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Finish with Confidence – how to leverage automated testing and remote monitoring technologies to close out projects

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Course Description

This presentation will explore how modern HVAC analytics can turbocharge the value a commissioning provider delivers.

The concept is simple, train algorithms to look for things that we care about – comfort issues, energy savings opportunities, and equipment health improvements.

We've always known how to do this manually, but technology has evolved to automate much of this investigation.

Fed with trend data from HVAC control systems, software can find things night and day, all year long, based on parameters defined by the commissioning professional.

We will review the core elements of hardware, software and expertise required to collect, visualize and analyze data from an HVAC control system, including both fault detection and automated functional testing.

Learning Objectives

1. Define the automated testing process for new construction.
2. Describe the barriers to successful system testing and turnover of critical systems.
3. Compare the use of fault detection and diagnostic remote monitoring to traditional BMS alarm and interfaces.
4. Identify opportunities to leverage FDD to improve seasonal testing and closeout outcomes for projects.

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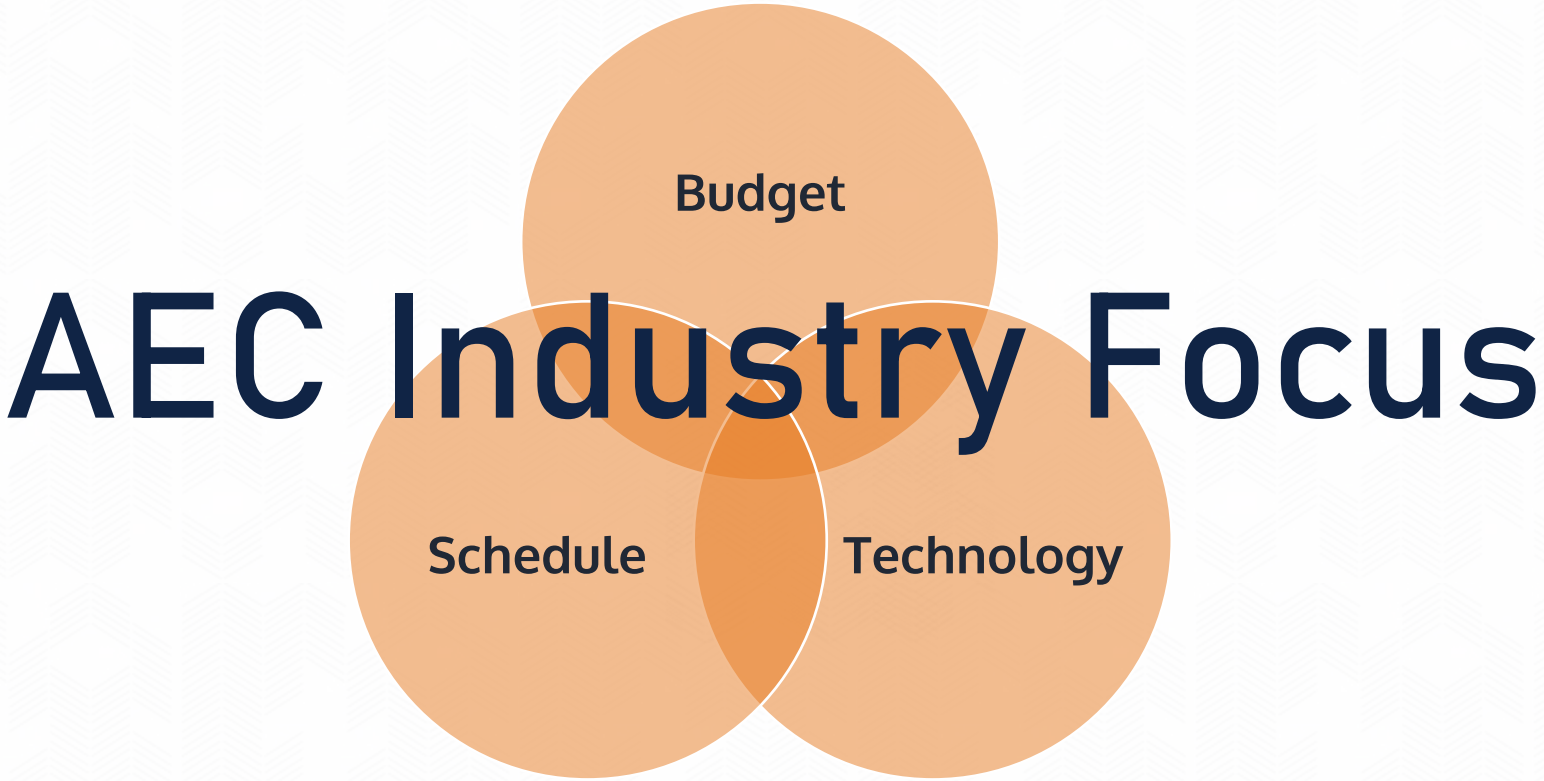
AEC Industry and Technology Struggle



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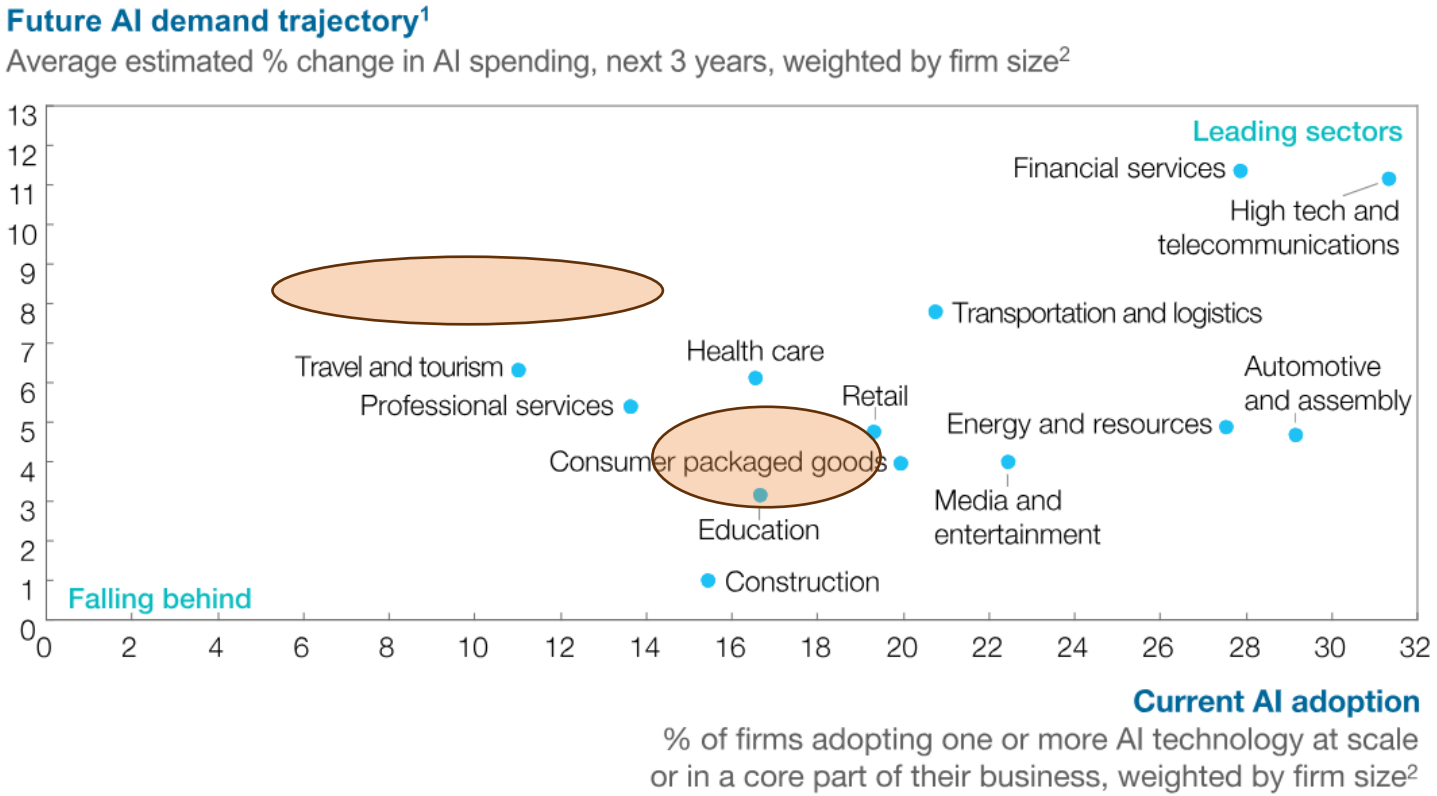
AEC Industry Opportunity

- AEC Industry AI Adoption
- $1.8 Trillion Opportunity
- FDD/Analytics
- Construction schedule optimization.



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AEC Industry and Technology Advancement

Source: Johnson Controls Inc.

Major Technology Advances in AEC:
- Building Management Systems
- Transition from manual drafting, to CAD, to Revit.
- Contractors implementing document management and Construction Cloud MEP coordination.

