Control Systems: Design, Performance and Commissioning Issues

Introduction

Instructor:

David Sellers

Senior Engineer

Facility Dynamics Engineering

October 23, 2017

Class Material Location

The slides and other supporting information for the class can be found at:

- http://www.av8rdas.com/pacific-energy-center-classes.html
- They will be there until the next class, at which time they will be relocated to the PEC Class materials link from my blog

About using my spreadsheets and other resources:

- They are my tools vs. tools I developed to be used by others
- Use at your own risk; I provide them as a resource for you to use as a starting point
- You still need to understand how it works and fix it if it doesn't work for you

Disclaimer

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Learning Objectives

After completing this course you should be able to:

1. Recognize the crucial role control systems play in managing the use of energy in our facilities
2. Understand the challenges associated with the control system design process and how they can be met successfully
3. Be familiar with the basic building blocks of a control system
4. Understand the crucial role commissioning plays in bringing a control system on line
5. Have a hands-on sense of some of the topics via the afternoon lab sessions

Agenda

- Introduction and Overview
- Inputs
- Outputs
- Control Processes
- Control Process Logic
- Set Points
- Commissioning
- Lab Rotations
  1. Packaged Economizer
  2. Pneumatic VAV Terminals
  3. 4-20 ma Current Loops
  4. Kinematics
  5. Actuator Sequencing
- Wrap-up

The Fundamental Goal of the Control System

Automatically adjust a piece of machinery to give us what we want by comparing what is going on to what we want to go on and making appropriate adjustments to the process we want to control

The Holistic (Green) Goal of the Control System

Automatically adjust a piece of machinery to give us what we want by comparing what is going on to what we want to go on and making appropriate adjustments to the process we want to control as efficiently and sustainably as possible

The “Three R’s”

Repeatable

- To make, do, or perform (an action) again (and again, and again, and again ….)

Reliable

- Giving the same result on successive trials

Robust

- Sturdy; capable of performing without failure under a wide range of conditions

A 1914 Central Control System

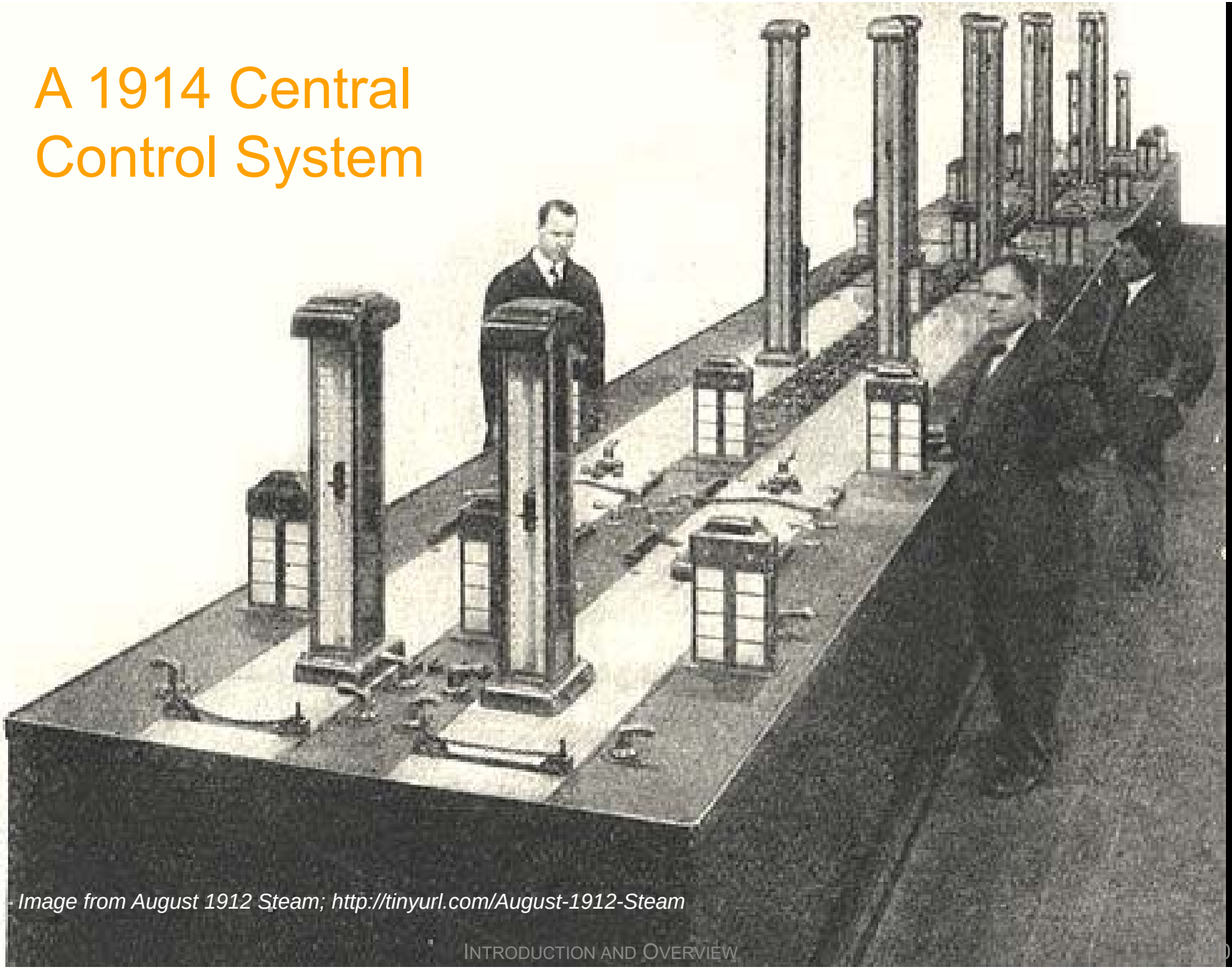


Image from August 1912 Steam; http://tinyurl.com/August-1912-Steam

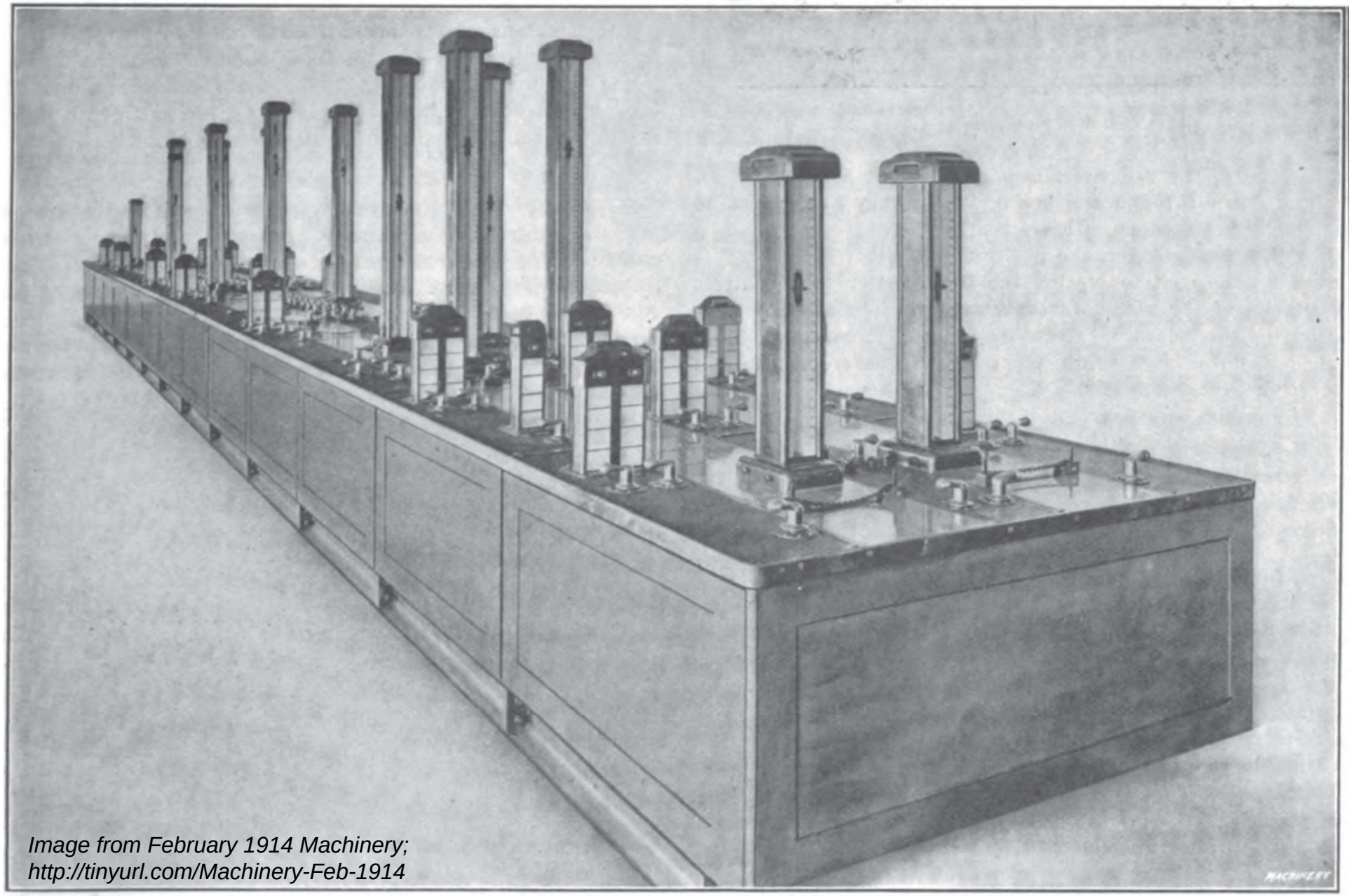


Image from February 1914 Machinery;
http://tinyurl.com/Machinery-Feb-1914

Fig. 1. Lock Control-board for Miraflores Locks of Panama Canal—The Water Levels in Different Chambers and Positions of Gates, Valves and Fender Chains are shown by the Indicators seen on Control-board

A 1914 Central Control System

- 2.25 miles of interlocking rod
- 1,100 miles of control wire in the form of 5 to 8 conductor cables
- 732 position indicators and transmitters
- 464 control switches
- 382 indicating lamps
- Accurate to 5/8 inch over a 50 foot span

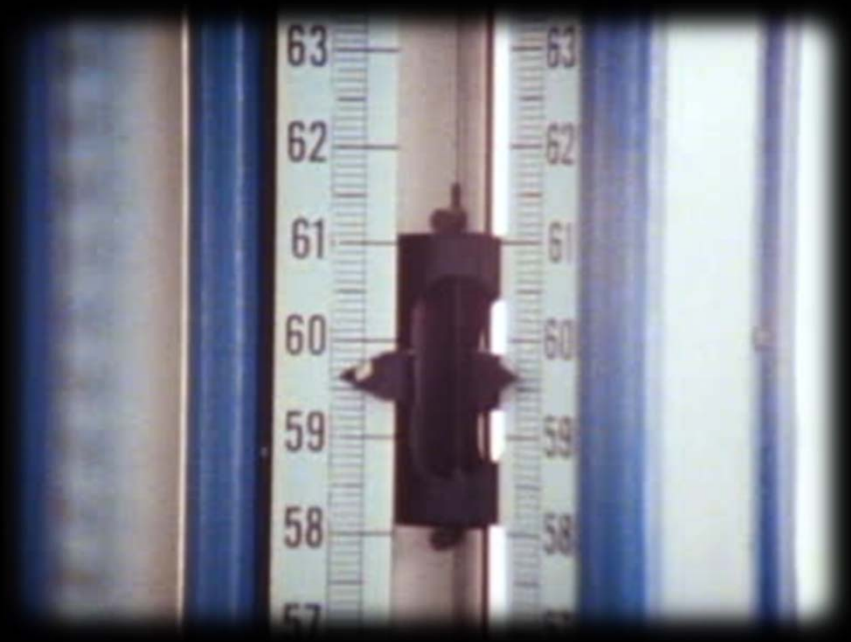


Image courtesy http://ak5.picdn.net/shutterstock/videos/3832016/preview/stock-footage-panama-canal-lock-control-room-close-up-moving-gauge.jpg

Still Doing Its Thing

Image courtesy www.ttnews.comgalleriespanama2014images05-IMG_3730_lg.jpg

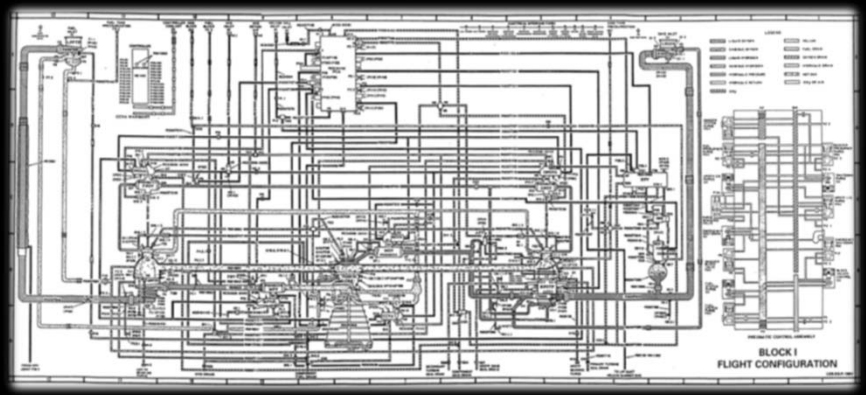
The Other End of the Spectrum

Image courtesy
http://image.dieselpowermag.com/f/news/9104552+w799+h499+cr1+ar0/0705dp_04_z%2Bnasa_diesel_shuttle_crawler%2Bshuttle.jpg

The Other End of the Spectrum

Main Engine and Controller

- About 50,000 parts
- Rated for multiple flights
- 135 flights with no failures

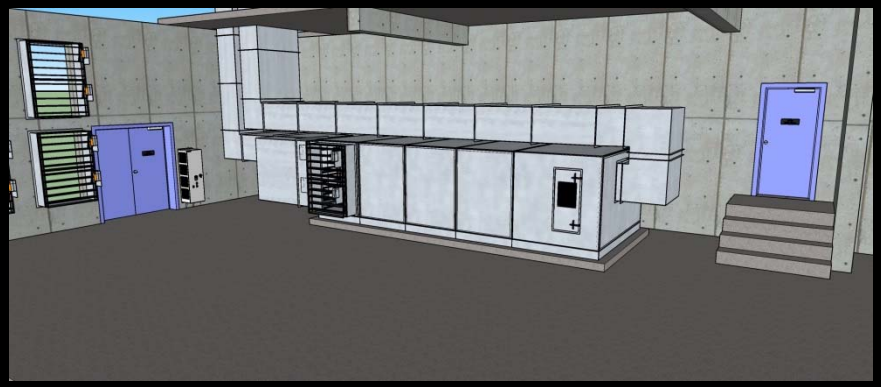


Images courtesy
http://image.dieselpowermag.com/f/news/9104552+w799+h499+cr1+ar0/0705dp_04_z%2Bnasa_diesel_shuttle_crawler%2Bshuttle.jpg

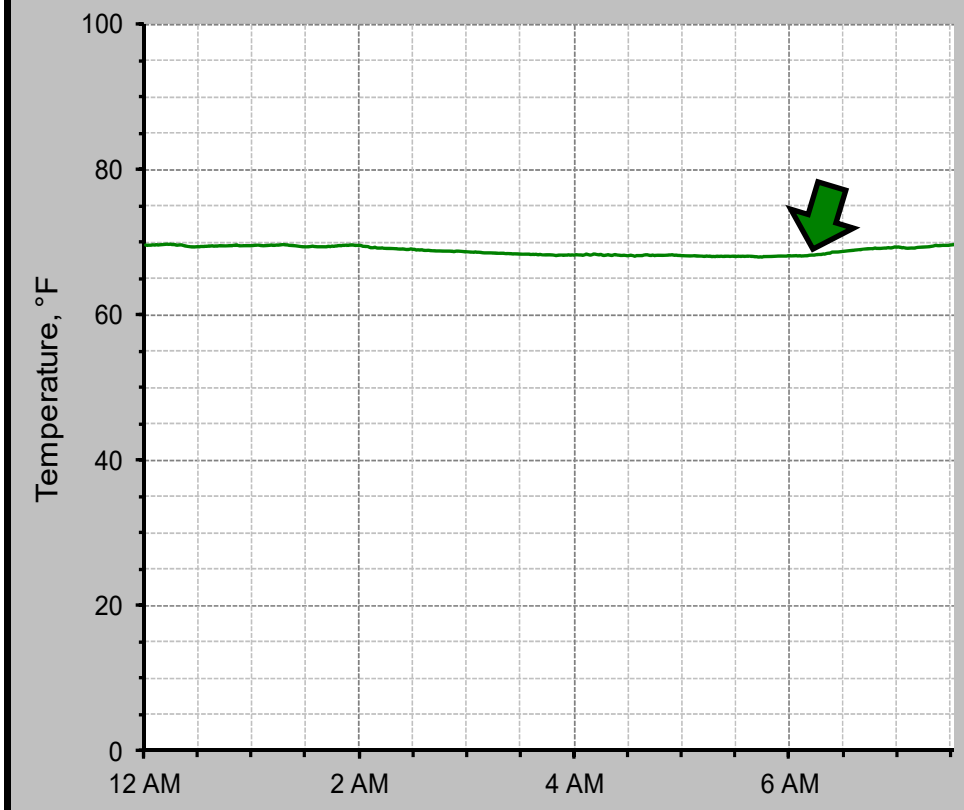
Us

Seems like:

- We should be able to maintain a 57°F discharge temperature by sequencing preheat with the economizer and the chilled water coil
- We should be able to start around 6:00 am and shut down around 7:00 pm



