



Emerson Impact Partner



Experience Industrial Innovation

Legacy Control Systems? How to Plan a Successful Upgrade

Andrew Yick, P.Eng, M.Eng
Sept 14, 2021



Spartan Controls – Automation Support Network in Western Canada



Emerson Impact Partner

Spartan Controls

Employees **1,040**

Locations **15**

DeltaV Systems **>500**

DeltaV I/O Install Base **>600,000**

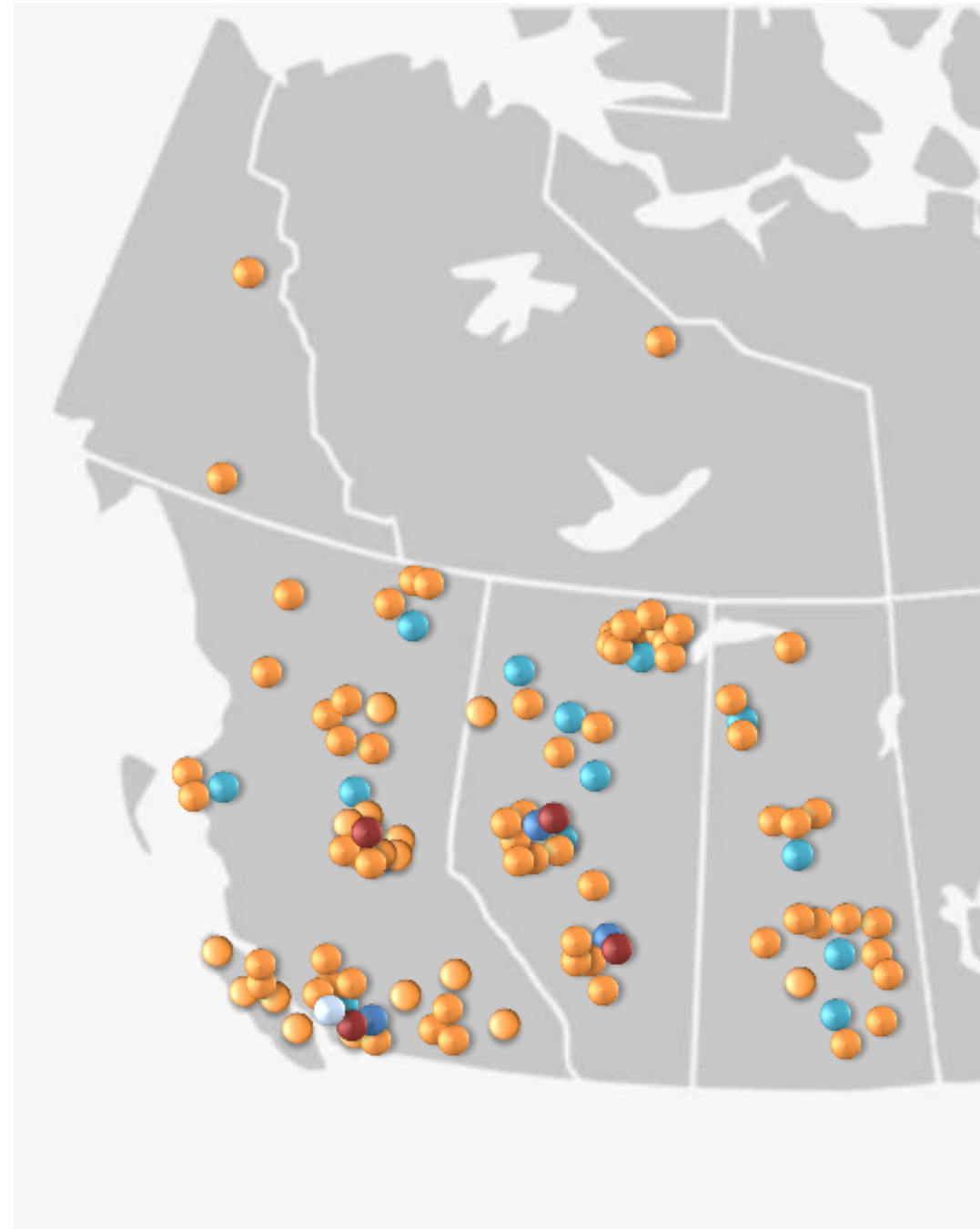
Automation Specialists **>150**

Verified Business Results **\$510M**

CO2 Emission Reduction **400,000T**

Expert Services

System Upgrades
Advanced Process Control
Digital Twin Simulation
OT Data Analytics
Alarm Management
Procedural Automation
Networks & Cybersecurity



Education & Training

Local Training to Over 5,000 Students/Year

NSERC Senior Industrial Research Chair in Control

Educational Institutes with DeltaV & Training Curriculum

Education Seminars (Bi-Annual)



- Institutional Educational Training
- Spartan Controls Burnaby
- Spartan Controls Regional Offices
- Spartan Controls Education Centers
- DeltaV Systems

Emerson Automation Solutions

Operations Management



Network Design
Cybersecurity



Operations
& Alarm
Management



Advanced
Process
Control



MES Planning
& Scheduling



Plant Asset
Management



Training &
Simulation



Real-time
Optimization



Production
Management



Asset Integrity
Management

ENGINEERING
& DESIGN

CONTROL SOFTWARE

OPERATIONS
MANAGEMENT

ASSET RELIABILITY
& PERFORMANCE

Control



CONTROL SYSTEMS



REMOTE CONTROL



SAFETY SYSTEMS



MACHINERY HEALTH

Field Devices



MEASUREMENT



ANALYTICAL



ISOLATION VALVES



FINAL
CONTROL



REGULATE &
PROTECT

Legacy Control Systems – You May Have One of These...

Bailey Infi90



Allen Bradley PLC5



Quantum Modicon



Moore APACS

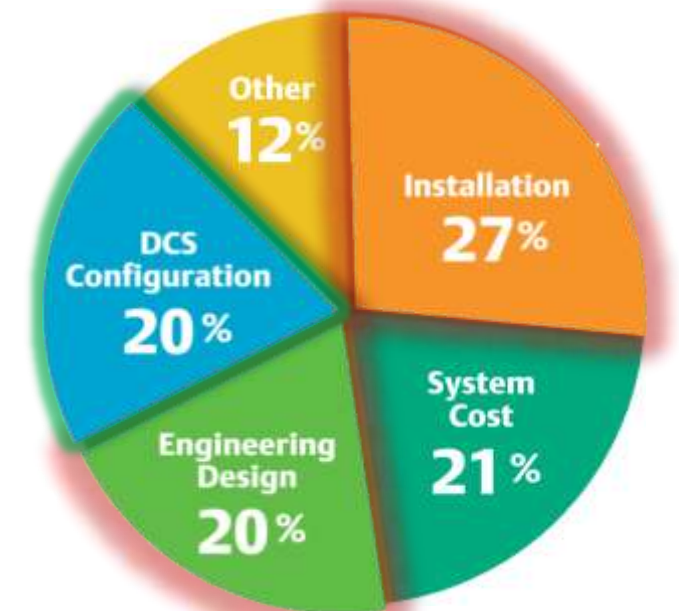
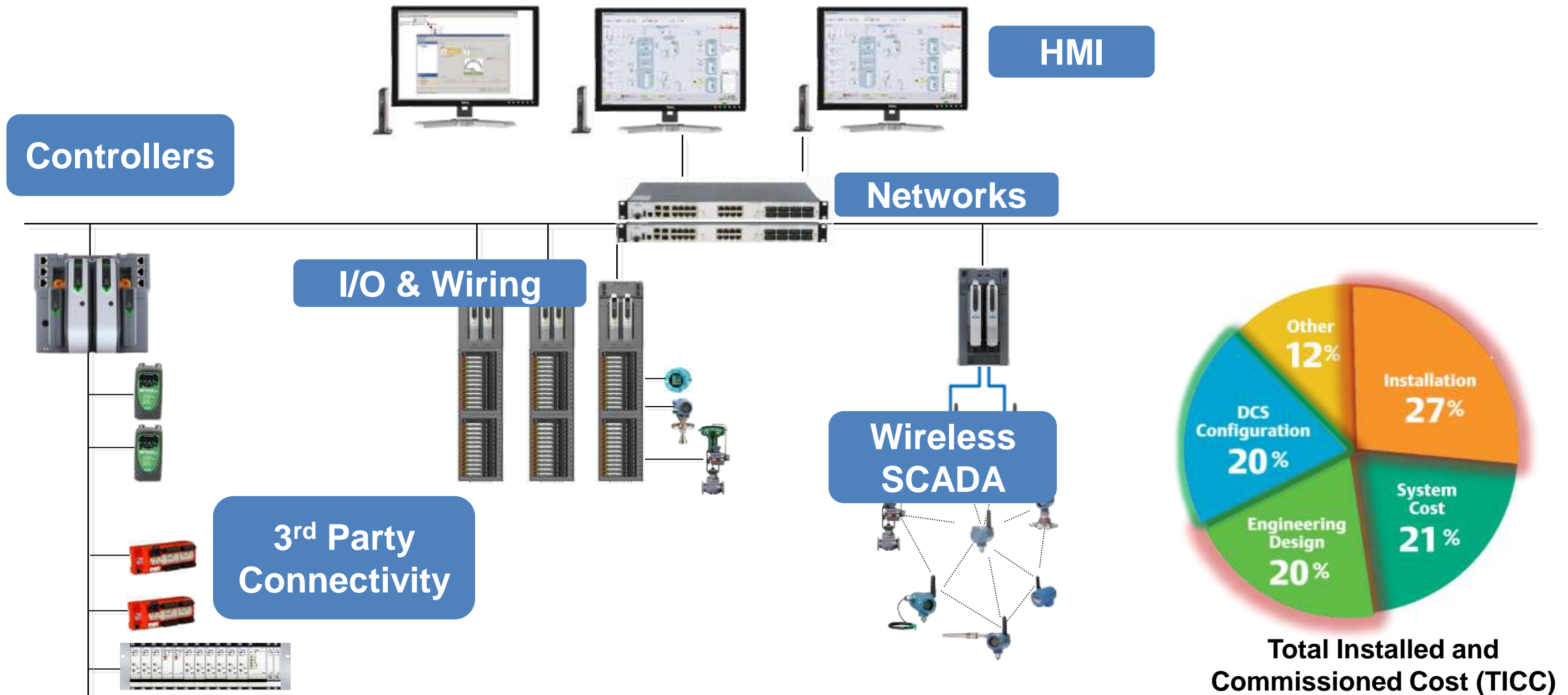


Why modernize? Justifications

- Hardware obsolescence
- Spares availability and high cost of obsolete parts (risk)
- Limited support
- Plant expansion
- Take advantage of new technology (Smart MCCs, Advance Process Control, Smart Instruments)
- New environmental regulations
- Lower costs, increase throughput and improve quality



Control System Upgrade – Lots to Consider



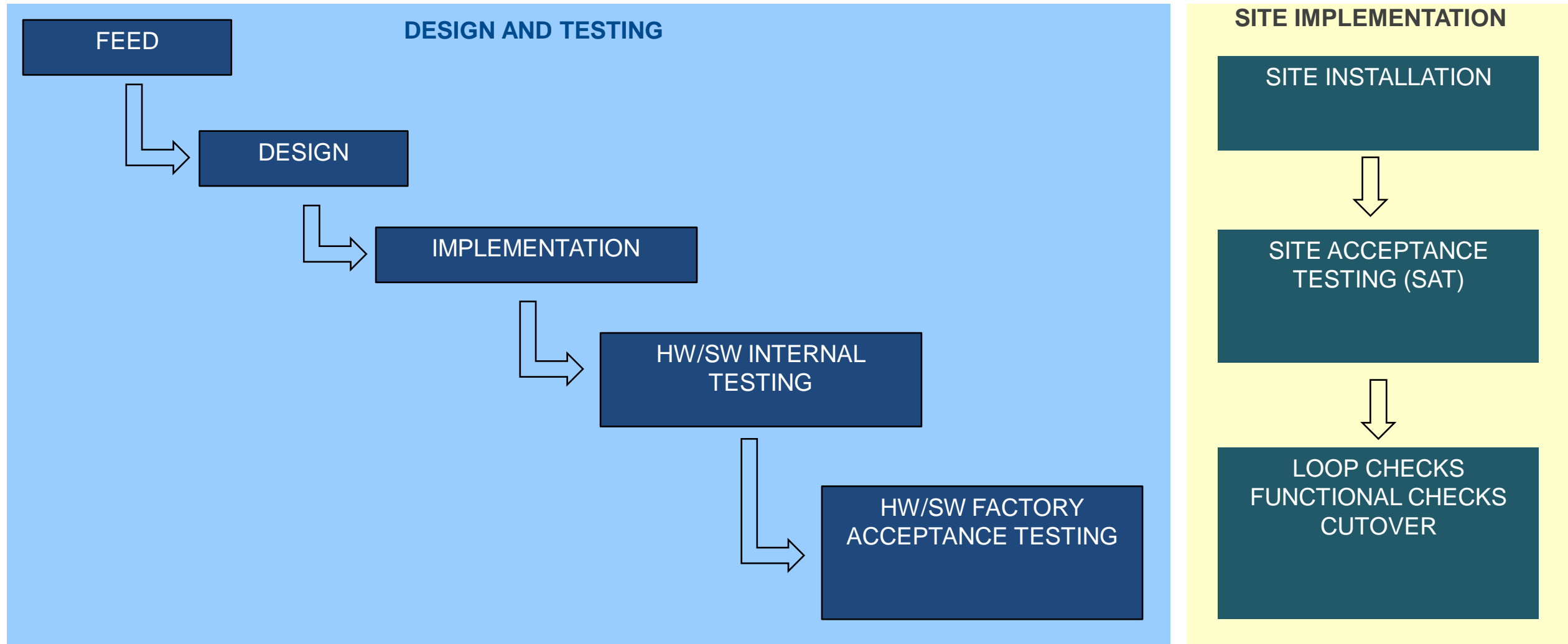
Total Installed and Commissioned Cost (TICC)

Challenges

- Fear of loss of service
- Past projects have been over-budget and late
- Existing plant documentation is poor or non-existent
- Space availability restrictions
- Tight schedule during outage
- On-line/Off-line migration and Wiring Cutover
- Fear of safety/environmental, interlocks or logic being missed
- Operator “buy-in” / MOC
- Costs



Project De-Risking Process



Aspects of implementation, install and commissioning

- Panels
- Wiring and I/O
- Networking
- Logic
- Consoles / Graphics
- Alarming
- Historians / Interfaces to other systems
- Documentation
- FAT / Operator training
- Commissioning
- APC enhancements

Aspects of implementation, install and commissioning

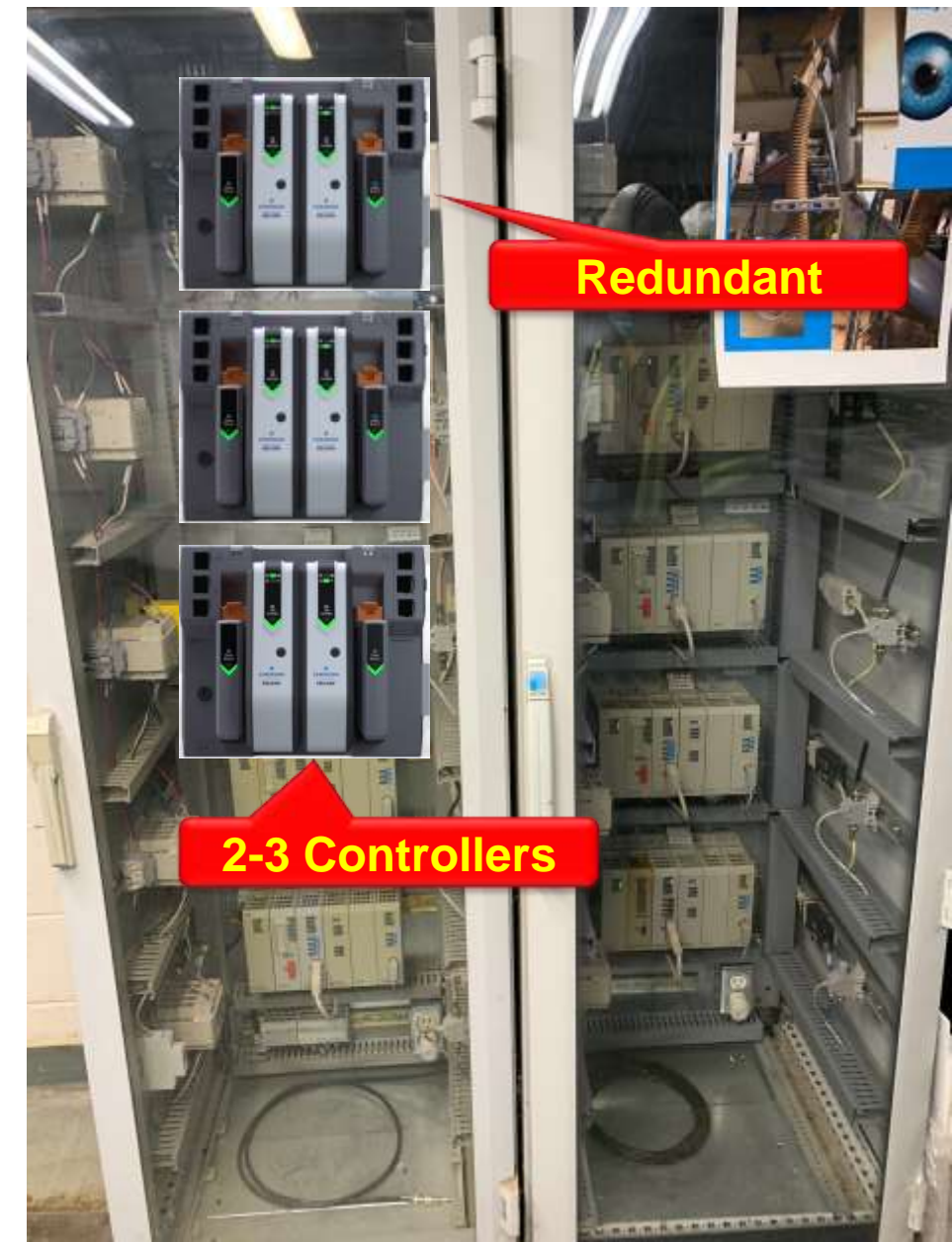
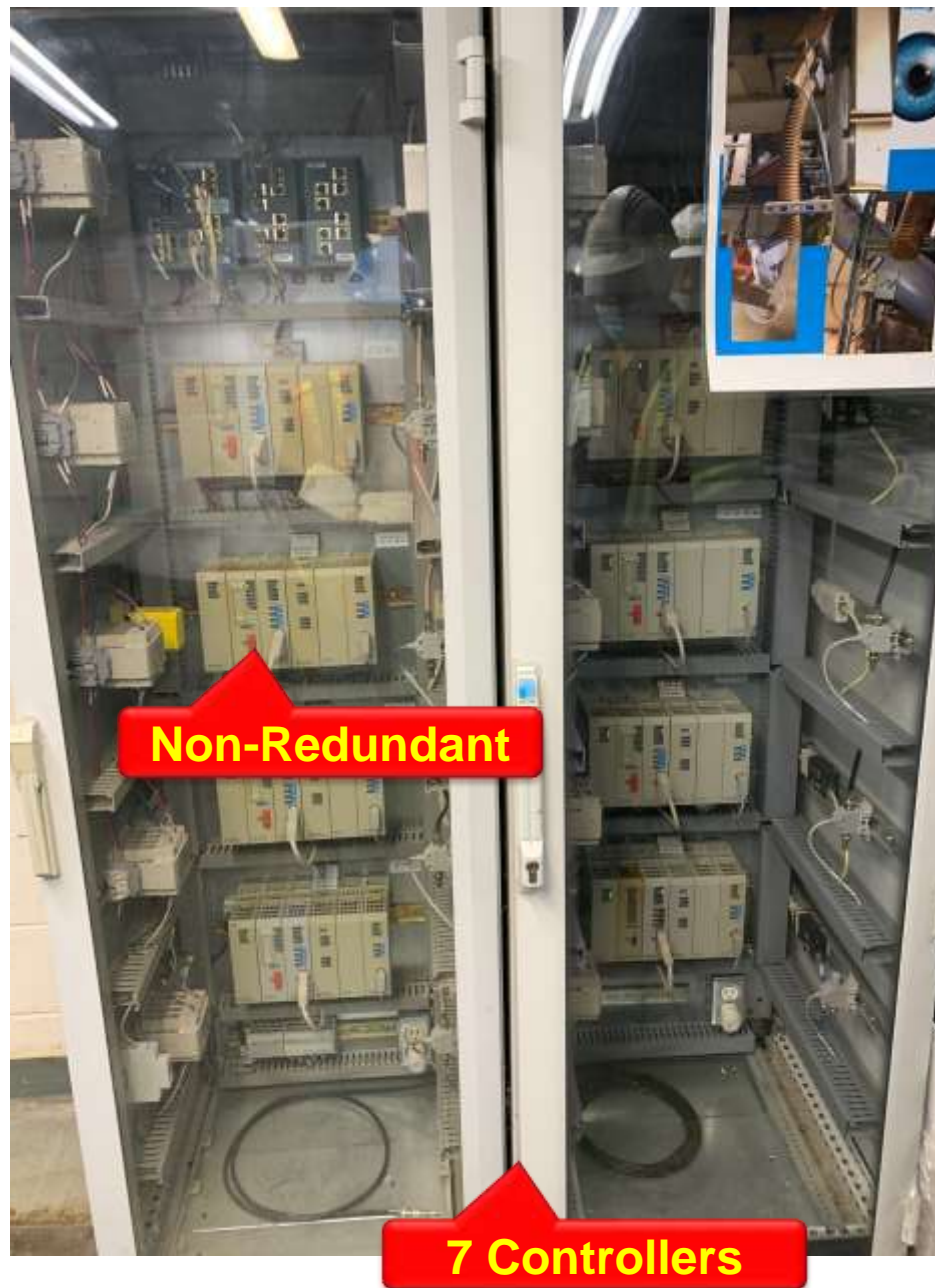
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Controller Replacement – The “Brain” of the Control System

