Commissioning the Building Automation System-
The overlooked key to successful building operations

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Learning Objectives

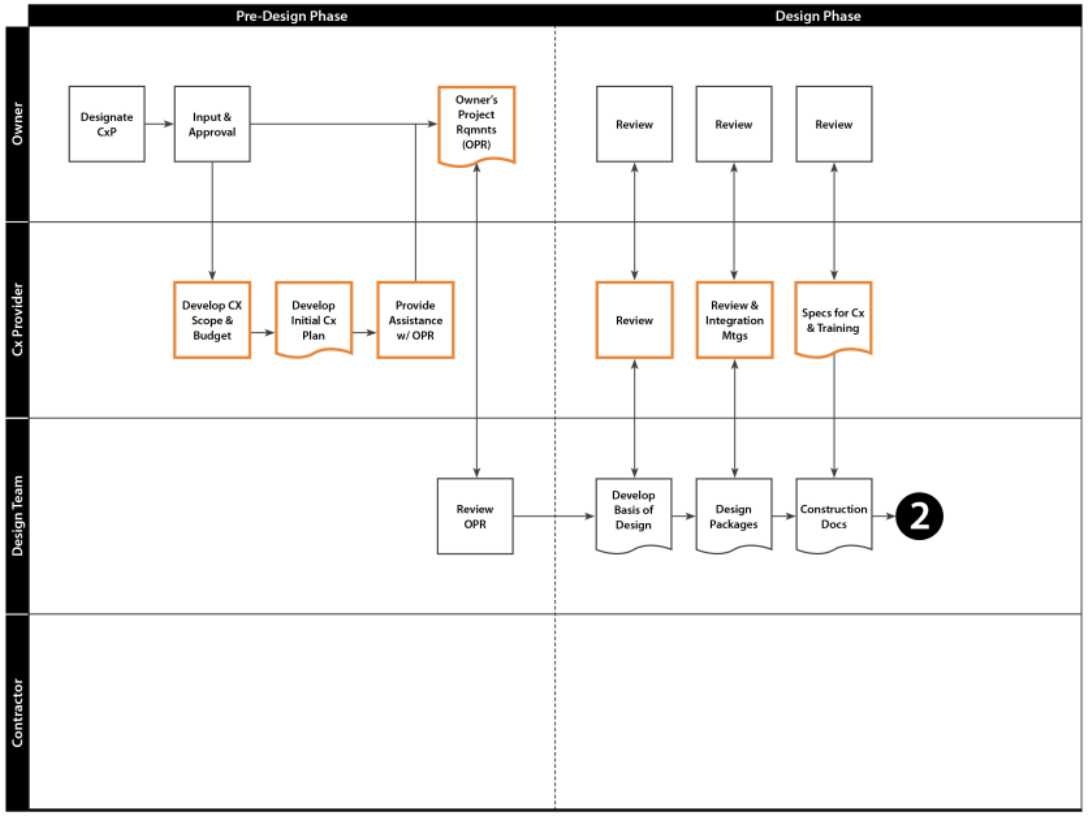
- Know how to integrate the BAS into the commissioning process
- Know the tools and techniques to specify the right BAS to meet the owner's needs
- Know how to request and review graphics submittals, network integration diagrams, and BAS programming
- Know how to functionally test BAS graphics, point naming, and trend setup for consistency and usability

Why commission the BAS?

- The Building Automation System (BAS) is the most touched component of the mechanical system
- Smart Building systems are more connected, more integrated
- Largely ignored by the commissioning process
  - Selected by the trades, not considered a maintainable asset
- Opportunity to provide significant value to the owner/operator

BAS Commissioning Phases

- Pre-Design Phase
  - Specifications
  - Network Architecture
- Design Phase
  - Submittal Review
  - Reviews and Bench Testing
- Construction Phase
  - IT Coordination
  - Functional Performance Testing (FPTs)



BAS/Graphics Specification

Pre-Design Phase – Specifying the BAS

- Owner's Project Requirements (OPR) / Basis of Design (BOD)
- Choose the BAS that fits the OPR/BOD
  - The BAS is typically ignored in the BOD - The CxA should push for more definition
- Questions to guide the BAS selection and network design
  - What systems are to be integrated?
    - Lighting? Room Scheduling? Metering?
    - Additional systems will require an open protocols or gateways for integration
  - How complex is the sequence of operations?
    - More complex sequences require customizable programs and devices

