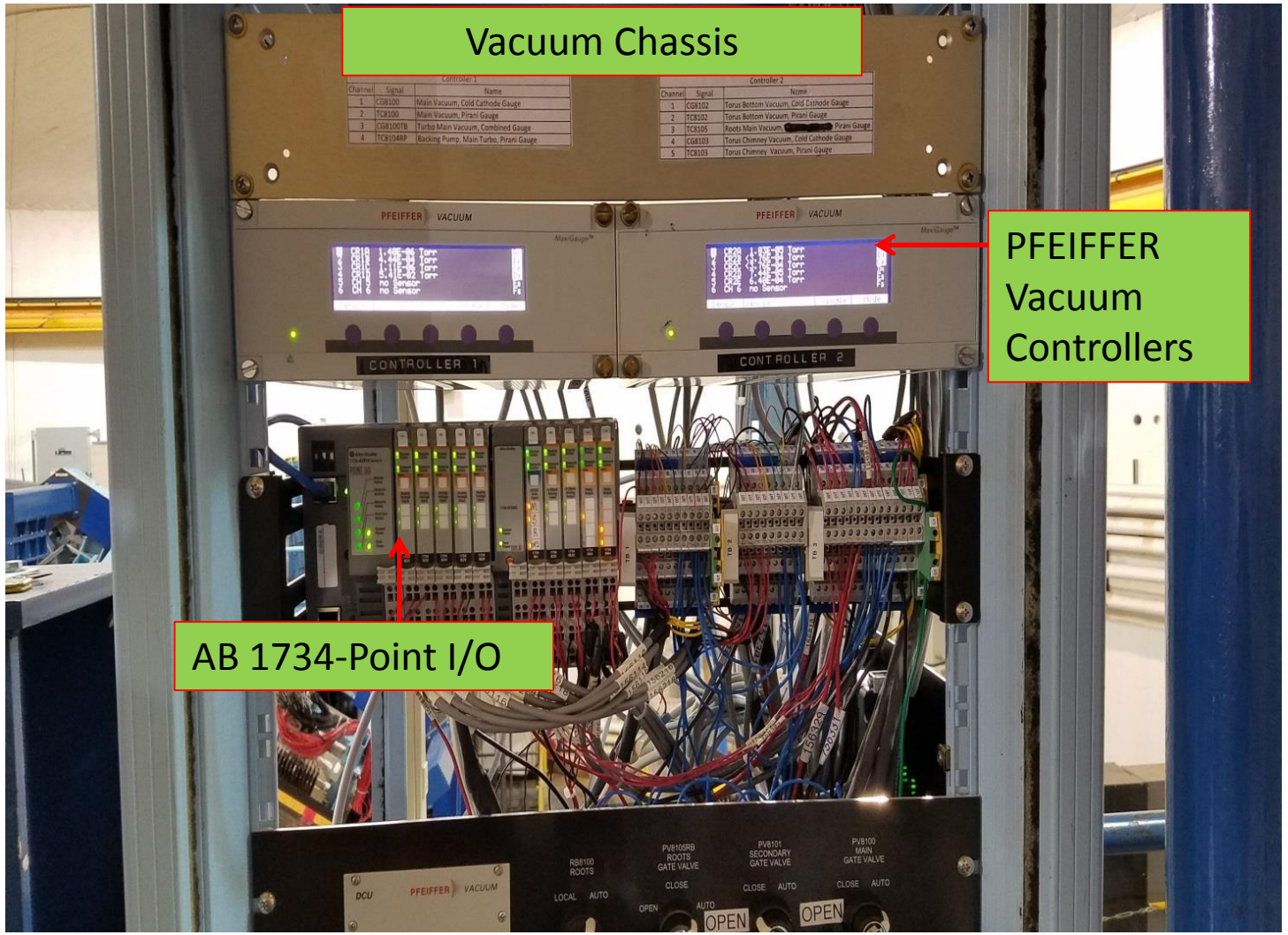


Control, Monitoring, and Interlock System
Torus: PLC Components

- AB 1756 L72 Contrologix Allen Bradley
- I/O digital and analog modules
- Relay and sequence of events (SOE) modules
- Point I/0 system
- 435 and 490 NBX modules
- Cryocon 18i temperature monitors
- Remote control power supply
- Touch panel monitors