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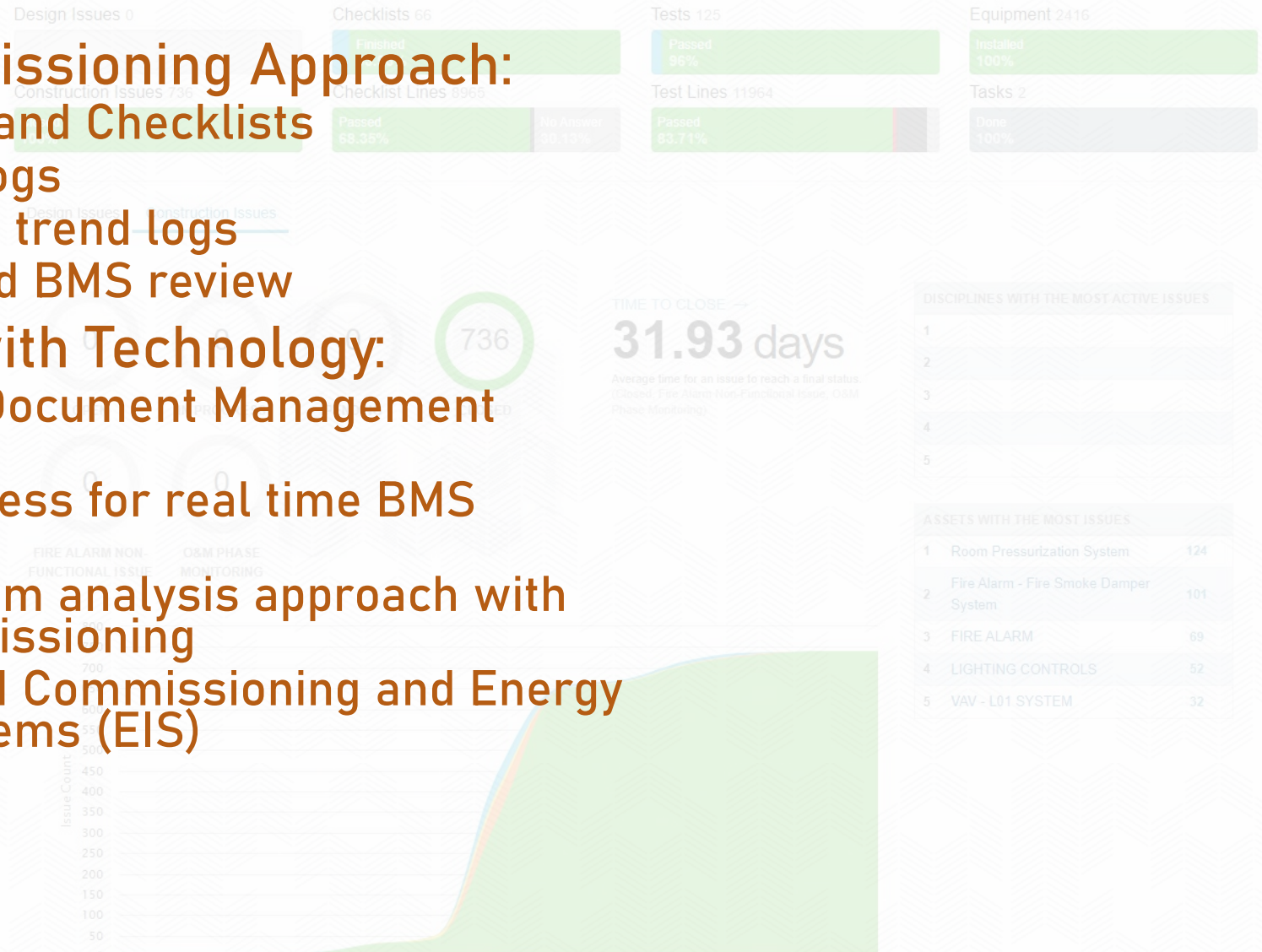
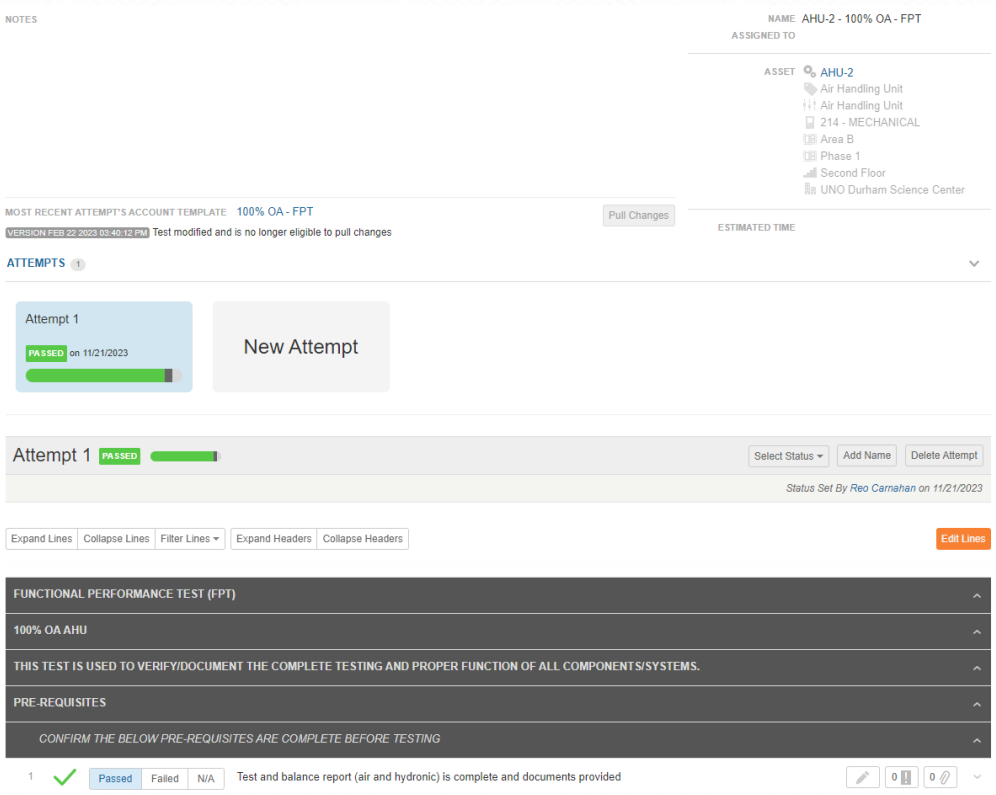
Leverage Technology with Commissioning

- Traditional Commissioning Approach:
  - Hard Copy Tests and Checklists
  - Excel file issue logs
  - Excel based BMS trend logs
  - Screenshot based BMS review
- Commissioning with Technology:
  - Commissioning Document Management Software
  - Remote/VPN access for real time BMS review
  - Testing and system analysis approach with connected commissioning
  - Monitoring Based Commissioning and Energy Information Systems (EIS)



Cx Document Management

- Real time tracking of project status.
- Integrate and connect into contractor document management.
- Track and update equipment assets.
- Integrate data into CMMS.
- Future AI options.
- Not just for new construction.



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Flavors of Commissioning

New Construction	Existing Facilities	Existing Facilities
"Project"	"Project"	"Program"
Short-Term	Short-Term	Long-Term

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What is MBCx

- Applies technology to traditional NCx and EBCx processes.
- Used to be heavy trend data review and ongoing manual analysis.
- Often leverages Fault Detection and Diagnostics (FDD).
  - Rule based data to identify possible performance issues.
- Drives energy savings.
- MBCx= Ongoing Trend Analyst + FDD + ongoing implementation

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Why MBCx

- Owner:
  - Data Transparency and Access.
  - Efficiently find opportunities.
  - Deeper energy savings.
- Cx Provider:
  - Ease of trend data.
  - See the big picture.
  - Easy to evaluate.
  - Embrace our inner nerd.

Analysis	Start Date	Notes Summary	Tasks	Cost	E	C	M	Actions
AHU Coils	3/9/2024	Leaking pre-heating coil valve. Simultaneous heating and cooling.	2	$30	10	0	6	
AHU Coils	3/9/2024	Heating and cooling cycling. Leaking pre-heating coil valve. Simultaneous heating and cooling. Valve short cycling.	1	$26	9	4	6	
CHW Loop	3/9/2024	Calculated load mismatch. Flow not correlated with pump speed(s). Low loop temp difference.	2	$13	5	0	4	
AHU Economizer	3/9/2024	Damper short cycling. Heating on, economizer should be off. Mixed air temp lower than setpoint.	1	$9	3	0	5	
AHU Economizer	3/9/2024	Excess mechanical cooling. Flow imbalance. Mixed air temp higher than setpoint.	1	$8	3	0	5	
AHU Coils	3/9/2024	Jumping sensor error. Out of range sensor error. Simultaneous heating and cooling.	0	$6	2	0	2	
AHU Fan	3/9/2024	Return air static pressure higher than setpoint. Room air static pressure lower than setpoint (IAQ).	1	$4	1	10	6	
HW Loop	3/9/2024	Low loop temp difference. Supply temp lower than setpoint.	0	$4	2	0	5	
AHU Fan	3/9/2024	Fan on while unoccupied. Filter pressure sensor drift (IAQ).	0	$4	2	0	4	
HW Loop	3/9/2024	Jumping sensor error. Low loop temp difference. Out of range sensor error.	0	$4	1	0	2	
Zone Unit	3/9/2024	Zone on while unoccupied.	0	$3	3	0	2	
AHU Heat Recovery	3/9/2024	Low heat recovery effectiveness.	0	$3	1	0	2	
Zone Unit	3/9/2024	Zone on while unoccupied.	0	$2	2	0	2	
Zone Unit	3/9/2024	Leaking heating coil valve. Supply air flow higher than setpoint (IAQ). Zone supply damper stuck open.	0	$1	2	10	4	
Zone Unit	3/9/2024	Heating and cooling setpoints close together. No night setback. Occupancy sensor on longer than expected.	0	$1	2	4	2	