Pre-Design Phase – Specifying the BAS

- IT and Networking requirements?
  - Will the BAS reside on the enterprise network or be stand alone?
  - Who will manage the BAS network and security?
    - IT staff is typically preferable to building operations, but will have their own standards for security and communication protocols
- Open vs. Proprietary architectures
  - Integration with existing enterprise systems
  - Serviceability and vendor networks
- Are analytics being used? Where will they live?
  - Local analytics will require additional servers
  - Cloud-Based analytics will require specific, secure protocols and internet connectivity

Design Phase – Provide a BAS/Graphics specification

- You can only commission to a specification or design
- Get specific
  - Communication protocols
  - Network guidelines
  - Interoperability
  - Trended Points
  - Graphics screenshots
- Specify equipment and point naming standards
- Performance Requirements

Design Phase – Provide a graphics specification

Building site page

This section describes the requirements for graphics on the building site page(s). For each building, the order of graphics or page creation may vary, depending on equipment utilized at the building site, applicability of functions such as summaries or notes, etc.

Aesthetics

- **Building 3D rendering:** create a three-dimensional (3D) rendering of the building for the building page or use a photo that accurately represents the building. The 3D rendering or photo must be produced in a format (e.g. .jpg) that can be uploaded as the building background graphic
- **Page caption:** the building site name should be added to the caption in the upper title bar[6]
- **Hyperlinks/ shortcut buttons:** blue hyperlink buttons should be created for:
  - Back to Main (to navigate to the home page)
  - Central Equipment Types, e.g. chilled water plant. HHWS Plant example shown below (to navigate to the heating hot water system plant, boiler, or other centralized equipment pages)
  - As-Built Drawings, Sequences of Operations, TAB report, and other relevant building documentation.

Design Phase – Provide a graphics specification

Medical Sciences B

BUILDING DOCUMENTATION

- Electrical As-Built Drawings
- Mechanical As-Built Drawings
- Plumbing As-Built Drawings
- BAS Submittal & SOO
- TAB Documentation
- Room Flow Data Sheets

- First Floor
- Second Floor
- AHU-B1
- AHU-B2 & B3
- Exhaust Lab & Gen.
- Exhaust Gen.

Design Phase – Provide a graphics specification

Summaries

This section describes the intent and graphic requirements for the summary tables. Examples of different types of summaries are provided.

- The summary tables allow the user to view at a glance a summary table for the selected type of equipment:
- Clicking on an individual summary will bring up the points listed in the summary table – if there is more than one point, a drop-down menu will allow the user to choose different points to view; a table format can also be viewed (e.g. via Roof page's hyperlink buttons):
- Summaries should be created for air handling units, terminal units, and exhaust & supply fans
- When creating a summary table,[17] select appropriate data points to display equipment operating status, and ensure summary tables are functional, writable, and are bound to the correct points

Summary examples are listed in this section. For the summary table types below, the graphic layout should look similar and all relevant points should be included but not limited to the example graphic, with the intent to assist in quickly troubleshooting and monitoring equipment performance.

- AHU Summary:
  - The graphic layout should look similar and all relevant points should be included but not limited to the example graphic, with the intent to assist in quickly troubleshooting and monitoring equipment performance:

Design Phase – Provide a graphics specification

Air Supply Systems			
	Research	Admin.	Clinic
	AHU-1	AHU-2	AHU-3
SupFanVFDSpeedCmd	71.3 %	72.9 %	73.6 %
SupAirTemp	55.5 °F	56.4 °F	54.7 °F
SupAirTempEffStpt	55.0 °F	55.000	55.0
SupAirStaticPress	1.001 in/wc	0.503 in/wc	0.225 in/wc
SupAirStaticPressEffStpt	1.000	0.500	0.230
RetFanVFDSpeedCmd	57.1 %	58.3 %	40.0 %
ChilledWaterVlvPos	100.0 %	8.9 %	70.7 %
OSAFlow	15864.7 cfm	476.2 cfm	136.8 cfm
EconOSAFlow	15864.7 cfm	876.7 cfm	4543.3 cfm
ExhDmpPos	41.2 %	6.7 %	4.3 %
OsaDmpPos	100.0 %	0.0 %	0.0 %
EconOsaDmpPos	100.0 %	86.9 %	100.0 %