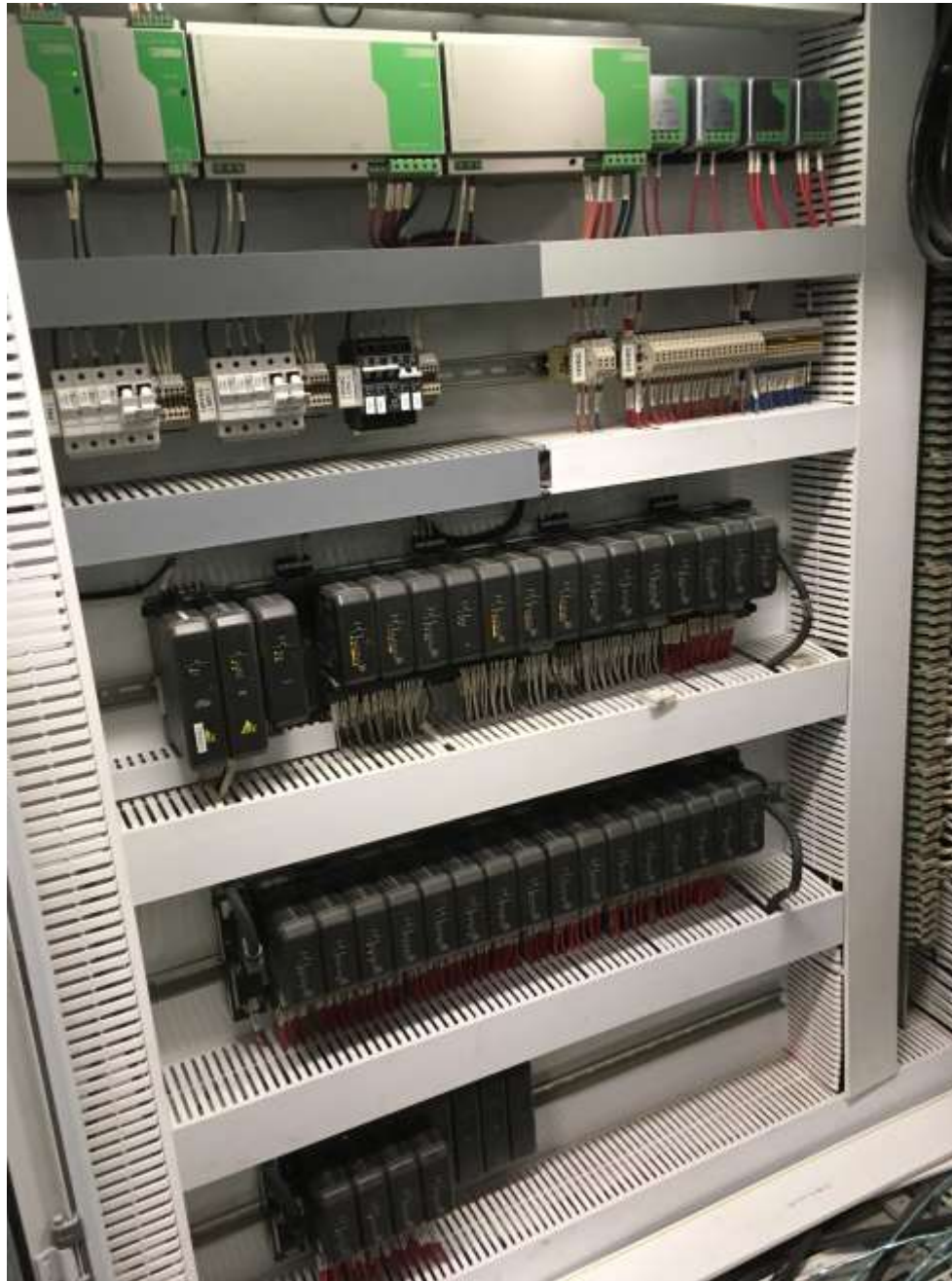
- Upgrade legacy controller with modern controllers
- Improve availability with redundancy
 - Controller card
 - Power Feed
 - Power Supplies
 - Network Ports
 - Network Communication
- Replace legacy communications (ie Coax) with redundant fault-tolerant Ethernet communications
- Take advantage of Ethernet protocols such as Ethernet/IP, Modbus TCP, etc. for Smart MCC/VFD/PLC Integration



Improving System Availability for Controllers by Consolidating



Panels – New Panels



- Cleanest solution
- No downtime – can be pre-installed
- Field wiring is re-terminated so time may not permit this (typically requires shutdown)
- Extra space in Electrical or IO rack room may be required

Panels – Use existing panels – May Require Downtime

Remove old hardware



New Hardware pre-mounted on backplane



Aspects of implementation, install and commissioning

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How to Tackle Legacy Wiring & I/O Installations?



Wiring & I/O Considerations

- What is the status of the existing wiring?
- How old? Does it need to be replaced?
- Replace I/O “in-place” or install new field “Smart Junction Box” with Remote I/O?
- Develop clean I/O list matches what’s in the field
- Clean up “dead” I/O
- I/O hardware can vary considerably
 - Signal types, voltages, power requirements, flexibility, footprint, arrangement, termination type
- Not all discrete DIs and DOs are the same
 - Existing wiring techniques may not work with new I/O
 - Output rating of new vs old may be different. (1A vs 100mA)
 - Isolated vs Non-Isolated
 - Location of Power (Field Powered vs Panel Powered)

Types of I/O

Traditional Card I/O

- All I/O cards currently available: bussed, analog, discrete, etc.



Ethernet I/O

- Open Standards - Ethernet/IP, Modbus, Profinet, IEC-61850
- Redundancy & PRP



CHARMs I/O

- Single Channel Flexibility & Integrity
- Smart Junction Boxes



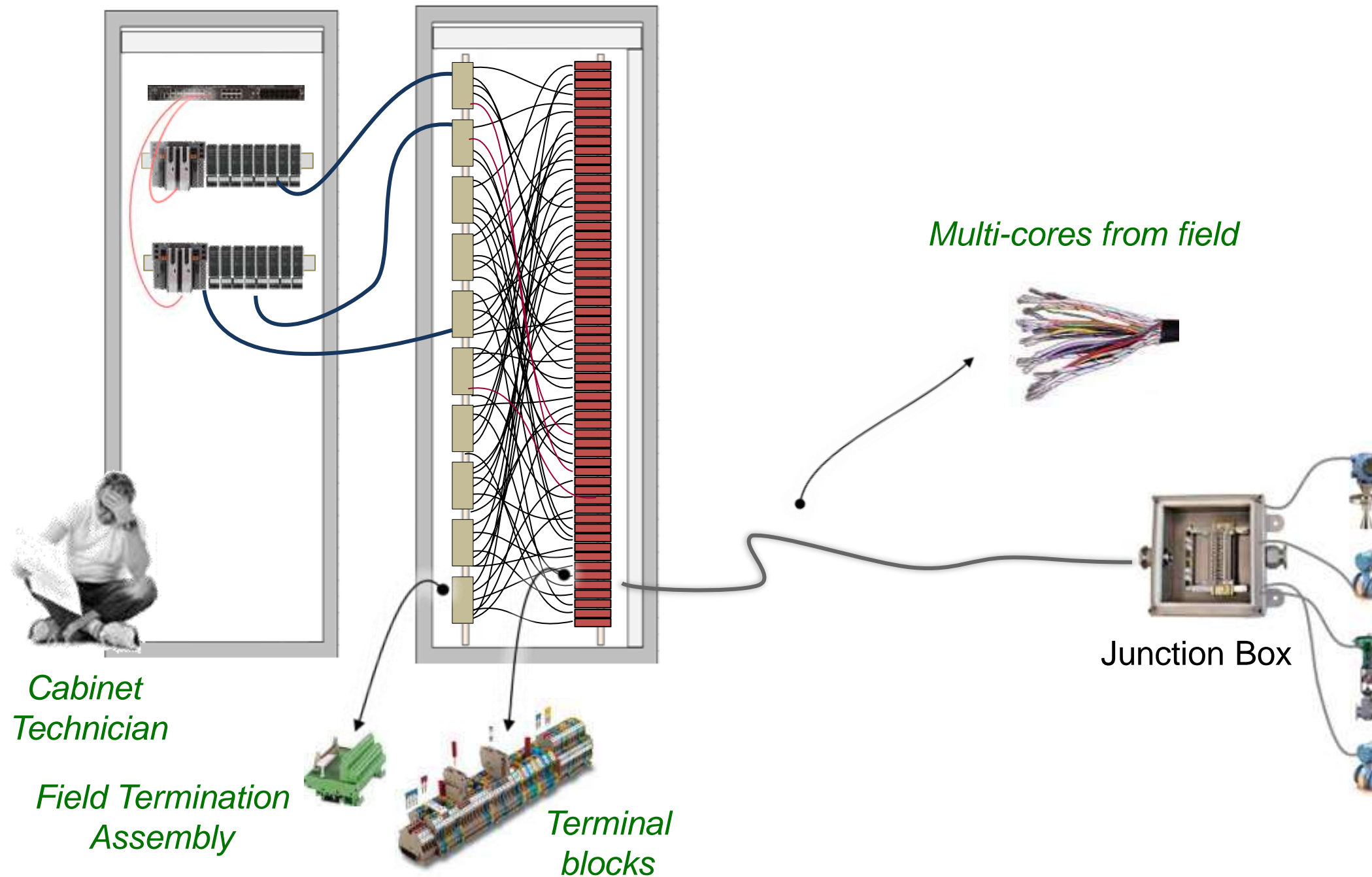
Wireless I/O

- WirelessHART Gateway



WIOC

Challenges with Legacy Wiring

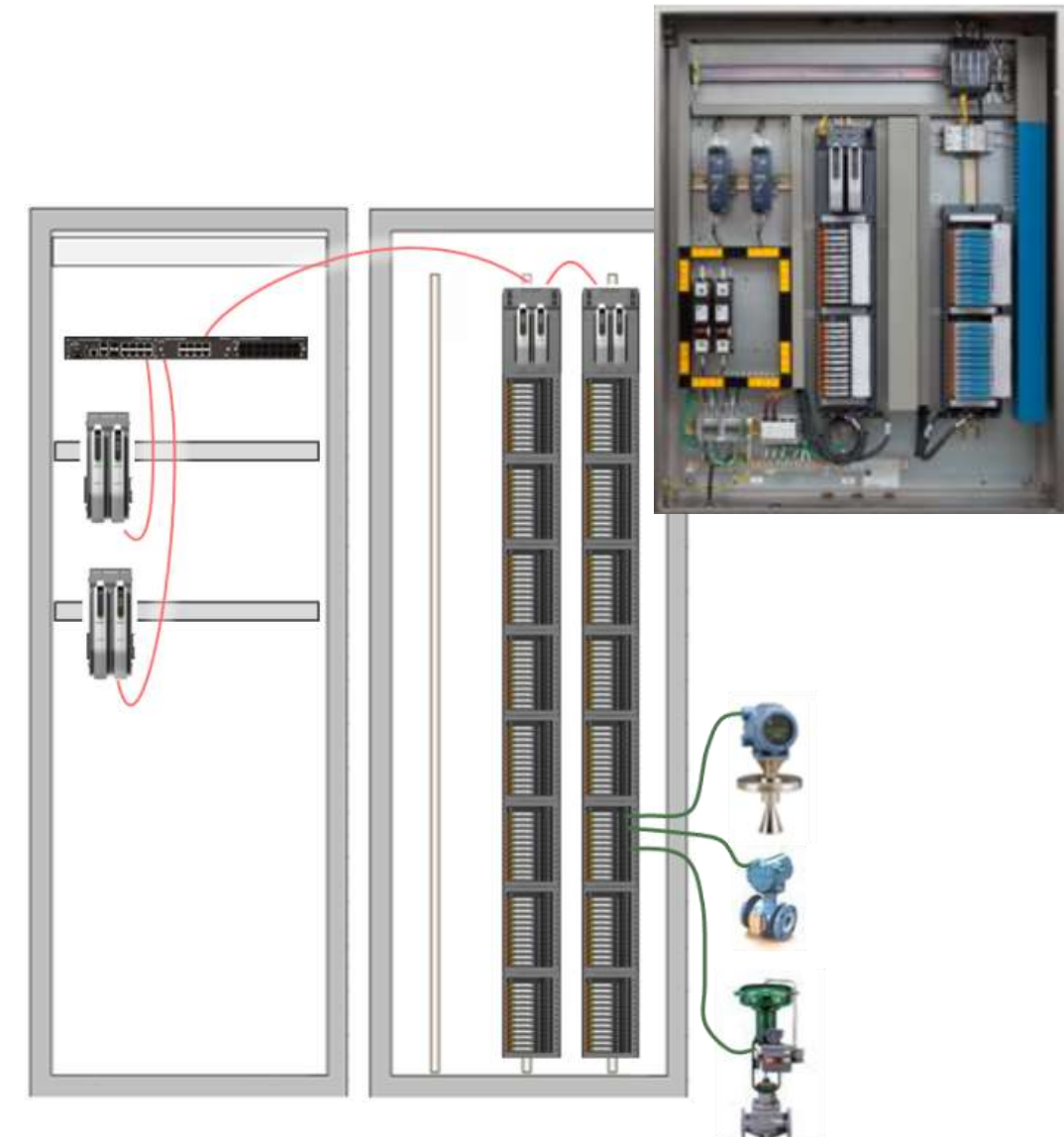


Remote I/O – Installation Flexibility

- Flexible Installation
 - Single Channel I/O (CHARM)
 - 12-96 I/O per CHARM I/O Card
 - Upside down/sideways mounting options
 - Displace junction box or marshalling terminations



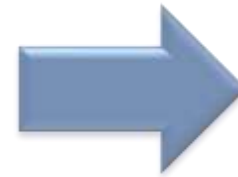
- Environmental flexibility
 - Mount inside or in the unit
 - Indoor / outdoor locations – extreme temperatures



Retrofit I/O Cards / Keep Existing Cabinets



Retrofit Horizontal I/O Termination Panels / FTA with CHARMS I/O Keep Existing Wiring



Wiring – Consider Footprint & Panel Space

**PROVOX Term Panel pre-upgrade
8 & 16 I/O Term panels**



**DeltaV CHARMs IO Panel post-upgrade
24 I/O Baseplate Migration Panels**



Electronic Marshalling – Easy Modernizations

Typical Marshalling I/O FTA Cabinet
(Field Termination Assembly)



Conditioning terminal
blocks (CHARMs)
match field wiring

Sets of 12 twisted pairs
to match existing field
wiring

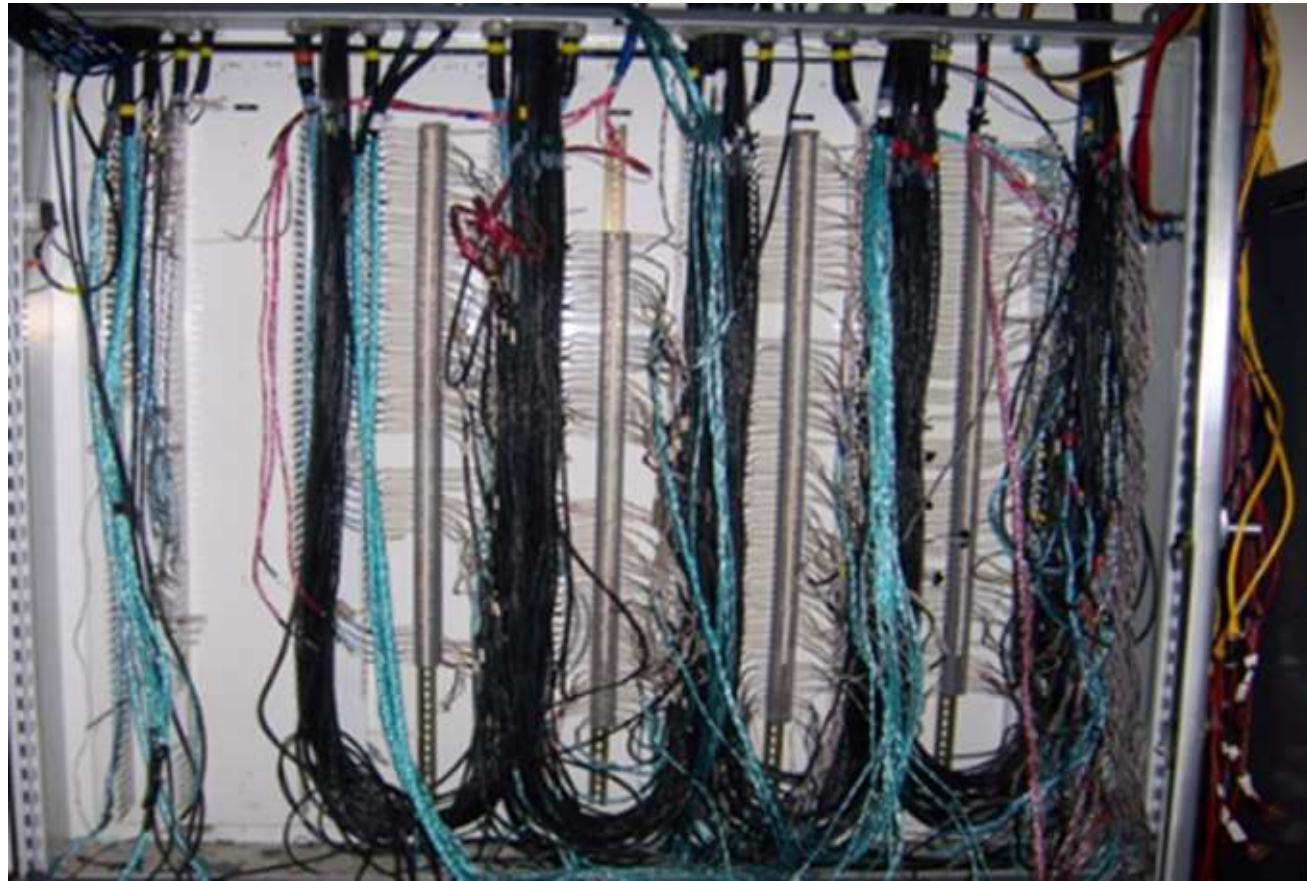
Fits perfectly in the FTA
footprint

Retrofit Vertical I/O Termination Panels / FTA with CHARMS I/O

Keep Existing Wiring



Retrofit Marshalling Panels with Electronic Marshalling CHARMS I/O Freeing up Rack Room / E-Room Space

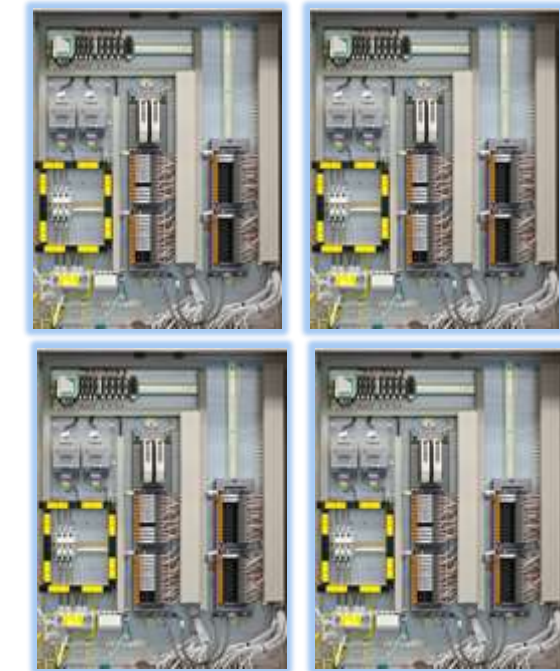
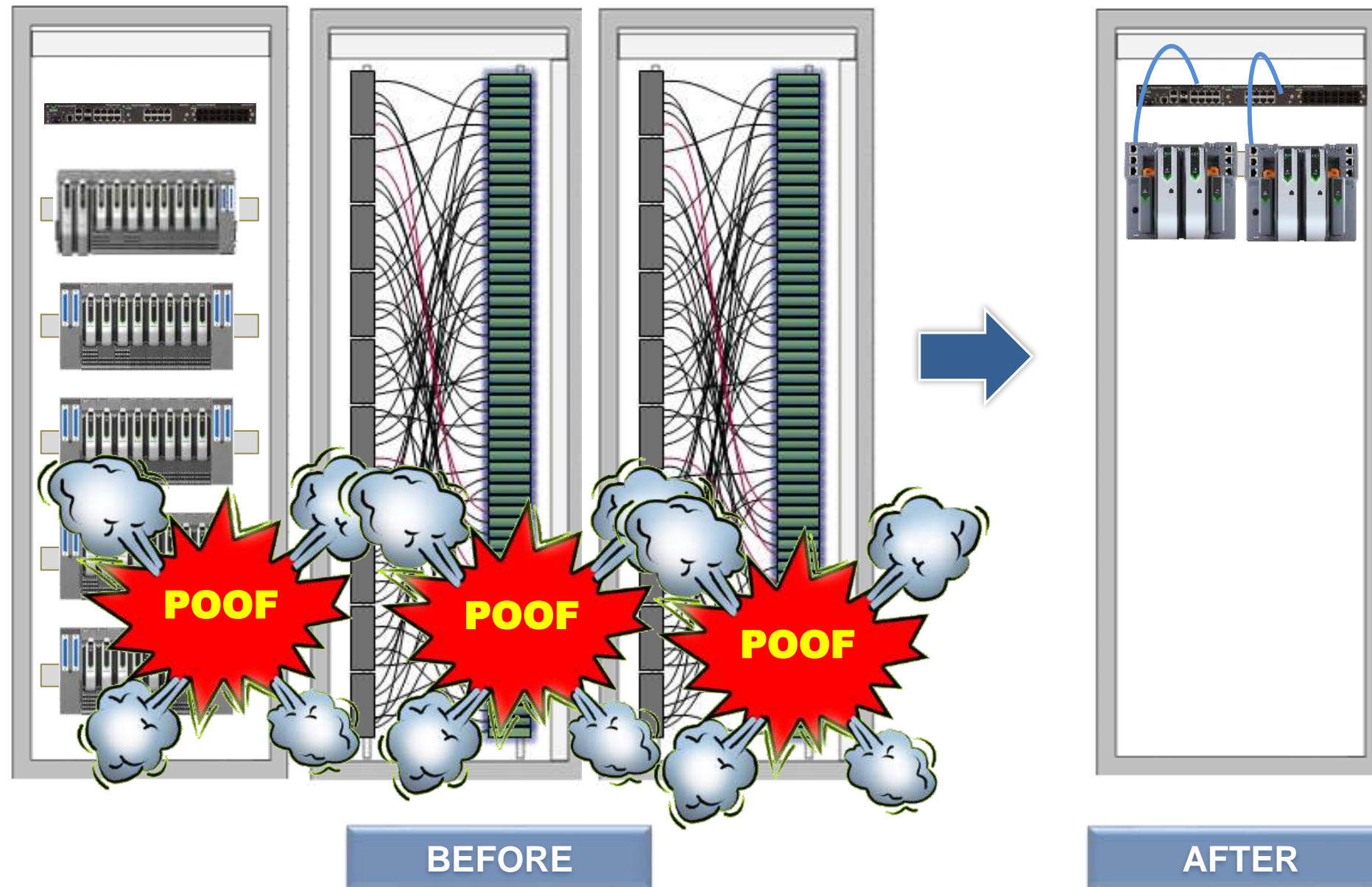