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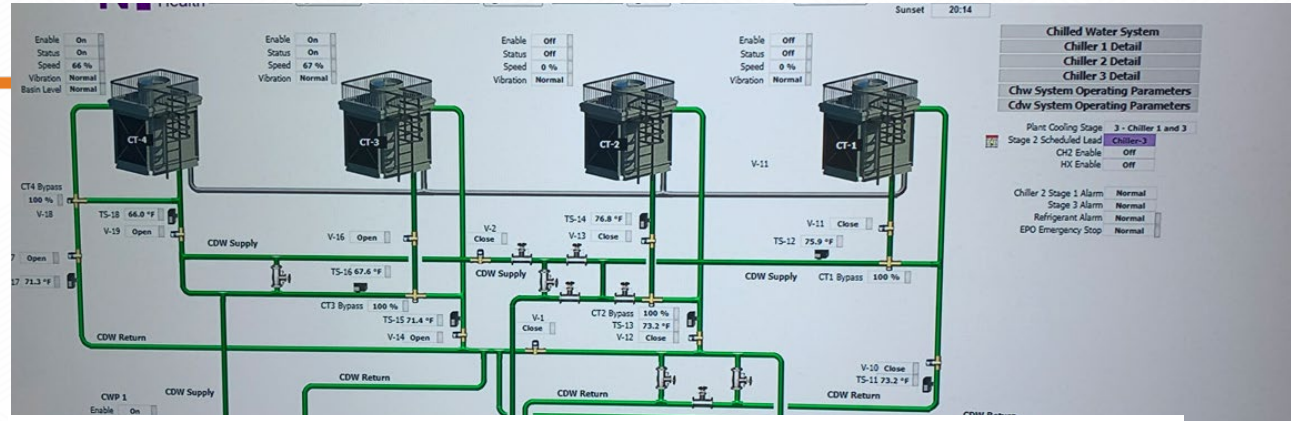
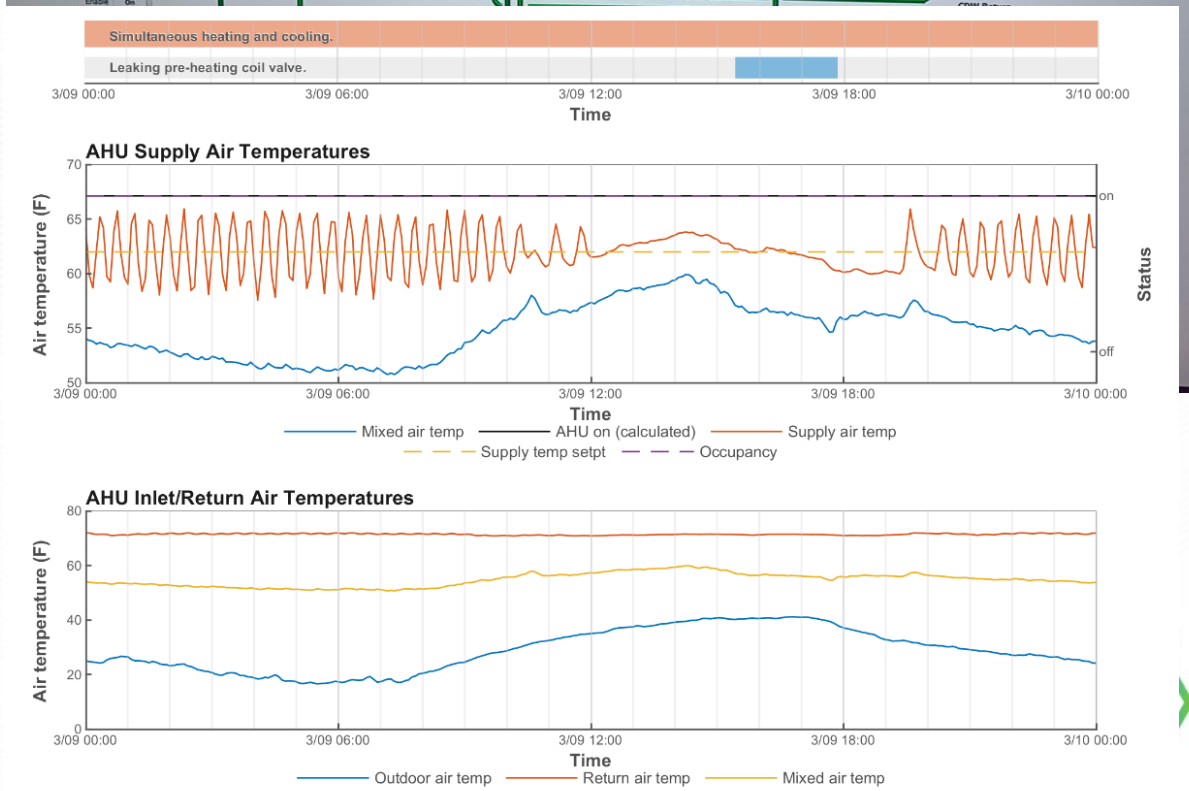
Can’t my BMS do that?

- Improved trend data resolution through FDD and MBCx software.
- BMS is largely reactive based to generate alarms based on simple thresholds.
- BMS trends are mostly archived or overridden after a certain time period.
- Integration across multiple vendors/platforms for many buildings is expensive.
- Deeper data transfer and integration to “outside” data points.
- MBCx programs can offer visibility beyond the BMS staff.





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Traditional NCx – Common Challenges

- ✕ Labor-Intensive
- ✕ Occupied Spaces
- ✕ Constrained Schedules
- ✕ Seasonal Aspects
- ✕ Remote Access to BAS Hard to Obtain
- ✕ Trend Data is Lacking

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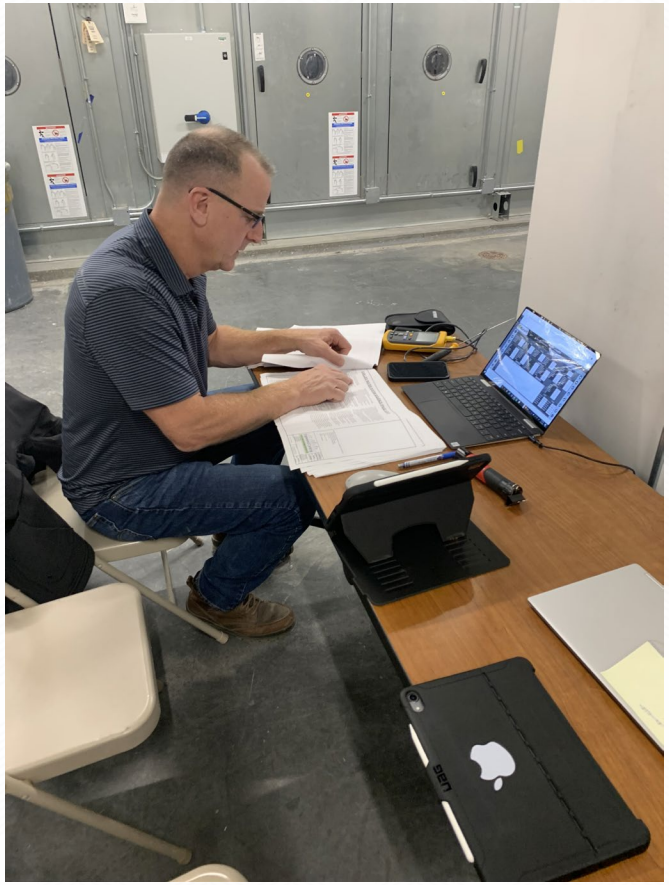
Traditional NCx – Testing Delays



- ✕ Contractor pre-testing
- ✕ Network install and connection
- ✕ Integration details
- ✕ Partial graphics/trends
- ✕ Details – the final 5%

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Monitoring Based Cx Approach to NCx

- Save time with clean trend formats
- More granular data
- Proactive review of system operation
- Eliminate scheduling headaches
- Adapt to seasonal changes
- Richer data to facilitate training

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Traditional EBCx – Common Challenges

- ✕ Screenshots with phone
- ✕ Excel downloads with messy formatting
- ✕ Occupancy challenges – live building
- ✕ Lacking trend data
- ✕ Inconsistent onsite BMS knowledge
- ✕ Report/Study Focused

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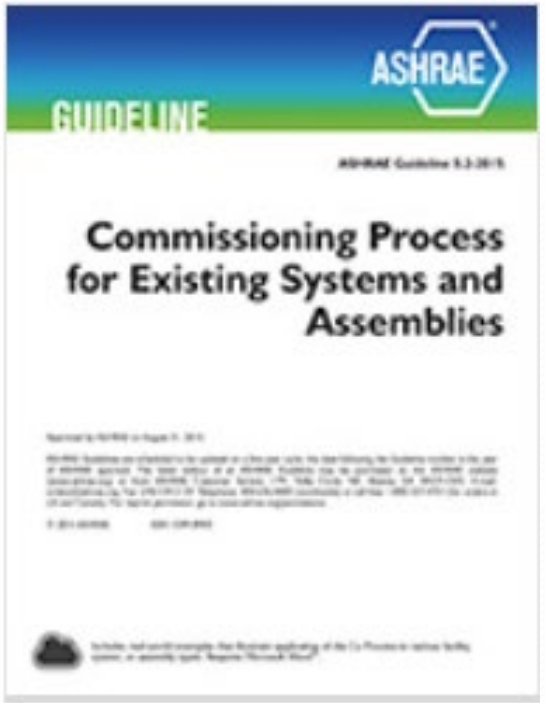
Monitoring Based Cx Approach to EBCx



- Access points that weren't originally integrated
- Utilize "virtual" metering to supplement energy metering
- Eliminate scheduling headaches
- Supports deeper analysis/findings
- Immediate feedback on operation

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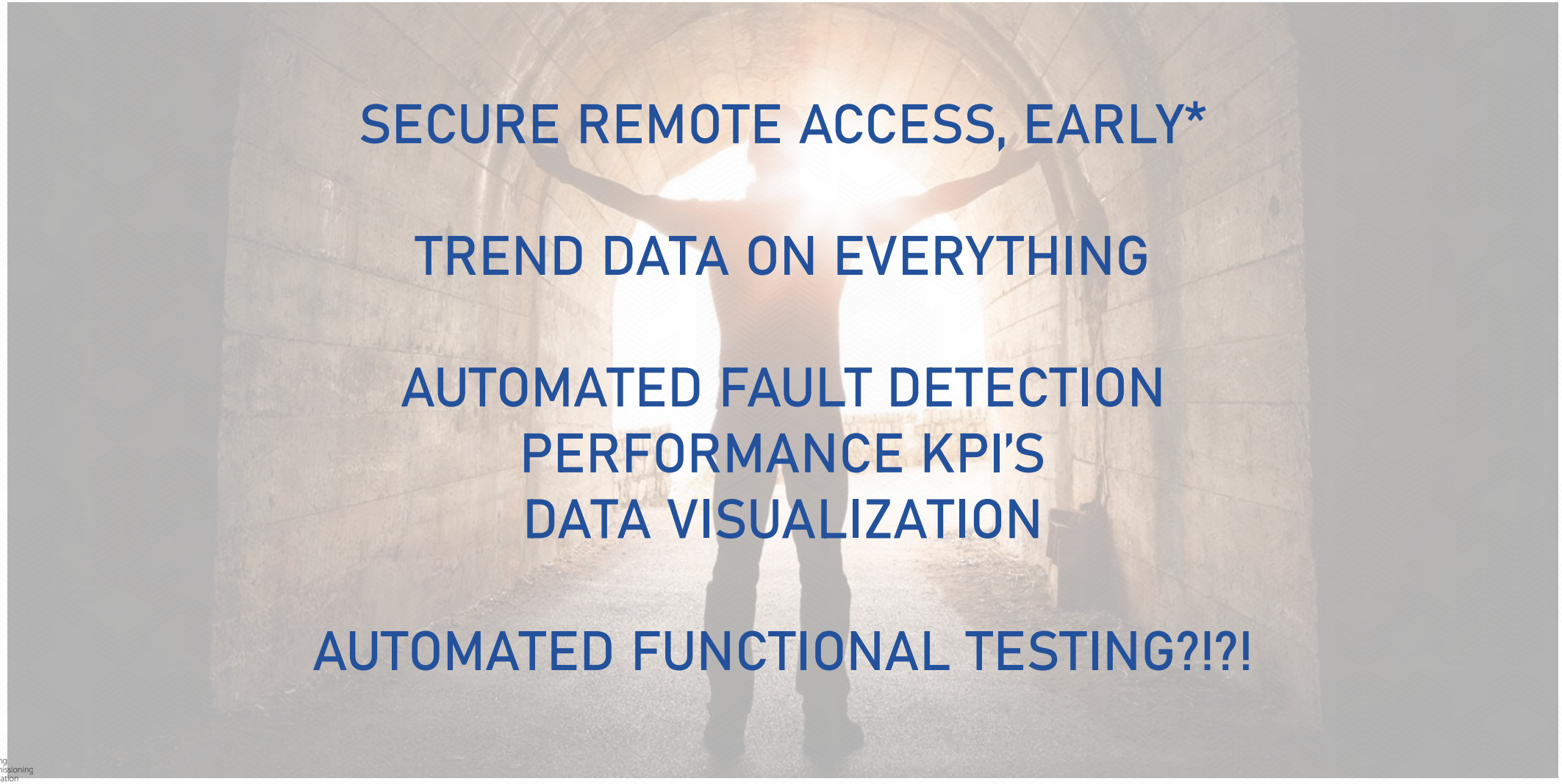
This is What We Really Want