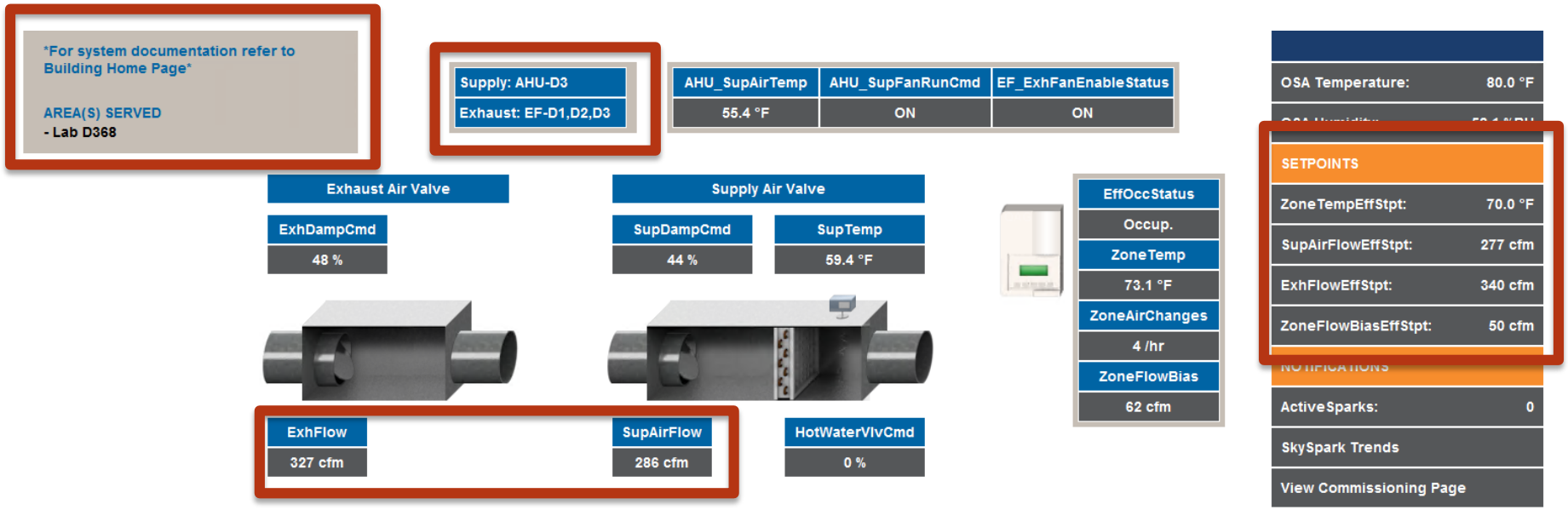
Water Systems					
	CHWP-1	CHWP-2		HHWP-1	HHWP-2
ChwpEnaCmd_1	ON	OFF	HwpEnaCmd	ON	
CHWPStatus_1	ON	OFF	HwpStatus	ON	
CHWPSpeedCmd_1	1.5 %	1.5 %	HwpSpeedCmd	70.6 %	
BldgCHWDiffPress_1	3.785 Δpsi		HotWaterDiffPress	59.9 psig	
BldgCHWDiffPress_2	12.742 Δpsi		BldgHotWaterDpSetpt	60.000 Δpsi	
BldgCHWDiffPressStpt	13.000 Δpsi				