Wiring – Clean up Wiring, Labelling and Panduits

Before During After



Wiring Too Old / Messy? Move I/O to Field and Abandon Old Wiring



Standard Junction Boxes

Smart Junction Boxes Design Philosophy

**Design Once
Build Many
Standard Sizes – 48, 96**

Fiber Optic
communications to
controllers

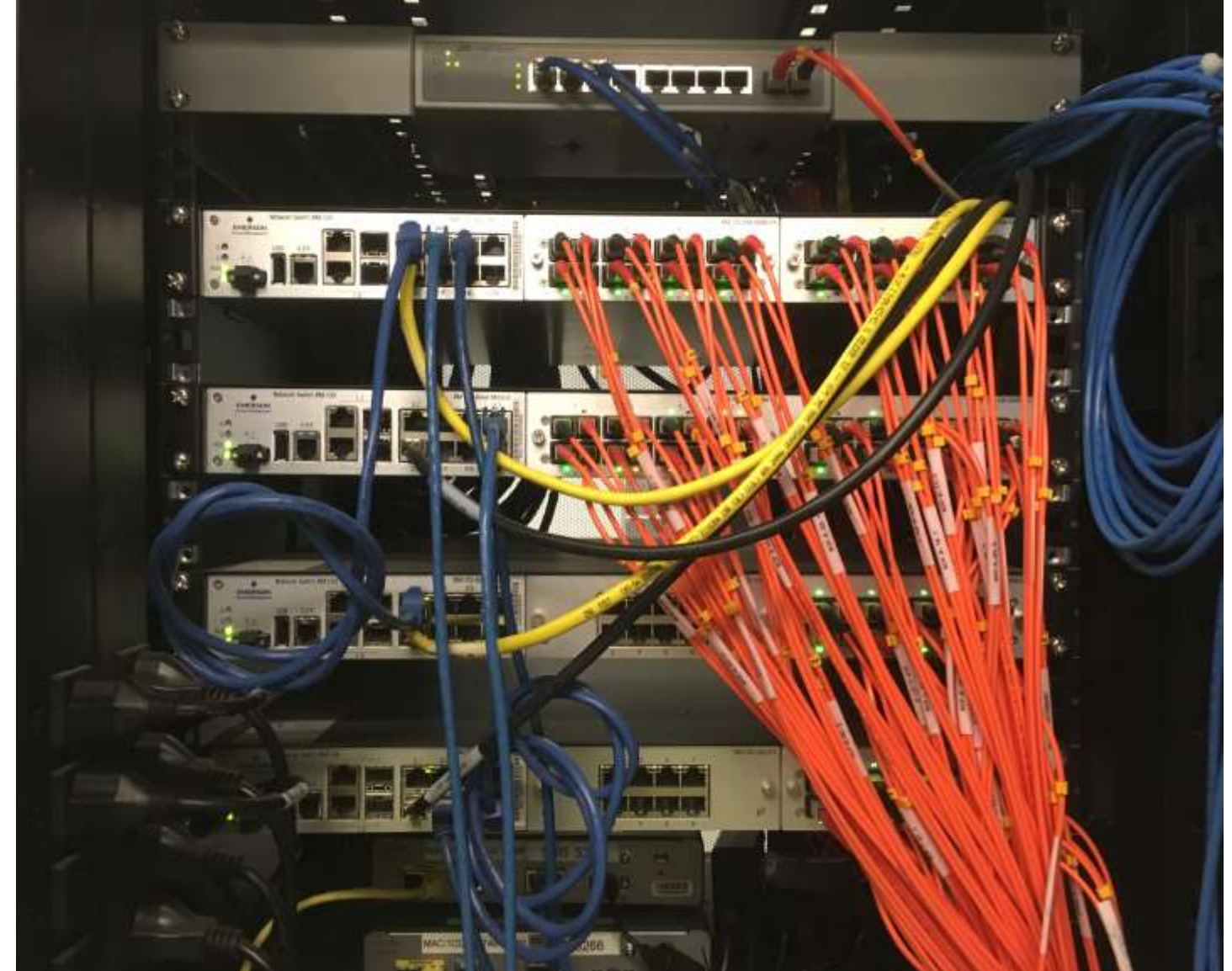


Aspects of implementation, install and commissioning

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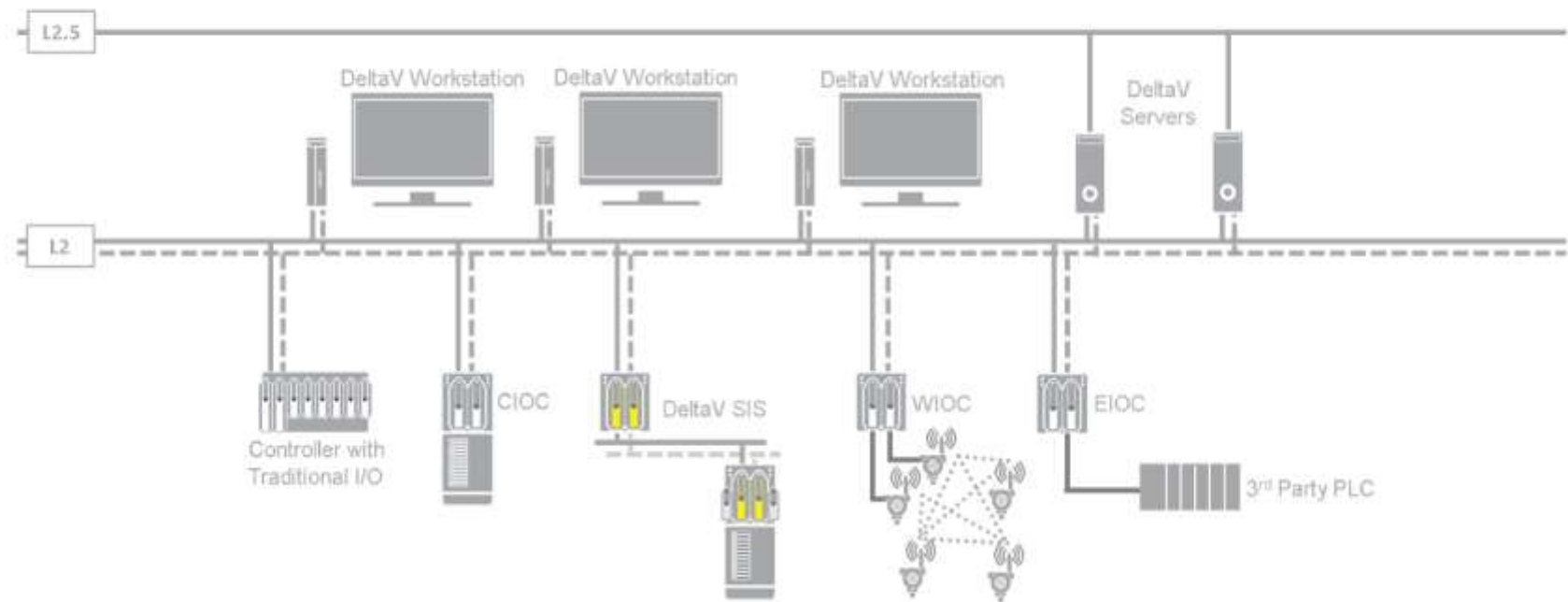
Networking

- Perform audit of networking required
 - Determine number, location and types of network switches
- Determine what new fiber (>100m) and copper cabling needed
 - Redundant networks (primary / secondary)
 - PLC / Field device networks
 - CCTV
 - Business Networks
 - Fiber backbone & patch panels
- Install as much as possible prior to conversion



Plan for Cybersecurity in Your Network Design

- ✓ Intrusion Protection (lock)
- ✓ DeltaV User Manager
- ✓ Network Device Command Center
- ✓ Domain Environment
- ✓ USB lockdown (GPOs)
- ✓ DeltaV Security Administration



Based on the “Seven Strategies to Defend Industrial Control Systems” – DHS, NCCIC – 2016



Application Whitelisting



Patch Management



Emerson Smart Firewall



Firewall-IPD



2-Factor Authentication



Security Monitoring



Secure Remote Access



ISA Secure® SSA Certification – IEC 62443

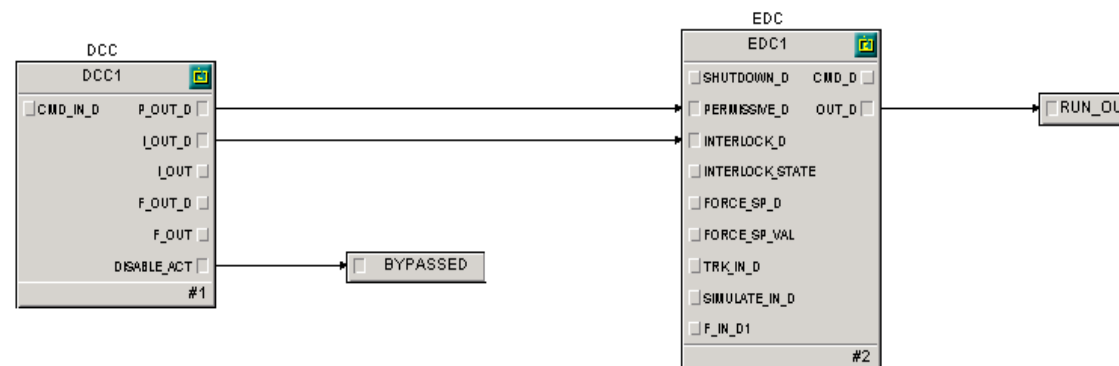


Aspects of implementation, install and commissioning

- Panels
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- **Logic**
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Logic

- Do control narratives exist and are they current?
- Do you need to reverse engineer what is there?
- Who verifies the narratives or documents from reverse-engineering?
- Use bulk import tools where possible (Excel - ranges, tuning values)
- Build standards and thoroughly test (critical first step)
- More efficient logic/Better comments
- Better information to operators (what's holding out a motor)



Logic - Caution

- Be leery of copying code from the legacy system
- Dead code not removed
- Legacy code does not take advantage of new control capabilities
- This applies to both control strategies and graphics
- With “As Found”, You’re paying to extend the life, but you don’t get any improvement

Logic – Developing Standards Documentation

Configuration Standards

33484-P-STD-0002

Client Project No. 168213

Revision 0

Dec 17, 2013

REVISION HISTORY

REV	DATE	BY	REVIEWED	DESCRIPTION
0	Dec 17, 2013	SMA	AYY	Issued for Construction

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Graphics Standards

33484-P-STD-0003

Client Project No. 168213

Revision 0

Dec 17, 2013

REVISION HISTORY

REV	DATE	BY	REVIEWED	DESCRIPTION
0	Dec 17, 2013	AYY	GUR	Issued for Construction

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Alarm Standards

33484-P-STD-0001

Client Project No. 168213

Revision 1

Dec 17, 2013

REVISION HISTORY

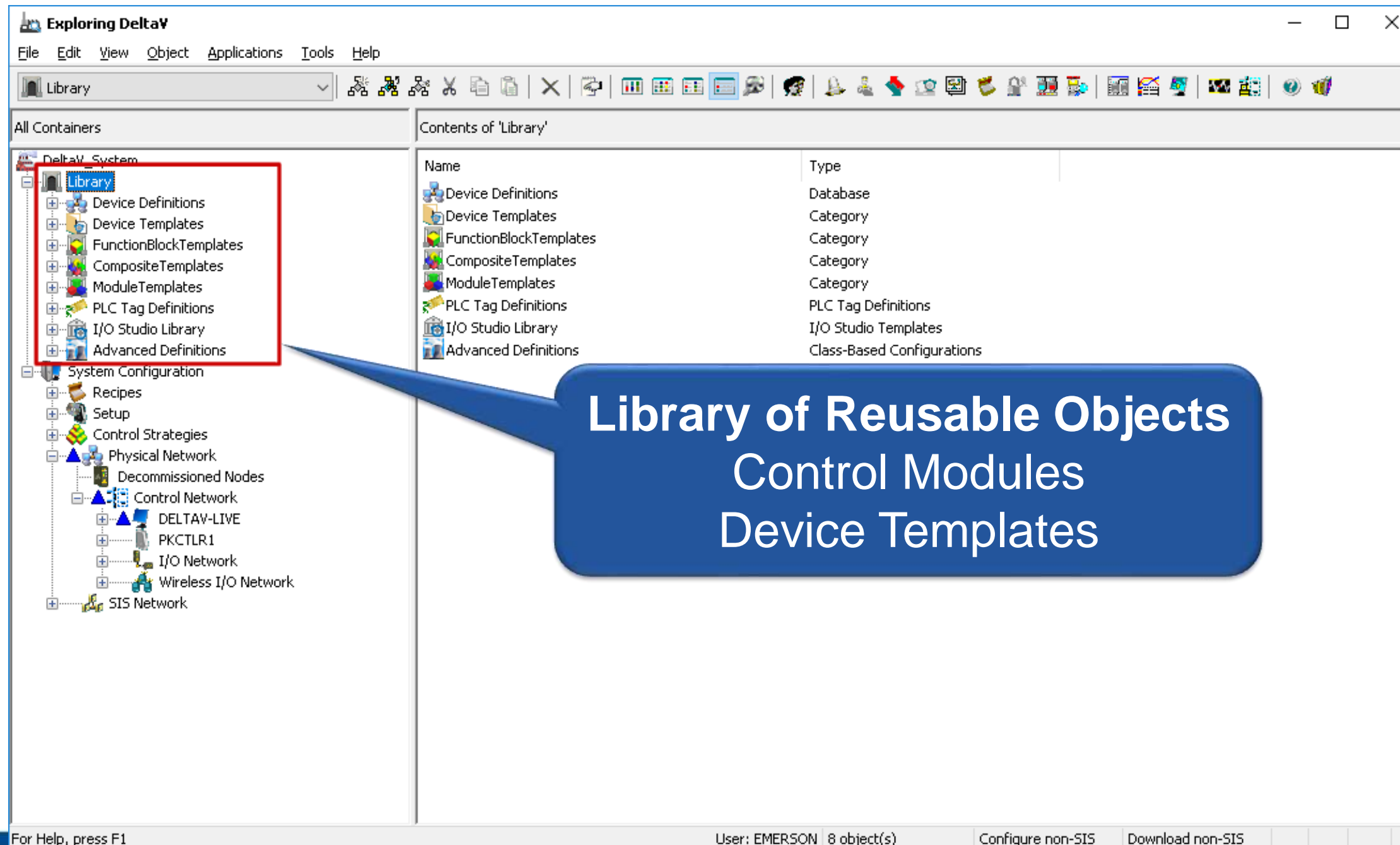
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0	Nov 8, 2013	AYY	GUR	Issued for Review
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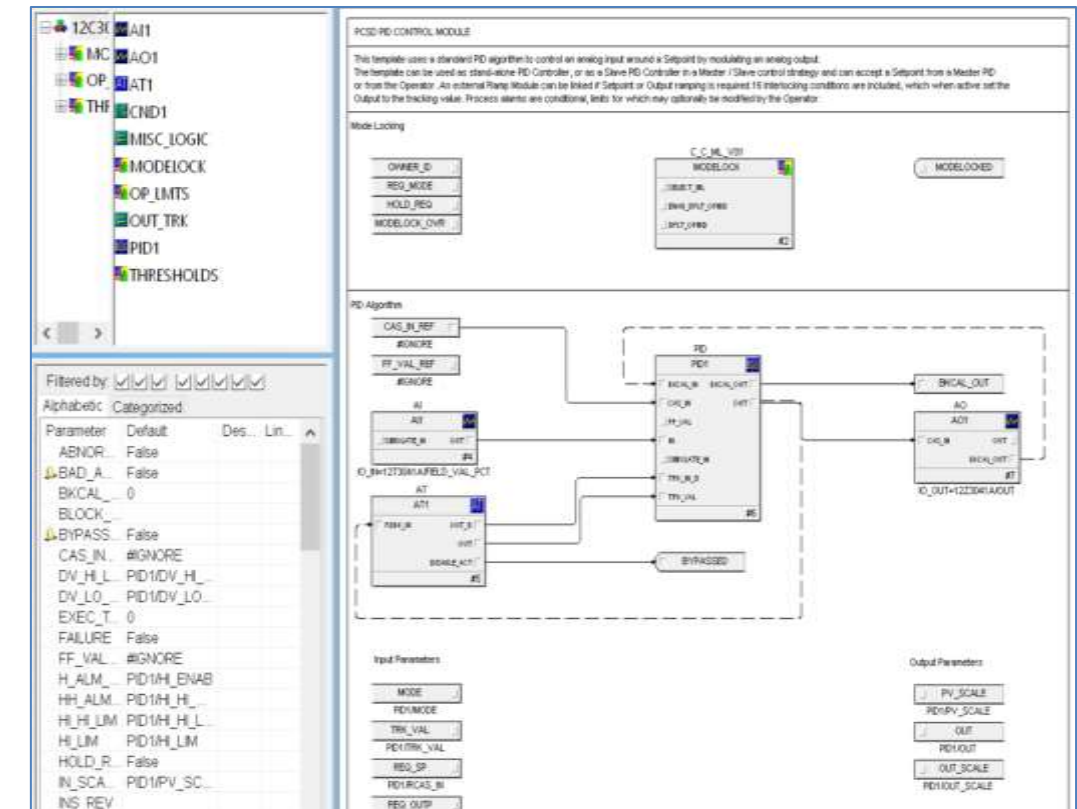
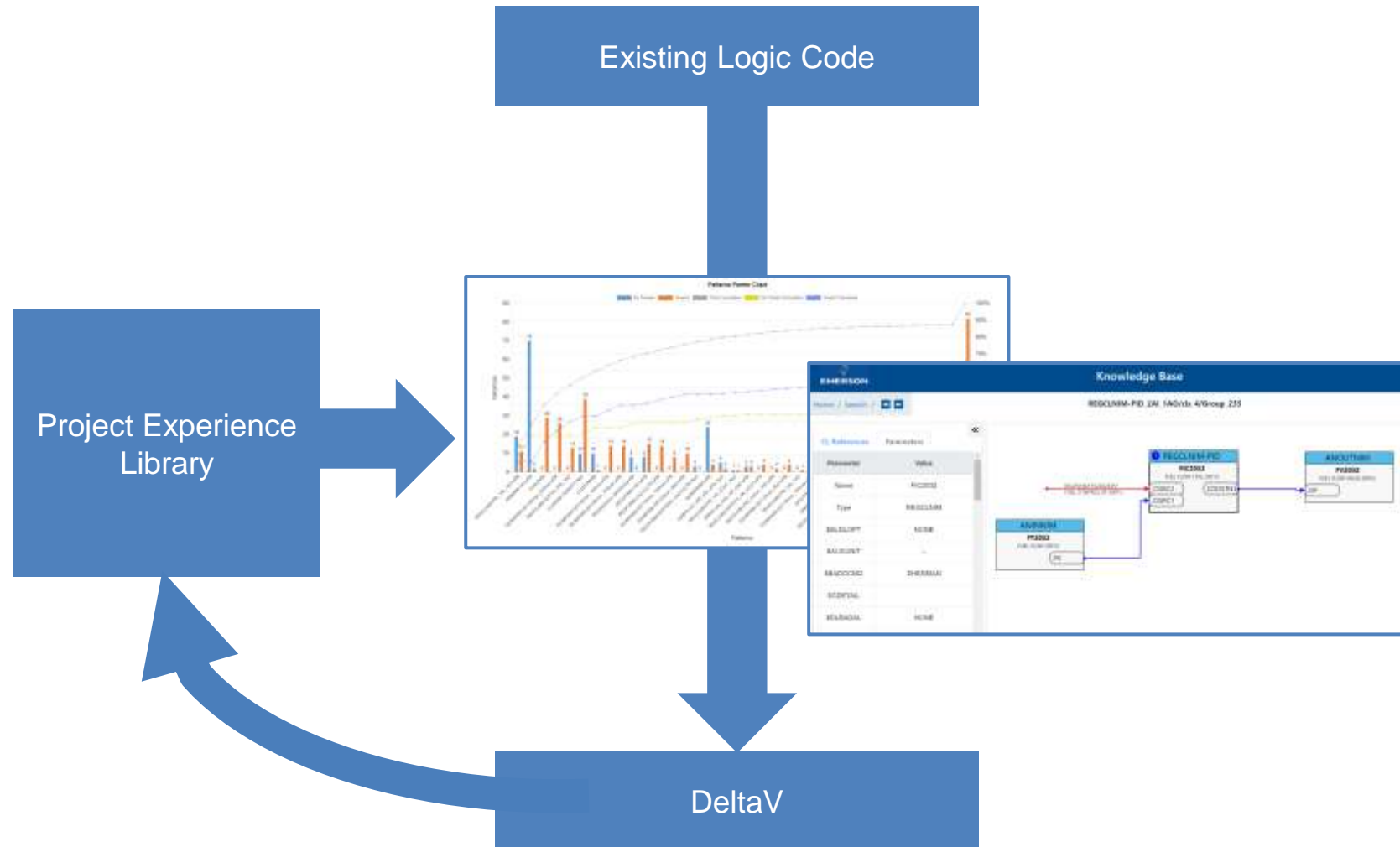
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Control System Software Setup – Library / Templates