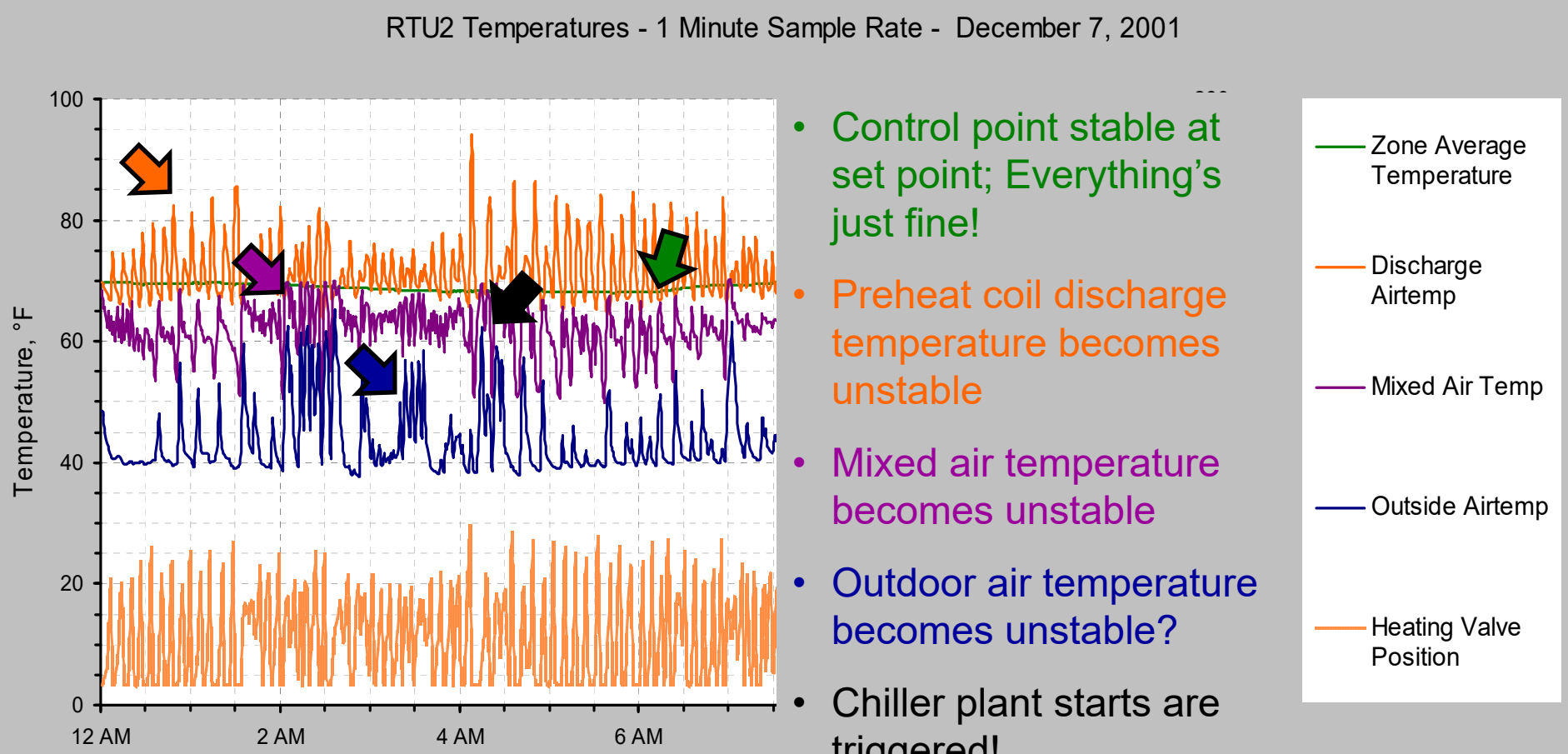
To the Casual Observer, We're Doing O.K.



- Control point stable at set point; Everything's just fine!

Zone Average Temperature

But Maybe Not if You Take a Closer Look



- Control point stable at set point; Everything's just fine!
- Preheat coil discharge temperature becomes unstable
- Mixed air temperature becomes unstable
- Outdoor air temperature becomes unstable?
- Chiller plant starts are triggered!

Getting Things Right

- Develop a detailed, well thought-out, well documented design
  - Required
    - Point list
    - System diagram
    - Narrative sequence
    - Detailed specifications
  - Desirable
    - Logic diagrams
    - Network diagram
    - Floor plans
    - Standard details
- Monitor the installation closely to ensure it reflects the design intent
- Thoroughly commission the installation to ensure the design intent is met
- Train the operating team so they understand how to make the design intent persist and adapt it to changes in the facility

Control Systems: Design, Performance and Commissioning Issues

Introduction

The Current Control Design Process; Problems and Solutions

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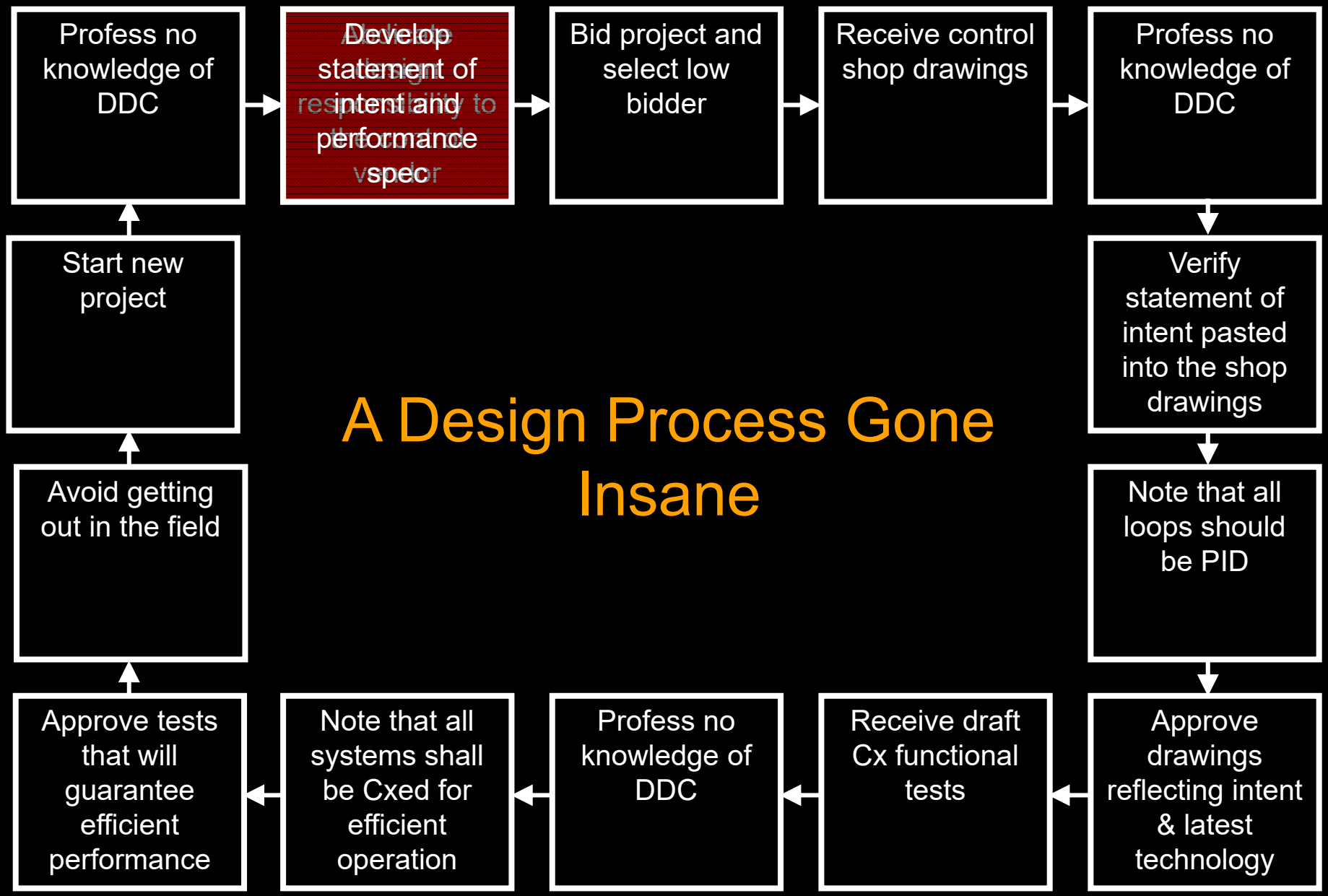
A Design Process Gone Insane



Solving the Problem: Own the Control Design Process

Not as Hard as You Might Think

- You Don’t need to have:
  - Intimate knowledge of computers
  - Intimate knowledge of networks
  - Intimate knowledge of sensing and actuating technologies
  - Intimate knowledge off differential calculus

Solving the Problem: Own the Control Design Process

Not as Hard as You Might Think

- You *DO* need to:
  - Understand your mechanical design and the related design targets
  - Apply sound physical principles in the development of your design
  - Communicate clearly
  - Think logically
  - Address the load profile
  - Recognize that all control systems *are not* created equal out of the box
  - Enforce your requirements

DDC System Point List																
Point Number	System and Service	Sensor Type	Accuracy	Features												Notes
				Alarms				Trending								
				Limit		Warning		Samples[1]	Commissioning[5]			Operating[5]				
				Hi	Lo	Hi	Lo		Time[2]	Local[3]	Archive[4]	Time[2]	Local[3]	Archive[4]		
Analog Inputs																
Match UCB Standard	Space Temperature	*RSPlus*	ALC Standard	Coordinate at submittal review				12	5 min.	X	X	5 min.	X	X		Note 6, *9, 11*
Match UCB Standard	Reheat Coil Discharge Temperature	ALC Standard	ALC Standard	Coordinate at submittal review				60	1 min.	X	X	5 min.	X	X		Note 6
Match UCB Standard	Space Set Point Adjustment	*RSPlus*	ALC Standard	Coordinate at submittal review				12	COV	X	X	COV	X	X		Note 6, *9, 11*
Match UCB Standard	Electric Meter Instantaneous kW - *480 volt system*	Note 7, *9, 10*	Note 7, *9, 10*	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X		Note 7, *9, 10*
Match UCB Standard	Thermal Meter Instantaneous Btu/hr	Note 7, *9, 10*	Note 7, *9, 10*	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X		Note 7, *9, 10*
Match UCB Standard	*Electric Meter Instantaneous kW - 208 volt system*	*Note 7, 9, 10*	*Note 7, 9, 10*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*1 min.*	*X*	*X*		*Note 7, 9, 10*
Match UCB Standard	*3rd Floor Supply Static Pressure*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*1min.*	*X*	*X*		*Note 15*
Match UCB Standard	*4th Floor Supply Static Pressure*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*1 min.*	*X*	*X*		*Note 16*
Analog Outputs																
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Match UCB Standard	*Zone Supply Damper Command*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*5 min.*	*X*	*X*		*Note 12, 13*
Match UCB Standard	*Zone Return Damper Command*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*5 min.*	*X*	*X*		*Note 12, 13*
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Match UCB Standard	*Zone Occupancy Sensor*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*12*	*COF*	*X*	*X*	*COV*	*X*	*X*		*Note 13*
Digital Outputs																
Match UCB Standard	*Occuppancy Status*	*RSPlus*	*ALC Standard*	*Coordinate at submittal review*				*12*	*COV*	*X*	*X*	*COV*	*X*	*X*		*Note 6, 9, 11*
Virtual Points																
Match UCB Standard	kWh - *480 volt system*	Note 7, 8, *9*	Note 7, 8, *9*	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X		Note 7, 8, *9*
Match UCB Standard	Therms	Note 7, 8	Note 7,8	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X		Note 7, 8
Match UCB Standard	*kWh - 208 volt system*	*Note 7, 8, 9*	*Note 7, 8, 9*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*1 min.*	*X*	*X*		*Note 7, 8, 9*

They're Not All Equal

But You Can Get Them Pretty Close

Point lists can drive controller capabilities and I/O requirements and quality

DDC System Point List

Point Number	System and Service	Sensor Type	Accuracy	Features: Alarms: Limit Hi	Alarms: Limit Lo	Alarms: Warning Hi	Alarms: Warning Lo	Trending: Samples[1]	Trending: Commissioning[5] Time[2]	Trending: Commissioning[5] Local[3]	Trending: Commissioning[5] Archive[4]	Trending: Operating[5] Time[2]	Trending: Operating[5] Local[3]	Trending: Operating[5] Archive[4]	Notes
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System and Service
Space Temperature
Reheat Coil Discharge Temperature
Space Set Point Adjustment
Electric Meter Instantaneous kW - *480 volt system*
Thermal Meter Instantaneous Btu/hr
Electric Meter Instantaneous kW - 208 volt system
3rd Floor Supply Static Pressure
4th Floor Supply Static Pressure

They're Not All Equal

But You Can Get Them Pretty Close

Point lists can drive controller capabilities and I/O requirements and quality

- Function

DDC System Point List

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Sensor Type
RSPlus
ALC Standard
RSPlus
Note 7, *9, 10*
Note 7, *9, 10*
Note 7, 9, 10
ALC Standard
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Match UCB Standard	*Occuppancy Status*	*RSPlus*	*ALC Standard*	*Coordinate at submittal review*				*12*	*COV*	*X*	*X*	*COV*	*X*	*X*	*Note 6, 9, 11*
Virtual Points															
Match UCB Standard	kWh - *480 volt system*	Note 7, 8, *9*	Note 7, 8, *9*	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X	Note 7, 8, *9*
Match UCB Standard	Therms	Note 7, 8	Note 7,8	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X	Note 7, 8
Match UCB Standard	*kWh - 208 volt system*	*Note 7, 8, 9*	*Note 7, 8, 9*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*1 min.*	*X*	*X*	*Note 7, 8, 9*

Accuracy
ALC Standard
ALC Standard
ALC Standard
Note 7, *9, 10*
Note 7, *9, 10*
Note 7, 9, 10
ALC Standard
ALC Standard

They're Not All Equal

But You Can Get Them Pretty Close

Point lists can drive controller capabilities and I/O requirements and quality

- Function
- Technology
- Accuracy

DDC System Point List															
Point	System and Service	Sensor		Features											Notes
Number		Type	Accuracy	Alarms				Trending							
				Limit		Warning			Commissioning[5]			Operating[5]			
				Hi	Lo	Hi	Lo	Samples[1]	Time[2]	Local[3]	Archive[4]	Time[2]	Local[3]	Archive[4]	
Analog Inputs															
Match UCB Standard	Space Temperature	*RSPlus*	ALC Standard	Coordinate at submittal review				12	5 min.	X	X	5 min.	X	X	Note 6, *9, 11*
Match UCB Standard	Reheat Coil Discharge Temperature	ALC Standard	ALC Standard	Coordinate at submittal review				60	1 min.	X	X	5 min.	X	X	Note 6
Match UCB Standard	Space Set Point Adjustment	*RSPlus*	ALC Standard	Coordinate at submittal review				12	COV	X	X	COV	X	X	Note 6, *9, 11*
Match UCB Standard	Electric Meter Instantaneous kW - *480 volt system*	Note 7, *9, 10*	Note 7, *9, 10*	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X	Note 7, *9, 10*
Match UCB Standard	Thermal Meter Instantaneous Btu/hr	Note 7, *9, 10*	Note 7, *9, 10*	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X	Note 7, *9, 10*
Match UCB Standard	*Electric Meter Instantaneous kW - 208 volt system*	*Note 7, 9, 10*	*Note 7, 9, 10*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*1 min.*	*X*	*X*	*Note 7, 9, 10*
Match UCB Standard	*3rd Floor Supply Static Pressure*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*1min.*	*X*	*X*	*Note 15*
Match UCB Standard	*4th Floor Supply Static Pressure*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*1 min.*	*X*	*X*	*Note 16*
Analog Outputs															
Match UCB Standard	Reheat Valve Command	ALC Standard	ALC Standard	Coordinate at submittal review				60	1 min.	X	X	5 min.	X	X	Note 6
Match UCB Standard	*Zone Supply Damper Command*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*5 min.*	*X*	*X*	*Note 12, 13*
Match UCB Standard	*Zone Return Damper Command*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*5 min.*	*X*	*X*	*Note 12, 13*
Digital Inputs															
Match UCB Standard	Over-ride Request	*RSPlus*	ALC Standard	Coordinate at submittal review				12	COV	X	X	COV	X	X	Note 6, *9, 11*
Match UCB Standard	*Zone Occupancy Sensor*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*12*	*COF*	*X*	*X*	*COV*	*X*	*X*	*Note 13*
Digital Outputs															
Match UCB Standard	*Occuppancy Status*	*RSPlus*	*ALC Standard*	*Coordinate at submittal review*				*12*	*COV*	*X*	*X*	*COV*	*X*	*X*	*Note 6, 9, 11*
Virtual Points															
Match UCB Standard	kWh - *480 volt system*	Note 7, 8, *9*	Note 7, 8, *9*	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X	Note 7, 8, *9*
Match UCB Standard	Therms	Note 7, 8	Note 7,8	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X	Note 7, 8
Match UCB Standard	*kWh - 208 volt system*	*Note 7, 8, 9*	*Note 7, 8, 9*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*1 min.*	*X*	*X*	*Note 7, 8, 9*

Alarms			
Limit		Warning	
Hi	Lo	Hi	Lo
Coordinate at submittal review			
Coordinate at submittal review			
Coordinate at submittal review			
Coordinate at submittal review			
Coordinate at submittal review			
Coordinate at submittal review			
Coordinate at submittal review			
Coordinate at submittal review			