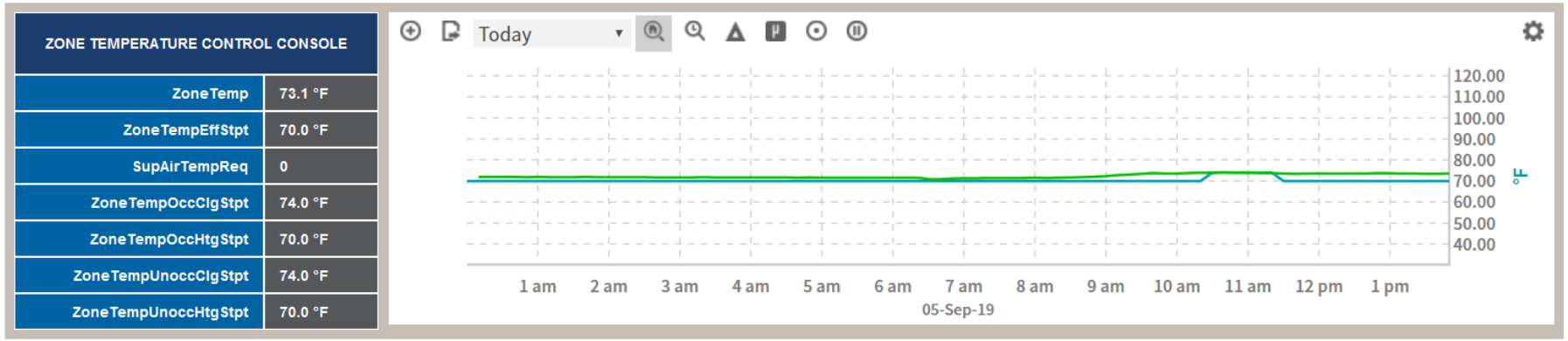
Environmental Rooms			
FanRunStop	ON	MaintenanceOvrd	OFF
RoomTemp1	4.263 °C	EntrapmentAlarm	OFF
RoomTemp2	4.757 °C	LiquidLineSolenoid	ON
AlarmLight	OFF	DoorWindowHeat	ON

Design Phase – Provide a graphics specification

- Terminal Units - Variable Air Volume (VAV) units:
  - Note: if there is no reheat coil, it should not be on the VAV graphic
  - **Hyperlink button:** create "Back to AHU-#" blue hyperlink button below the Back to Floor hyperlink button, to navigate to the AHU serving the VAV; (note: not shown on example graphic below)
  - **Location and Served By labels:** create accurate data displays showing the room location for the terminal unit, and which air handling unit (AHU) serves that terminal unit (see example graphic below)
  - **Room numbers/names:** Room numbers or names should not be hard coded to the graphics, but should be an adjustable point. Should the room number or name change, the graphics will need to be updated. See the section on Floor Page – Functionality – Room numbers/names for more detailed information.
  - **Data points and Overview boxes:** create appropriate and accurate data point displays [e.g. occupancy CMD (occupied), occupancy status (occupied), heating output CMD (%), discharge air temp, damper position CMD (%); supply air temp, heating valve position (%)], and overview boxes, [e.g. Air Flow with flow (cfm), SP (cfm); Zone Temperature with temp, cooling SP, heating SP; Occupied/Unoccupied Set Points with occupied heating & cooling SPs, warm/cool adjustment (+/- degF), unoccupied heating & cooling SPs, Occupied Air Flow Set Points with occupied cooling max & min SPs, occupied heating max & min SPs]