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Quick Revisit – Flavors of Cx

New Construction	Existing Facilities	Existing Facilities
"Project"	"Project"	"Program"
Short-Term	Short-Term	Long-Term

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Connected Cx Today

- ✓ Do-It-Yourself Options
- ✓ BAS Vendor Optionality
- ✓ Tech/FDD Providers
- ✓ Turn-Key Options

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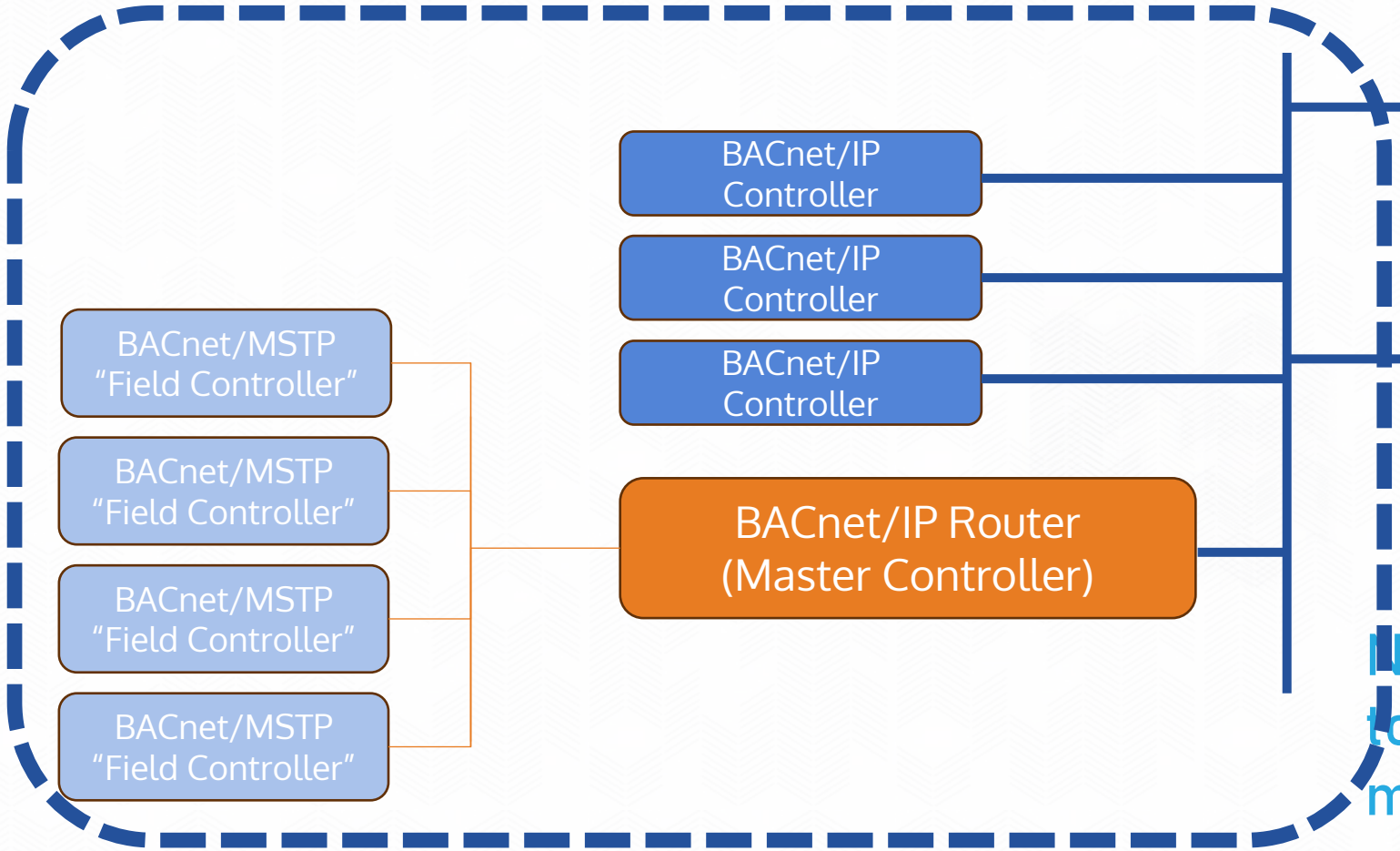
Get Connected



Need a way to connect software to the BAS network… there are multiple ways to accomplish this.

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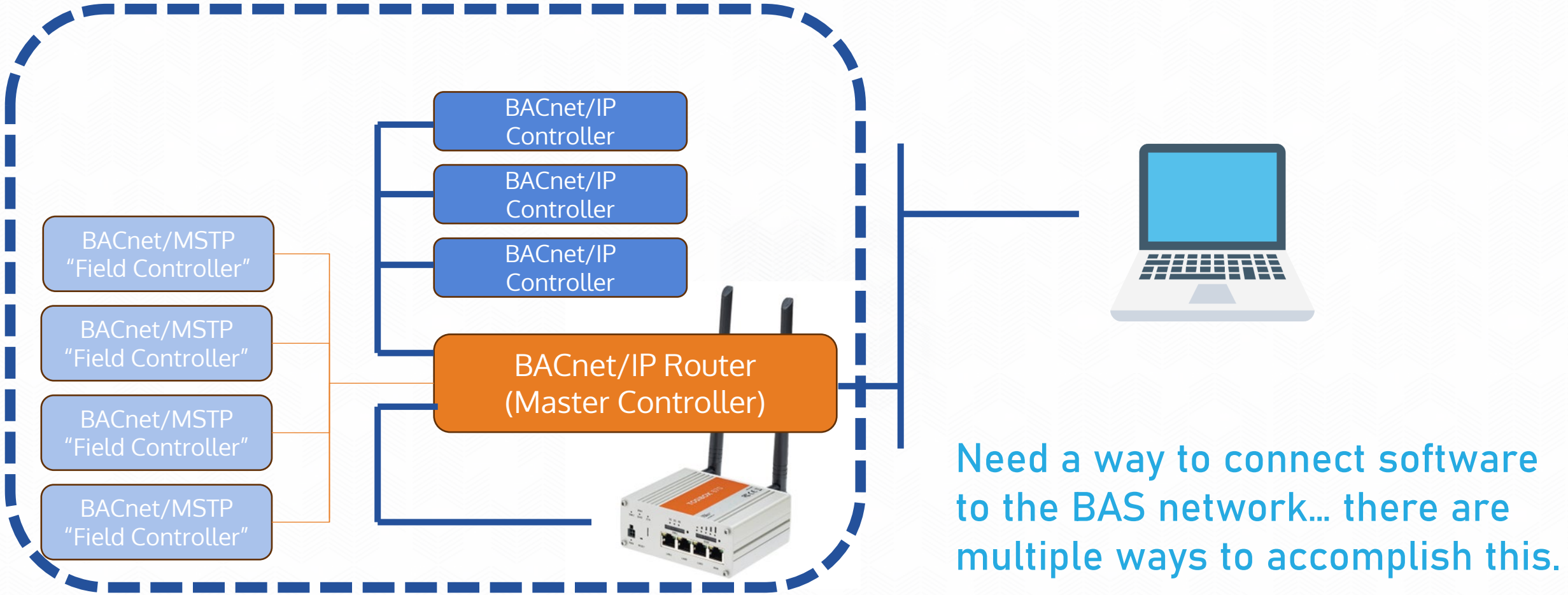
Secondary Subnet – Isolated From Owner



Need a way to connect software to the BAS network… there are multiple ways to accomplish this.