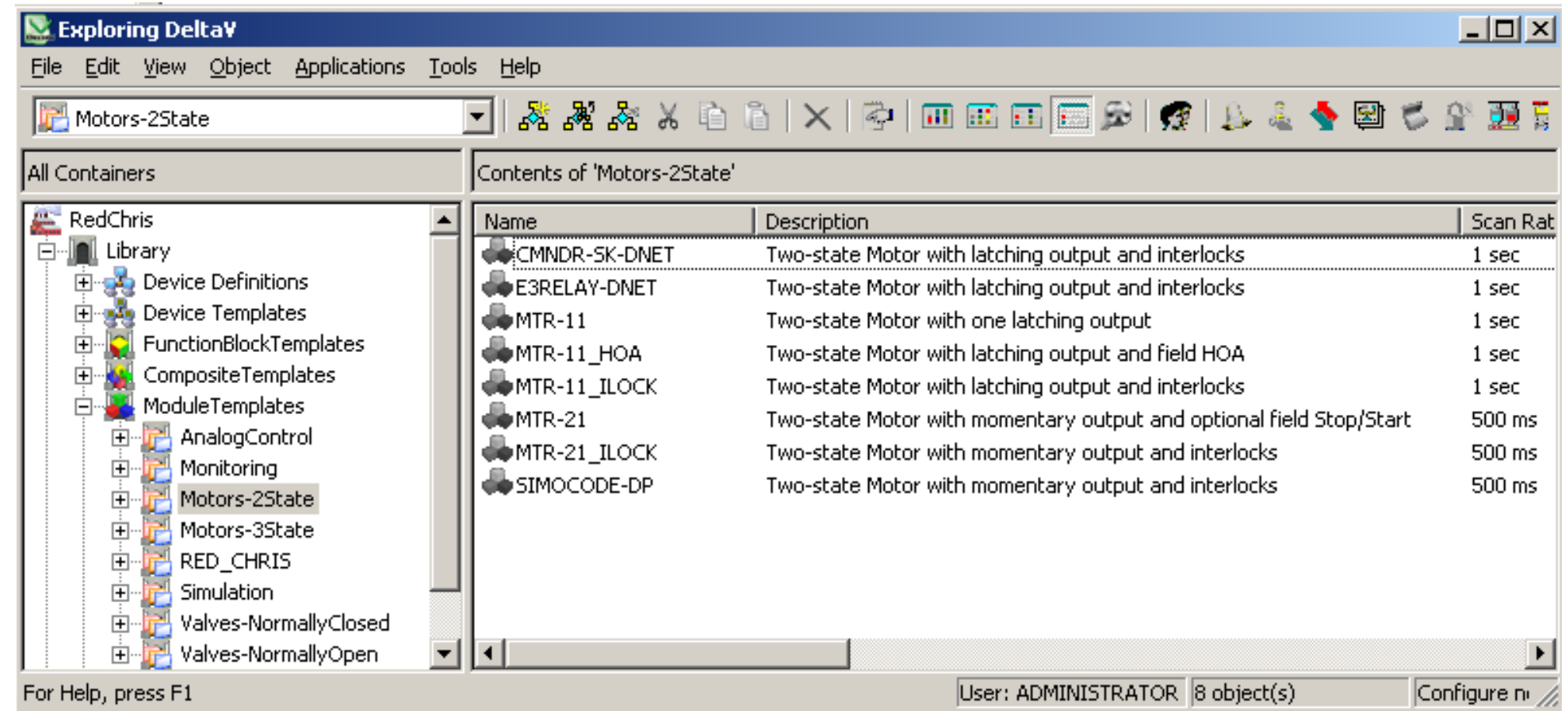
Standardized & Structured Logic



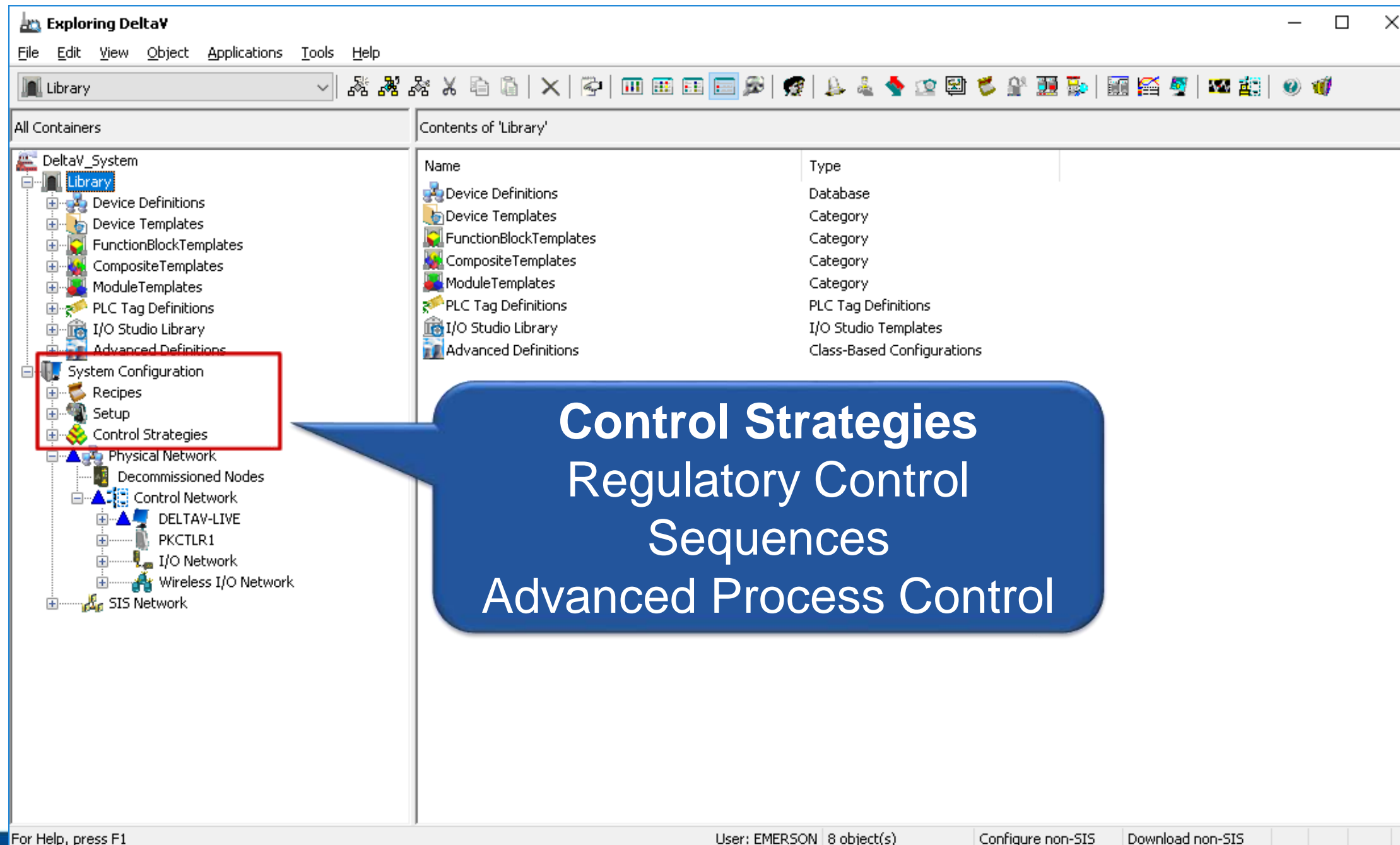
Auto-generated (as-built in the DeltaV System)

Logic – Improve Consistency & Speed with Standard Templates

- AI
- DI
- DO
- On/Off Control
- PID
- Totalizers
- On/Off Valves
- Motors



Control System Software Setup – Control Modules & Sequences



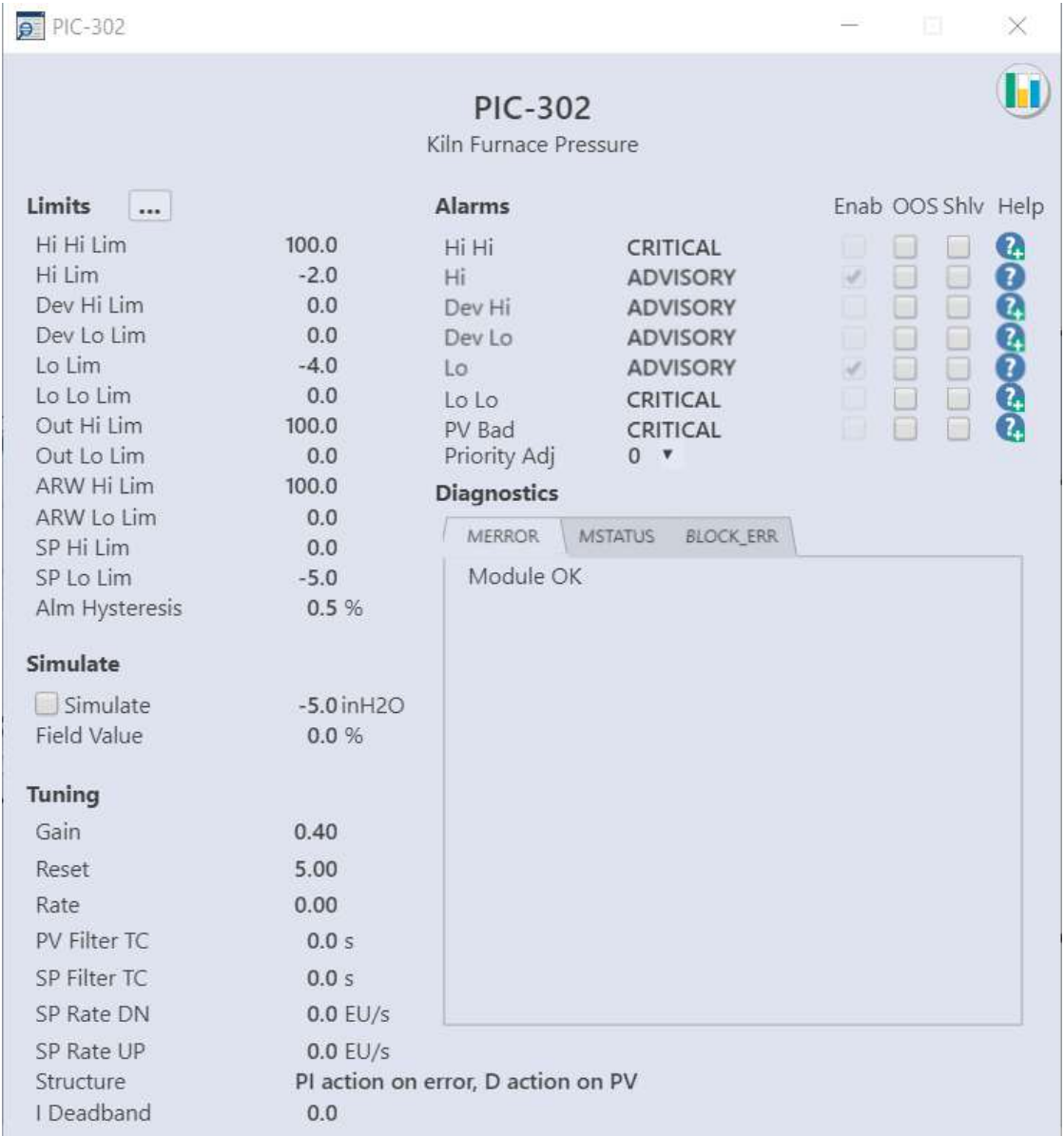
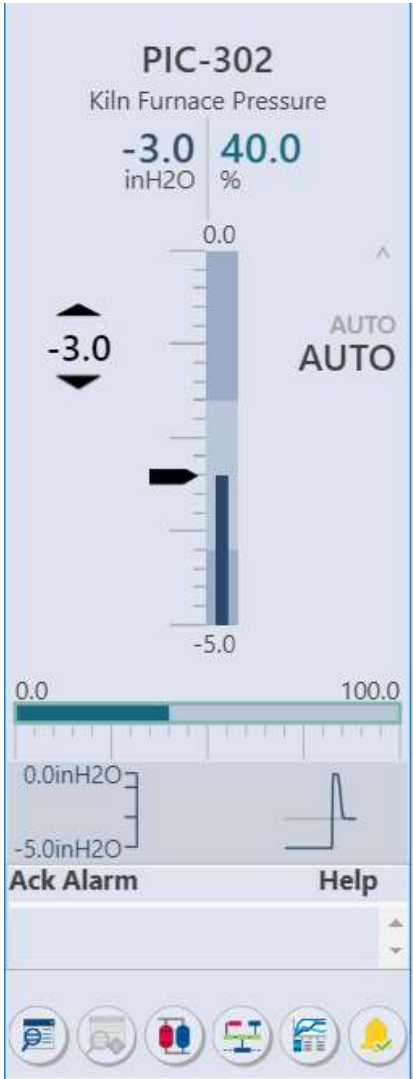
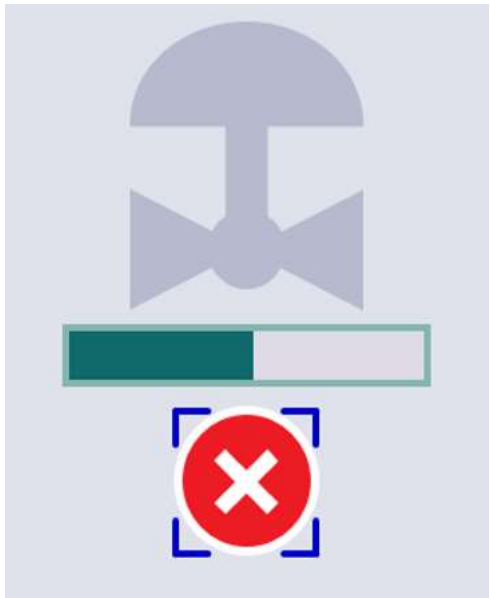
Control System Software Setup – Logic Modules

The screenshot displays the Control Studio software interface for a PID control system. The main workspace shows a diagram with three primary blocks: an AI1 (Analog Input) block, a PID1 (PID Controller) block, and an AO1 (Analog Output) block. The AI1 block is connected to the PID1 block's IN port. The PID1 block's OUT port is connected to the AO1 block's CAS_IN port. The AO1 block's BICAL_OUT port is connected back to the PID1 block's BICAL_IN port, forming a feedback loop. The PID1 block has several other ports, including BICAL_IN, BICAL_OUT, CAS_IN, OUT, IN, SIMULATE_IN, TRK_IN_0, TRK_VAL, SP, and RCAS_IN. The AO1 block has CAS_IN, OUT, and BICAL_OUT ports. A blue callout bubble points to the PID1 block with the text "Easy to Maintain Standardized".

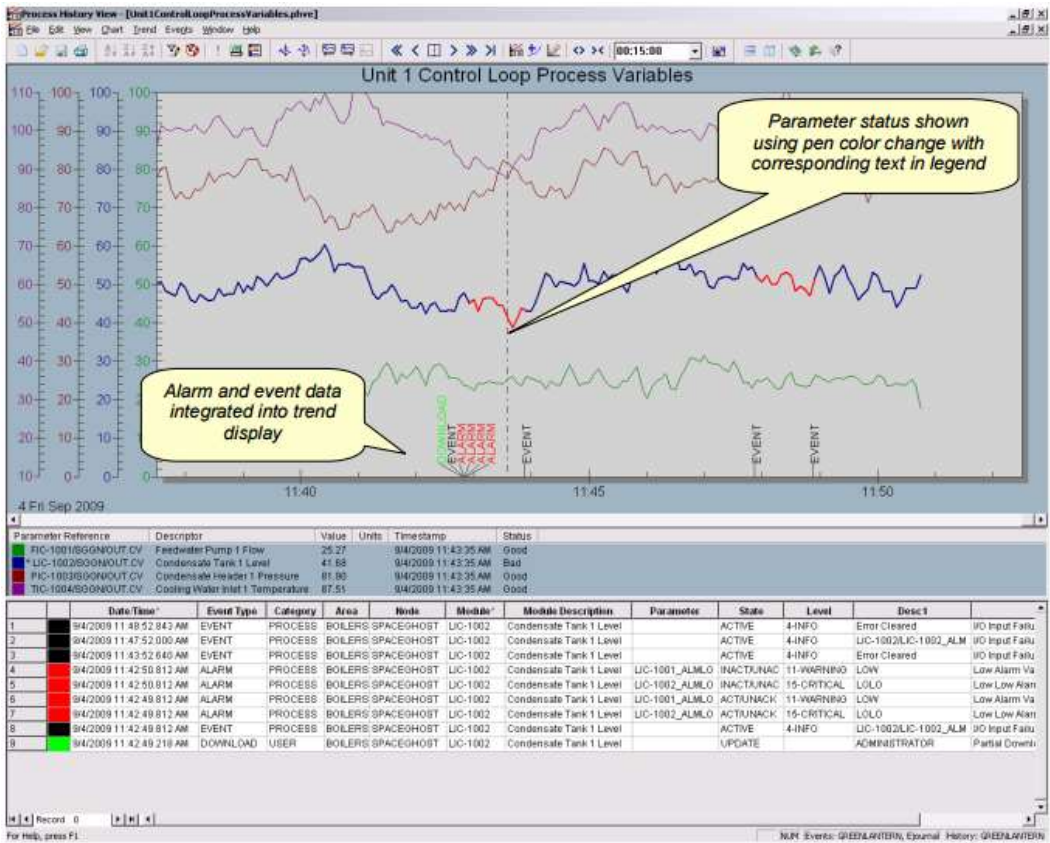
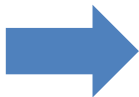
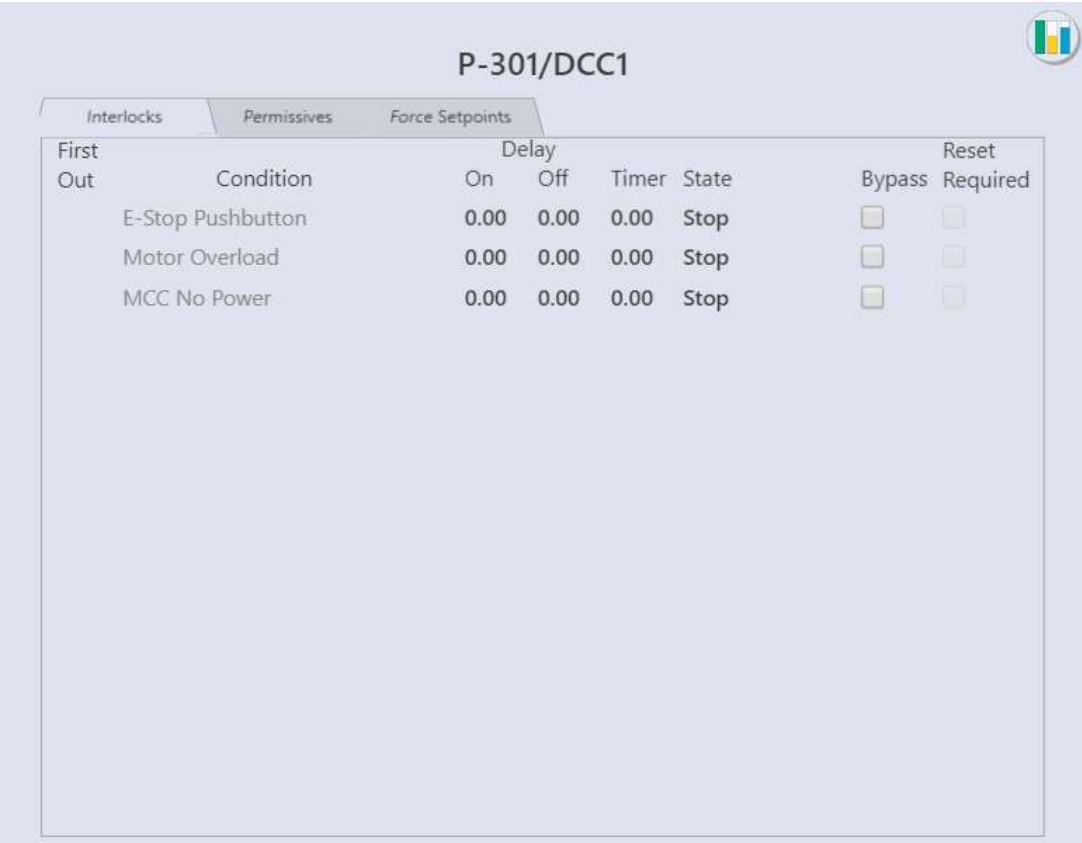
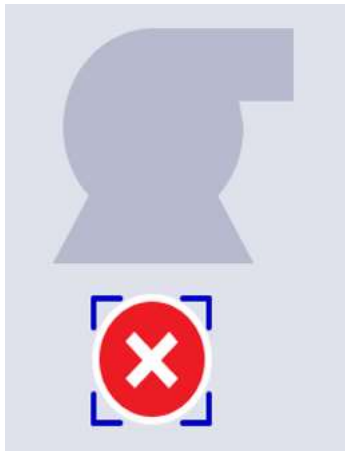
The interface includes a top toolbar with various icons for file operations, diagram manipulation, and simulation. The left sidebar shows a project tree with a folder named "FIC_100" containing sub-items "AI1", "AO1", and "PID1". The bottom status bar displays "Assigned to: <unassigned> 100%".

Alarm	vWord	State	Parameter	Limit value	Enable	Inverted	Priority	%P1 parameter
DV_HI_ALM	DEV		PID1/DV_HI_ACT	0	False	False	ADVI...	PID1/SP
DV_LO_ALM	DEV		PID1/DV_LO_ACT	0	False	False	ADVI...	PID1/SP
HI_ALM	HIGH		PID1/Hi_ACT	115	True	False	WAR...	PID1/PV
HI_HI_ALM	HIHI		PID1/Hi_HI_ACT	120	False	False	CRITI...	PID1/PV
LO_ALM	LOW		PID1/LO_ACT	5	True	False	WAR...	PID1/PV
LO_LO_ALM	LOLO		PID1/LO_LO_ACT	0	False	False	CRITI...	PID1/PV
PVBAD_ALM	IOF		PID1/BAD_ACTI...		True	False	CRITI...	

Logic to HMI Device Diagnostics



Logic to HMI Device Diagnostics – Motors / Interlocks & Logs



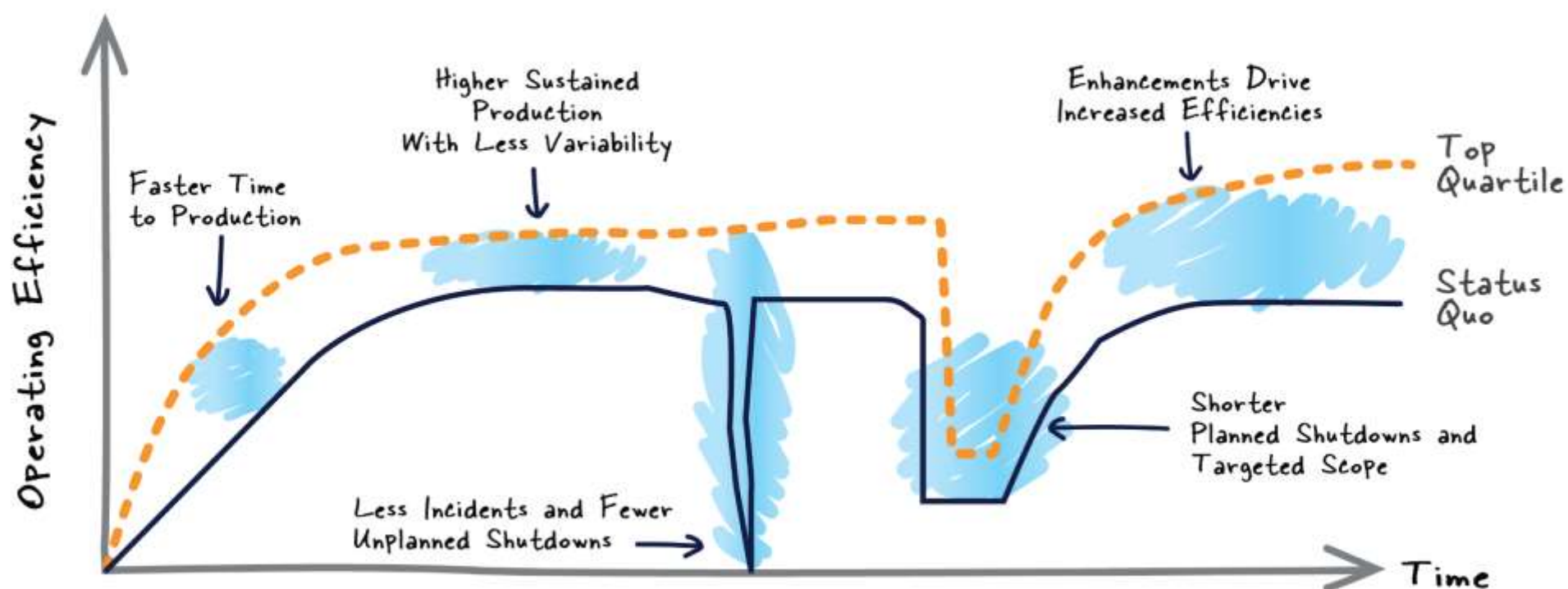
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Why Change Graphics?