Design Phase – Provide a graphics specification





Network Architecture

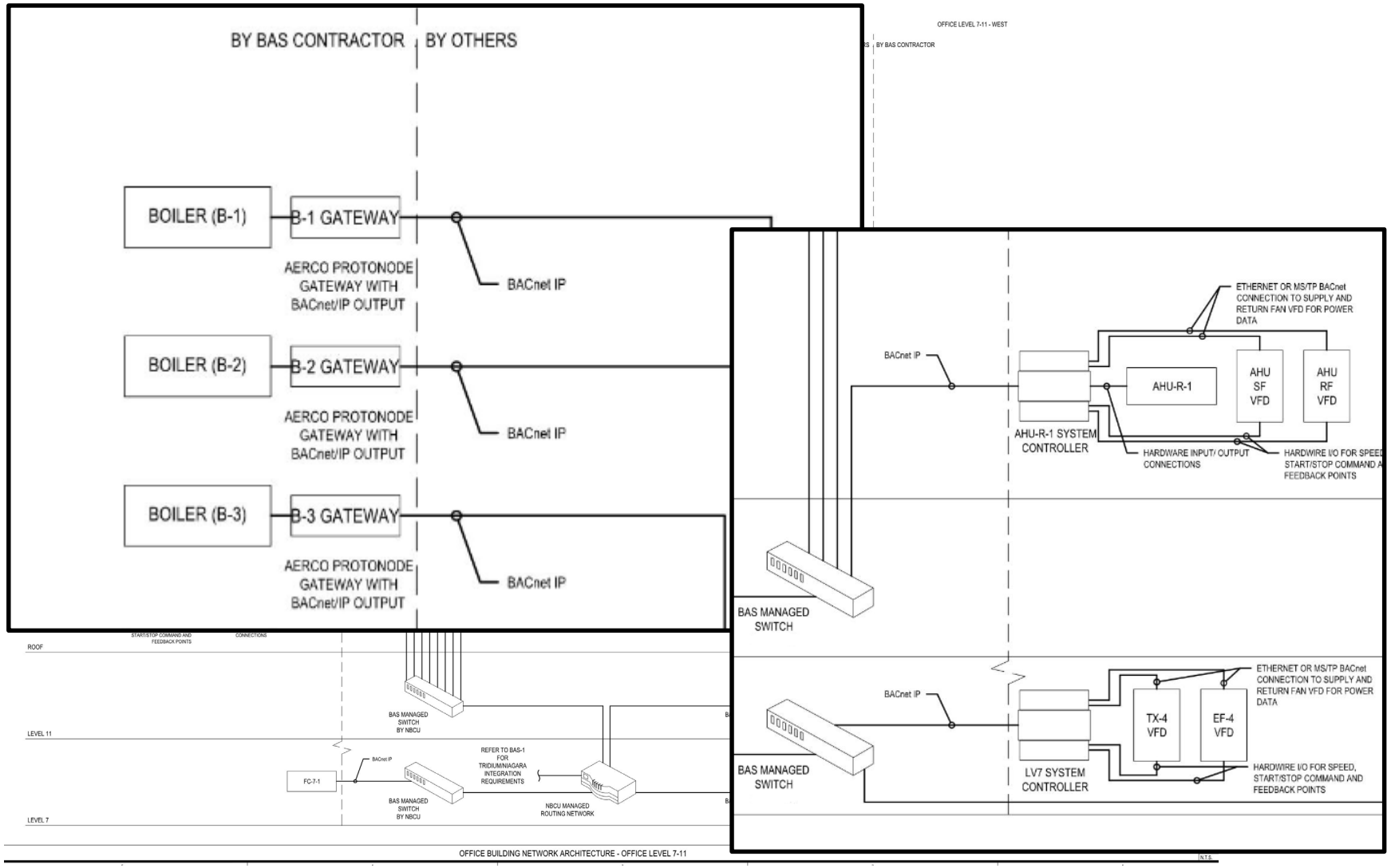
Design Phase – Network Architecture

- Coordination is necessary between the Owner's IT team and the controls contractor
  - Define what protocols are to be used
    - Secure vs. Unsecure
    - Routable vs. Non-routable
    - Proprietary vs. Open
  - Determine who is responsible for providing equipment, IP addresses, and maintenance
- Expectations for non-BAS vendor supplied devices

Submittal Phase – Network Architecture

- Single-line diagram of networked systems
  - Include communication protocols
  - Include firewalls and managed switches
  - Include non-BAS vendor provided systems
- Network responsibility matrix
  - BAS contractor vs. IT
  - 3rd-party gateways

Submittal Phase – Network Architecture



Construction Phase – Coordination is key

- IT personnel should be included in construction meetings
- Make sure information is available to those who need it, when they need it
- IT equipment needs clean, conditioned space
- Delays in IT will lead to delays in commissioning