They're Not All Equal

But You Can Get Them Pretty Close

Point lists can drive controller capabilities and I/O requirements and quality

- Function
- Technology
- Accuracy
- Alarm capabilities

DDC System Point List															
Point Number	System and Service	Sensor Type	Accuracy	Features											Notes
				Alarms				Trending							
				Limit		Warning		Samples[1]	Commissioning[5]			Operating[5]			
				Hi	Lo	Hi	Lo		Time[2]	Local[3]	Archive[4]	Time[2]	Local[3]	Archive[4]	
Analog Inputs															
Match UCB Standard	Space Temperature	*RSPlus*	ALC Standard	Coordinate at submittal review				12	5 min.	X	X	5 min.	X	X	Note 6, *9, 11*
Match UCB Standard	Reheat Coil Discharge Temperature	ALC Standard	ALC Standard	Coordinate at submittal review				60	1 min.	X	X	5 min.	X	X	Note 6
Match UCB Standard	Space Set Point Adjustment	*RSPlus*	ALC Standard	Coordinate at submittal review				12	COV	X	X	COV	X	X	Note 6, *9, 11*
Match UCB Standard	Electric Meter Instantaneous kW - *480 volt system*	Note 7, *9, 10*	Note 7, *9, 10*	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X	Note 7, *9, 10*
Match UCB Standard	Thermal Meter Instantaneous Btu/hr	Note 7, *9, 10*	Note 7, *9, 10*	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X	Note 7, *9, 10*
Match UCB Standard	*Electric Meter Instantaneous kW - 208 volt system*	*Note 7, 9, 10*	*Note 7, 9, 10*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*1 min.*	*X*	*X*	*Note 7, 9, 10*
Match UCB Standard	*3rd Floor Supply Static Pressure*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*1min.*	*X*	*X*	*Note 15*
Match UCB Standard	*4th Floor Supply Static Pressure*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*1 min.*	*X*	*X*	*Note 16*
Analog Outputs															
Match UCB Standard	Reheat Valve Command	ALC Standard	ALC Standard	Coordinate at submittal review				60	1 min.	X	X	5 min.	X	X	Note 6
Match UCB Standard	*Zone Supply Damper Command*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*5 min.*	*X*	*X*	*Note 12, 13*
Match UCB Standard	*Zone Return Damper Command*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*5 min.*	*X*	*X*	*Note 12, 13*
Digital Inputs															
Match UCB Standard	Over-ride Request	*RSPlus*	ALC Standard	Coordinate at submittal review				12	COV	X	X	COV	X	X	Note 6, *9, 11*
Match UCB Standard	*Zone Occupancy Sensor*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*12*	*COF*	*X*	*X*	*COV*	*X*	*X*	*Note 13*
Digital Outputs															
Match UCB Standard	*Occuppancy Status*	*RSPlus*	*ALC Standard*	*Coordinate at submittal review*				*12*	*COV*	*X*	*X*	*COV*	*X*	*X*	*Note 6, 9, 11*
Virtual Points															
Match UCB Standard	kWh - *480 volt system*	Note 7, 8, *9*	Note 7, 8, *9*	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X	Note 7, 8, *9*
Match UCB Standard	Therms	Note 7, 8	Note 7,8	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X	Note 7, 8
Match UCB Standard	*kWh - 208 volt system*	*Note 7, 8, 9*	*Note 7, 8, 9*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*1 min.*	*X*	*X*	*Note 7, 8, 9*

Features			
	Trending		
Samples[1]	Commissioning[5]		
	Time[2]	Local[3]	Archive[4]
12	5 min.	X	X
60	1 min.	X	X
12	COV	X	X
60	1 min.	X	X
60	1 min.	X	X
60	*1 min.*	*X*	*X*
60	*1 min.*	*X*	*X*
60	*1 min.*	*X*	*X*

They're Not All Equal

But You Can Get Them Pretty Close

Point lists can drive controller capabilities and I/O requirements and quality

- Function
- Technology
- Accuracy
- Alarm capabilities
- Trending samples
- Trending memory
- Archiving requirements

DDC System Point List																	
Point Number	System and Service	Sensor Type	Accuracy	Features													Notes
				Alarms				Trending									
				Limit		Warning		Samples[1]	Commissioning[5]			Operating[5]					
				Hi	Lo	Hi	Lo		Time[2]	Local[3]	Archive[4]	Time[2]	Local[3]	Archive[4]			
Analog Inputs																	
Match UCB Standard	Space Temperature	*RSPlus*	ALC Standard	Coordinate at submittal review				12	5 min.	X	X	5 min.	X	X			Note 6, *9, 11*
Match UCB Standard	Reheat Coil Discharge Temperature	ALC Standard	ALC Standard	Coordinate at submittal review				60	1 min.	X	X	5 min.	X	X			Note 6
Match UCB Standard	Space Set Point Adjustment	*RSPlus*	ALC Standard	Coordinate at submittal review				12	COV	X	X	COV	X	X			Note 6, *9, 11*
Match UCB Standard	Electric Meter Instantaneous kW - *480 volt system*	Note 7, *9, 10*	Note 7, *9, 10*	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X			Note 7, *9, 10*
Match UCB Standard	Thermal Meter Instantaneous Btu/hr	Note 7, *9, 10*	Note 7, *9, 10*	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X			Note 7, *9, 10*
Match UCB Standard	*Electric Meter Instantaneous kW - 208 volt system*	*Note 7, 9, 10*	*Note 7, 9, 10*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*1 min.*	*X*	*X*			*Note 7, 9, 10*
Match UCB Standard	*3rd Floor Supply Static Pressure*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*1min.*	*X*	*X*			*Note 15*
Match UCB Standard	*4th Floor Supply Static Pressure*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*1 min.*	*X*	*X*			*Note 16*
Analog Outputs																	
Match UCB Standard	Reheat Valve Command	ALC Standard	ALC Standard	Coordinate at submittal review				60	1 min.	X	X	5 min.	X	X			Note 6
Match UCB Standard	*Zone Supply Damper Command*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*5 min.*	*X*	*X*			*Note 12, 13*
Match UCB Standard	*Zone Return Damper Command*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*5 min.*	*X*	*X*			*Note 12, 13*
Digital Inputs																	
Match UCB Standard	Over-ride Request	*RSPlus*	ALC Standard	Coordinate at submittal review				12	COV	X	X	COV	X	X			Note 6, *9, 11*
Match UCB Standard	*Zone Occupancy Sensor*	*ALC Standard*	*ALC Standard*	*Coordinate at submittal review*				*12*	*COF*	*X*	*X*	*COV*	*X*	*X*			*Note 13*
Digital Outputs																	
Match UCB Standard	*Occuppancy Status*	*RSPlus*	*ALC Standard*	*Coordinate at submittal review*				*12*	*COV*	*X*	*X*	*COV*	*X*	*X*			*Note 6, 9, 11*
Virtual Points																	
Match UCB Standard	kWh - *480 volt system*	Note 7, 8, *9*	Note 7, 8, *9*	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X			Note 7, 8, *9*
Match UCB Standard	Therms	Note 7, 8	Note 7,8	Coordinate at submittal review				60	1 min.	X	X	1 min.	X	X			Note 7, 8
Match UCB Standard	*kWh - 208 volt system*	*Note 7, 8, 9*	*Note 7, 8, 9*	*Coordinate at submittal review*				*60*	*1 min.*	*X*	*X*	*1 min.*	*X*	*X*			*Note 7, 8, 9*

Notes
Note 6, *9, 11*
Note 6
Note 6, *9, 11*
Note 7, *9, 10*
Note 7, *9, 10*
Note 7, 9, 10
Note 15
Note 16

They're Not All Equal

But You Can Get Them Pretty Close

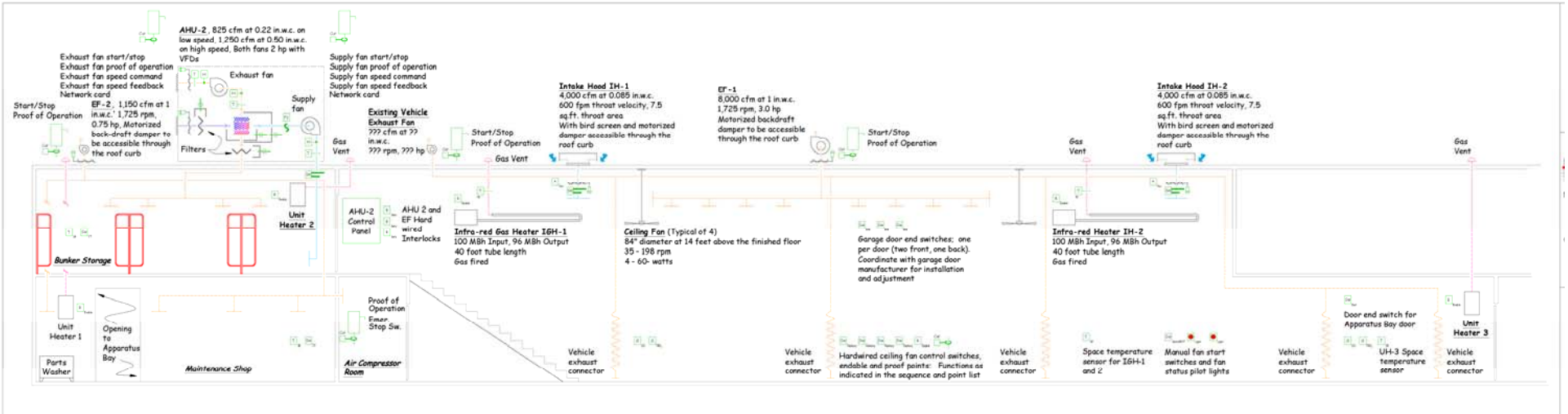
Point lists can drive controller capabilities and I/O requirements and quality

- Function
- Technology
- Accuracy
- Alarm capabilities
- Trending samples
- Trending memory
- Archiving requirements
- Installation details

System Diagrams

Address the *system* not just the the equipment

- Show relationships between the various components
- Show relationships between the components and the system
- Show relationships between the components and building



Think Logically

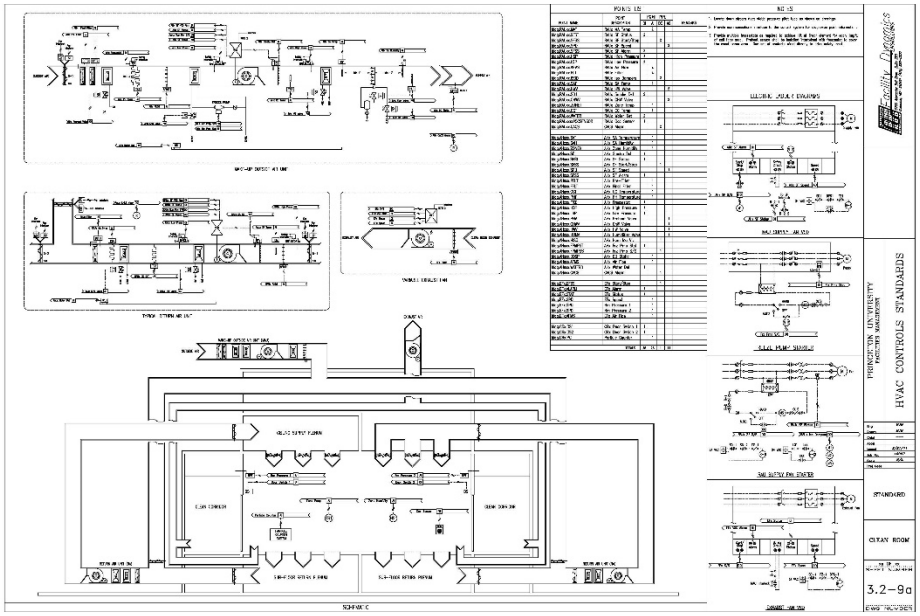
The English language can be a bit tricky; consider:

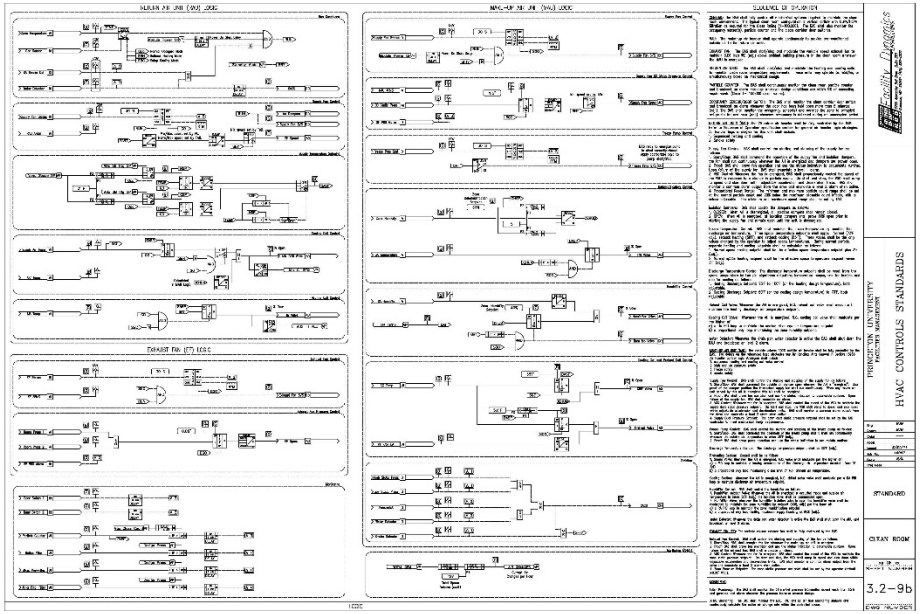
- What's that on the road ahead?

versus

- What's that on the road? A head?

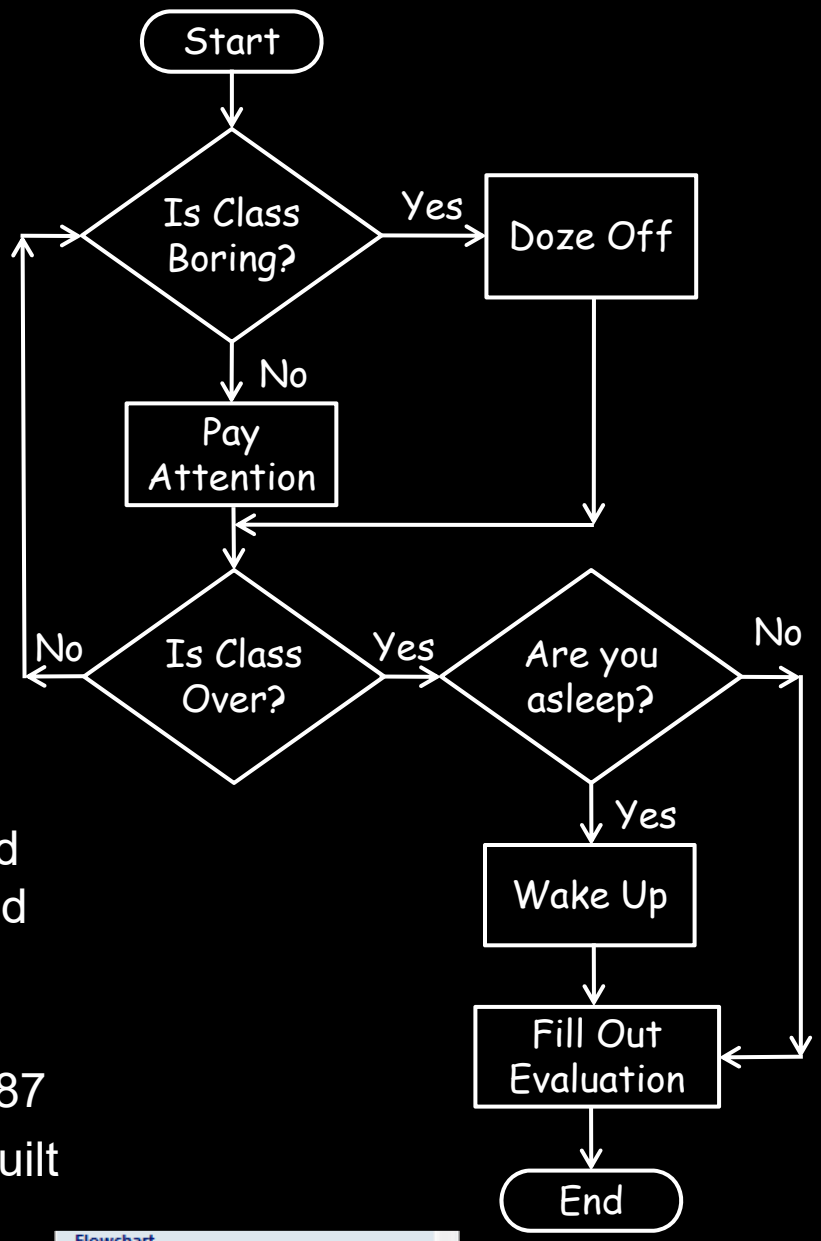
- Detailed narrative sequences will will surpass statements of intent
- Logic diagrams will surpass narrative sequences

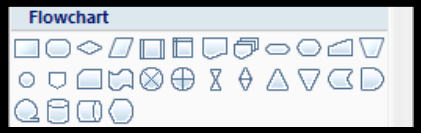




Consider Writing it All Down in the Form of a Logic Diagram

- As early as 1968, standards were developed for documenting computer logic using flow charts (ANSI X3.5 – 1968)
- In 1974, functional testing demonstrated this was a good idea (also demonstrated that a flow chart in reverse is a trouble shooting diagram)
- Current version – ANSI – AIIM – 4 – 1987
- Microsoft Office has standard shapes built in to the drawing tools drop down menu