Control, Monitoring, and Interlock System
Torus: PLC Components

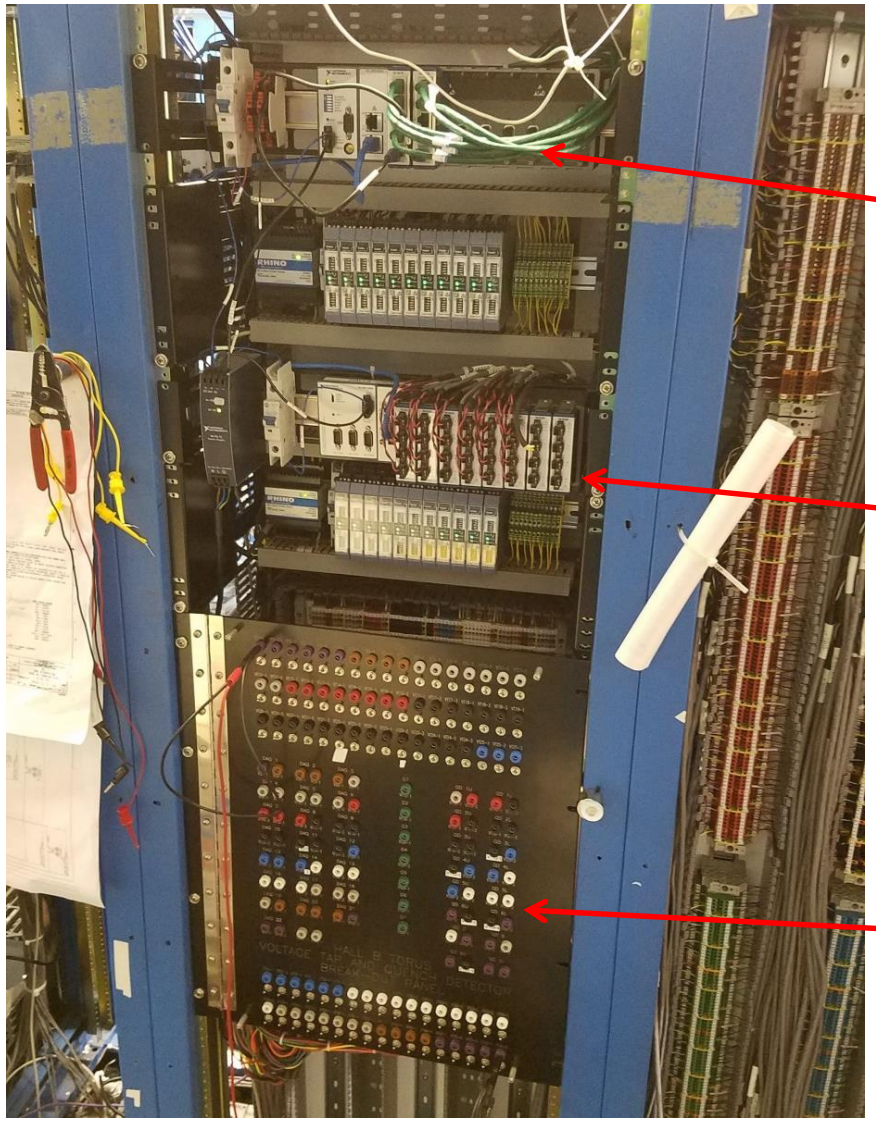




Control, Monitoring, and Interlock System
Torus: cRIO Components

- NI 9068 cRIO and NI 9074 cRIO Controllers
- (2) NI 9870 cRIO RS-232 modules
- (8) NI 9239 Analog Input modules
- Low voltage excitation readback chassis
- Temperature, voltage, strain, pressure and hall sensors

Control, Monitoring, and Interlock System
Torus: Instrumentation



Low Voltage Torus
NI-9074 cRIO Controller

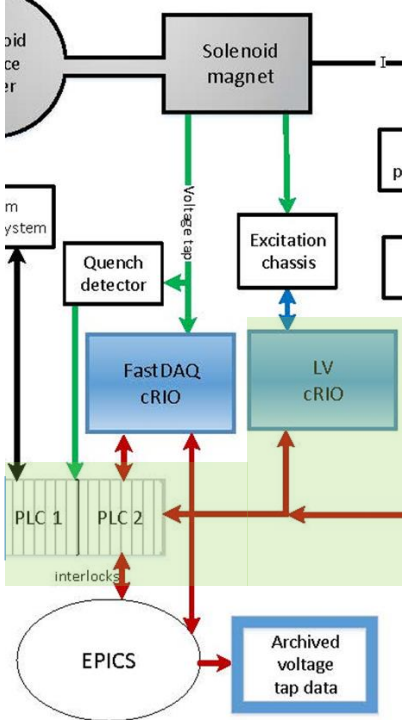
Fast_DAQ Torus
NI-9068 cRIO Controller

Voltage Tap and Quench
Detector Breakout Panel

Solenoid Tasks

- **Communication between PLC ↔ Hall B network - Completed**
  - Assigned new IP address and host name for 1756-EN2T1 (local chassis) and 1756-EN2T2 (remote chassis) Ethernet modules, to set up communication with PLC solenoid
  - Set up configurations for each I/O module in local and remote chassis
    - Modified PLC software