Drive Operating Efficiency

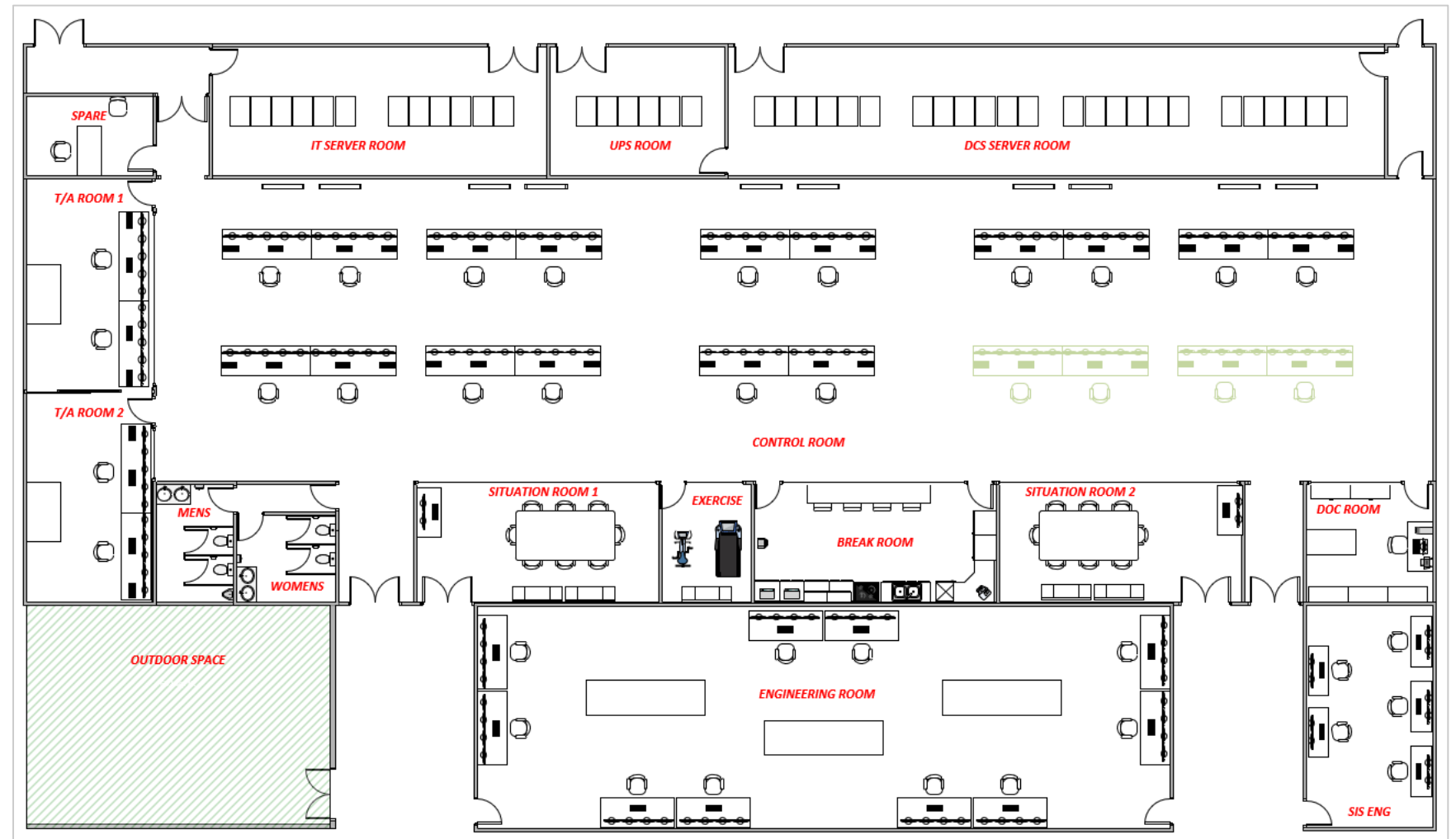
- Reduce risk
- Improve ease-of-use
- Increase stable plant operations
- Optimize plant operation
- Reduce unplanned events



Control Room Design

ISO 11064-2

- Location
- Facilities
- Security
- Abnormal Operations
- Communications
- Traffic and Routing
- Entrances and Exits
- Environmental conditions
- Cleaning
- Maintenance
- Visitors
- Supporting Information storage



Console Design

ISO 11064-4

- (ISO 9241 parts 3 and 5)
- Console Layout
- Viewing angles
- Sit / Stand
- Other equipment
- Anthropometric design (P5 / P95)

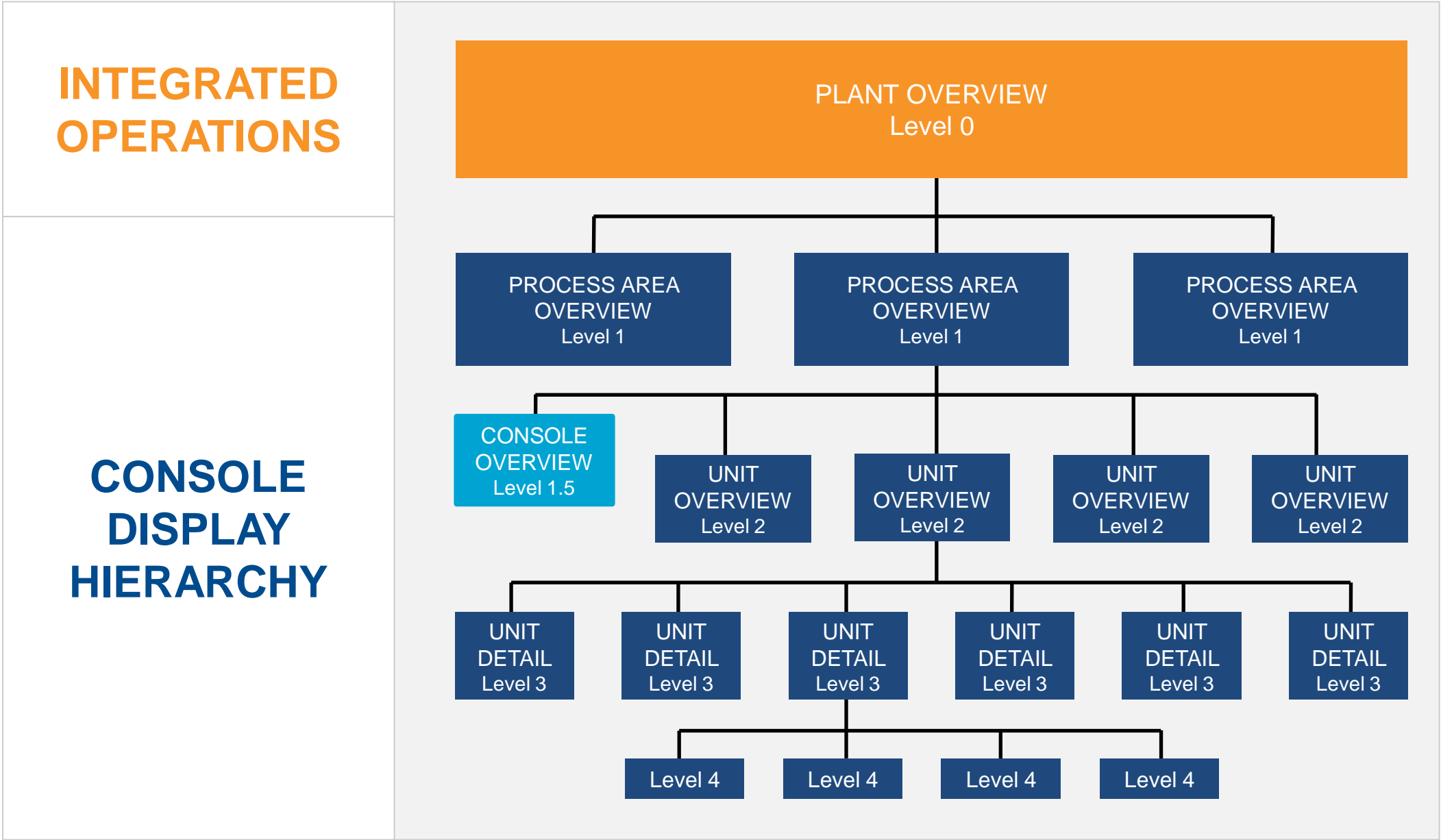


Console Layouts

- Arrange an operator's available screen real-estate and define regions for:
 - L1 Overview displays
 - L2 Area displays
 - Alarm banners, etc.

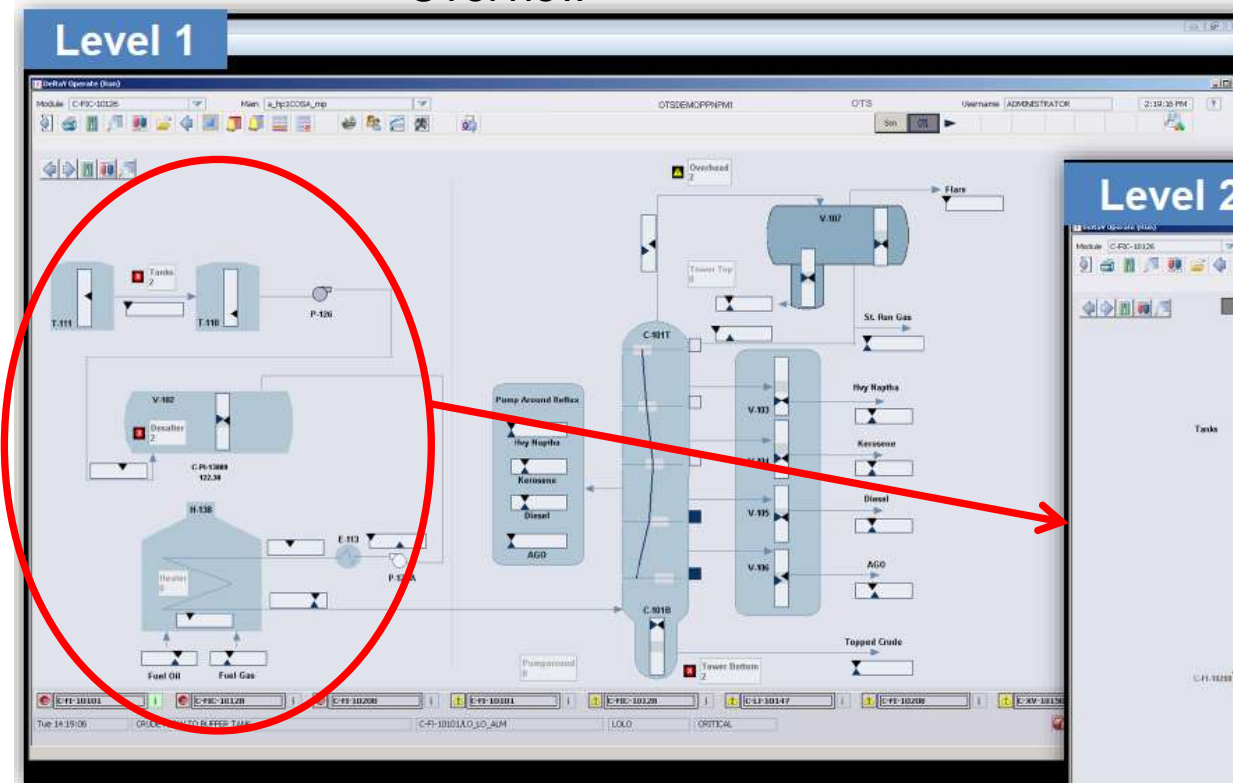


Integrated Operations

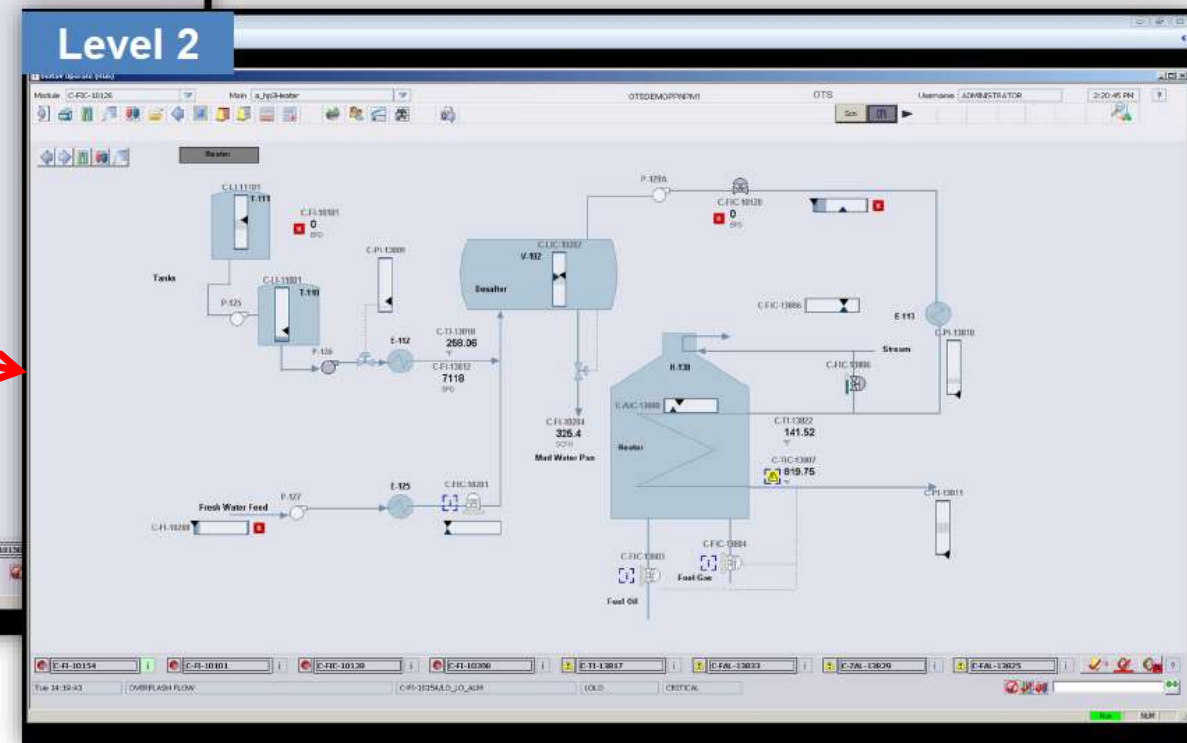


Graphics – L1 / L2 / L3 Navigation

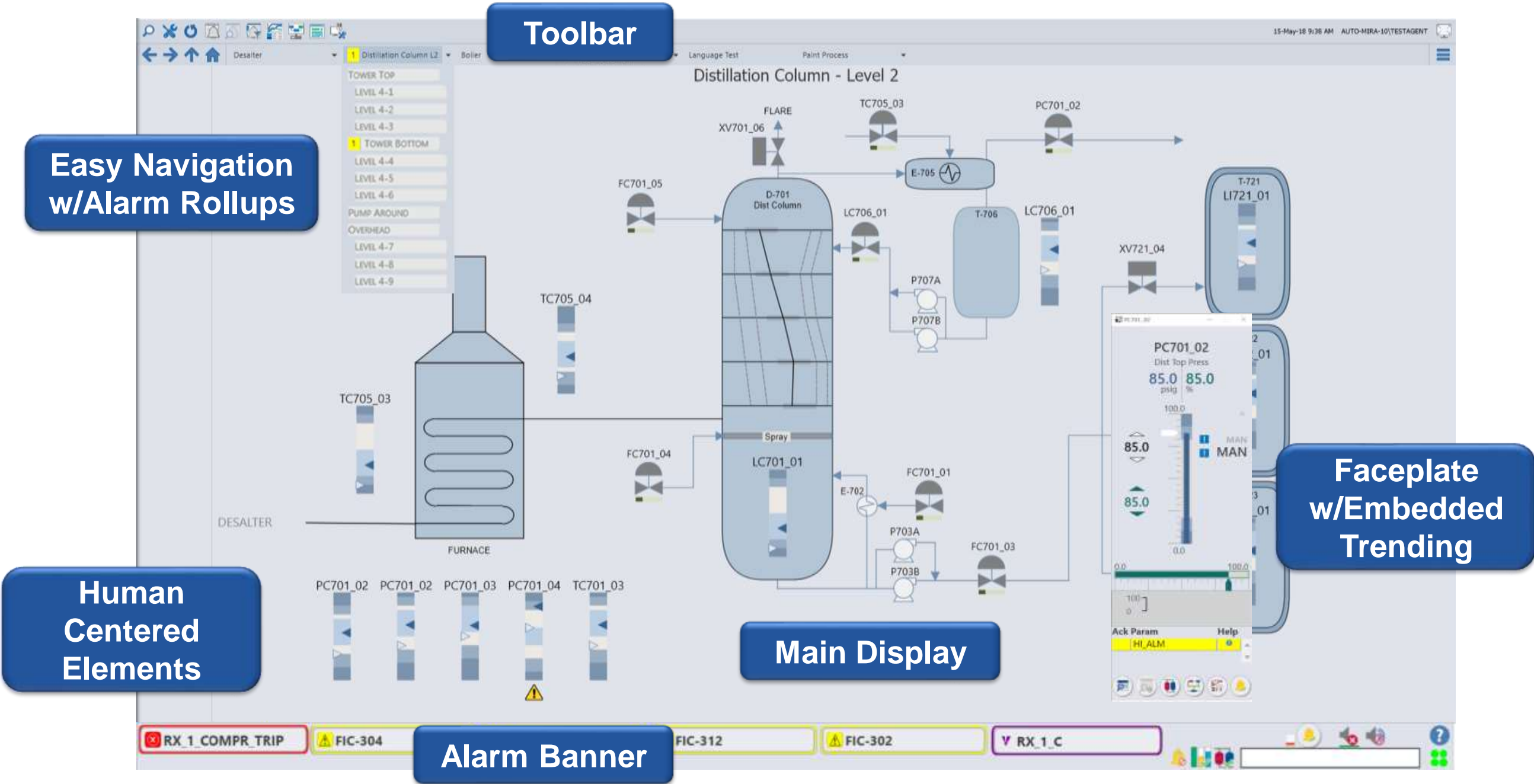
Overview



Detail



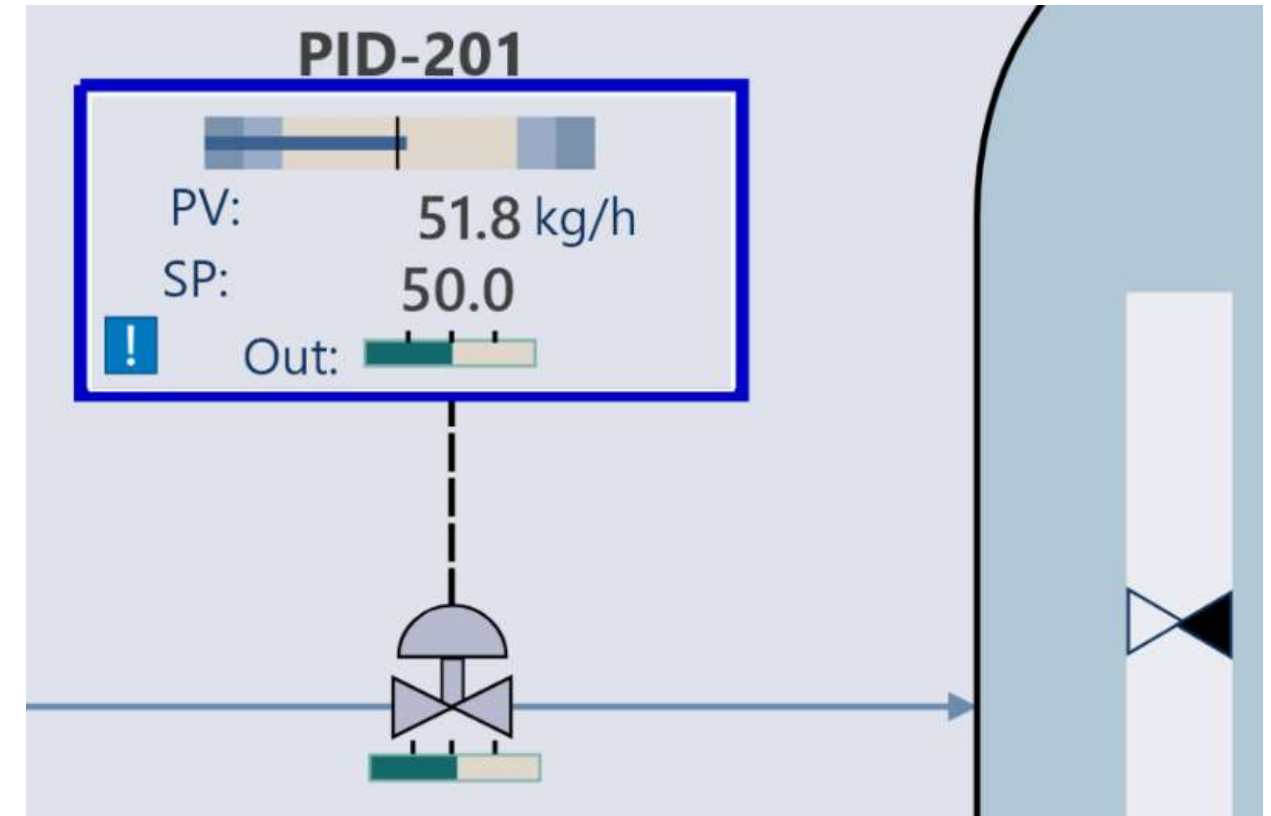
Designing ISA-101 High Performance Graphics - Operator Performance



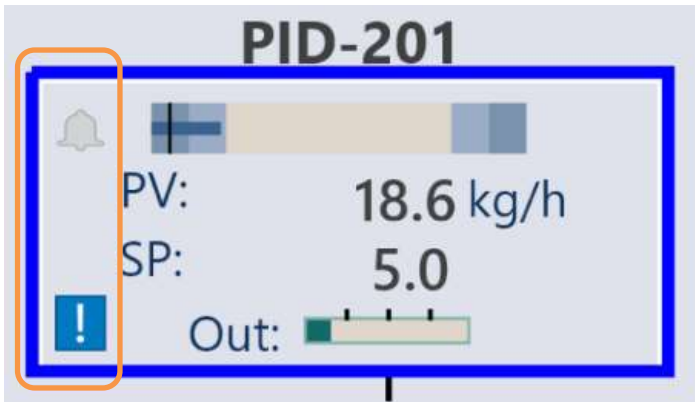
Improving User Experience

Visual approach to information:

- Out-of-box color themes
- “smart” loop/tag dynamos for control displays
- Color-coded borders for alarms and abnormal condition indication
- PV, SP & alarms limits shown graphically
- Easy click option to show or hide tags and tag names