Functional Testing Phase– Verify Network Performance

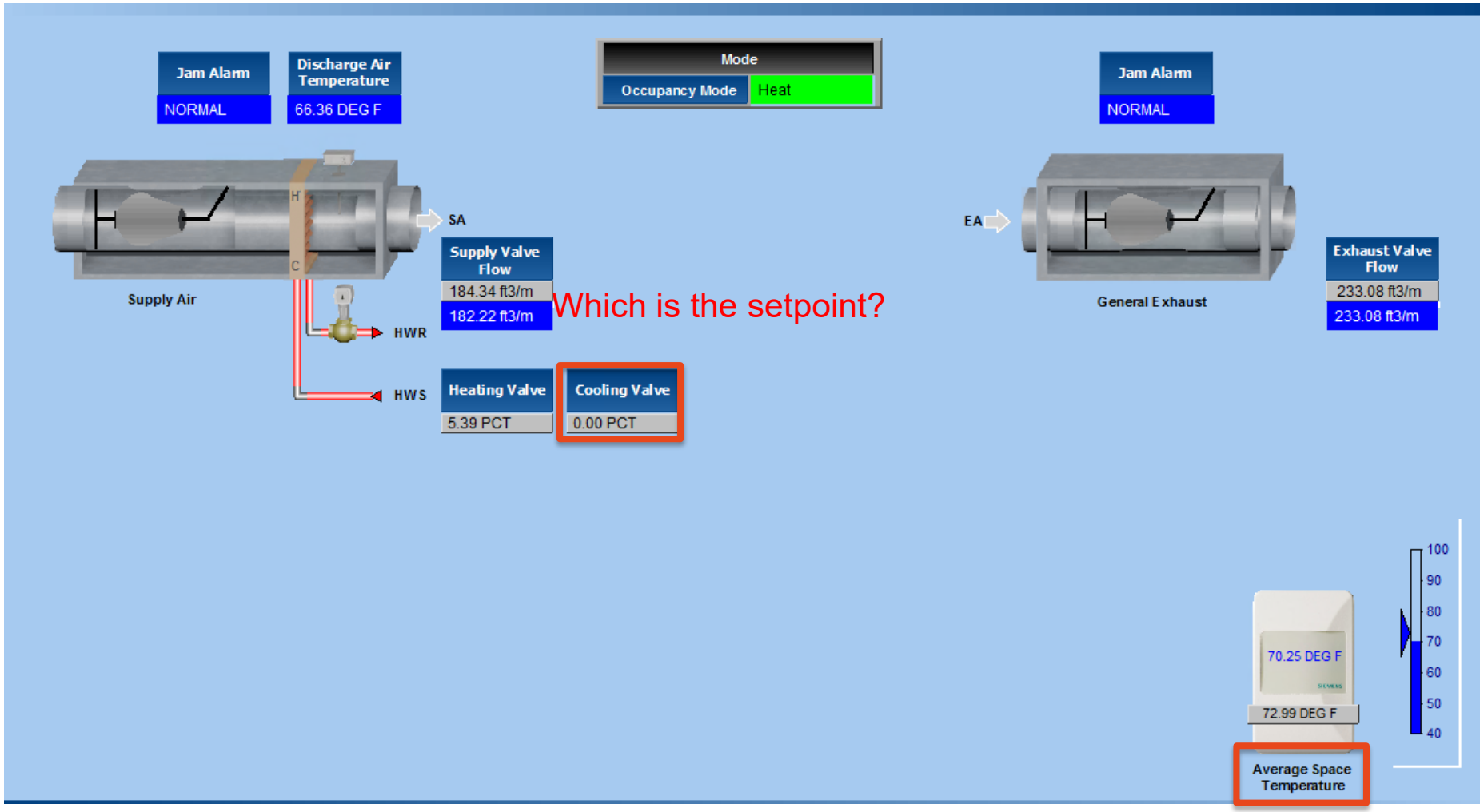
- Graphics should load quickly
- Point values should be displayed quickly
- Equipment should respond to commands almost immediately
- Overrides should take effect within a few seconds
- Verify access through VPN, web, etc.
- Network discovery tools

Commissioning Graphics

Submittal Phase – Graphics Submittals

- Graphic examples for each type of equipment should be submitted
  - Review against specification
  - If possible, get buy-in from building engineer
  - Are the graphics clear? Are the point values where you would expect them? Is all the necessary information shown?
  - If applicable, are graphics similar to other portfolio buildings?

Submittal Phase – Graphics Submittals



Submittal Phase – BAS Bench Testing

- Programs should be written prior to controller installation
  - Override sensor values and watch program response
- Logic review vs. SOO
- Verify point and equipment naming
- Verify trend setup

Construction Phase - Functional Testing

- Challenge: How to write functional tests for the BAS
  - Develop a checklist based on the specification