Solenoid Tasks



- **Communication between PLC ↔ LV cRIO: Programming - Completed**

— Generated four subroutines
  - Load cells (force/ strain)
  - Cernox Sensors, PT-100 (temperature)
  - Hall Sensors (**B**-field)

— Modified logic and sequence to control common errors, which appear when communication fails while data is being read

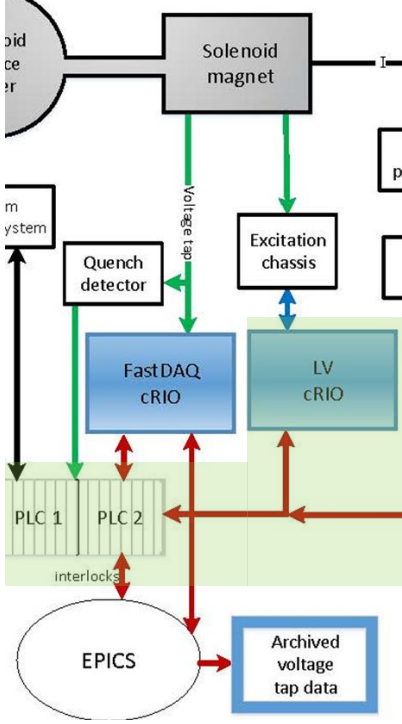
— Created array to read tags sent by cRIO system for each sensor value

— Generated Status_Error and Error_Fill routines to check errors during communication test

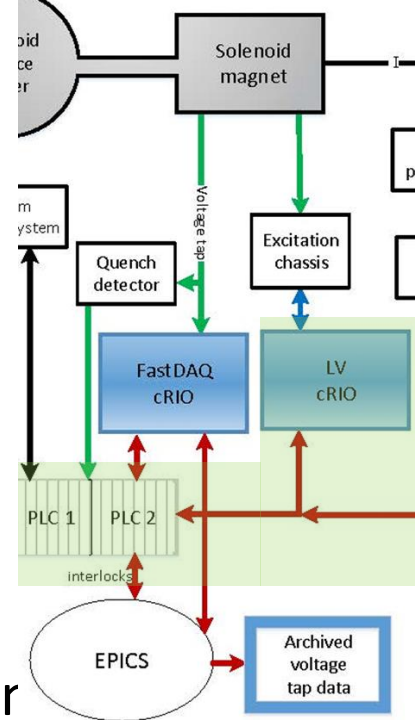
— Generated new file project for PLC program for testing purpose

Solenoid Tasks

- **Communication between PLC ↔ LV cRIO: Networking** - **Completed**
  - Made diagram of communication between PLC, cRIO Fast-Daq, cRIO LV, and EPICS
  - Configured communication of Ethernet generic modules on PLC program to set up communication with Fast_Daq and LV cRIO systems



Solenoid Tasks



- **Communication between PLC ↔ LV cRIO: Testing - Completed**
  - Set up different resistor values to simulate temperature sensors
    - 60, 50, 40 and 30 KΩ for Cernox sensors
    - 82 and 150 Ω for PT-100 sensors
  - Connected resistors in DB9 connectors and plugged into low voltage excitation readback chassis
  - Monitored readback values in PLC Solenoid from 9/9 to 9/13
    - Test was completed successfully for these type of sensors

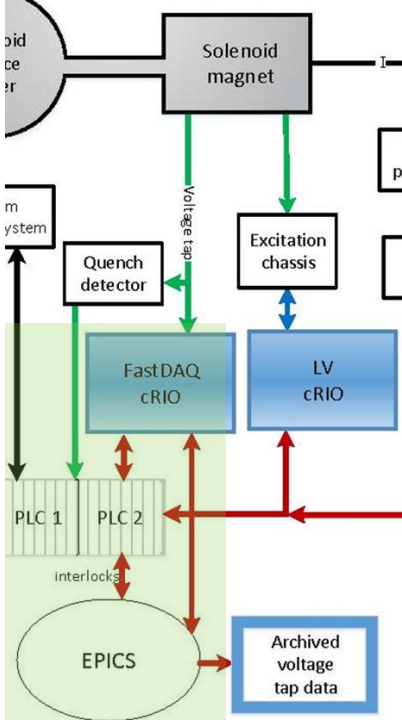
Solenoid Tasks

- **Analysis of PLC spreadsheets, layouts, and drawings of control system - Completed**
  - Solved mismatch in drawing 0638
    - Signal SV8622_Open was deleted from this drawing; it corresponds only to drawing 0641 in slot 2 remote chassis PLC
  - Added four readback signals for heaters 8620 and 8672 in local Solenoid PLC
    - Spreadsheet and drawing modified
  - Added Current Source Polarity signal in drawing 0639
    - Spreadsheet and drawing modified