Diagnostics for Operators



Mode Not Normal



Module Not Running



Bad I/O



Interlock Active



Bypass Active



No Permissive

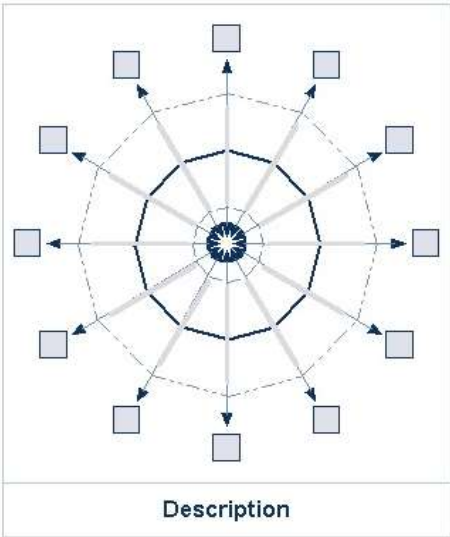


Simulation Active

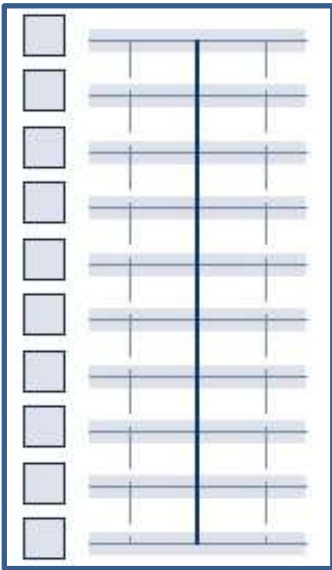


Active Suppressed Alarm

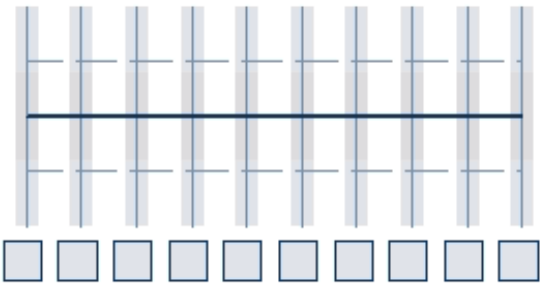
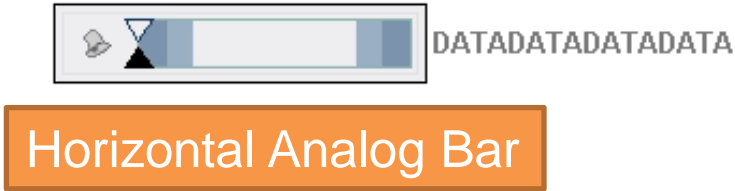
High Performance Icons / Elements for Operator Effectiveness



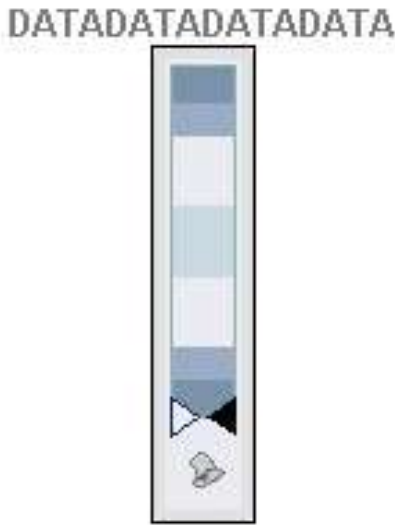
Radar Plot



Vertical Multipoint



Horizontal Multipoint



Vertical Analog Bar



Numeric Indicator



Unit Alarm Indicator



Pump



Control Valve



Block Valve

Graphics – audit and markups



Graphics Technology

Modern console graphics technology:

- HTML5
- Vector Based Scalable Graphics
- Template based icons
- Mobile ready
- ISA-101 Compliant



Aspects of implementation, install and commissioning

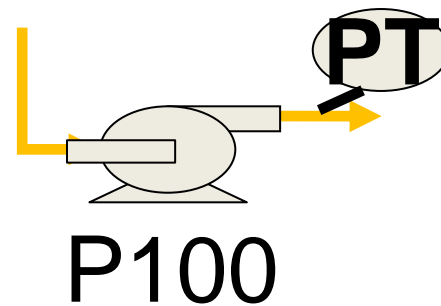
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Alarming

- Modify graphics so alarms are distinctive
- Full alarm rationalization (major task) per ISA 18.2
- Clean up nuisance alarms with conditional alarming



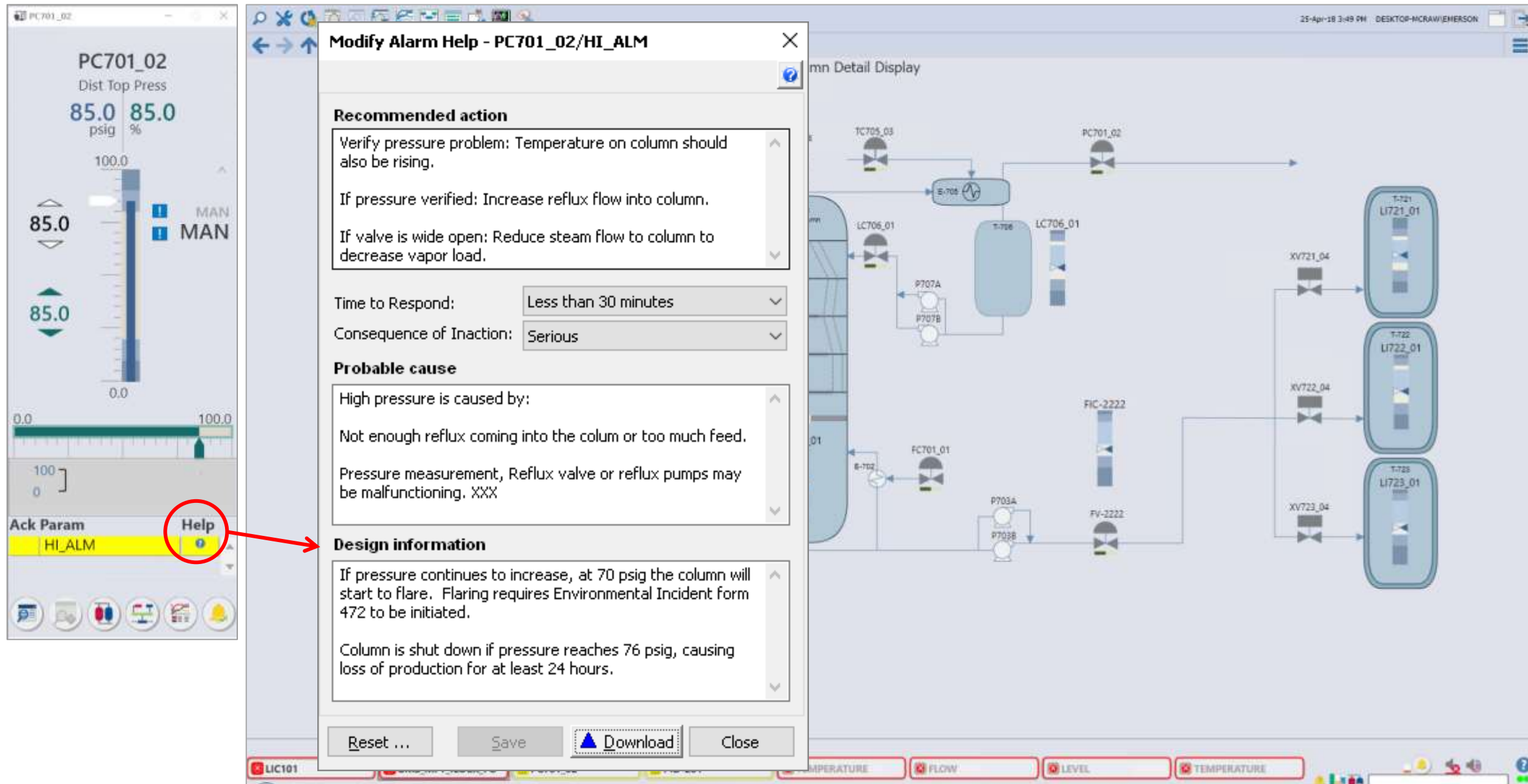
PI100 LO_ALM enabled when pump has been active for 10 seconds



The screenshot shows the 'AI1: Block Alarms' configuration window. It has a title bar with 'AI1: Block Alarms' and a close button. The window is divided into several sections:

- Alarm Detection Parameters:** A list of checkboxes for alarm types: ☒ HI, ☒ HI_HI, ☐ INSPECT, ☒ LO, and ☒ LO_LO. There are 'OK' and 'Cancel' buttons to the right.
- Conditional alarming for all alarms:** A checkbox labeled ☒ Conditional alarming for all alarms.
- Alarm Properties For LO:** A section with a checkbox ☐ Enabled. Below it are fields for:
 - Alarm name: LO_ALM
 - Alarm type: Low Alarm
 - Alarm priority: WARNING (dropdown menu)
 - Limit value: 5
 - Alarm message: Low Alarm Value 0 Limit 5
- Conditional alarming parameters for LO:** A section with four rows of input fields:
 - Enable delay time: 10 Sec
 - On delay time: 5 Sec
 - Off delay time: 5 Sec
 - Alarm hysteresis: 0.5 %

Embedded Alarm Help Enables Operator Guidance

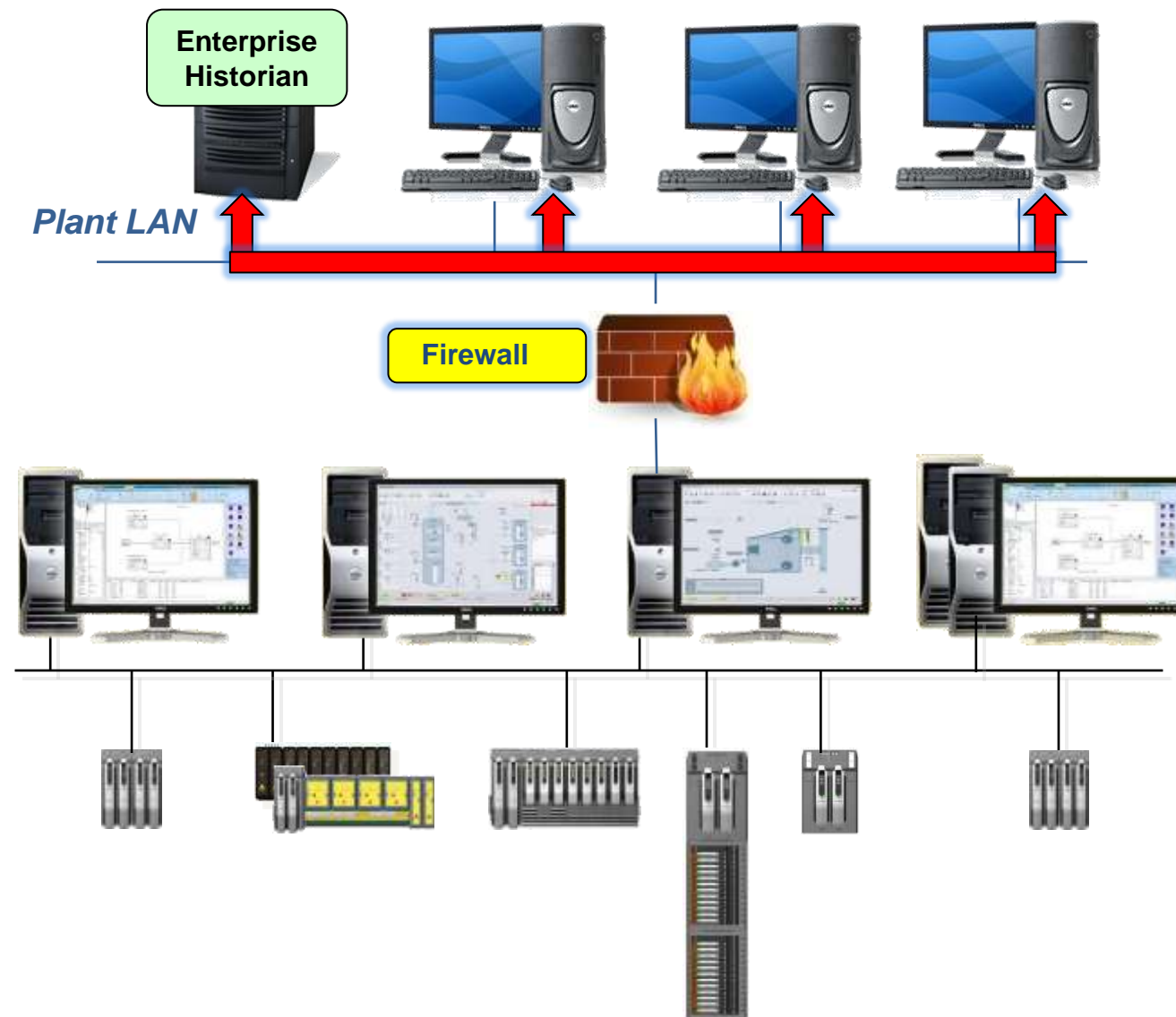


Aspects of implementation, install and commissioning

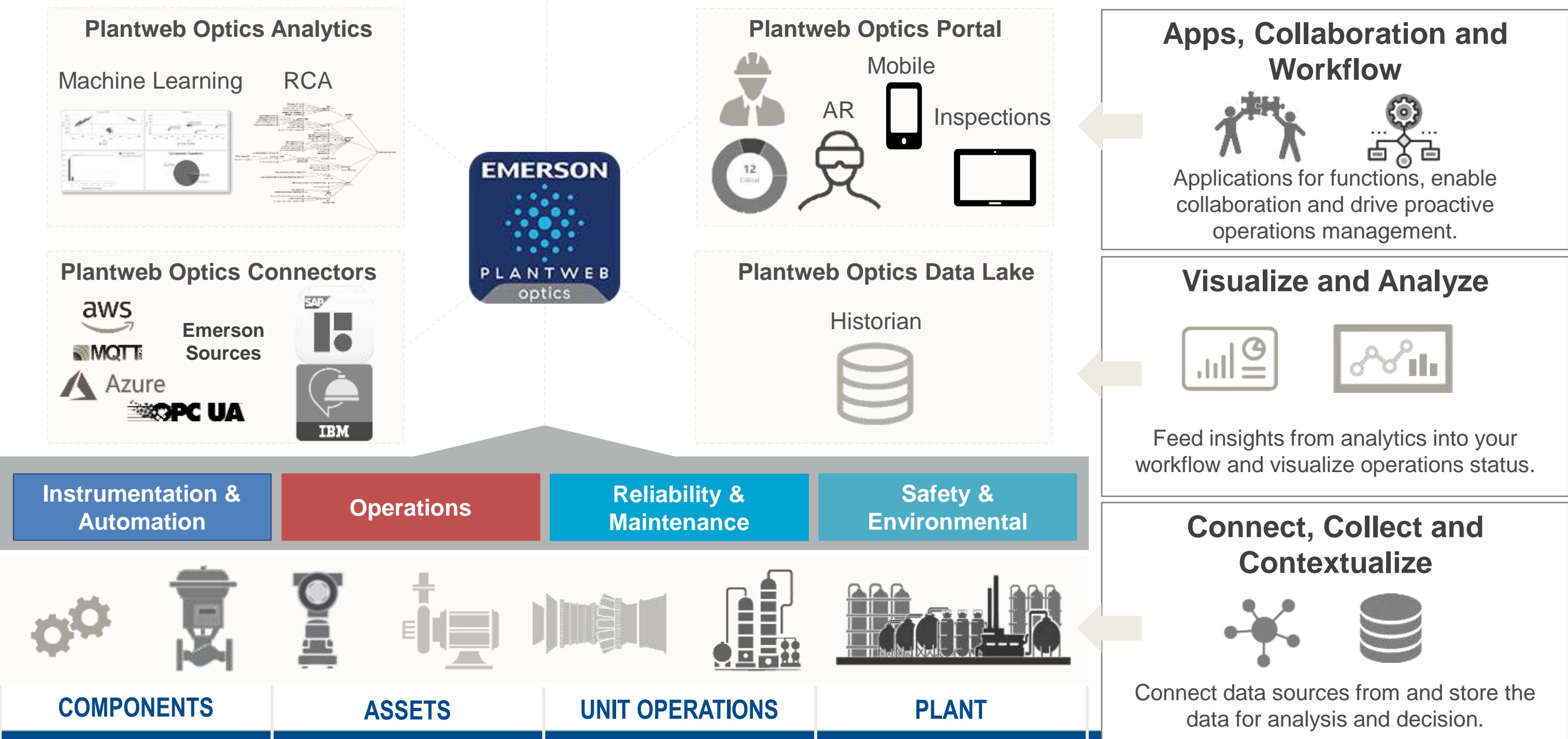
- Panels
- Wiring and I/O
- Networking
- Logic
- Consoles / Graphics
- Alarming
- **Historians / Interfaces to other systems**
- Documentation
- FAT / Operator training
- Commissioning
- APC enhancements

Historians / Interfaces to other systems

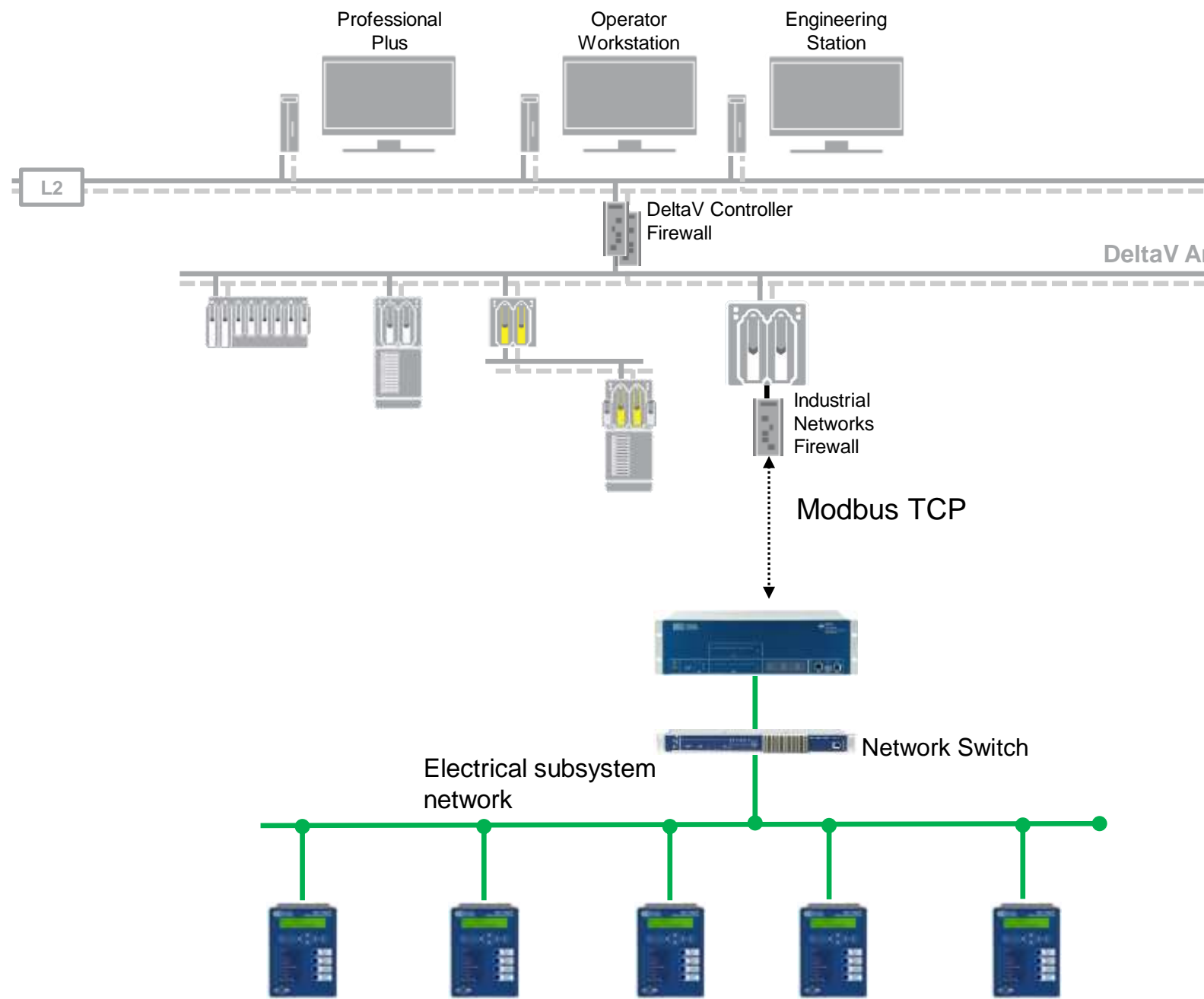
- OPC connections
 - Enterprise Historian
- PLC's
 - Serial connections
 - Ethernet connections
- Remote Access



Enterprise Historian & Reporting System Design



Electrical Smart MCC/VFD Interfacing



Detail

YASKAWA_MOTOR8

Yaskawa DeviceNet Motor, Run Status, HOA, Maintain Stop / Pulse Start (3 DI, 2 D)

Tuning

Drive Data

Trend

Communications Status

●

OINTEG

Good

Drive Status

●

Faulted

●

Warning

●

Run Forward

●

Run Reverse

●

Ready

●

Control from Network

●

Speed Reference from Network

●

At Speed

State

Ready

Monitor

Frequency Reference

0.00

Hz

Output Frequency

0.00

Hz

Output Current

0.00

A

Motor Speed

0.00

Hz

DC Bus Volts

331.00

V

Output Power

0.00

kW

Maintenance Life Monitors

Cooling Fan

0.00

%

Main Circuit Capacitor

0.00

%

Soft Charge Bypass Relay

0.00

%

IGBT

0.00

%

Fault Status

Current Faults

None

Most Recent Faults

1st

Undertorque Detection 2 - UL4

965

h

2nd

Communication Error - bUS

945

h

3rd

Communication Error - bUS

944

h

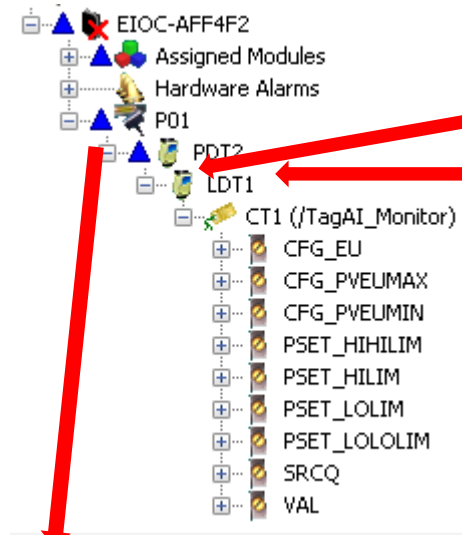
4th

Communication Error - bUS

944

h

3rd Party PLC Interfacing & Data Mapping



PDT1 Properties

General | Advanced

IP address: 192 . 168 . 0 . 1

Subnet mask: 255 . 255 . 255 . 0

Redundant connection

IP address: . . .

Subnet mask: . . .

Interface

☐ Supports Redundant Owner

OK Cancel Help

2 Enter IP Address of Field Target device

LDT1 Properties

General | Device

Messaging Class: Class 3 with PCCC

Requested Packet Interval (ms): 400

Number of values: 5

Data direction: Input

Data type: 16 bit signed integer

File type: N

File number: 14

Starting Address: 0

OK Cancel Help

Data Mapping Tables

Ethernet I/O Port Properties

General | Advanced

Primary connection

IP address: 192 . 168 . 0 . 1

Subnet mask: 255 . 255 . 255 . 0

Outbound messages physical port: 1

Redundant connection

IP address: . . .