Address the Details;
Specifications

250800 - Integrated Automation - Commissioning

251116 - Integrated Automation - Network Hardware

251413 - Integrated Automation - Remote Control Panels

251516 - Integrated Automation - Software

253500 - Integrated Automation - Instrumentation and Terminal Devices

253513 - Integrated Automation - Actuators and Operators

253516 - Integrated Automation - Sensors and Transmitters

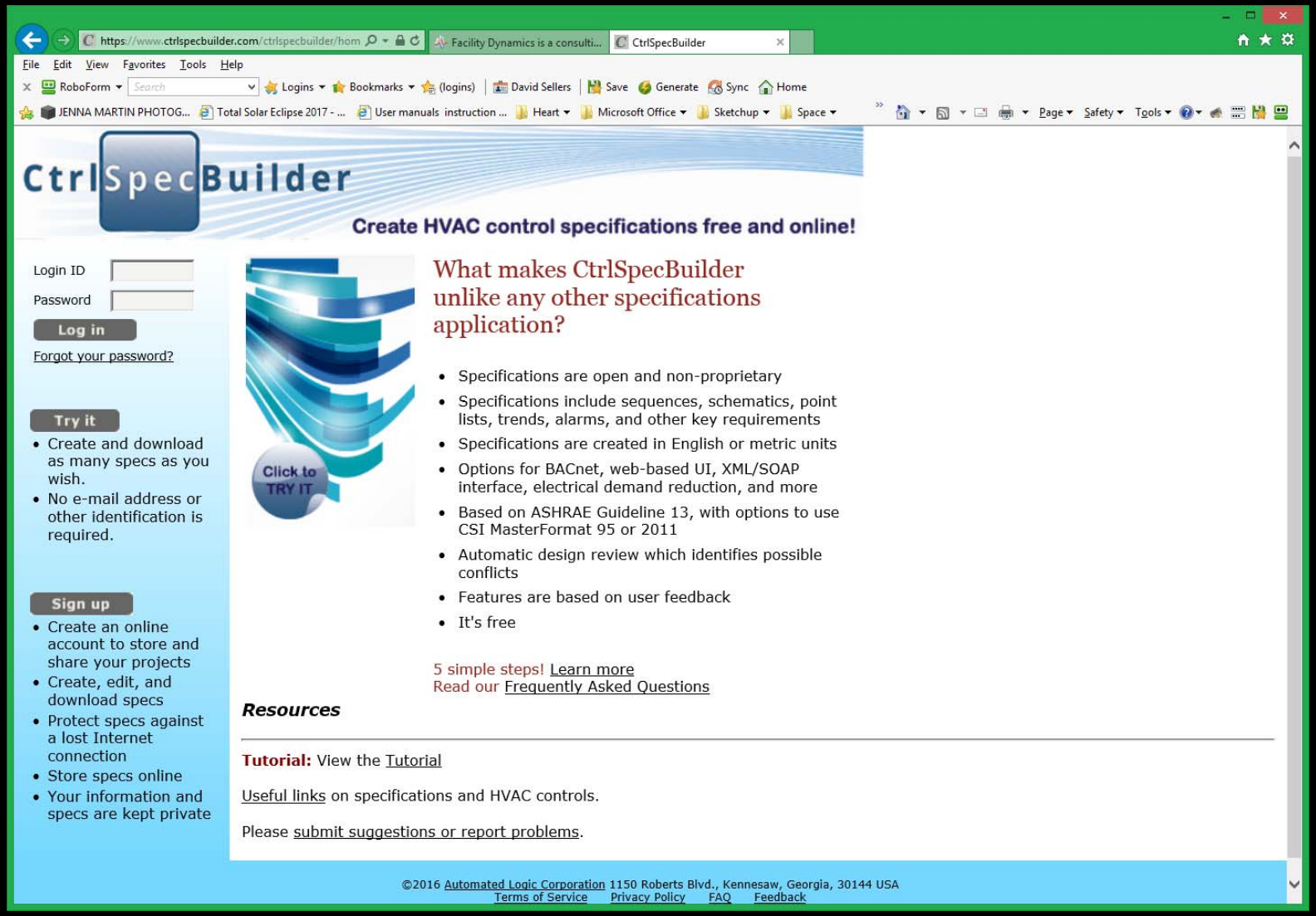
253519 - Integrated Automation - Control Valves

255500 - Integrated Automation - Control of HVAC

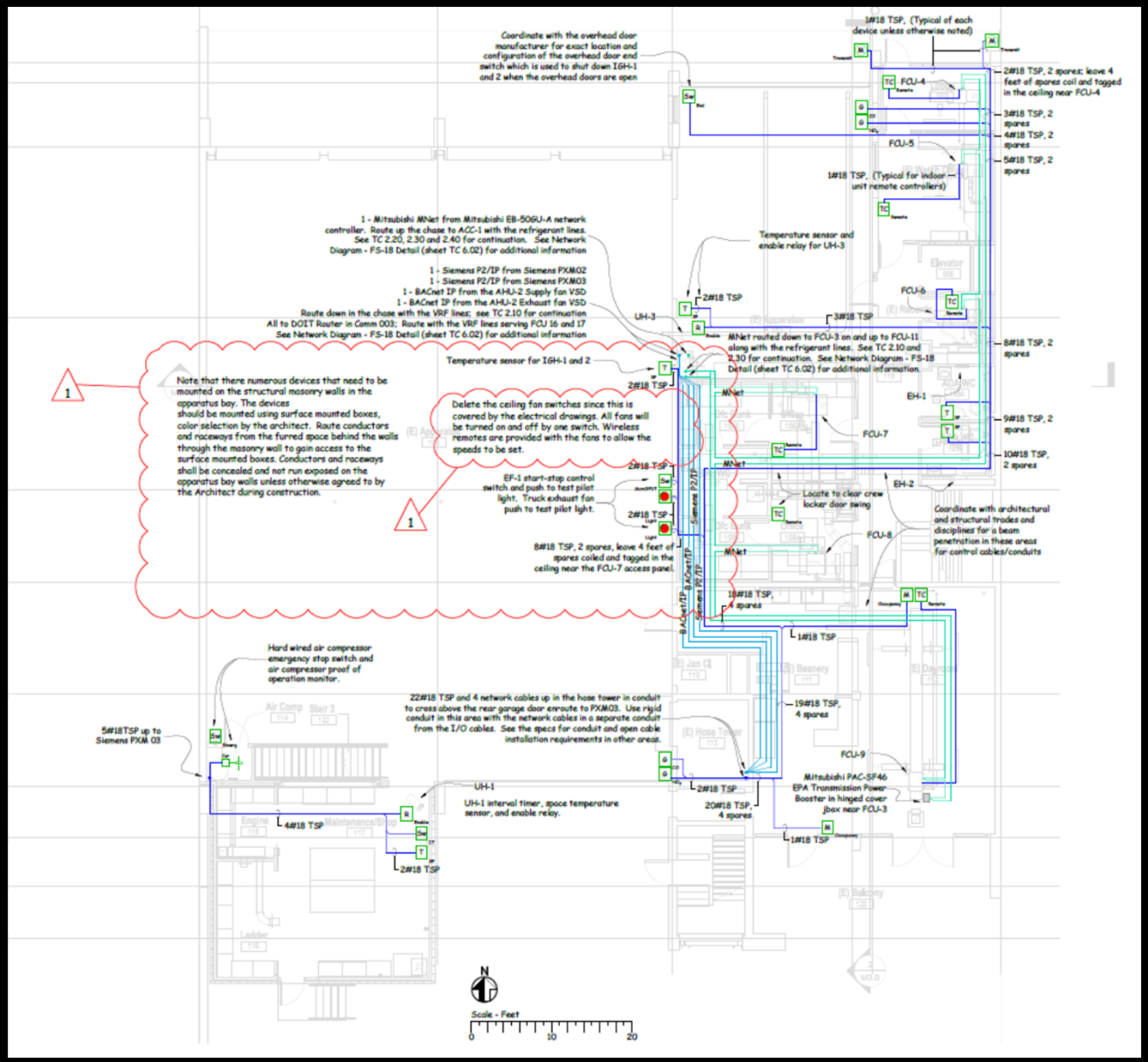
255500.13 - Integrated Automation - Control of HVAC- Object Naming Conventions

Address the Details;

Specifications – A Resource

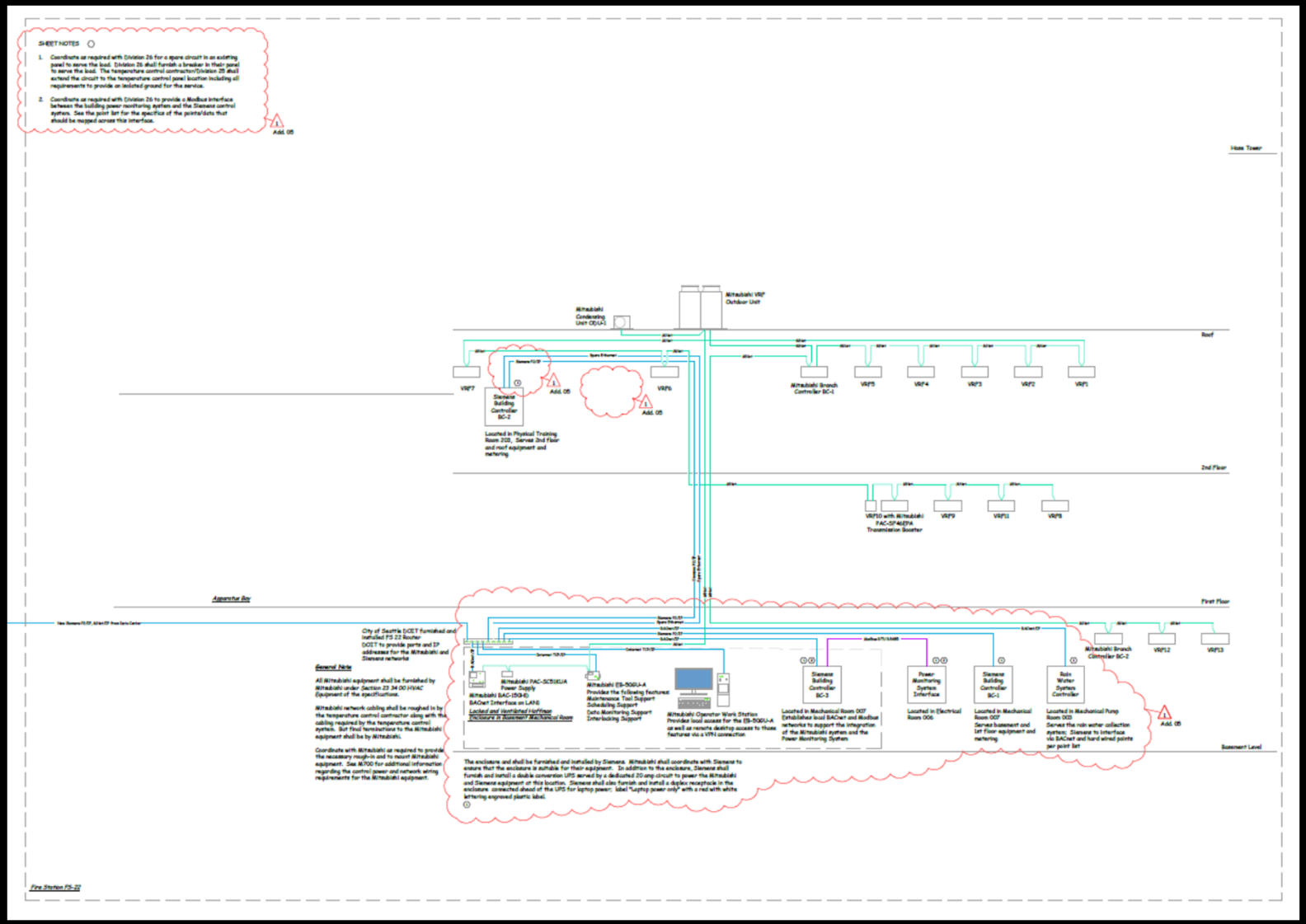


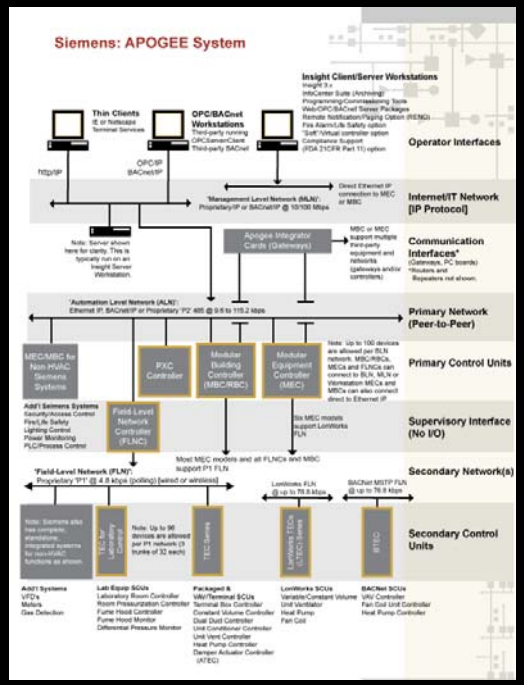
Present the Design in the Context of the Building

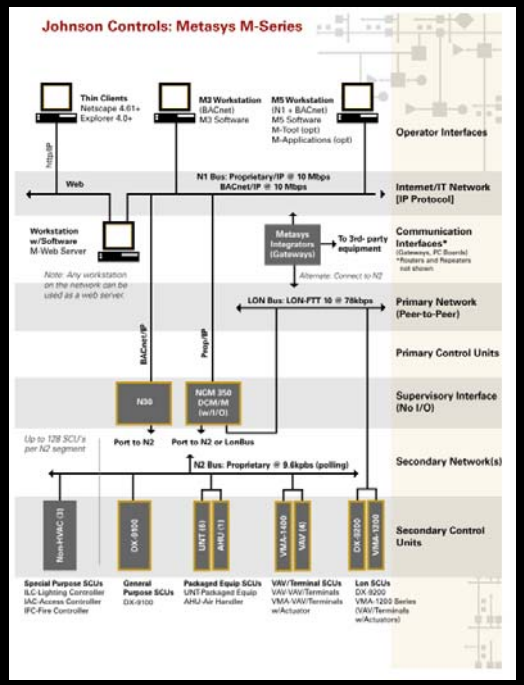


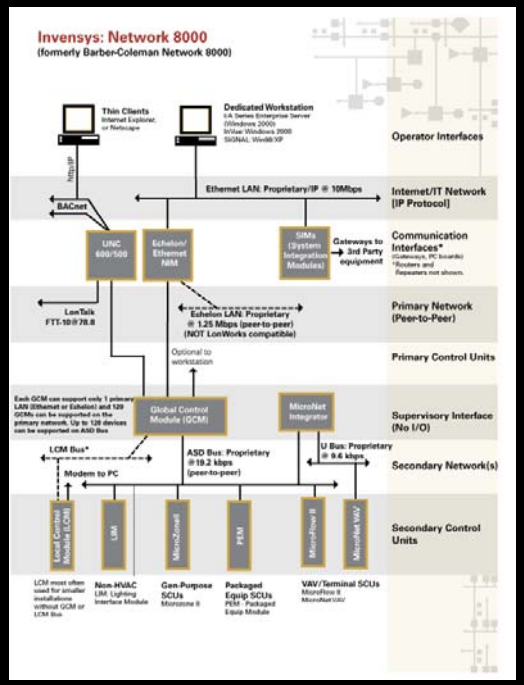
Network Diagrams;

The System in the Context of the IT Infrastructure





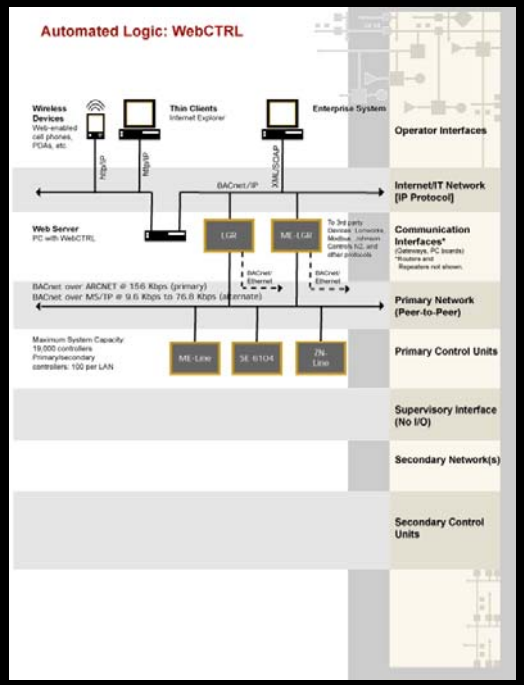




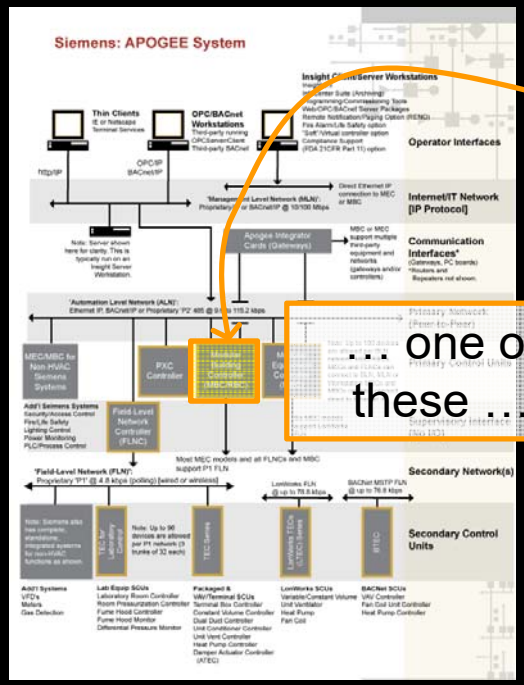
They're Not All Equal

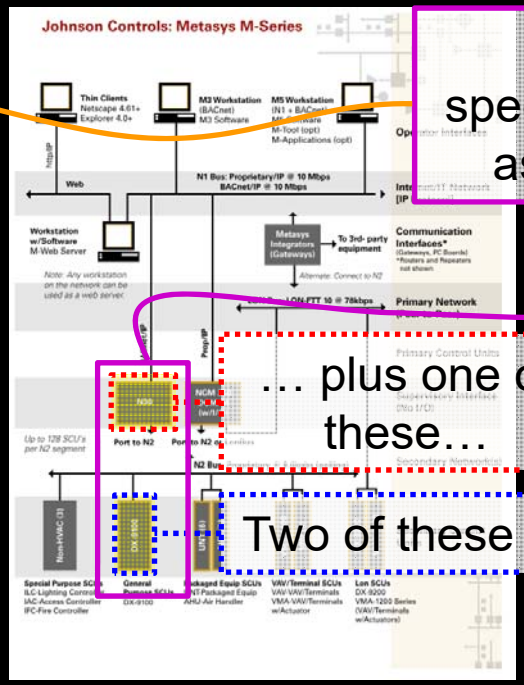
Network Architecture is Critical for Determining:

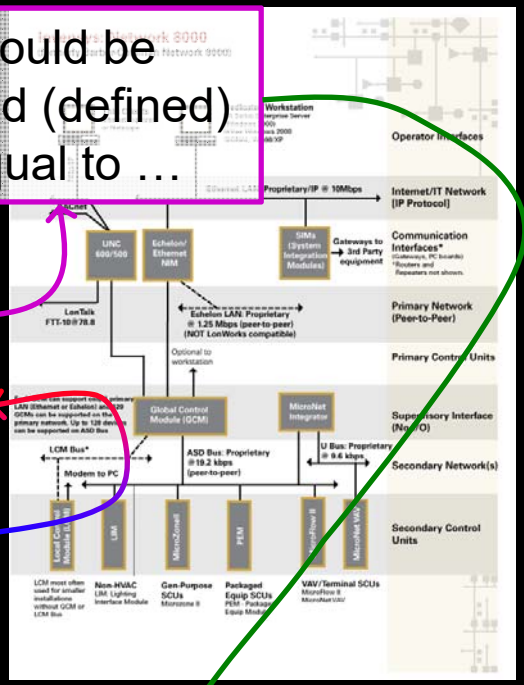
- Network speed
- Data handling capability
- Future flexibility and expansion
- Interoperability