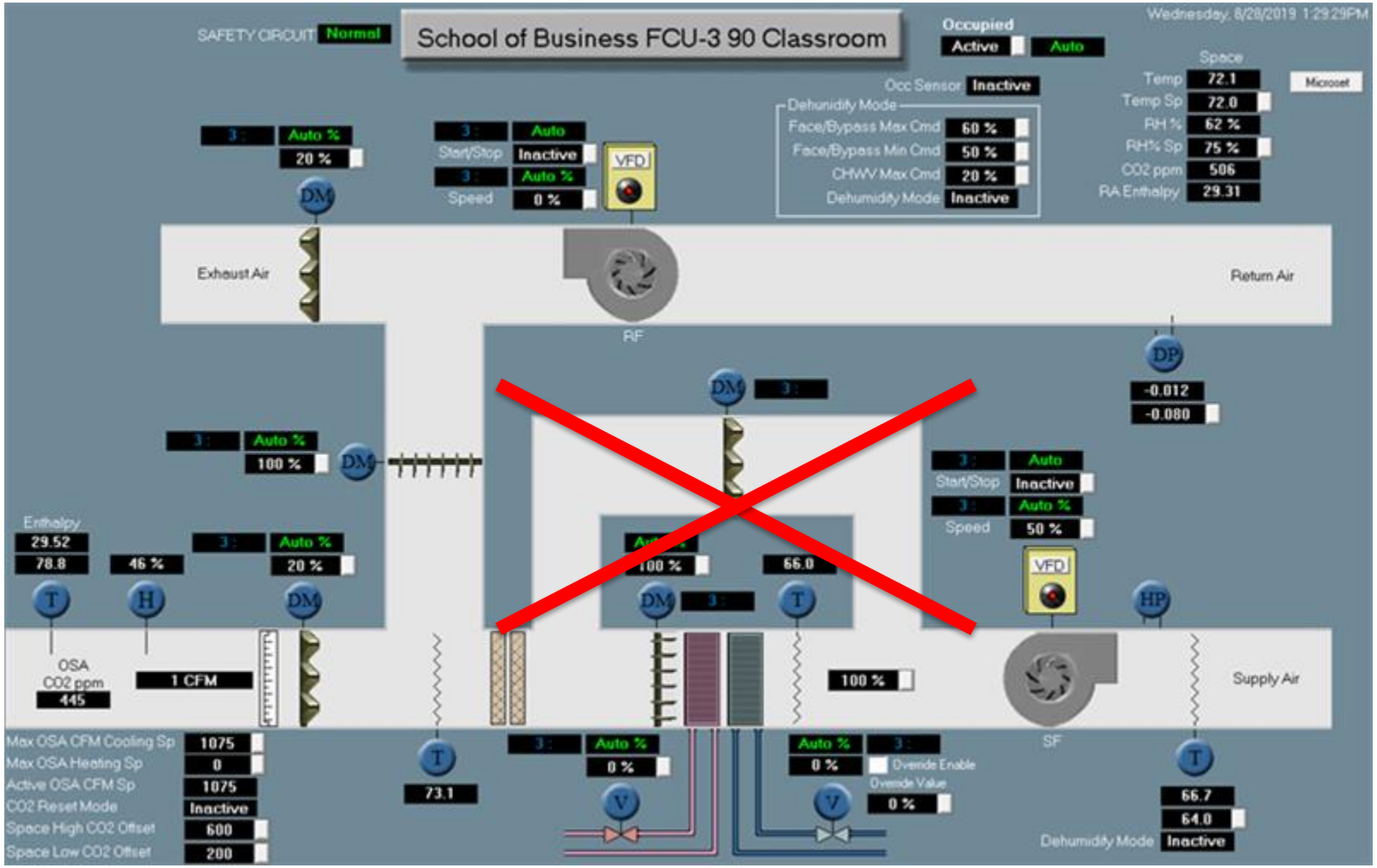
4.14 Graphic Generation

A. ☐The graphical user's interface has been provided and is based on University furnished BAS graphical templates to insure consistency with other campus building graphics.
B. ☐Graphics are in comprehensive alignment with the furnished University templates and graphics guidelines. This includes all links, icons, functionality, miscellaneous or supplemental graphic pages (where applicable), and custom features.
C. ☐All hardware instrumentation points, virtual setpoints, points integrated from associated systems and as shown on the drawings have been included.
D. ☐Links to allow user friendly navigation of all graphics in a hierarchical manner have been provided.
E. ☐As built sequences of operation, BAS schematics, and mechanical drawings, approved by facility Management have been added to each primary system schematic as icon hyperlink in the right-hand navigation pane.