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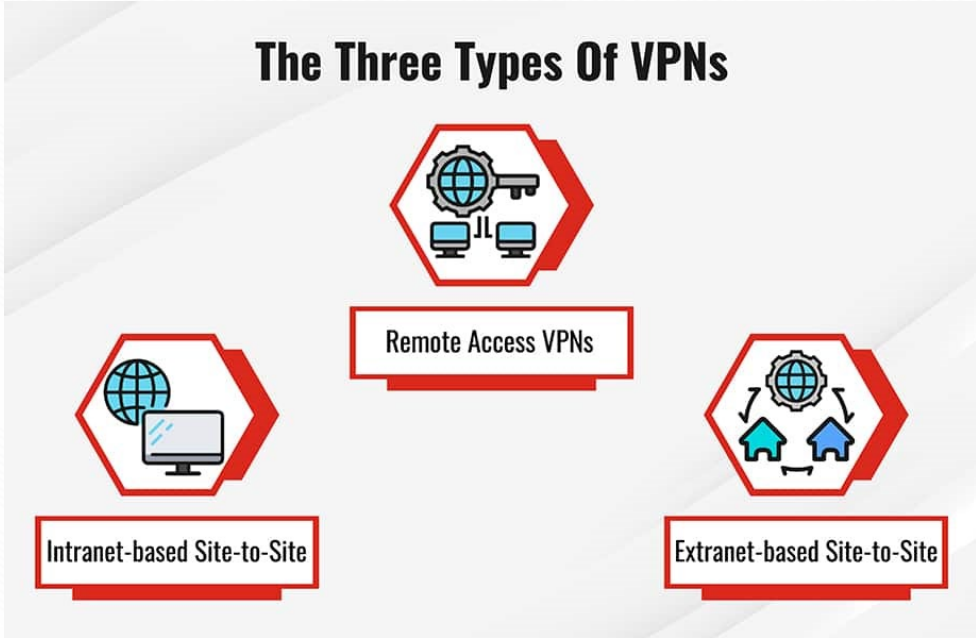
Cybersecurity – The VPN

- ✓ Point-to-Point VPN Technology (Private and Invisible from the Internet)
- ✓ 256 AES Encrypted
- ✓ Physical First, Multi-Factor Authentication
- ✓ Outbound Ports Only (No Inbound Ports Ever, No Port Forwarding, No Static IP)
- ✓ User Access Control and Auditing



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Make Connections to HVAC Devices

IP Address + DeviceID + Network No. + MAC Address

- ✓ “Discovery”
- ✓ BAS Submittal
- ✓ BAS Vendor
- ✓ BAS UI

id	connStatus	connState	uri	bacnetConn	bacnetDeviceName
AC-1	Ok	Open	bacnet://10.155.214.4/12012?dnet=12&dadr=c	✓	MelcoBEMS MINI (A1M)
AC-2	Ok	Open	bacnet://10.155.214.4/23009?dnet=23&dadr=9	✓	MelcoBEMS MINI (A1M)
AC-3	Ok	Open	bacnet://10.155.214.4/23010?dnet=23&dadr=a	✓	MelcoBEMS MINI (A1M)
AC-4	Ok	Open	bacnet://10.155.214.3/12013?dnet=12&dadr=d	✓	MelcoBEMS MINI (A1M)
AC-5	Ok	Open	bacnet://10.155.214.3/12014?dnet=12&dadr=e	✓	MelcoBEMS MINI (A1M)
AHU-1	Ok	Open	bacnet://10.155.214.3/11026?dnet=11&dadr=1a	✓	AHU-1 DiningRm
AHU-2	Ok	Open	bacnet://10.155.214.3/11027?dnet=11&dadr=1b	✓	AHU-2 MultiPurposeRm
AHU-3	Ok	Open	bacnet://10.155.214.3/11024?dnet=11&dadr=18	✓	AHU-3
AHU-4	Ok	Open	bacnet://10.155.214.4/22012?dnet=22&dadr=c	✓	AHU-4
AHU-5	Ok	Open	bacnet://10.155.214.4/21026?dnet=21&dadr=1a	✓	AHU-5
AHU-6	Ok	Open	bacnet://10.155.214.4/21027?dnet=21&dadr=1b	✓	AHU-6
AHU-7	Ok	Open	bacnet://10.155.214.4/22031?dnet=22&dadr=1f	✓	AHU-7
BCI-R	Ok	Open	bacnet://10.155.214.3/11025?dnet=11&dadr=19	✓	RTU-1
CHW-PLANT	Ok	Open	bacnet://10.155.214.3/11029?dnet=11&dadr=1d	✓	CHW-Plant
HW-PLANT	Ok	Open	bacnet://10.155.214.3/11030?dnet=11&dadr=1e	✓	HW-Plant
VAV-3-1	Ok	Open	bacnet://10.155.214.3/11001?dnet=11&dadr=1	✓	VAV-3.01-Rm-A131
VAV-3-2	Ok	Open	bacnet://10.155.214.3/11002?dnet=11&dadr=2	✓	VAV-3.02-Rm-A130
VAV-3-3	Ok	Open	bacnet://10.155.214.3/11003?dnet=11&dadr=3	✓	VAV-3.03-Rm-A142
VAV-3-4	Ok	Open	bacnet://10.155.214.3/11004?dnet=11&dadr=4	✓	VAV-3.04-Rm-A143
VAV-3-5	Ok	Open	bacnet://10.155.214.3/11005?dnet=11&dadr=5	✓	VAV-3.05-Rm-A149
VAV-3-6	Ok	Open	bacnet://10.155.214.3/11006?dnet=11&dadr=6	✓	VAV-3.06-Rm-D101
VAV-3-7	Ok	Open	bacnet://10.155.214.3/11007?dnet=11&dadr=7	✓	VAV-3.07-Mech-C138
VAV-3-8	Ok	Open	bacnet://10.155.214.3/11008?dnet=11&dadr=8	✓	VAV-3.08-IDF-C142
VAV-3-9	Ok	Open	bacnet://10.155.214.3/11009?dnet=11&dadr=9	✓	VAV-3.09-Elec-C143
VAV-3-10	Ok	Open	bacnet://10.155.214.3/11010?dnet=11&dadr=a	✓	VAV-3.10-Rm-C100

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Map Points

id	curVal	curStatus	cur...	w...	write...	writeSt...	wri...	hisStat...	h...	bacnetConnRef	bacnetCur	bacnetDis
Columbia Heights ES CH-CP-11 Building-Schedule	ON	Ok			17	Un...		Ok		CH-MainController	BV1	BUILDING_SCH_BV_MUX
Columbia Heights ES CH-CP-11 CP-Command	ON	Ok			17	Un...		Ok		CH-MainController	BO1202	CH_DHW_CP11_C
Columbia Heights ES CH-EF-14 Building-Schedule	ON	Ok			17	Un...		Ok		CH-MainController	BV1	BUILDING_SCH_BV_MUX
Columbia Heights ES CH-EF-14 EF-Command	ON	Ok			17	Un...		Ok		CH-MainController	BO1203	CH_EF14_C
Columbia Heights ES CH-EF-15 Building-Schedule	ON	Ok			17	Un...		Ok		CH-MainController	BV1	BUILDING_SCH_BV_MUX
Columbia Heights ES CH-EF-15 EF-Command	ON	Ok			17	Un...		Ok		CH-MainController	BO1204	CH_EF15_C
Columbia Heights ES CH-F-1 Building-Schedule	ON	Ok			17	Ok		Ok		CH-MainController	BV1	BUILDING_SCH_BV_MUX
Columbia Heights ES CH-F-1 Heat	OFF	Ok			17	Un...		Ok		CH-MainController	BO1101	CH_F1_HEAT_C
Columbia Heights ES CH-F-1 MA-Damper	10%	Ok			17	Un...		Ok		CH-MainController	AO1301	CH_F1_MAD_C
Columbia Heights ES CH-F-1 Min-OA-Damper	10%	Ok						Ok		CH-MainController	AV23	CH_F1_MIN_OAD_POS
Columbia Heights ES CH-F-1 Mode	Occupied	Ok						Ok		CH-MainController	MSV1	F1_MODE
Columbia Heights ES CH-F-1 OccSpaceSP	68°F	Ok			17	Ok		Ok		CH-MainController	AV11	F1_OCC_RT_SP
Columbia Heights ES CH-F-1 SA-Temp	75.43°F	Ok						Ok		CH-MainController	AI1101	CH_F1_SAT
Columbia Heights ES CH-F-1 SF-Command	ON	Ok			17	Un...		Ok		CH-MainController	BO1102	CH_F1_SF_C
Columbia Heights ES CH-F-1 SF-Status	ON	Ok						Ok		CH-MainController	BV11	CH_F1_SF_S_BV
Columbia Heights ES CH-F-1 Space-CO2	412ppm	Ok						Ok		CH-MainController	AI201004	CH_F1_CO2

May have to look at live values to confirm what you want

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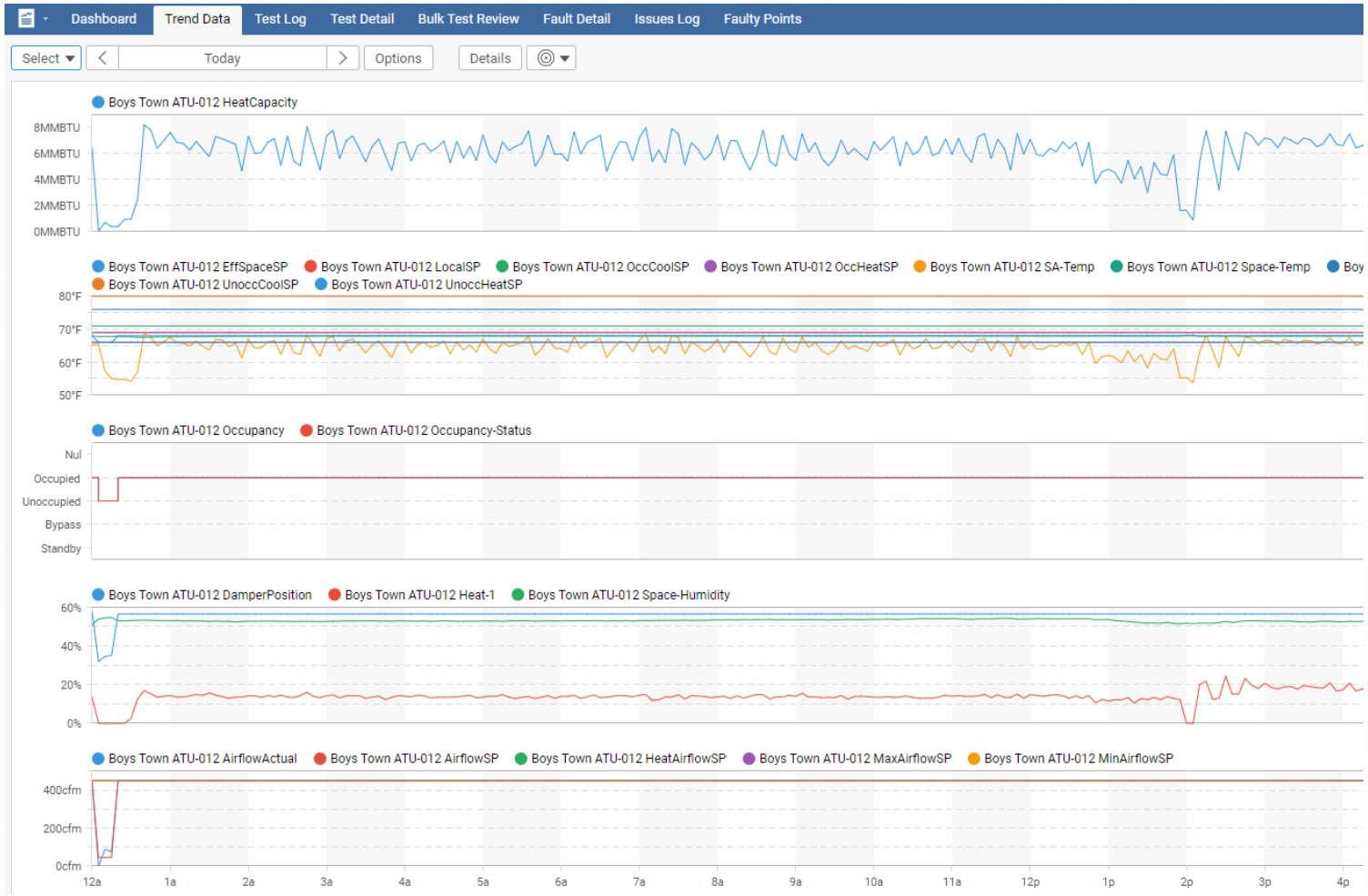
Start Collecting Trend Data