Images courtesy www.ddc-online.org







… could be specified (defined) as equal to …

… one of these …

… plus one of these…

Two of these …

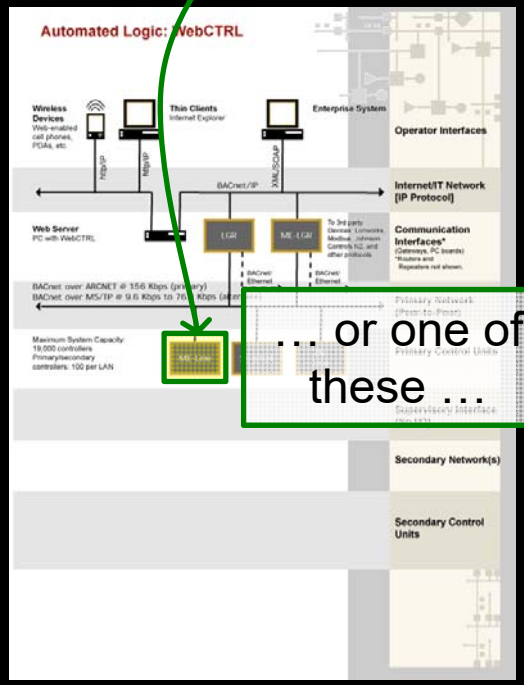
They're Not All Equal

But You Can Get Them Pretty Close

Specs can define controller capabilities

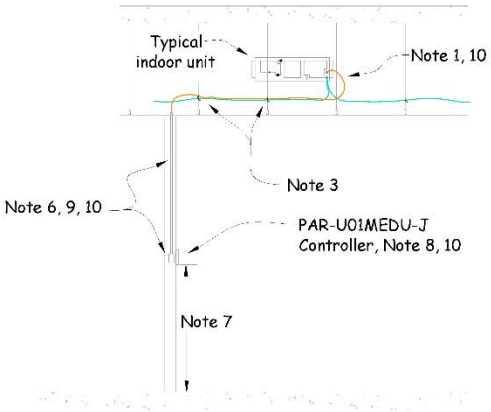
- Software
- Point capacity
- Global strategies
- A to D resolution
- Speed
- Network protocol
- Memory
- Real time clock
- Buffers
- Fully programmable
- Downloadable
- PC interface

Images courtesy www.ddc-online.org



… or one of these …

Address the Details;
Installation and Coordination

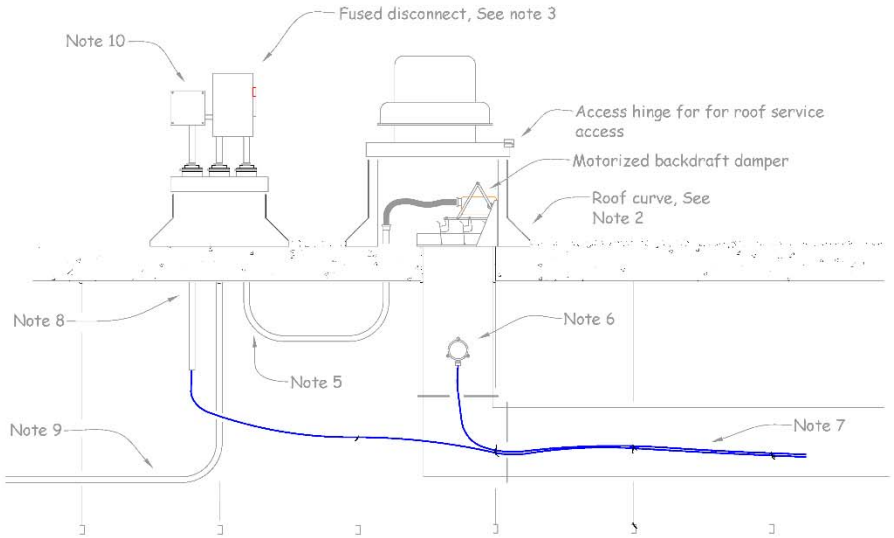


Typical Indoor Unit Control Wiring

No Scale

NOTES:

1. Furnish and install cord and cable connectors where the network and controller wiring enter the VRF unit control compartment.
2. Cables to be plenum rated with electrical characteristics suitable for the application. Verify cable selections with Mitsubishi.
3. Route cables in a neat and orderly fashion where concealed above a ceiling, securing them to structure. Do not secure cables to fire protection system piping or HVAC elements with surface temperatures above 100°F under operating conditions.
4. In areas with open ceiling, run cables in appropriately sized and supported conduit routed parallel or perpendicular to other pipes, ducts, or structural elements in the area.
5. Where possible, follow the variable flow refrigeration piping route for concealed cables and exposed control system conduit.
6. Provide EMT conduit stubs with switch boxes, all securely mounted to structure at all controller locations.
7. Controller mounting heights to be as required by local codes and the Americans with Disabilities Act.
8. Verify controller location in the field with the Architect, Control Designer, and Mechanical Designer prior to installation.
9. Where controllers are mounted on an exterior wall or a wall surrounding or located within an area served by an underfloor air plenum, insulate the switch box with1 inch of fire rated expanding foam on all sides; Abesco FP200 FR or approved equal. After the cable is pulled into the box, seal the conduit where it enters the box with the same product.
10. Siemens to furnish and installation all cable for the control and network system associated with the Mitsubishi VRF system. At each termination point, Siemens shall provide 24" of cable coiled for final termination by Mitsubishi.
11. Where conduit is required, furnish and install a separate raceway system for each of the following cable system types.
    11.1. MNet, Siemens P2, and Modbus cables
    11.2. Input/output cables (#18 Twisted Shielded Pairs)
    11.3. VRF Controller cables



Typical Roof Exhaust Fan Control

(Intake hoods to be similar)
No Scale

1. Coordinate with Division 23 and 26 details for roof mounted equipment and roof penetrations. See specifications,roof plans and M801 details 3 and 4.
2. Coordinate with Division 23 to include with the curb:
   2.1. Factory furnished hinged access.
   2.2. A damper tray with a motorized back-draft damper with the size and number of actuators as required by the specifics of each fan and its duct.
3. Fused disconnect by Division 16. Coordinate with Division 16 to provide one roof curb to serve all control and power conduit penetrations; Pate PCA or equal. Coordinate with the roofing contractor for the installation details and other requirements for the roof curb to ensure the roofing warranty is maintained.
4. Coordinate with Division 23 and 26 to verify the motorized back draft damper is provided for the line voltage associated with the exhaust fan.
5. Conduit with line voltage, across the line back draft damper interlock by the temperature control contractor
6. Duct pressure sensor for fan proof of operation input by the temperature control contractor.
7. Low voltage control cables by the temperature control contractor.
8. Low voltage fan command signal through conduit to roof by the temperature control contractor.
9. Power wiring and conduit by Division 16.
10. Temperature control contractor to furnish and install a stainless steel, hinged cover NEMA 4 enclosure to house fan interface relay and fused terminals for the damper actuator interlock circuit. Keep the enclosure clear of the equipment service and air flow paths.

A Free Control System Design Resource

- *For a narrative discussion of the preceding, see Chapter 2 of the Control Design Guide at: http://www.ftguide.org/csdg/CSDG.htm*
- *The other chapters of the Control Design Guide include a chapter on the selection and installation of control and monitoring points, and a chapter common system configurations*
- *The system configurations chapter includes a free Excel point list tool to help you develop your own point lists with the characteristics mentioned previously*

Control Systems: Design, Performance and Commissioning Issues

Introduction

Control Systems and Code Requirements

Instructor:

David Sellers

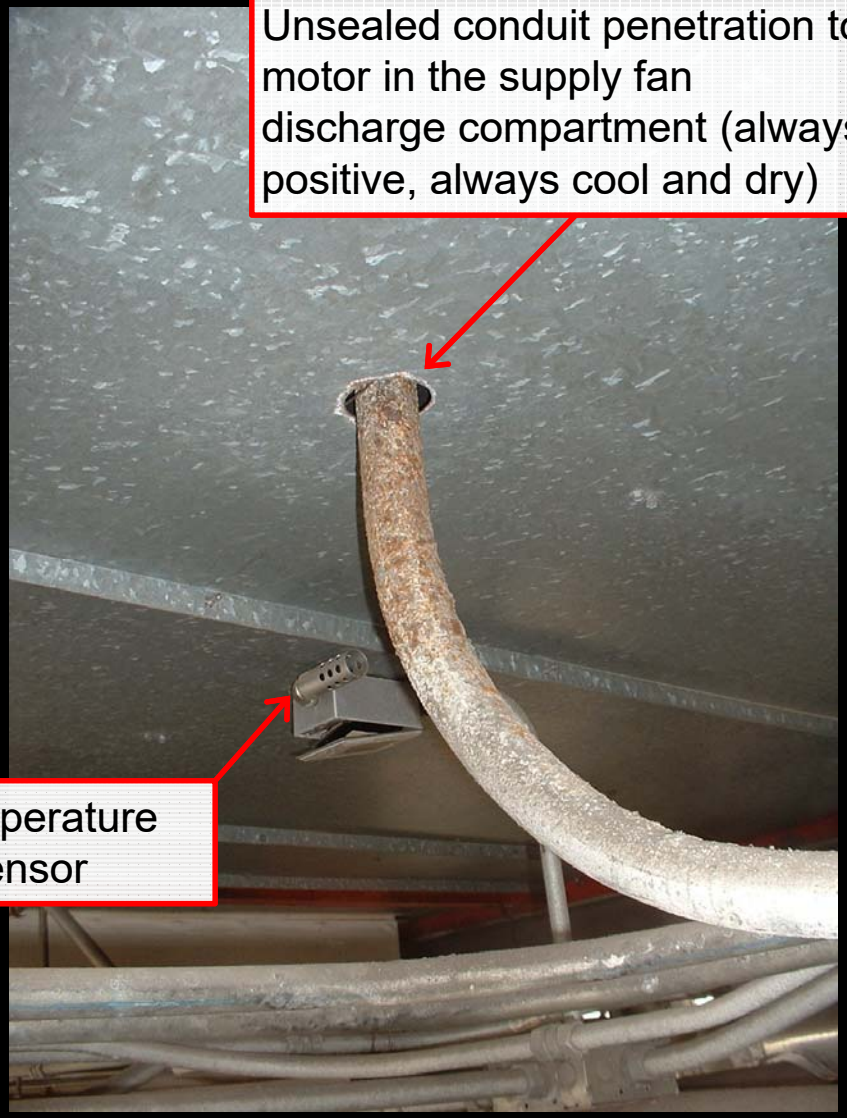
Senior Engineer

Facility Dynamics Engineering

October 23, 2017

DDC Systems are Electrical Systems

The electrical installation can be critical to the performance of the DDC system



DDC Systems are Electrical Systems

We need to comply with the National Electric Code (NFPA 70)

- Article 100
  - General information
  - Definitions
  - Working space dimensions
- Article 200
  - Terminal identification
  - Grounding conductors

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- Article 725
  - Class 1, Class 2, and Class 3 Remote-Control, Signaling, and Power-Limited Circuits

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- Article 725
  - Class 1, Class 2, and Class 3 Remote-Control, Signaling, and Power-Limited Circuits

- Article 750
  - Energy Management Systems
  - Prohibits shedding life safety/missiong critical loads
  - Prohibits overloading circuits

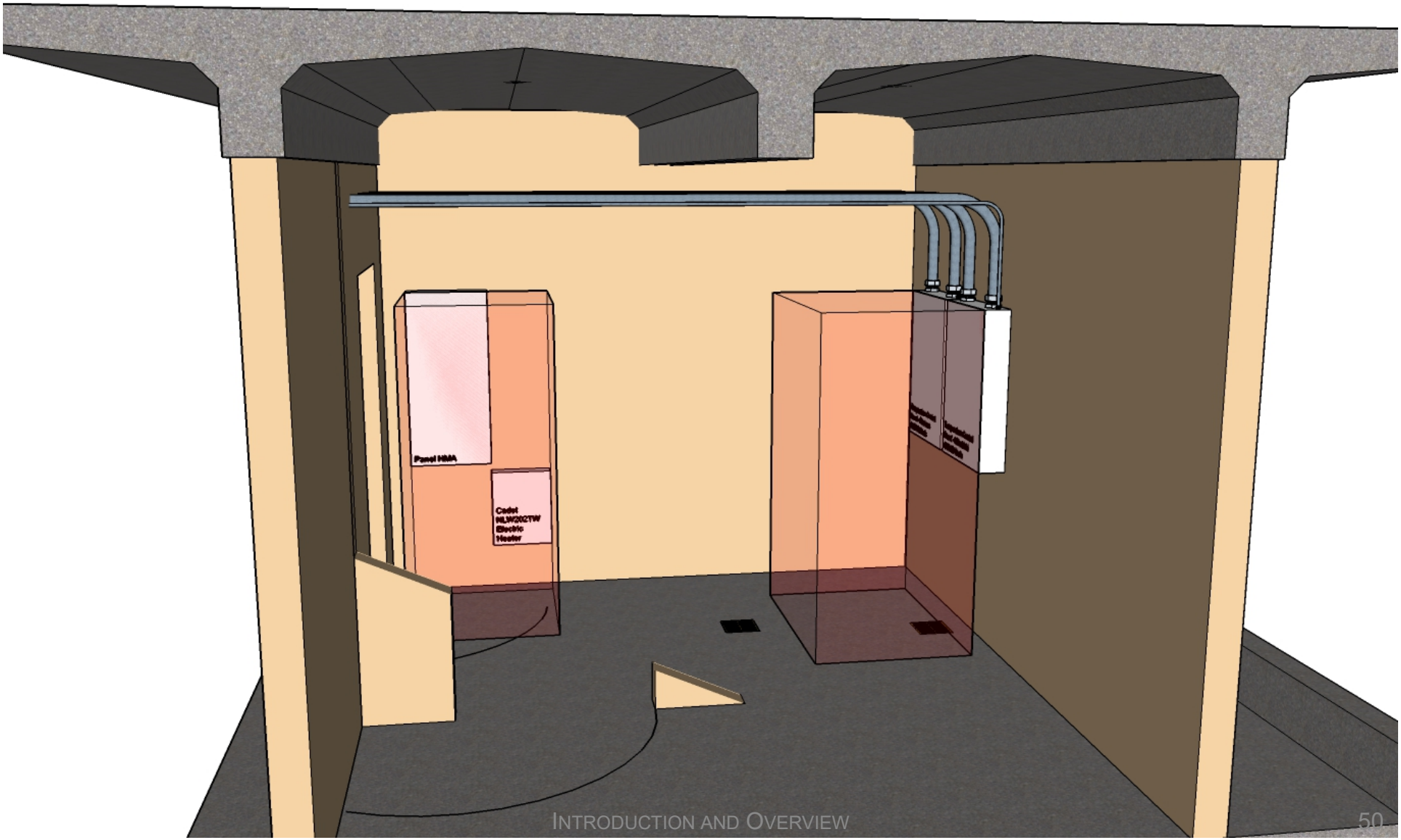
NEC Article 725

- Places limitations on the power that can be delivered through a cable
  - Voltage limits
  - Current limits
- Class 1
  - Two types
  - Digital outputs
- Class 2 and 3
  - Table 11
  - Digital inputs, analog inputs, analog outputs
- Class 1 must be segregated from Class 2 and 3 and also high voltage wiring

Working Space Requirements

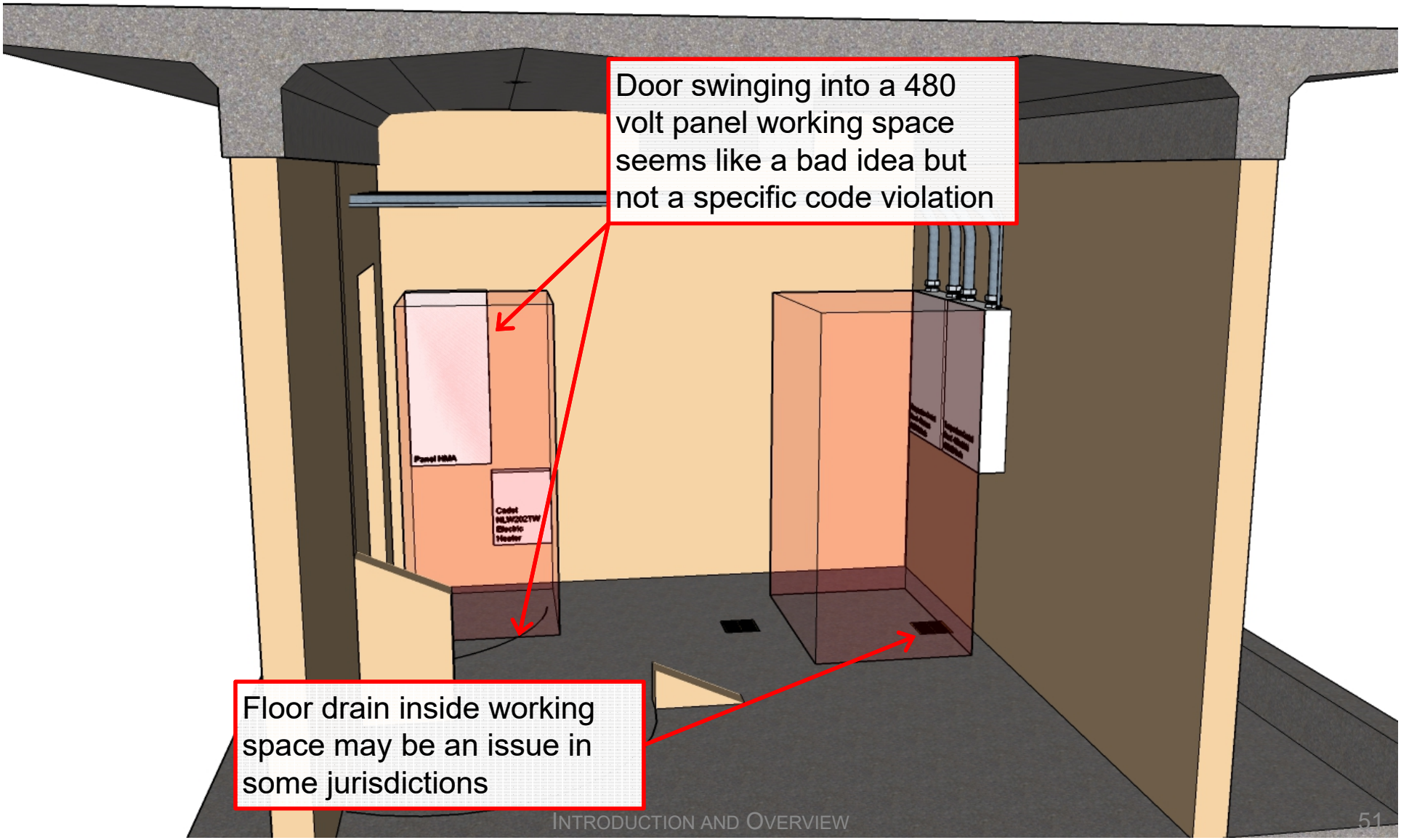
- Concerned with clearance to grounded objects
  - Table 110.26
  - Different requirements for different voltages to ground
  - Different requirements for different defined conditions
  - For most control systems
    - 3 feet in front of the panel
    - You have to be able to open the door
    - The space extends from the floor to 6’6” or the top of the panel