Subnet mask: . . .

Outbound messages physical port: 1

Interface

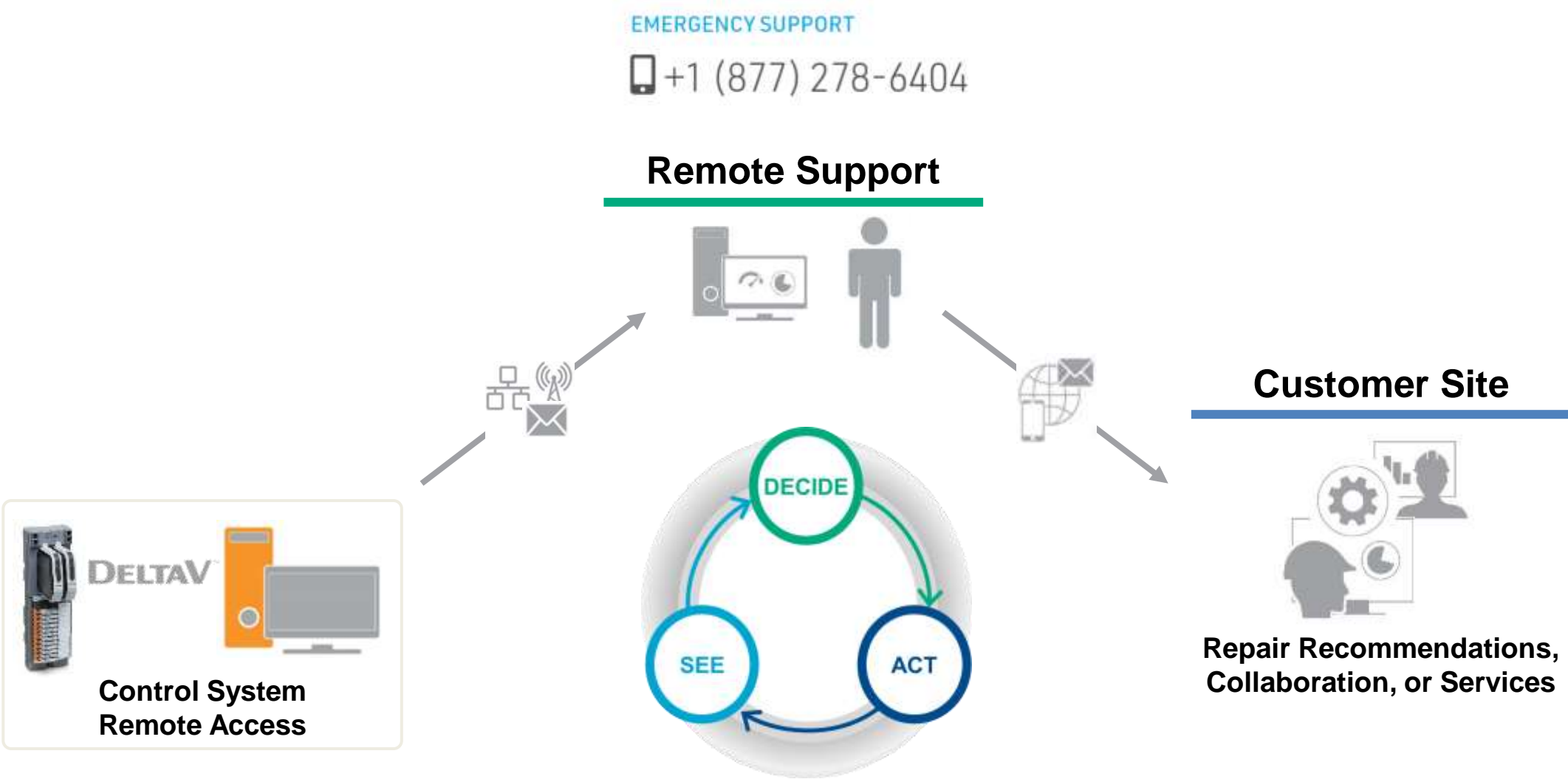
Protocol: Ethernet/IP

Port: 44018

OK Cancel Help

1 Select Ethernet/IP for the Port

Remote Access & Support



Remote Access Architecture

Business & Remote



Remote Access Server(s)



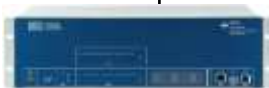
DMZ network



Field device & electrical network



PLC



Relays &
RTAC



VFD



Smart Motor
Controllers



CHARMS



Expert Network Design Services



Steve Barker
Manager, Digital Fou...



Christopher Lloyd
Solution Architect



Wayne Hendrickson
Connected Services L...



Gordon Gillespie
Network Solutions Specialist



Richard Diolata
Network Solutions Specialist



Ed Rathonyi
Network Solutions Sp...



DeltaV network



PK Controller

Aspects of implementation, install and commissioning

- Panels
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Documentation

- This is your opportunity to get documentation updated:
 - Wiring
 - Control narratives
 - Safety & alarming
 - Operating procedures,
 - P&IDs
 - Instrument and motor databases
- Document motor settings on smart MCCs
- Network layout, IP addresses
- Firewall settings
- User accounts
- Backup and restore procedures
- MOC process

Aspects of implementation, install and commissioning

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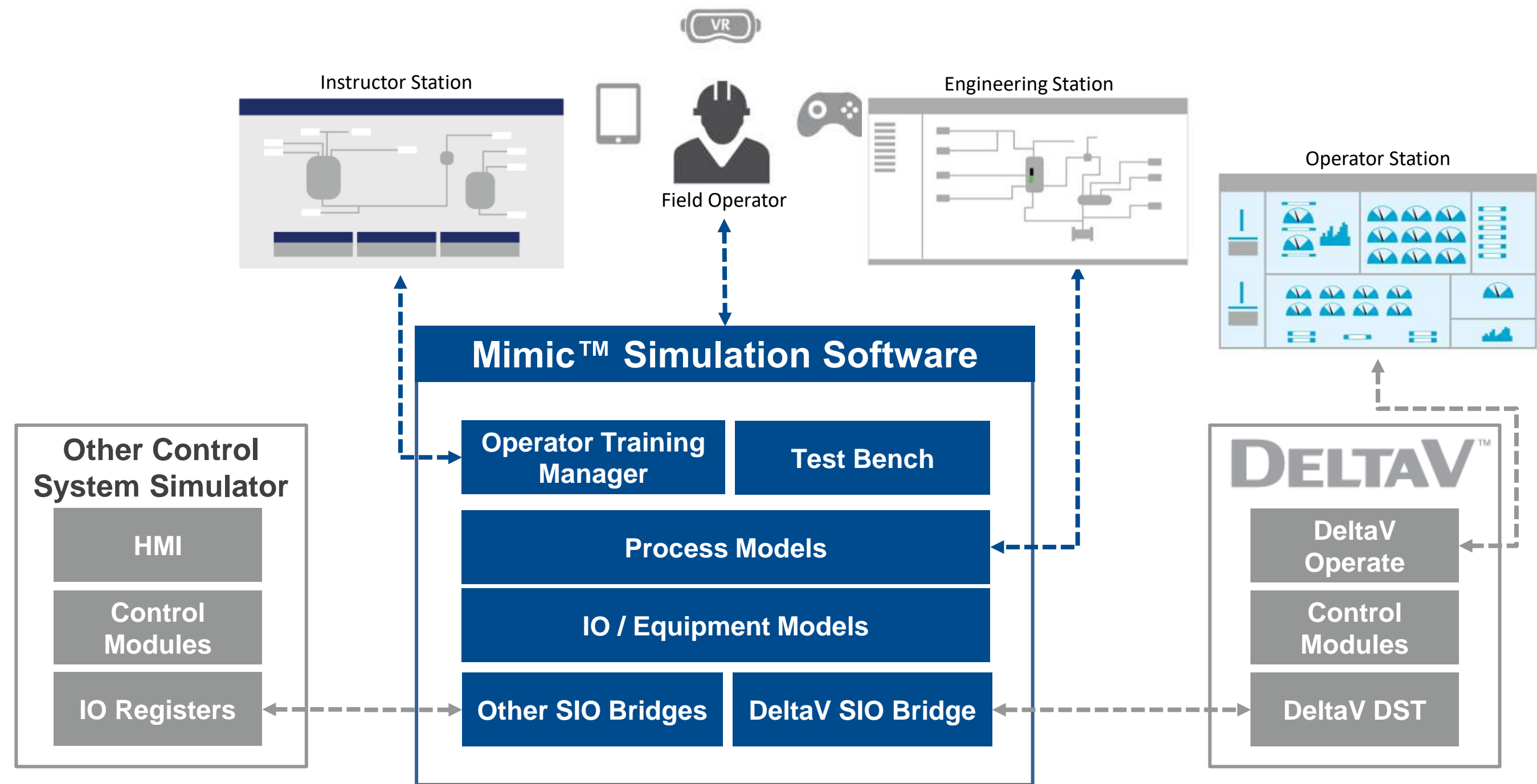
FAT Testing - Hardware

Minimize Start-Up Issues with Thorough FAT Hardware Test (Pre-Ship)

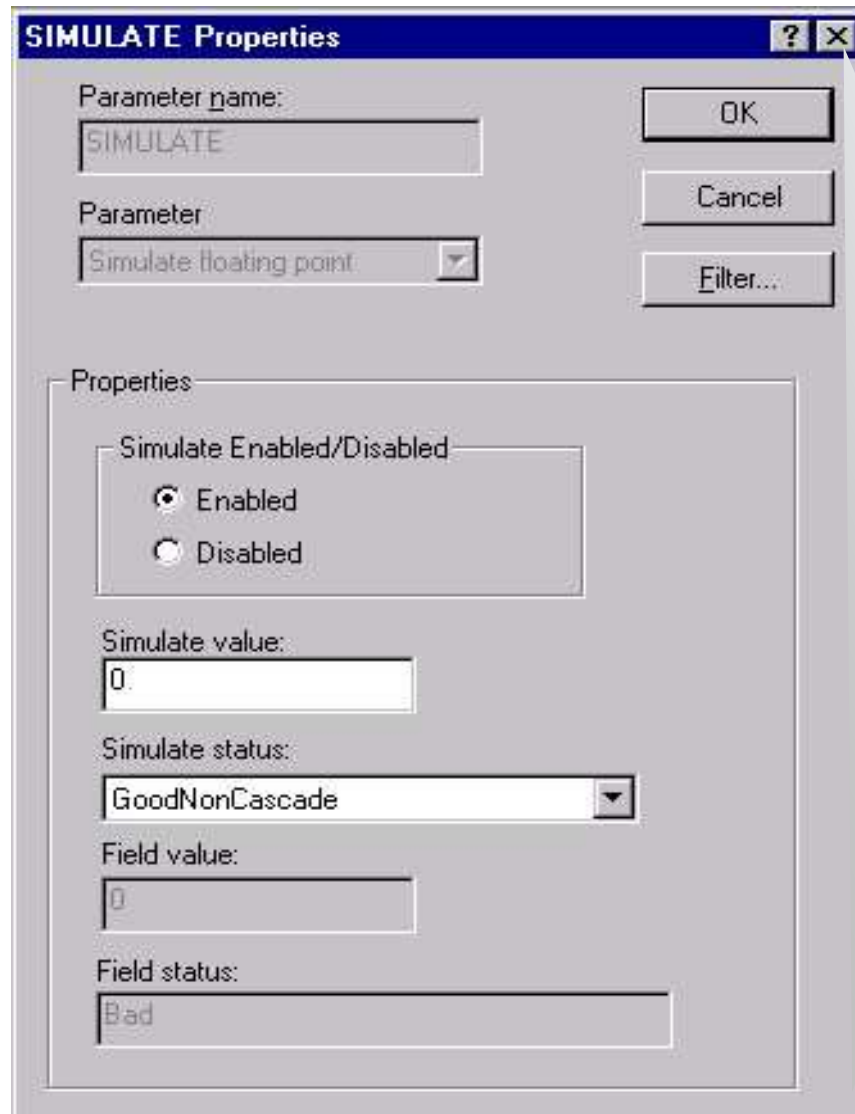
- Power & Grounding
- Communications
- I/O
- Redundancy Test
- Drawing Review
- Interface Testing



Simulation for FAT Testing, Operator Training & Virtual Startup



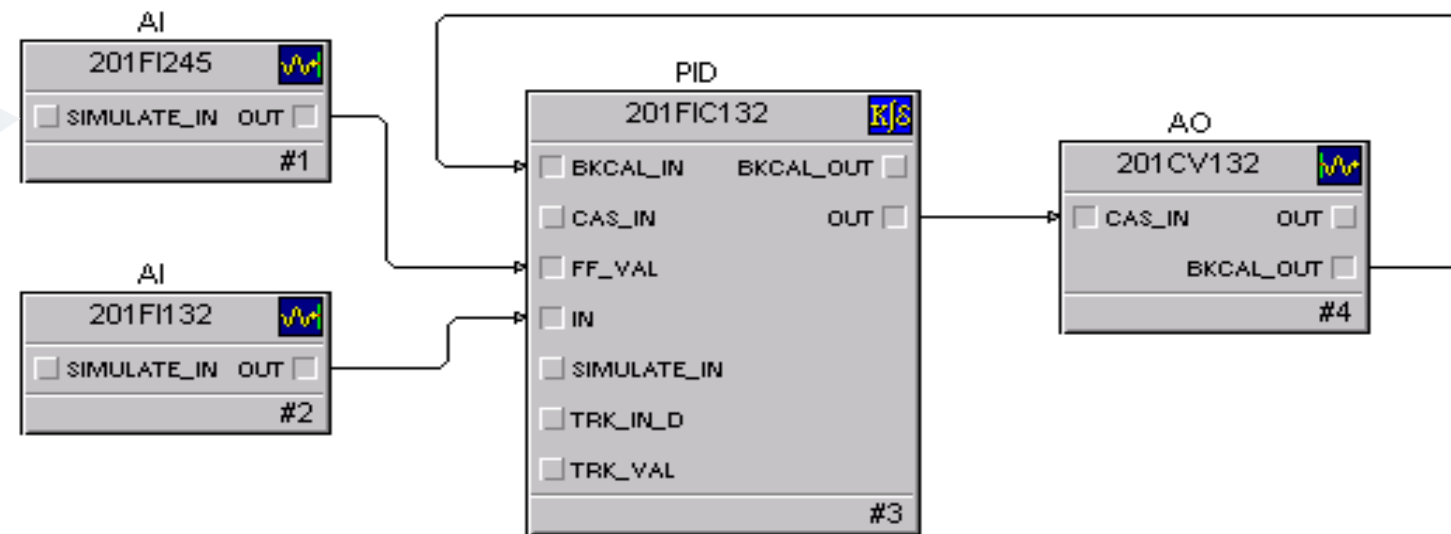
All I/O Can Be Simulated **Automatically** With Mimic Software



The SIMULATE Properties dialog box is shown with the following fields and controls:

- Parameter name: SIMULATE
- Parameter: Simulate floating point
- Buttons: OK, Cancel, Filter...
- Properties section:
 - Simulate Enabled/Disabled: ☒ Enabled, ☐ Disabled
 - Simulate value: 0
 - Simulate status: GoodNonCascade
 - Field value: 0
 - Field status: Bad

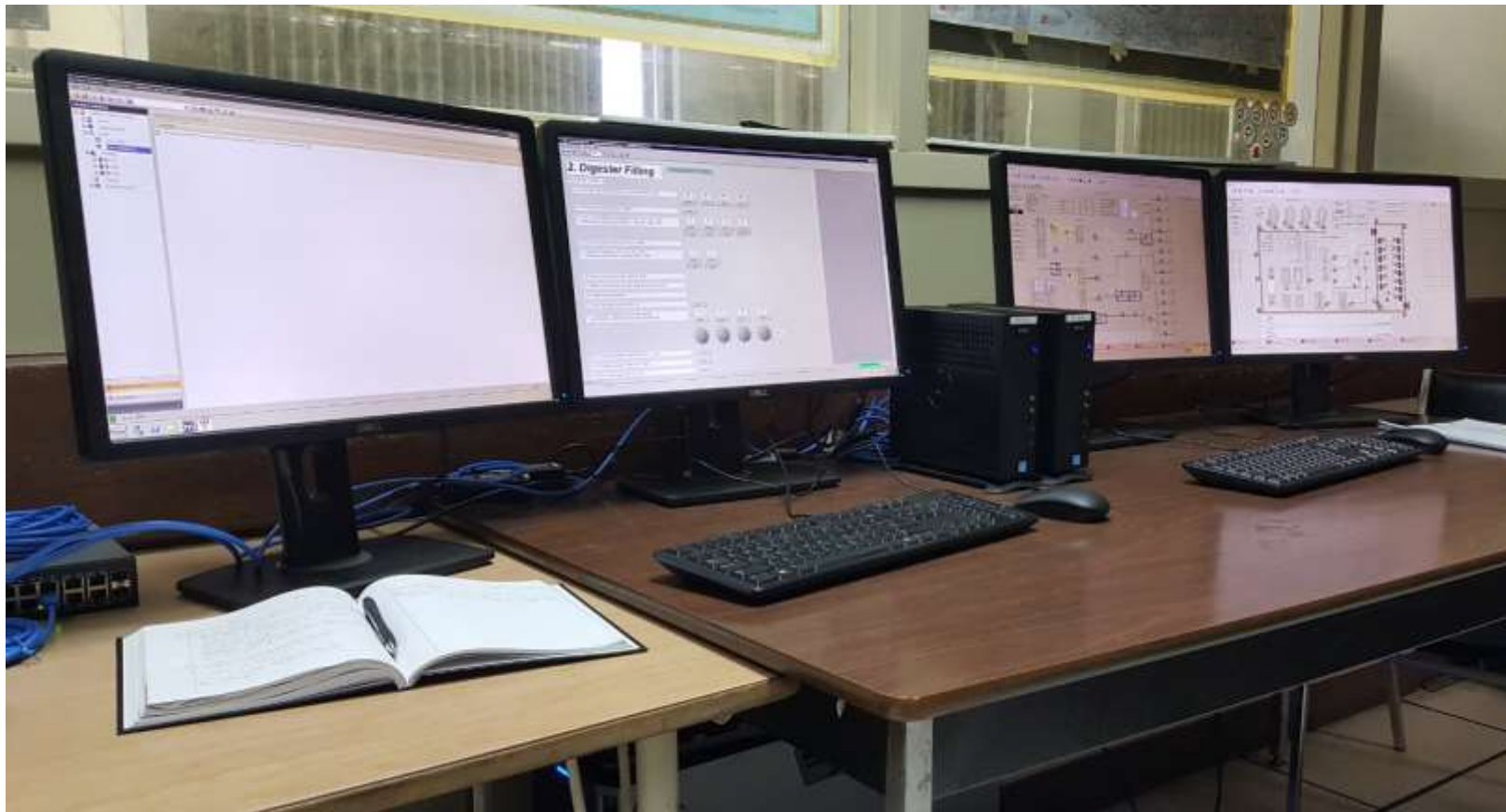
- Low fidelity models typically used for Factory Acceptance Tests
- High Fidelity models used for Operator Training



DeltaV PID Control Module

FAT Testing - Software

- IO Panels not required – simulated I/O to test configuration
- Process simulators are ideal for testing sequences
- Multi-disciplinary team approach
- Operator Training Systems (Prior to Startup)



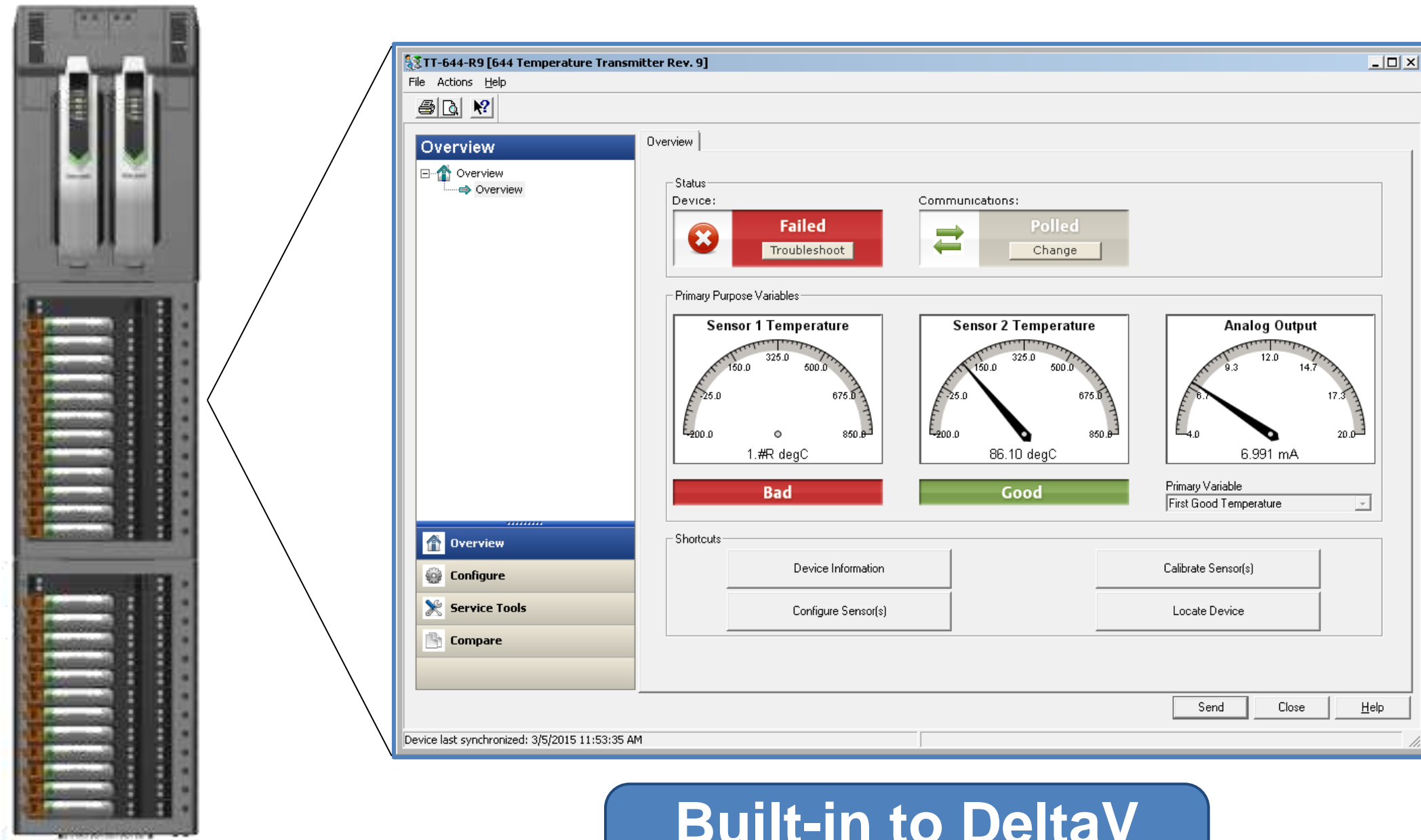
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Commissioning