Solenoid Tasks

- **PID Program for Control Systems - In Progress**
  - Researched Piping & Instrumentation diagrams and information related to Solenoid
  - Made list of instrumentation controlled by Solenoid PLC
  - Set up main functions for each electro valve, pneumatic valve, and heater in cryogenic process
  - Modified PID_Controls program and routines to set up control over cryogenics valves (EV and PV) and heaters

Solenoid Task



- **Testing of communication Fast_DAQ cRIO ↔ PLC - In Progress**
  - Simulate injection voltage in channel 1 of analog input module of cRIO
  - Modified Magnet_Calculation Program in PLC code
    - Generated array to write 20 voltage taps from cRIO_Fast_DAQ.
  - Monitored values in PLC software
- **Communication PLC ↔ EPICS – In Progress**
  - Generated a list with tag names
  - Defined tags for the Danfysik magnet power supply

Torus Tasks

- **UPS power transfer for Torus controls system - Completed**
  - Reconnected all electric strips of control racks into UPS power supply
  - Plugged UPS in outlet that is part of generator circuit for hall
  - Reset communication of PLC for DBX, Torus, and Solenoid
  - Reset communication of cRIO for Torus and Solenoid

- **Voltage injection test in Fast_DAQ cRIO module - Completed**
  - Set up voltage injector at channel 1 of cRIO analog input module
  - Injected 2 V for first test and 3 V in second test
  - Monitored reading in PLC Torus — as expected, for both values

Torus Tasks

- **Correct networking information - Completed**
  - Generated new spreadsheet with corrected IP addresses and host names for Torus and Solenoid

- **Stabilize pressure in LN_2 reservoir - Completed**
  - Programmed cascade PID (2 PIDs max, min) for HTR8554 (heater element)
  - Modified PID_Control program to link HTR8554.MIN tag variable
    - Set default value of tag to 32% of maximum

Conclusions

Solenoid

- Developing programs
  - —Fast_Daq Processing
  - —Communincation_PLC _Solenoid
  - —Magnet_Calculation
  - —PID_ Controls
  - —Networking configurations software
- Testing Communications
- Improving control, monitoring, and interlock systems
- Solving discrepancies with documentation (Solenoid-Torus)

Torus

- Supporting
  - —Cooldown control activities
  - —PLC code debugging


Thank you

Solenoid-Technical Parameters

Number of Coils	5
Coil Structure	Layer wound
Number of turns in main coils	3704 (2 x 840 + 1012)
Number of turns in shield coil	1392
Nominal Current [A]	2416
Central Field [T]	5.0
Peak Field [T]	6.56
Field homogeneity in ∅ 2.5x4 cm cylinder	$1x10^{-4}$
Peak field location	Inner turn near warm
B-Symmetry	Yes
Inductance [H]	5.89
Store Energy	< 20[MJ]
Warm bore ∅ [mm]	780
Total weight [Kg]	18800
Cooling mode	Conduction cooled
Supply Temperature[K]	4.2

Torus -Technical Parameters

Number of Coils	6
Coil structure	Double pancake potted in Aluminum Case
Warm bore ∅ (mm)	124
Total weight (Kg)	25,500
Number of turns per pancake	117
Number of turns per coil	2x117 = 234
Conductor	SSC outer dipole cable soldered in 20 mm x 2.5 mm Cu channel
Turn to Turn Insulation	0.003” E-Glass Tape ½ Lap
Nominal current (A)	3770
Ampere turns (-)	882,000
Peak Field (T)	3.58
Peak Field Location	Inner turn near warm bore adjacent to cooling tube
B-Symmetry	Yes
∫Bdl @ nominal current (Tm)	2.78 @ 5 degree , 0.54 @ 40 degree
Inductance (H)	2
Stored Energy (MJ)	14.2
Quench Protection/Dump Resistor	Hard wired quench detector / 0.124 Ω dump resistor
Coil Cooling	Conduction Cooled by Supercritical Helium
Supply temperature (K)	4.6
Temperature margin (K)	Min 1.52 (@5.3 K) to Generation temperature 6.82
Heat Shield Cooling	LN2 Thermo-Siphon