Working Space; An Example



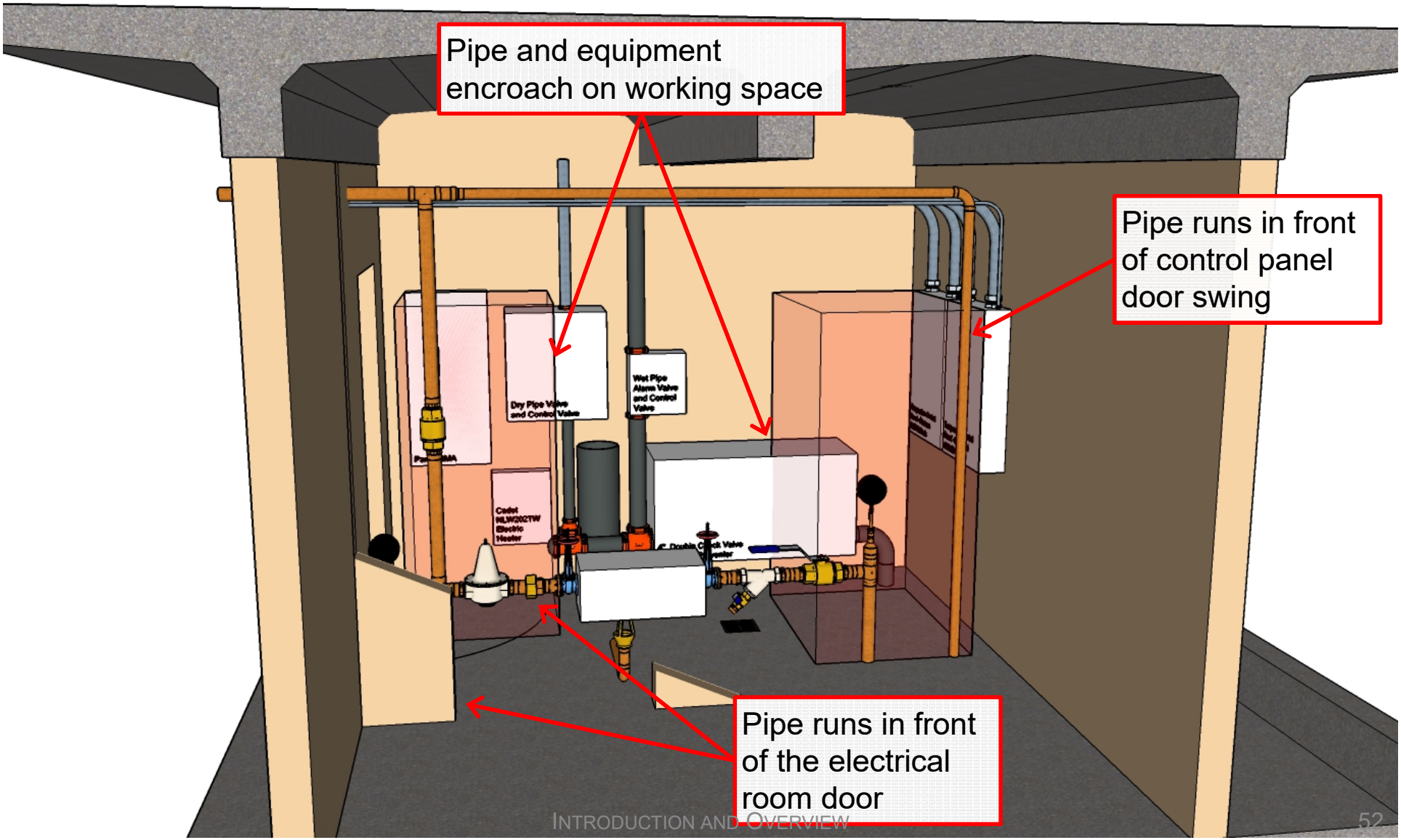
Working Space; An Example

Coordinated at 60% CDs; Everything Looks Fine



Working Space; An Example

Situation at 90% CDs; A Few Coordination Issues Show Up



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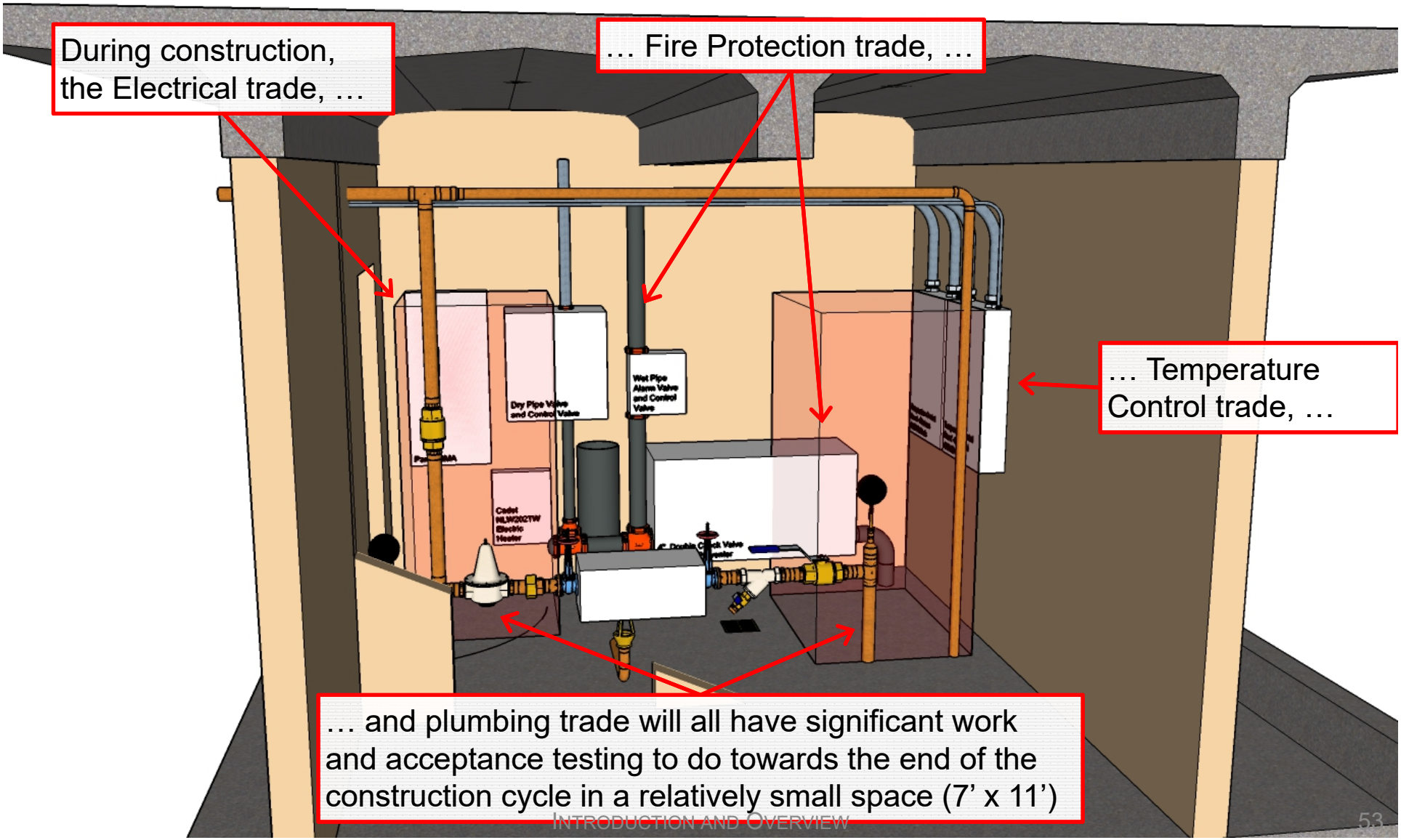

Working Space; An Example

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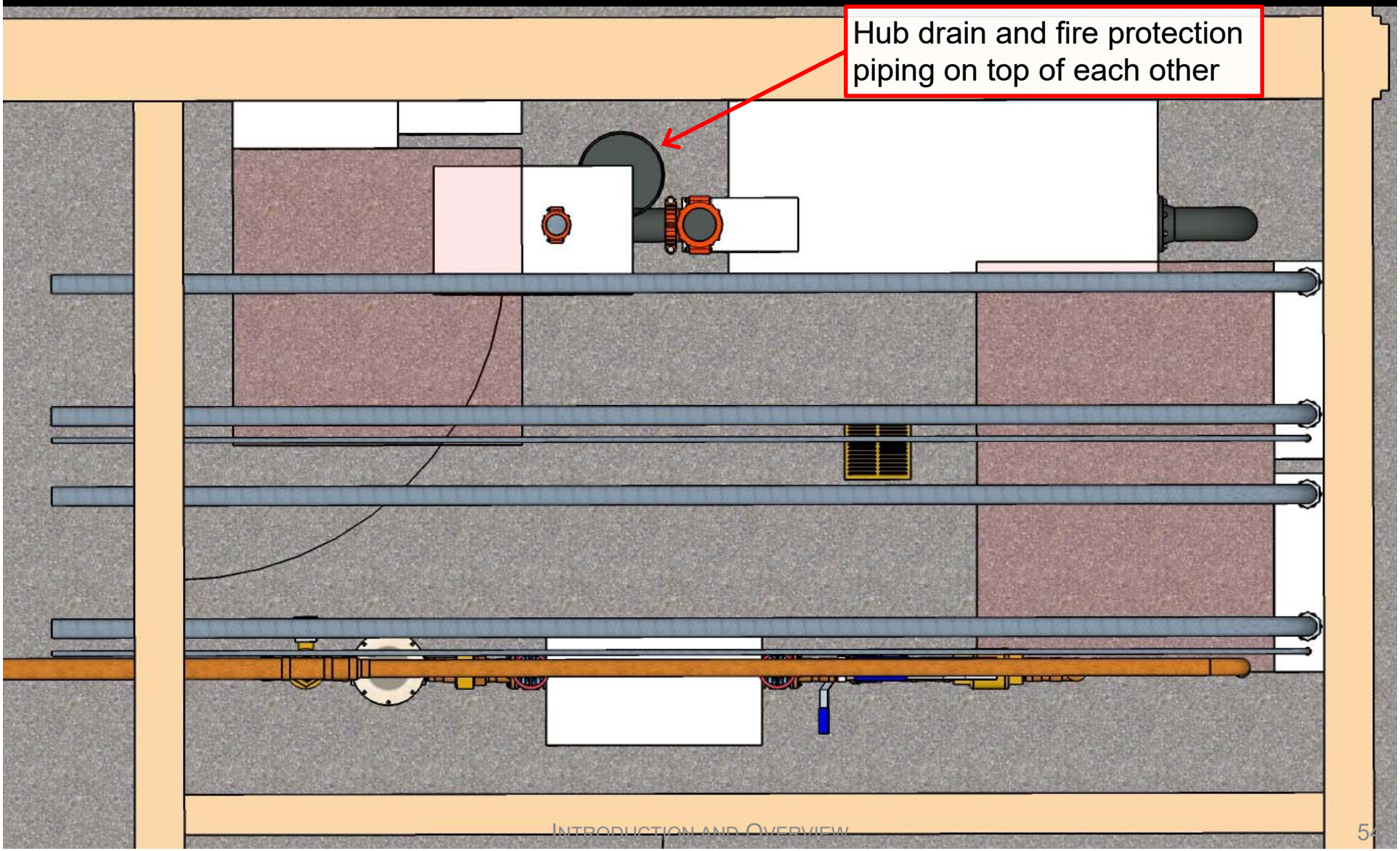
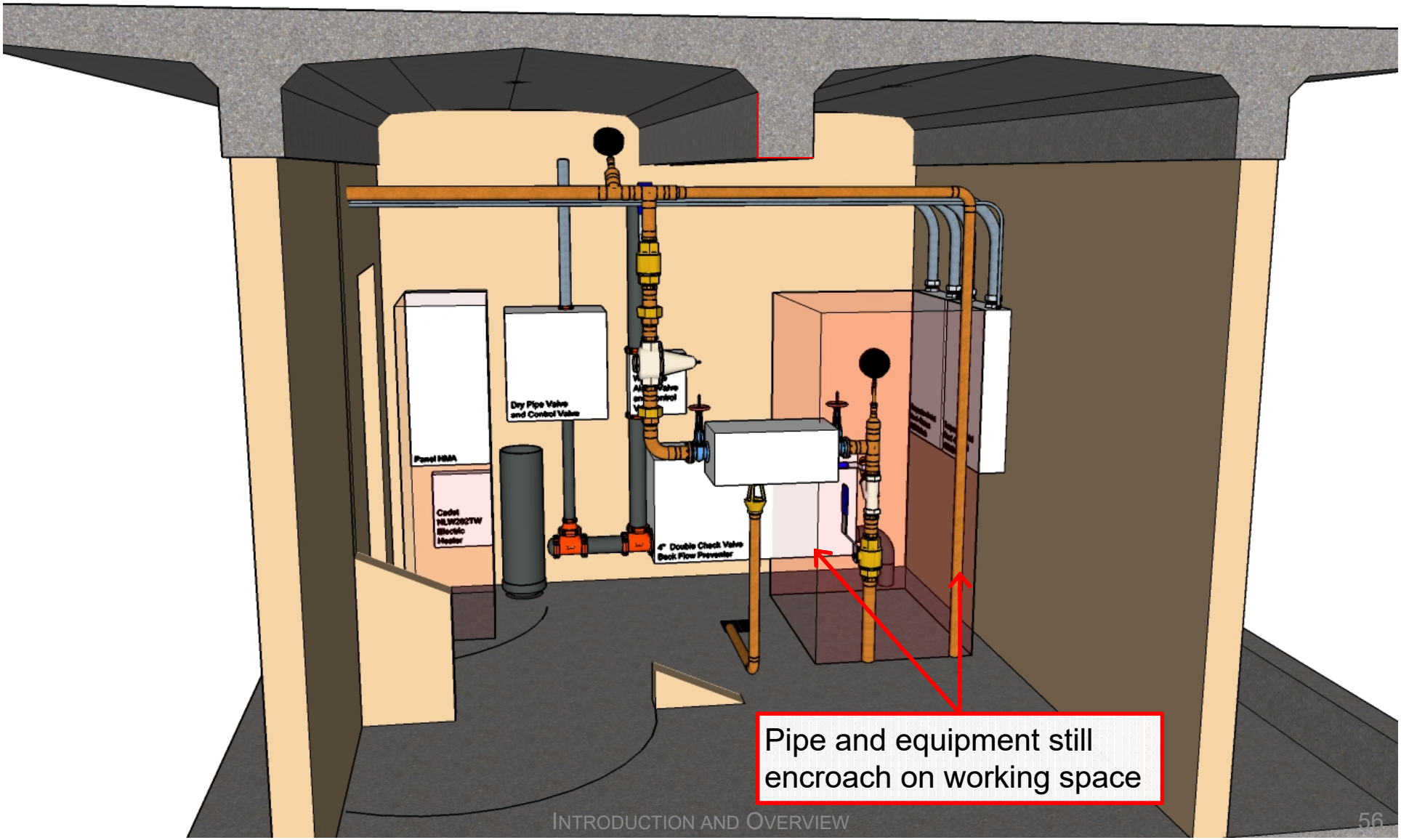