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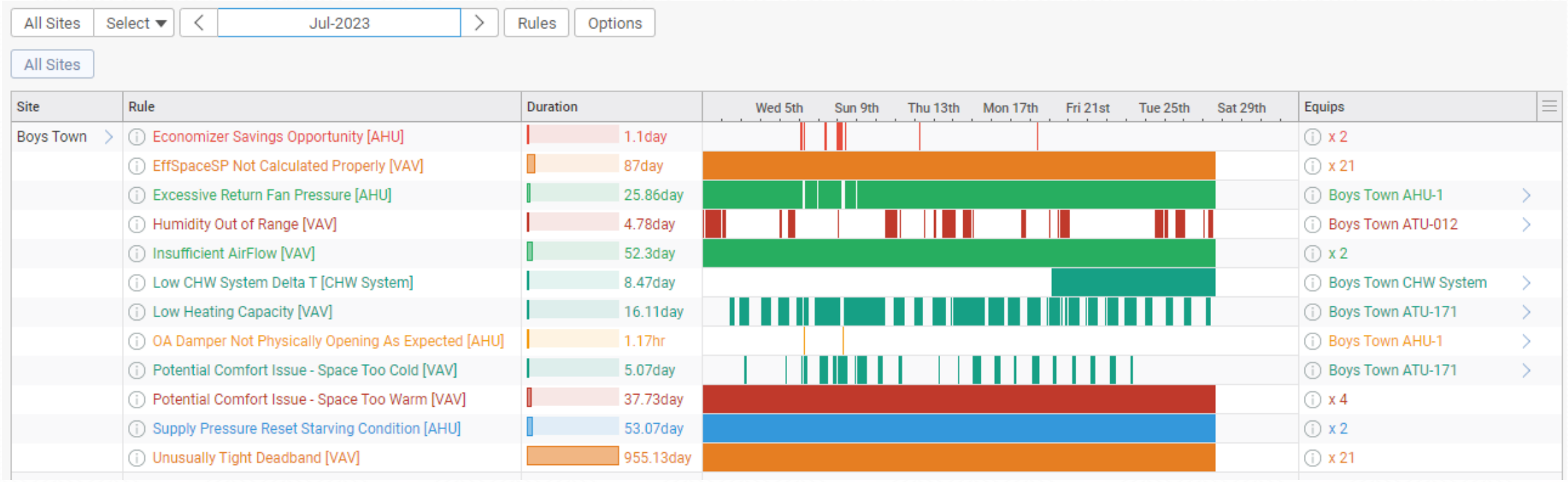
Automated Fault Detection



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Automated KPI’s

All Sites | Select | 26-Jul-2023 | Rules | Options

All Sites | Boys Town

Equip	Run Hours - Heating [VAV]
Boys Town ATU-005	23.92hr
Boys Town ATU-116A	23.92hr
Boys Town ATU-135	23.92hr
Boys Town ATU-139	23.92hr
Boys Town ATU-146B	23.92hr
Boys Town ATU-156	23.92hr
Boys Town ATU-159	23.92hr
Boys Town ATU-169	23.92hr
Boys Town ATU-171	23.92hr
Boys Town ATU-173	23.92hr
Boys Town ATU-174	23.92hr
Boys Town ATU-131	23.83hr
Boys Town ATU-168	23.58hr
Boys Town ATU-012	23.42hr
Boys Town ATU-161	23.08hr
Boys Town ATU-152	20.67hr
Boys Town ATU-143	18.25hr
Boys Town ATU-157	
Boys Town ATU-146C	
Boys Town ATU-113	
Boys Town ATU-141	
Boys Town ATU-105	
Boys Town ATU-125	
Boys Town ATU-013	
Boys Town ATU-106	
Boys Town ATU-108	11hr
Boys Town ATU-177	9.58hr
Boys Town ATU-121	7.42hr
Boys Town ATU-126	3.25hr

Site	Equipment	Type	FaultActivity Yesterday	FaultActivity LastWeek	FaultActivity LastMonth	Fault Detail	AvgCHWSTemp LastWeek	Chiller RunHours LastWeek	Pumping RunHours LastWeek
Marshall MS	CHILLER-PLANT-1	VarPrimary-CHW-System	844	4,916	15,340	Review	52.46°F	167.88h	167.88h
Kingswood ES	CH-1	CV-CHW-System	479	3,339	20,694	Review	71.4°F	167.12h	167.87h
Marshall MS	BLDG-15-CHILLER	CV-CHW-System	95	1,102	6,006	Review	47.29°F	167.88h	167.88h

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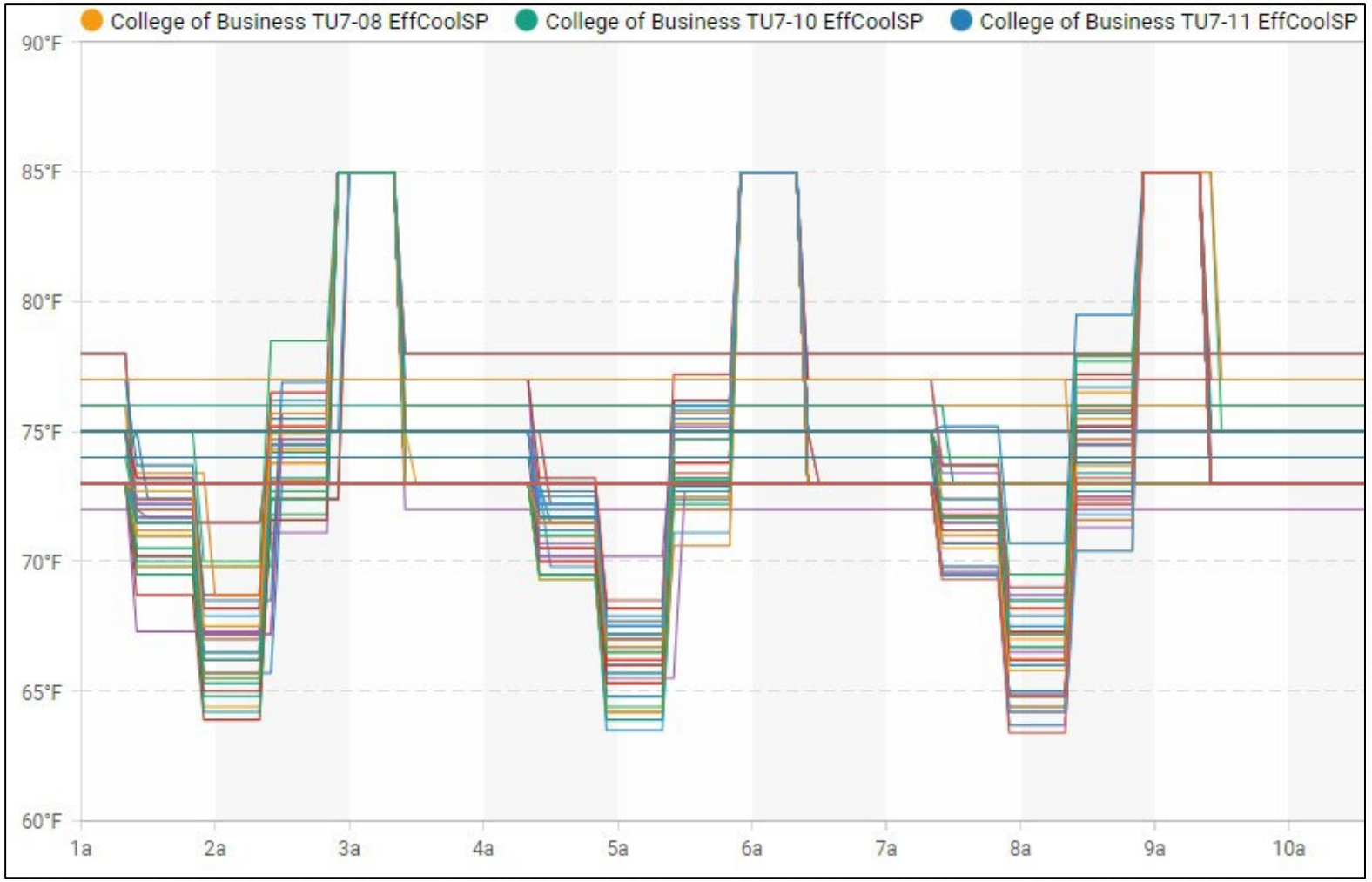
Automated Testing – Force Conditions



"Active"
vs
"Passive"