- **Organization is important**
 - Divide migration into sections so continuous progress and focus can be achieved
 - Group similar tasks vs areas, more efficient to do 20 of the same device type (motors) vs a few of many different types (transmitters, valves)
 - Work in teams – operator, programmer, IE tech
- **Take advantage of new technology**
 - Wireless tablets for commissioning, startup
 - Smart Commissioning tools to auto-commission and test devices
 - AMS to configure devices at control system (instead of in the field)

DeltaV – Built in AMS Device Configurator for Remote Commissioning



**Built-in to DeltaV
Zero Configuration**

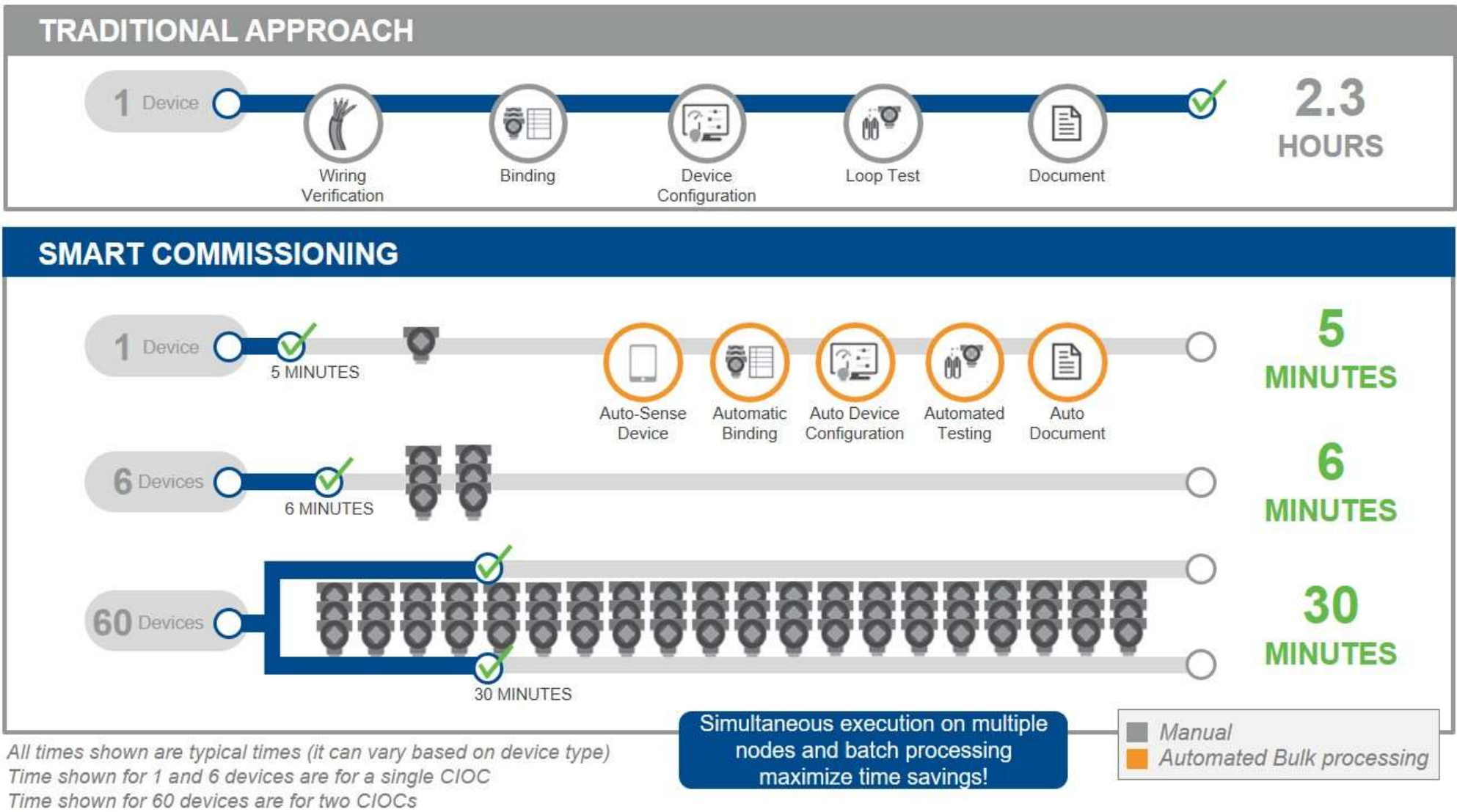
Smart Commissioning

REDUCE COMPLEXITY
OF DEVICE
COMMISSIONING

Automated processes

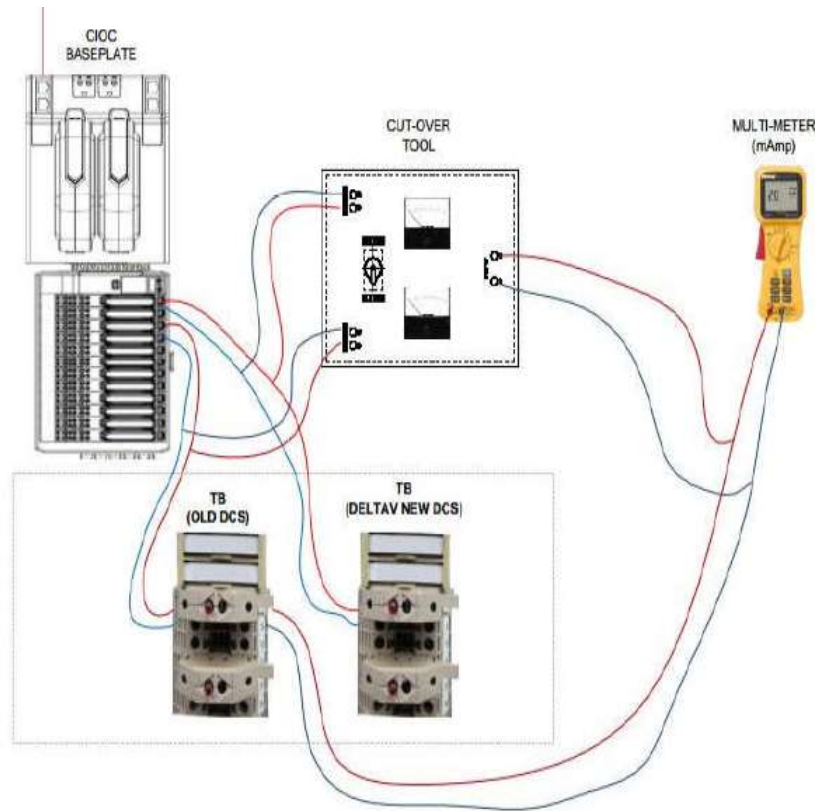
Configure devices in less
time and use less
resources

Execution – HART Device Commissioning



On-Line Wiring Cutover Solutions

Analog Output Cutover Switch



Transition analog outputs on-line!

- Cutover tool used on-loop at a time
- Simple procedure for performing cutover
- Small investment
- No downtime!

Commissioning

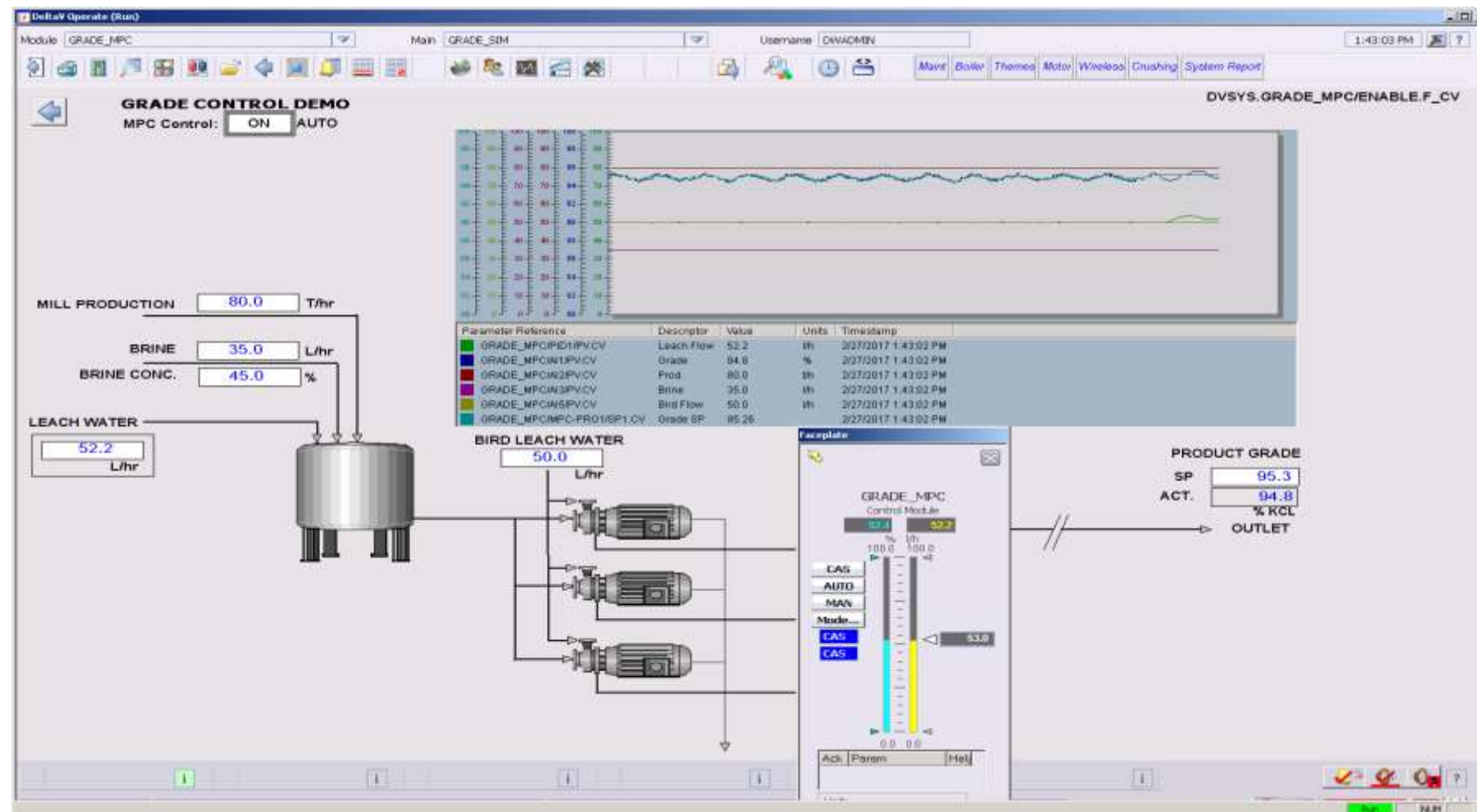
- Commission when construction, maintenance, and operation activities are low.
Ex) 4pm to midnight or night shift
- Communicate with alternative technology, cell phone, text messages, short wave radios
- Plan adequate resources so teams don't get burnt out
- Fix problems immediately if possible so don't have to loop back (unless it is going to be a major fix then document it and come back to it)

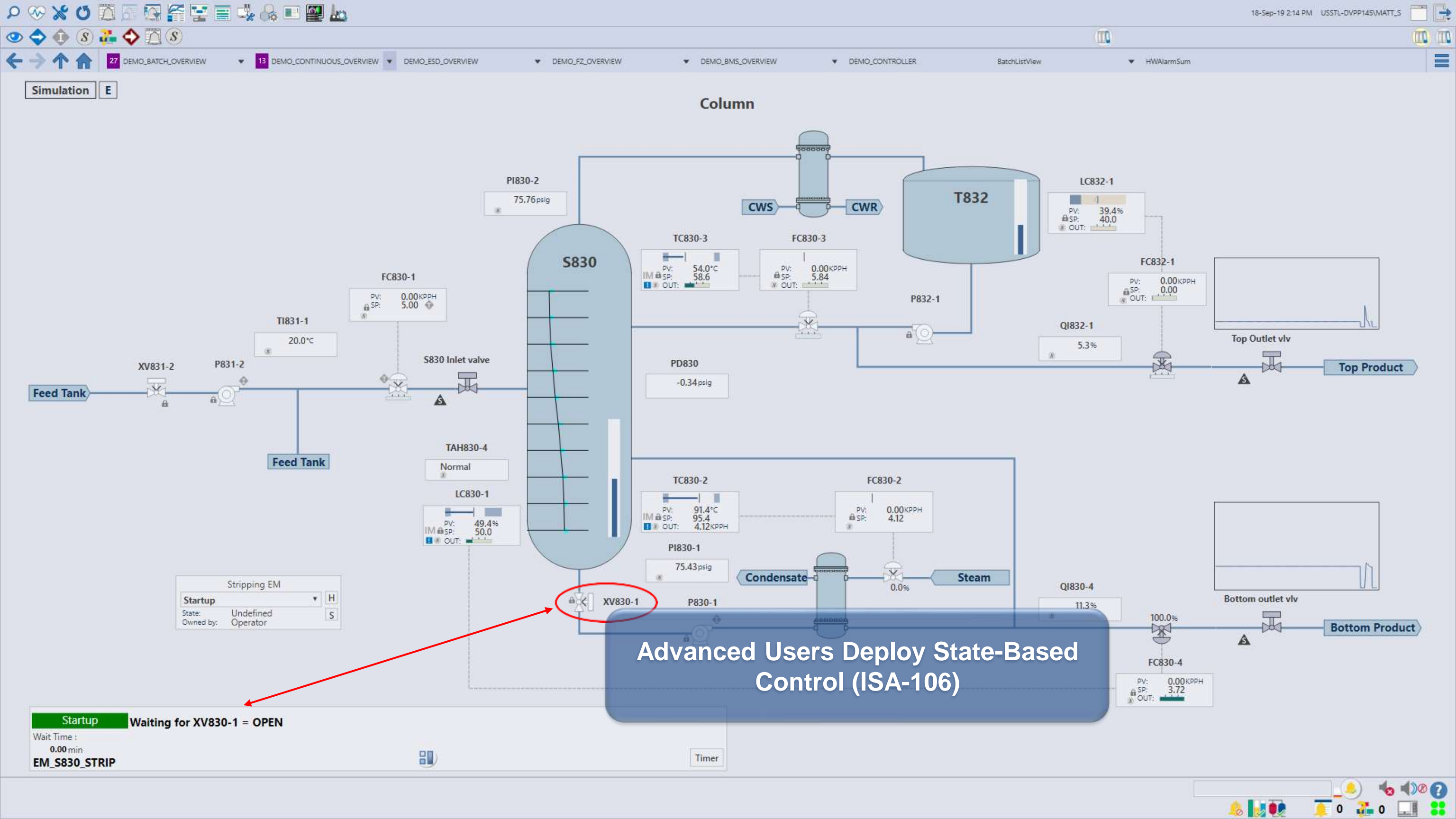
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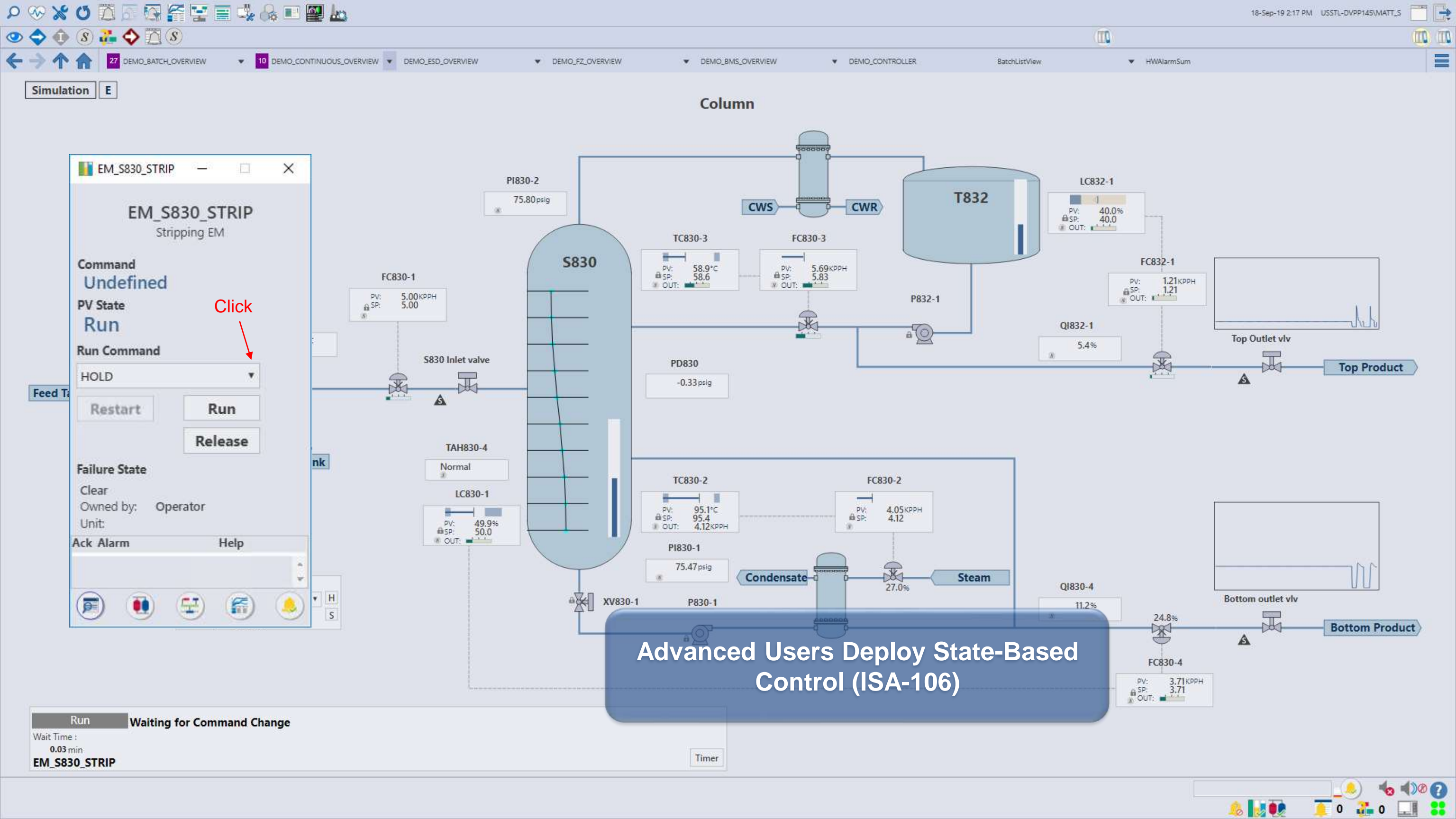
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- **APC enhancements**

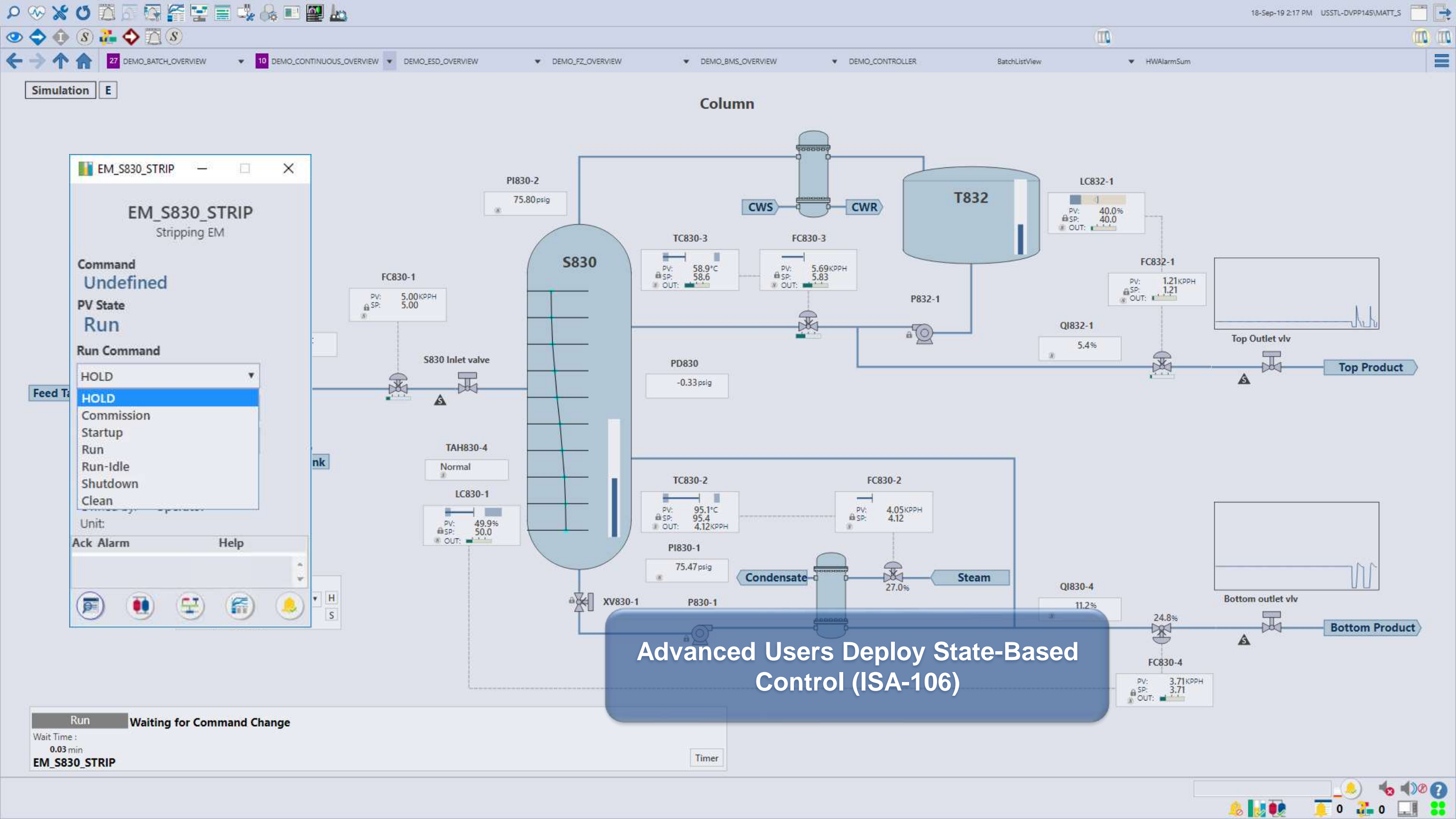
Advanced Process Control Enhancements

- Automated start-up/shutdown sequences have significant value
- Complex control – utilize model predictive control (MPC)
- Operators are learning new controls so kill two birds with one stone









Conclusion

- Following these steps can achieve an on-time, on-budget migration
- Get existing documentation up to date and keep it there
- No surprises with late changes
- Meet tight schedule during outage or live migrations
- Verify all logic is accounted for and any old code is removed
- Improve and enhance operator efficiency
- Set yourself up for success for the next 20+ years.

Contact Me

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ANY
Questions?