Working Space; An Example

Other Than Those Items, It Should Be Fine

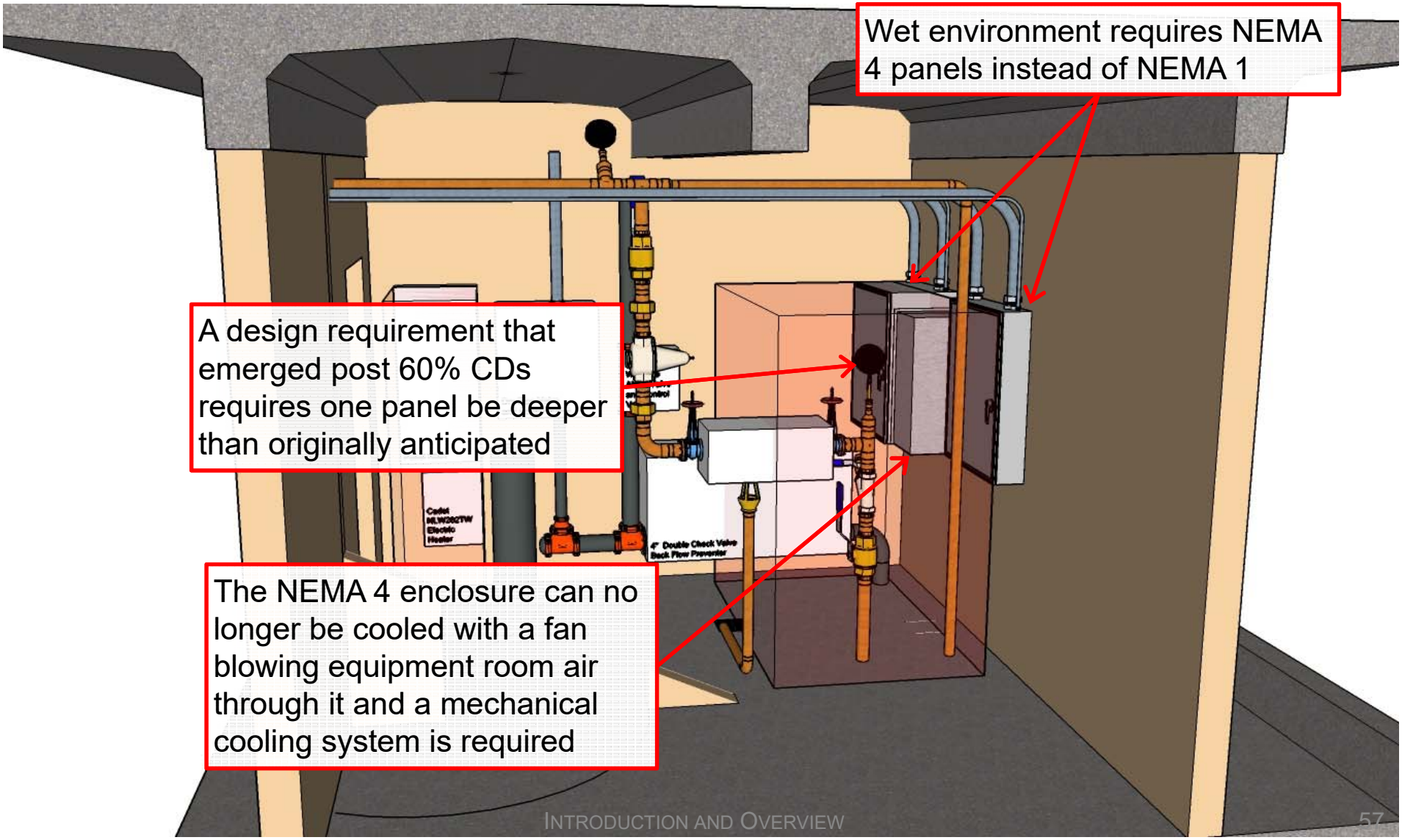
Working Space; An Example

Resolving the Non-Control System Coordination Issues



Working Space; An Example

A Few (and New) Control System Coordination Issues Remain



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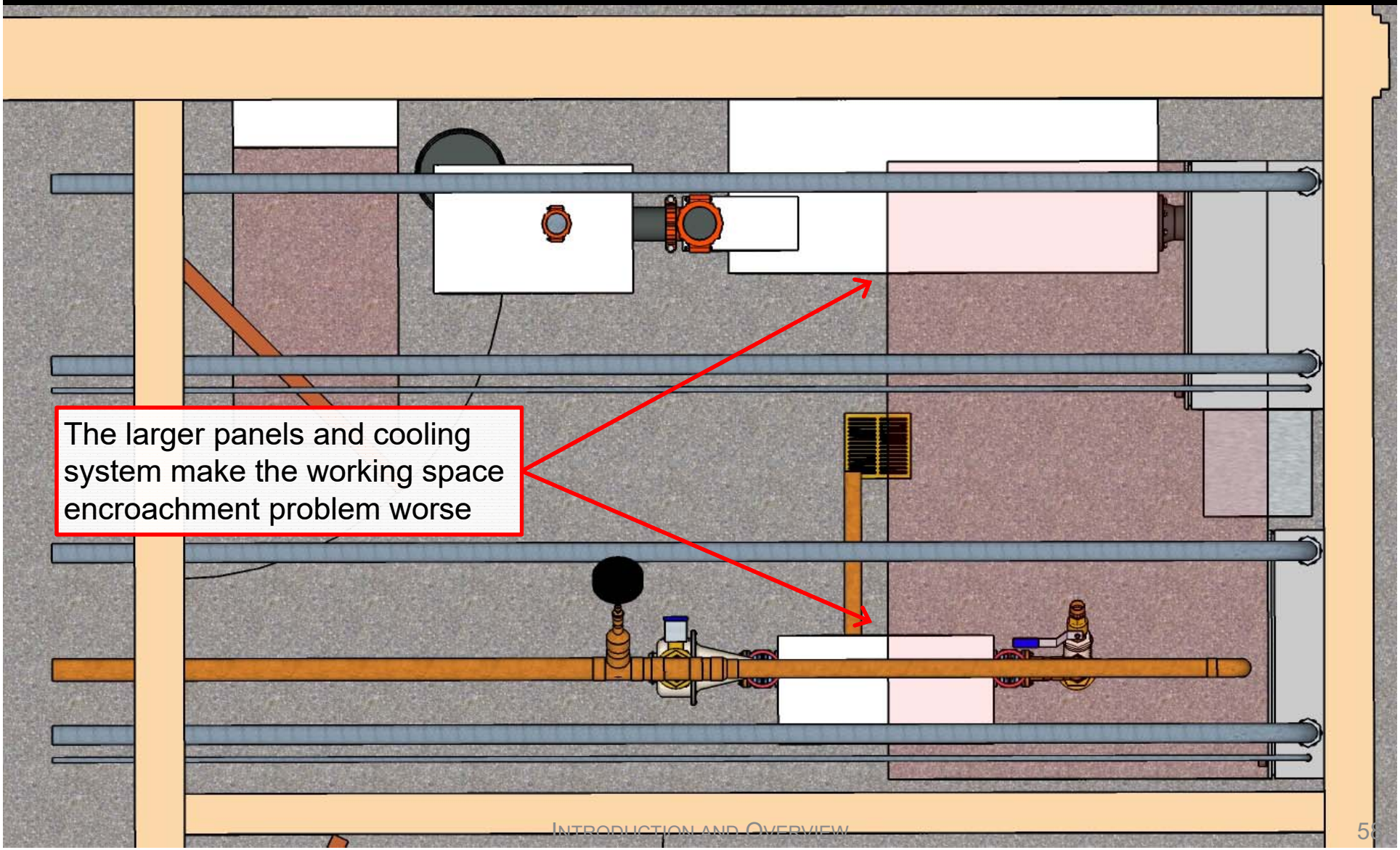

Working Space; An Example

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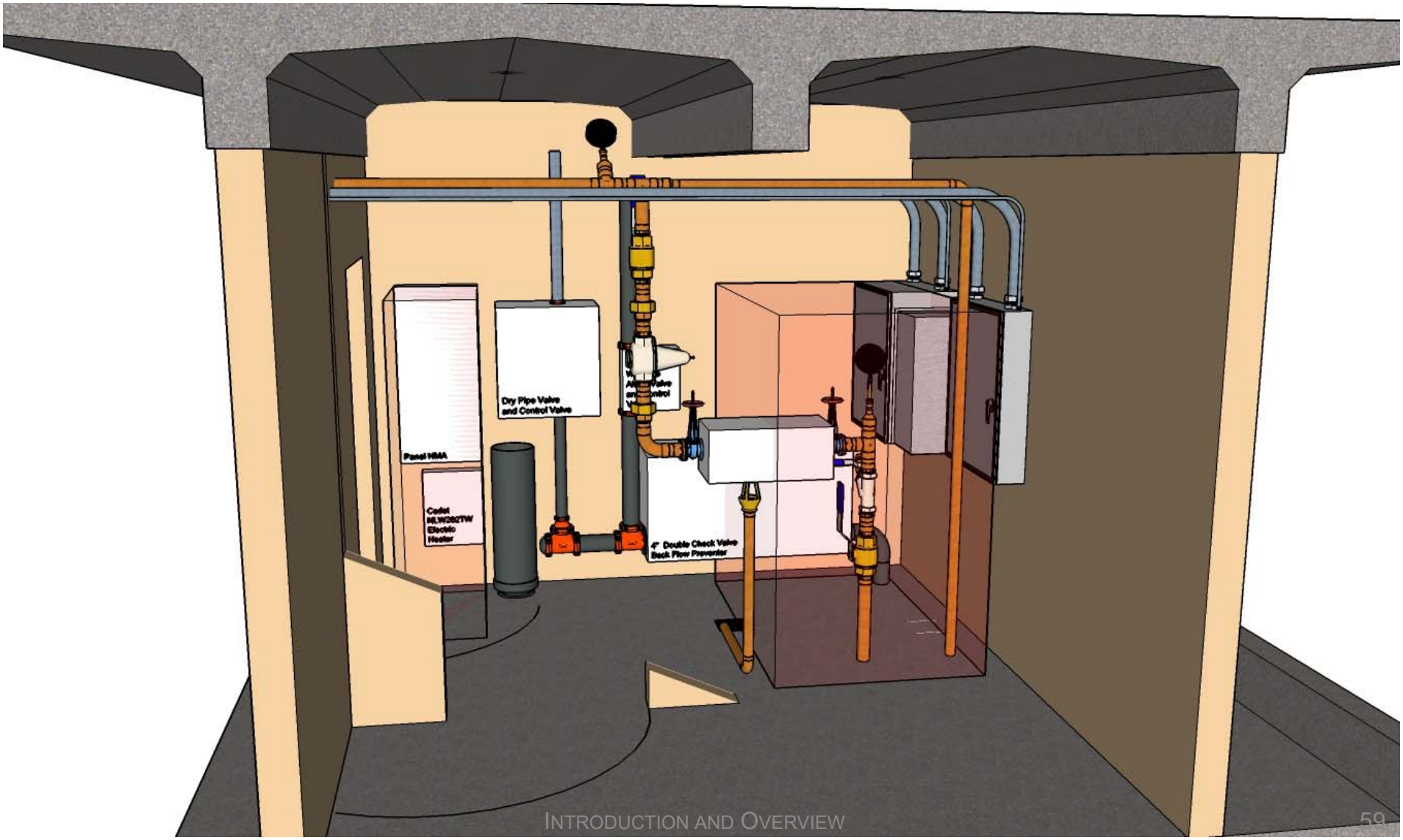
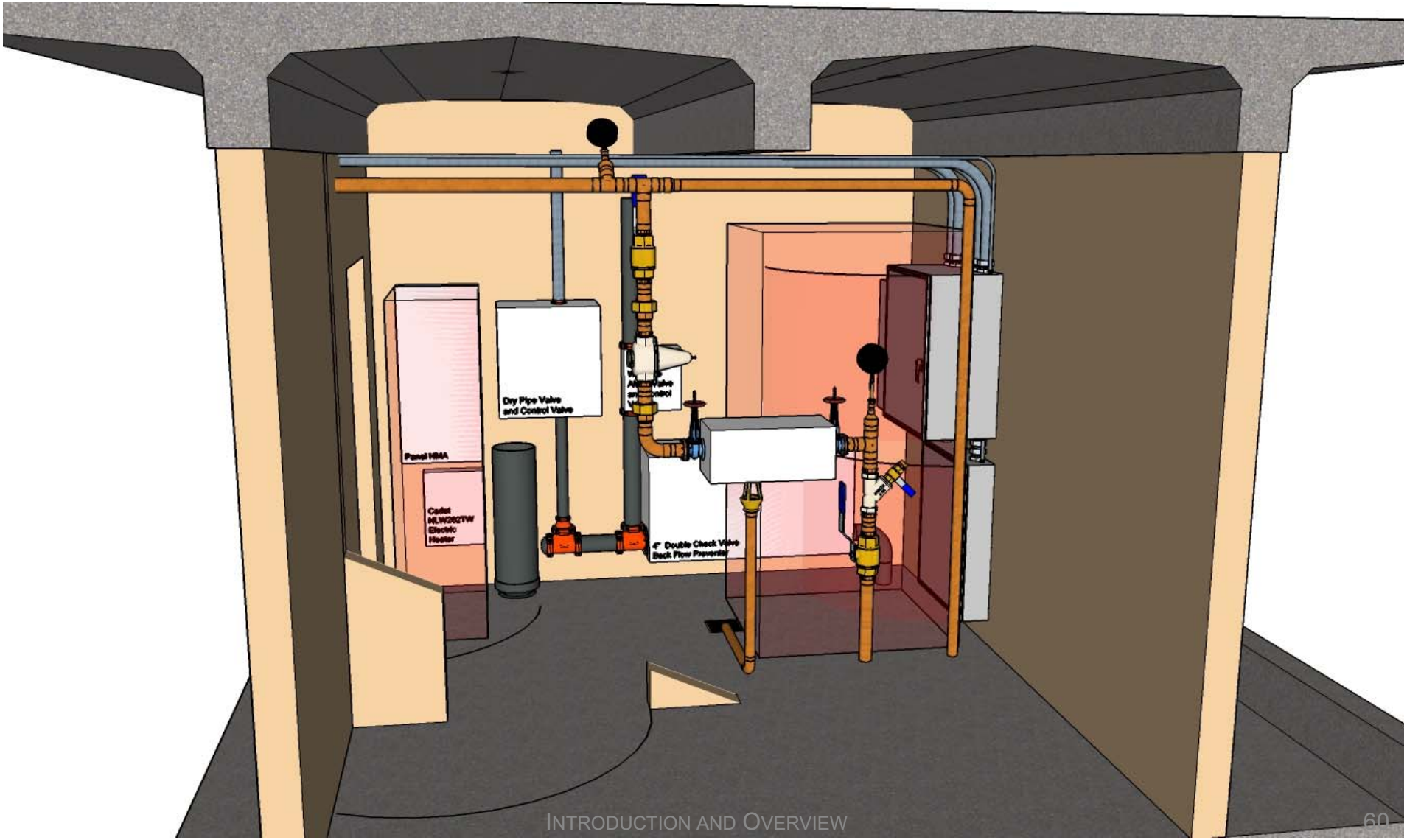