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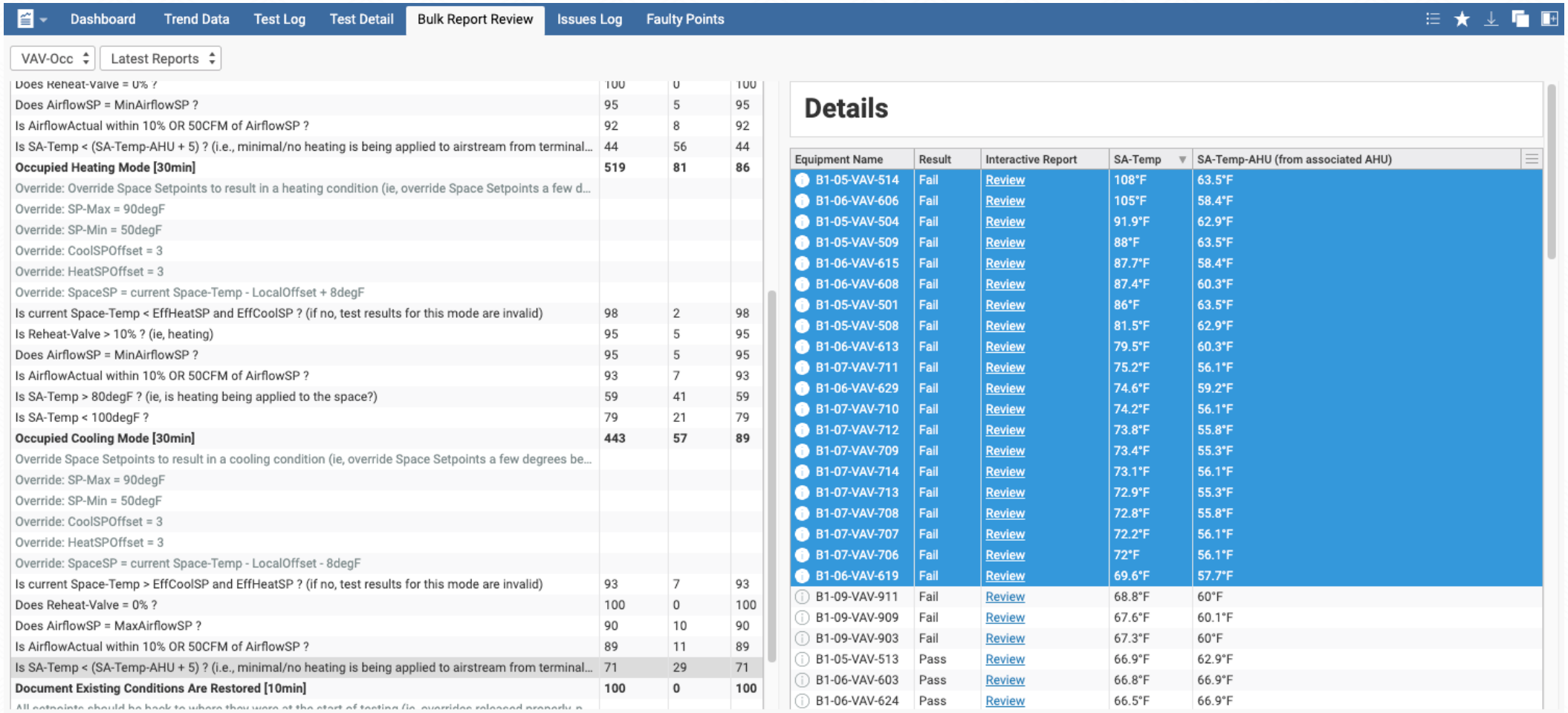
Automated Testing – Review in Bulk



Does Reheat-Valve = 0% ?	100	0	100
Does AirflowSP = MinAirflowSP ?	95	5	95
Is AirflowActual within 10% OR 50CFM of AirflowSP ?	92	8	92
Is SA-Temp < (SA-Temp-AHU + 5) ? (i.e., minimal/no heating is being applied to airstream from terminal...	44	56	44
Occupied Heating Mode [30min]	**519**	**81**	**86**
Override: Override Space Setpoints to result in a heating condition (ie, override Space Setpoints a few d...			
Override: SP-Max = 90degF			
Override: SP-Min = 50degF			
Override: CoolSPOffset = 3			
Override: HeatSPOffset = 3			
Override: SpaceSP = current Space-Temp - LocalOffset + 8degF			
Is current Space-Temp < EffHeatSP and EffCoolSP ? (if no, test results for this mode are invalid)	98	2	98
Is Reheat-Valve > 10% ? (ie, heating)	95	5	95
Does AirflowSP = MinAirflowSP ?	95	5	95
Is AirflowActual within 10% OR 50CFM of AirflowSP ?	93	7	93
Is SA-Temp > 80degF ? (ie, is heating being applied to the space?)	59	41	59
Is SA-Temp < 100degF ?	79	21	79
Occupied Cooling Mode [30min]	**443**	**57**	**89**
Override Space Setpoints to result in a cooling condition (ie, override Space Setpoints a few degrees be...			
Override: SP-Max = 90degF			
Override: SP-Min = 50degF			
Override: CoolSPOffset = 3			
Override: HeatSPOffset = 3			
Override: SpaceSP = current Space-Temp - LocalOffset - 8degF			
Is current Space-Temp > EffCoolSP and EffHeatSP ? (if no, test results for this mode are invalid)	93	7	93
Does Reheat-Valve = 0% ?	100	0	100
Does AirflowSP = MaxAirflowSP ?	90	10	90
Is AirflowActual within 10% OR 50CFM of AirflowSP ?	89	11	89
Is SA-Temp < (SA-Temp-AHU + 5) ? (i.e., minimal/no heating is being applied to airstream from terminal...	71	29	71
Document Existing Conditions Are Restored [10min]	**100**	**0**	**100**

Equipment Name	Result	Interactive Report	SA-Temp	SA-Temp-AHU (from associated AHU)
B1-05-VAV-514	Fail	Review	108°F	63.5°F
B1-06-VAV-606	Fail	Review	105°F	58.4°F
B1-05-VAV-504	Fail	Review	91.9°F	62.9°F
B1-05-VAV-509	Fail	Review	88°F	63.5°F
B1-06-VAV-615	Fail	Review	87.7°F	58.4°F
B1-06-VAV-608	Fail	Review	87.4°F	60.3°F
B1-05-VAV-501	Fail	Review	86°F	63.5°F
B1-05-VAV-508	Fail	Review	81.5°F	62.9°F
B1-06-VAV-613	Fail	Review	79.5°F	60.3°F
B1-07-VAV-711	Fail	Review	75.2°F	56.1°F
B1-06-VAV-629	Fail	Review	74.6°F	59.2°F
B1-07-VAV-710	Fail	Review	74.2°F	56.1°F
B1-07-VAV-712	Fail	Review	73.8°F	55.8°F
B1-07-VAV-709	Fail	Review	73.4°F	55.3°F
B1-07-VAV-714	Fail	Review	73.1°F	56.1°F
B1-07-VAV-713	Fail	Review	72.9°F	55.3°F
B1-07-VAV-708	Fail	Review	72.8°F	55.8°F
B1-07-VAV-707	Fail	Review	72.2°F	56.1°F
B1-07-VAV-706	Fail	Review	72°F	56.1°F
B1-06-VAV-619	Fail	Review	69.6°F	57.7°F
B1-09-VAV-911	Fail	Review	68.8°F	60°F
B1-09-VAV-909	Fail	Review	67.6°F	60.1°F
B1-09-VAV-903	Fail	Review	67.3°F	60°F
B1-05-VAV-513	Pass	Review	66.9°F	62.9°F
B1-06-VAV-603	Pass	Review	66.8°F	66.9°F
B1-06-VAV-624	Pass	Review	66.5°F	66.9°F

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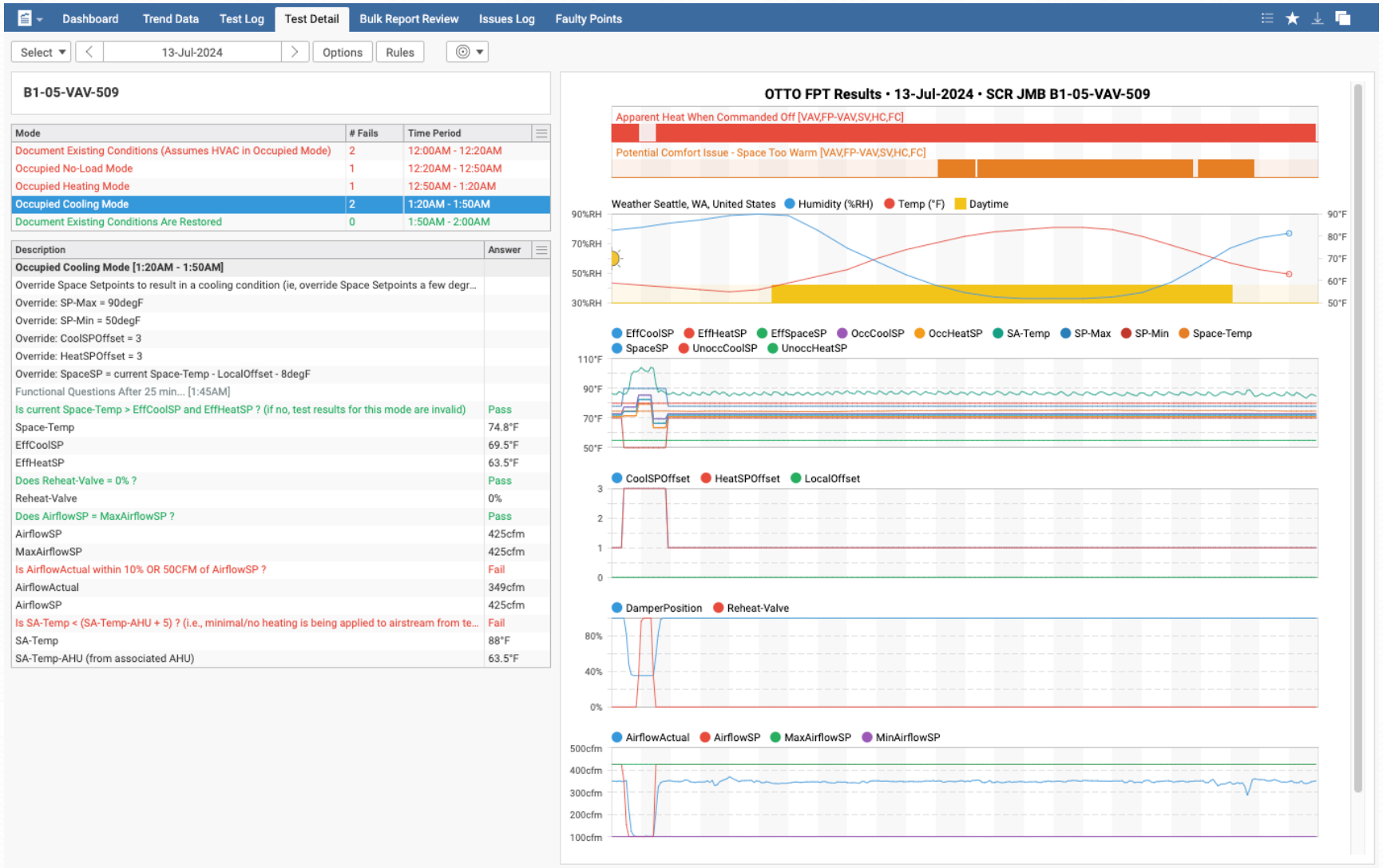
Results in Detail = Confidence



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What Can't (or Shouldn't) be Automated?