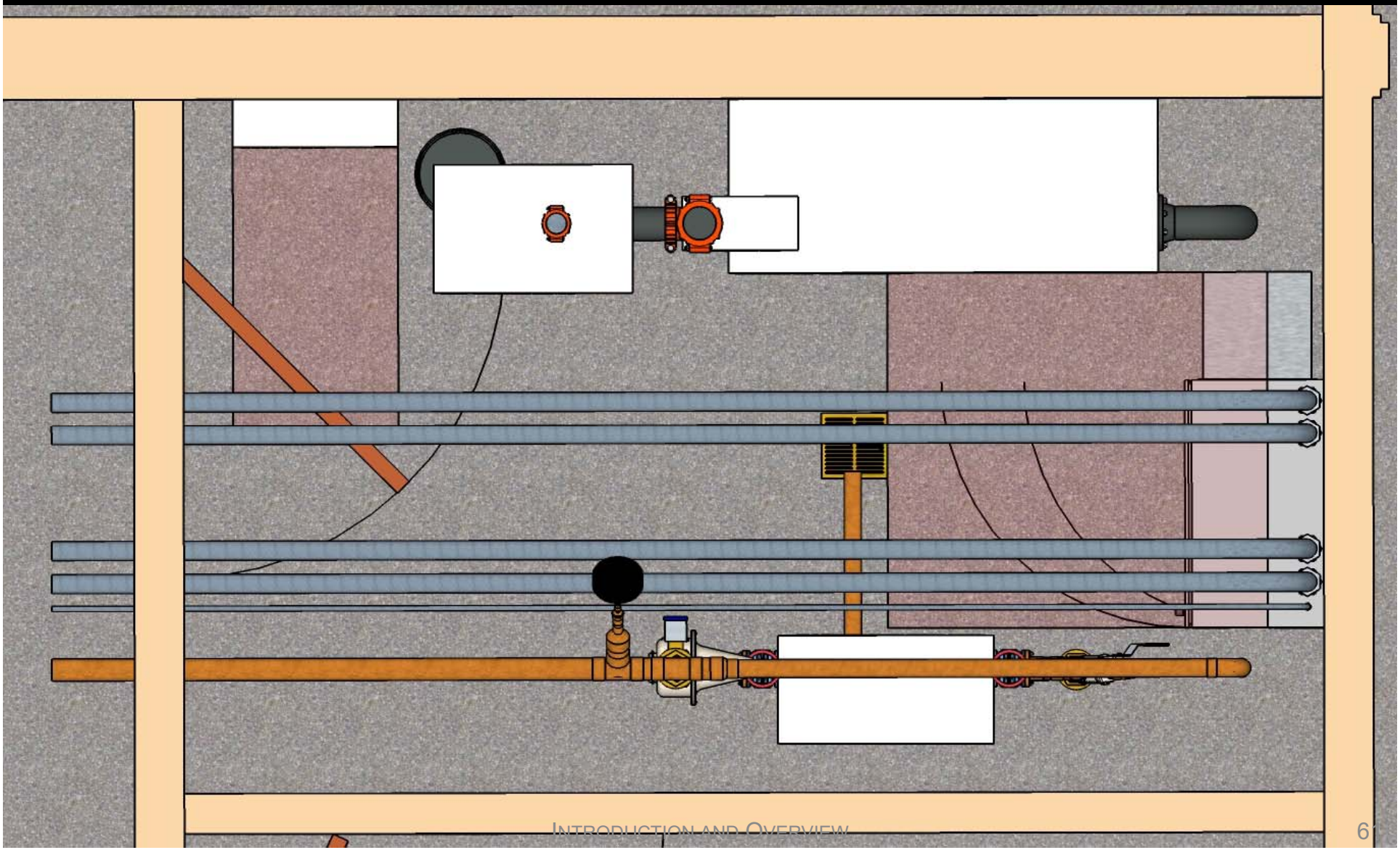
Working Space; An Example

Solving the Problem



Working Space; An Example

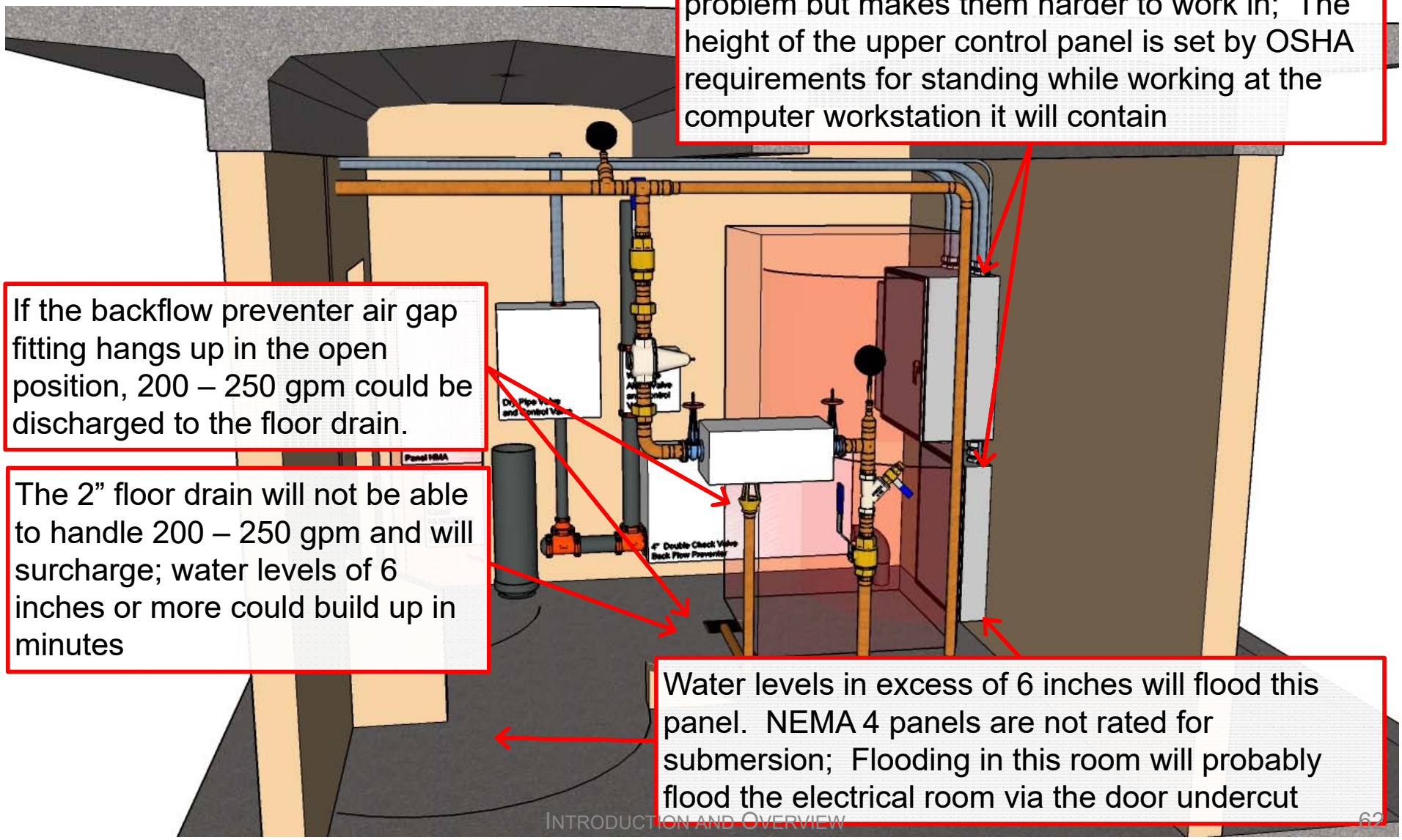
Solving the Problem (Barely)



Working Space; An Example

Still a Few Issues

Stacking the panels solves the encroachment problem but makes them harder to work in; The height of the upper control panel is set by OSHA requirements for standing while working at the computer workstation it will contain



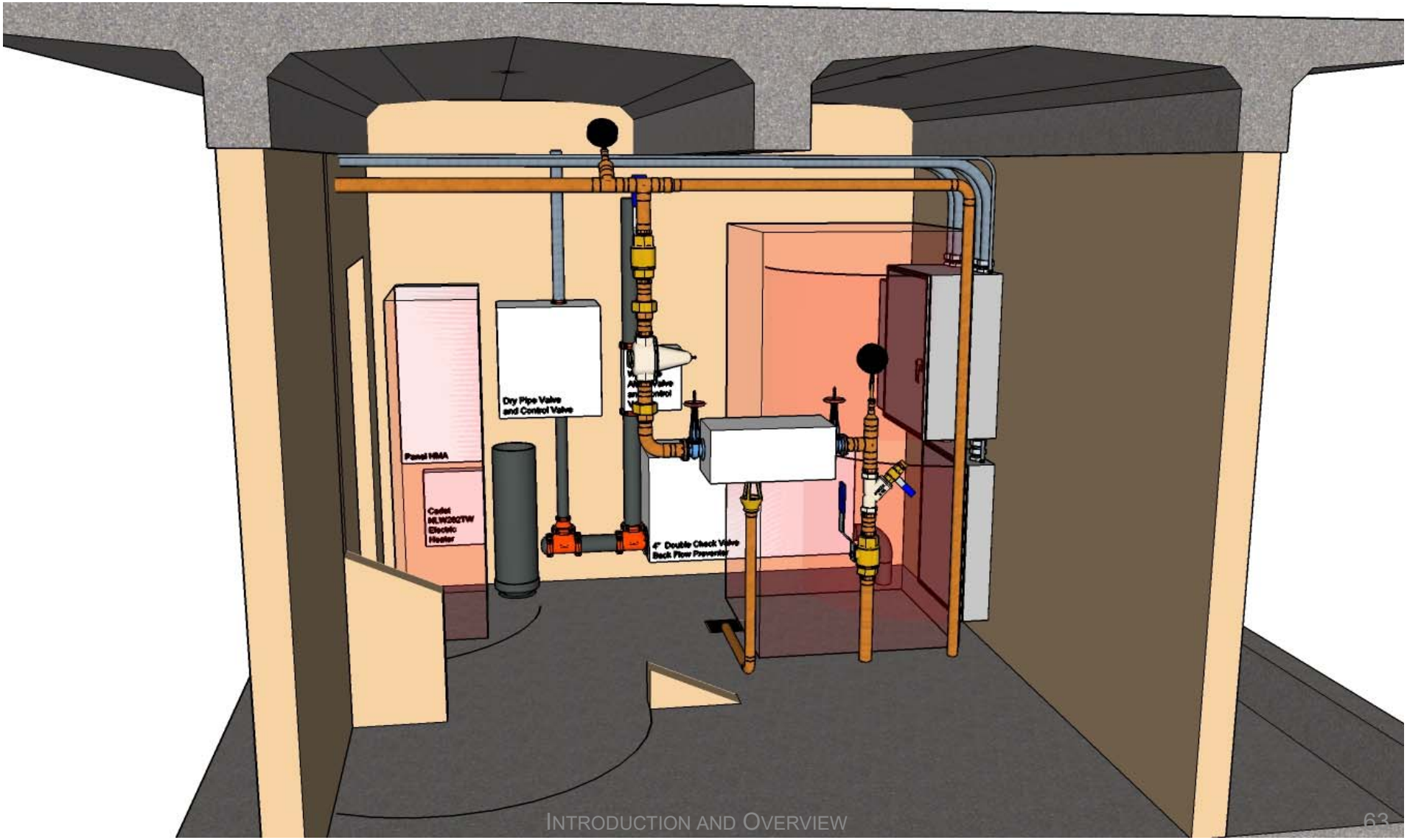
If the backflow preventer air gap fitting hangs up in the open position, 200 – 250 gpm could be discharged to the floor drain.

The 2" floor drain will not be able to handle 200 – 250 gpm and will surcharge; water levels of 6 inches or more could build up in minutes

Water levels in excess of 6 inches will flood this panel. NEMA 4 panels are not rated for submersion; Flooding in this room will probably flood the electrical room via the door undercut

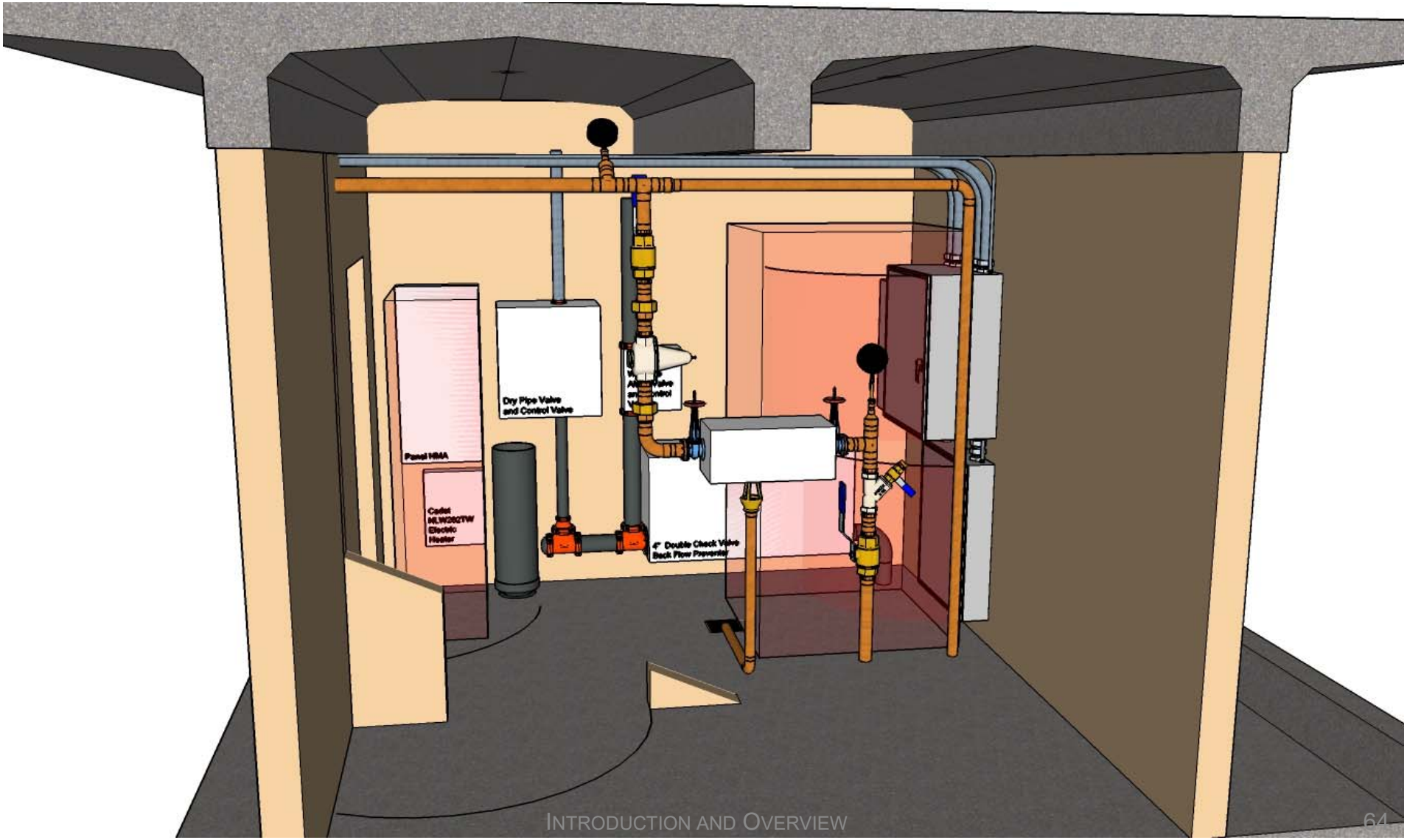
Working Space; An Example

Why not move the panels?



Working Space; An Example

The Architect says “No we coordinated at 60%; live with it”



Control Systems: Design, Performance and Commissioning Issues

Introduction

Achieving Success by Enforcing Your Design Requirements

Instructor:

David Sellers

Senior Engineer

Facility Dynamics Engineering

October 23, 2017

Enforce Your Requirements

Reject equipment and materials that don't meet the specification requirements

Test for what you need

- Need the fan to be running with-in 15 seconds of a command?

Complete the commissioning process

- All processes running
- All required trends running
- Building in a normal cycle

Put one person at the OWS and one person at the fan

Give them walkie-talkies

Synchronize their watches

Send a start command

Time how long it takes the fan to react

Enforce Your Requirements

Reject equipment and materials that don't meet the specification requirements

Test for what you need

- Need the fan to be running with-in 15 seconds of a command?
- Need to know if the air temperature changes with-in 10 seconds?

Complete the commissioning process

- All processes running
- All required trends running
- Building in a normal cycle

Put one person at the OWS and one person at the sensor

Give them walkie-talkies

Synchronize their watches

Pull the sensor out of the duct

Time how long it takes the change to show up at the OWS

Enforce Your Requirements

Reject equipment and materials that don't meet the specification requirements

Test for what you need

- Need the fan to be running with-in 15 seconds of a command?
- Need to know if the air temperature changes with-in 10 seconds?
- Need a graphic to populate in 60 seconds?

Complete the commissioning process

- All processes running
- All required trends running
- Building in a normal cycle

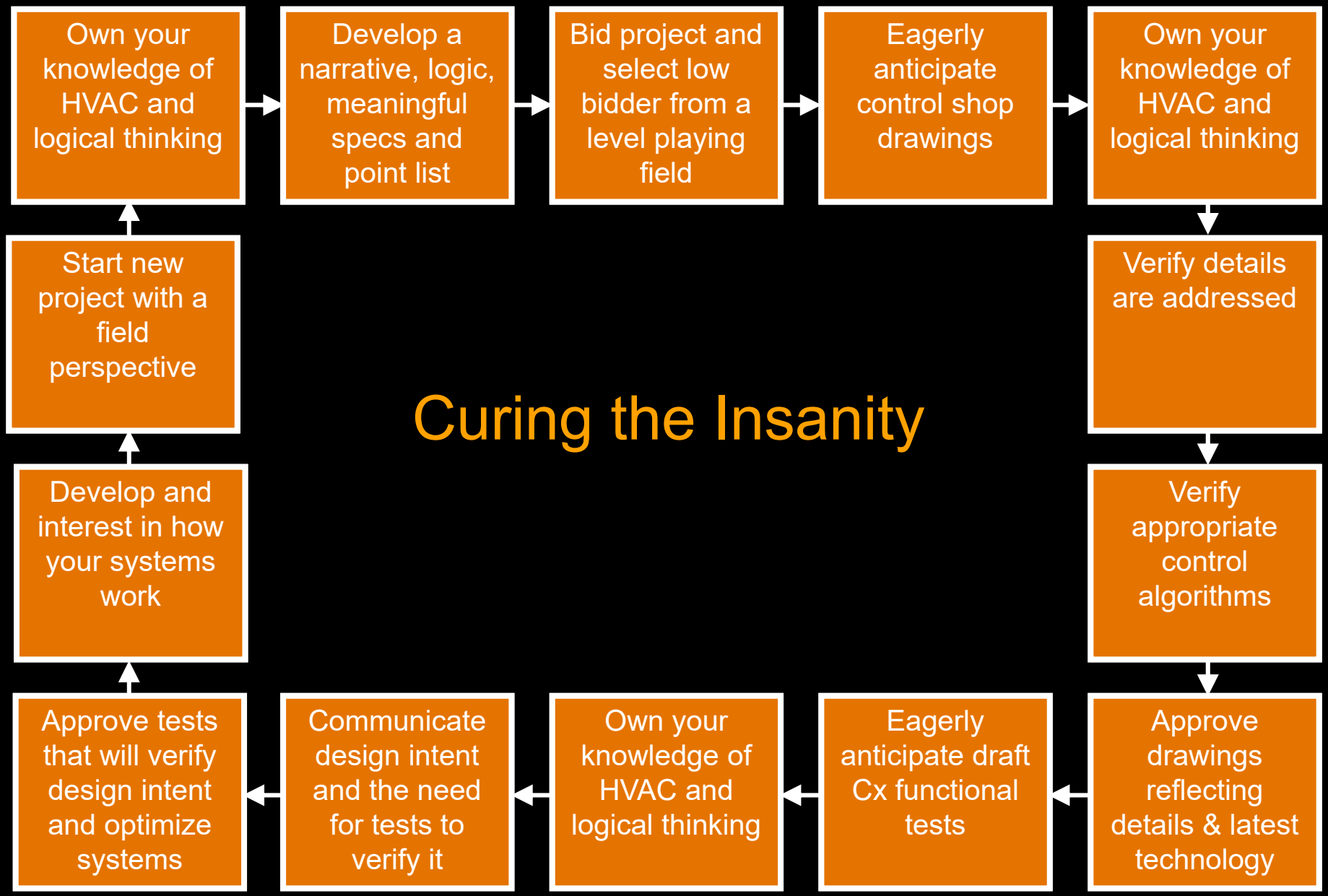
Call up complex graphics

Time how long it takes for them to populate

(While you're at it, see if the data makes sense)

- Mixed air temperature between the OAT and the RAT
- Fan that is commanded on shows "On" status

Curing the Insanity



Control Systems: Design, Performance and Commissioning Issues

Introduction

Control System Building Blocks

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Control System Building Blocks

Automatically adjust a piece of machinery to give us what we want by comparing what is going on to what we want to go on and making appropriate adjustments to the process we want to control

Control System Building Blocks

Automatically adjust a piece of machinery to give us what we want by comparing what is going on to what we want to go on and making appropriate adjustments to the process we want to control

Inputs

Measure the process variable

Control System Building Blocks

Automatically adjust a piece of machinery to give us what we want by comparing what is going on to what we want to go on and making appropriate adjustments to the process we want to control

Inputs	Measure the process variable
Outputs	Adjust the controlled variable

Control System Building Blocks

Automatically adjust a piece of machinery to give us what we want by comparing what is going on to what we want to go on and making appropriate adjustments to the process we want to control

Inputs	Measure the process variable
Outputs	Adjust the controlled variable
Set Point	Our requirements for the process that is under control, which can be fixed or variable

Control System Building Blocks

Automatically adjust a piece of machinery to give us what we want by comparing what is going on to what we want to go on and making appropriate adjustments to the process we want to control

Inputs	Measure the process variable
Outputs	Adjust the controlled variable
Set Point	Our requirements for the process that is under control, which can be fixed or variable
Control Process	Logic and algorithms that tries to bring the controlled variable into agreement with the set point