Pre-Test Activities:

Start-Up Checklist, Pre-Functional Testing, I/O Verification, Test and Balance

Physical Safeties:

Critical Safety Tests, High Duct Static, Smoke Alarm Interlocks

Other:

Critical zones or processes sensitive to failure

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Project Example

- 125,000 SF Cancer Center
- FDD and automated testing not originally part of commissioning plan.
- Schedule was compressing and project expectation was 100% VAV testing for 170+ VAV terminals.
- Completion date of March 2024, decision for FDD and automated testing in August 2023.
- Graphics online and visible January 2024.
- MBCx program was live early December 2023
- Immediate impact on pre-testing and readiness visibility.
- Tested test batch in January 2024. First batch of VAVs over 4-day period in February 2024.

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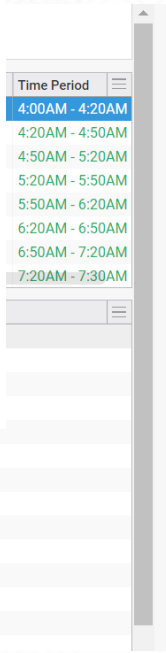
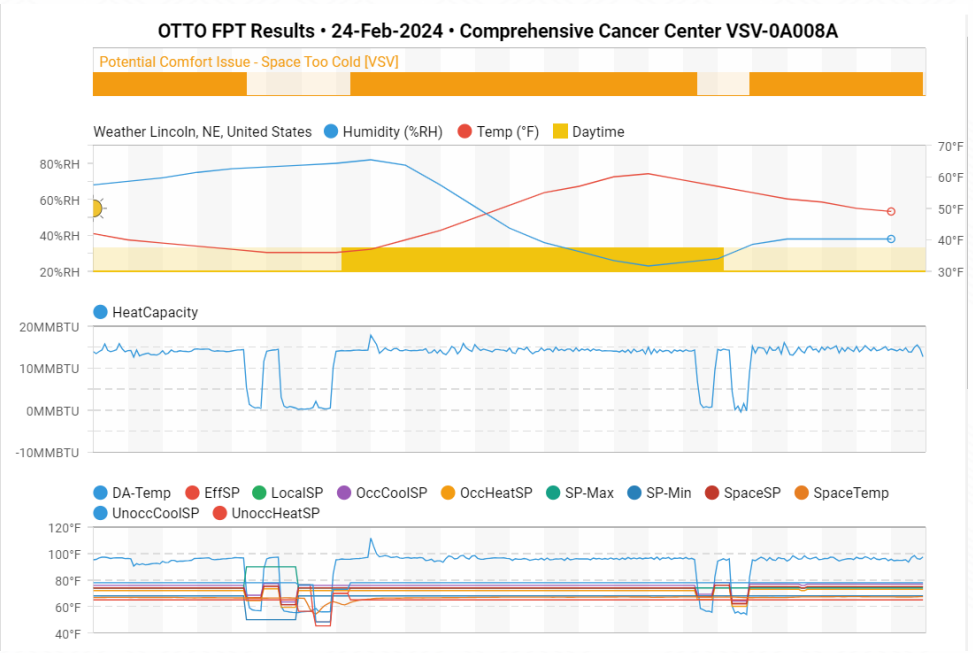
Automated Testing – Lessons Learned

- Equipment running at design set point for HWS, CHWS, and Discharge Air.
- Setpoints on BMS are in place for VAV/terminal unit modes.
- Select VAVs in batches to avoid nuisance trips.
- Run test batch as needed to avoid bulk re-testing.
- Understand zone set points and coil sizing



Does MaxAirflowSP = MaxAirflowSP-Design ?	Pass
MaxAirflowSP	600cfm
MaxAirflowSP-Design	600cfm
Does MinAirflowSP = MinAirflowSP-Design ?	Pass
MinAirflowSP	320cfm
MinAirflowSP-Design	320cfm
Does HeatAirflowSP = HeatAirflowSP-Design ?	Pass
HeatAirflowSP	320cfm
HeatAirflowSP-Design	320cfm
Is Space-Temp < EffSP + 3degF ? (i.e., is steady state ...	Pass



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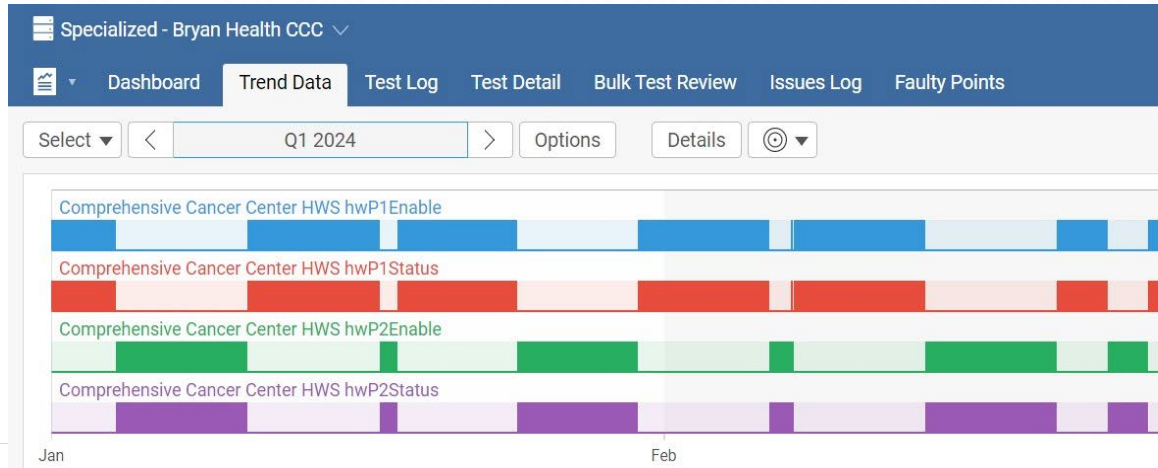
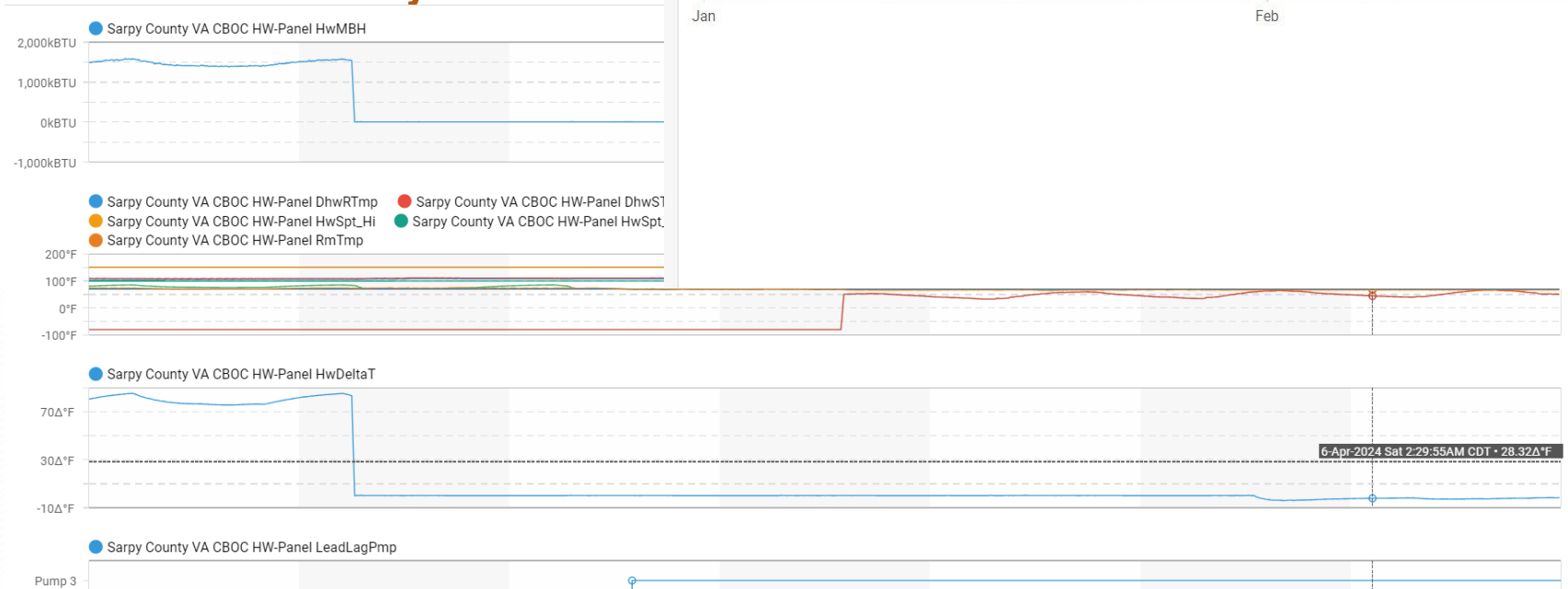
Remote Monitoring/FDD– Lessons Learned

- Getting remote monitoring and FDD started early is a great pre-test before graphics are online.
- Tune faults to actual sequences.
- Provide early input on integrated points.
- Faults and issues should lower as you work through testing.





Finish with Confidence - how to leverage automated testing and remote monitoring technologies to close out projects

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