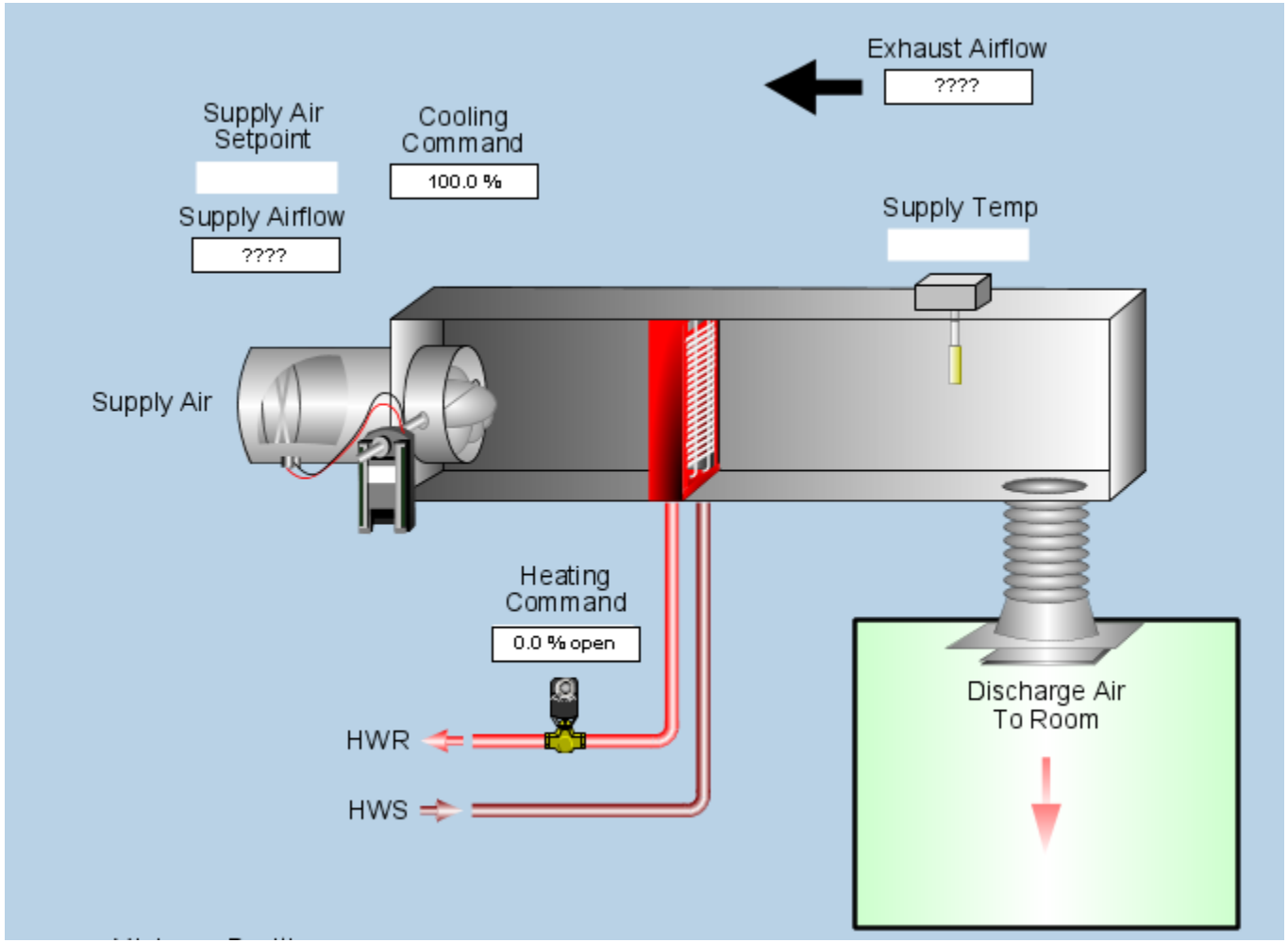
Construction Phase– Incorporate BAS into the FPTs

- Reviewing graphics during functional testing is a natural fit
- Look at graphics with the building engineer in mind
  - Are the graphics set up to make troubleshooting easier?
  - Is it easy to navigate?
  - Are alarms easy to see?
  - Is all of the necessary information visible and obvious?
  - If possible, don't let the programmer drive

Construction Phase – Verify Graphic Accuracy



Construction Phase – Verify Graphic Accuracy



Construction Phase– Verify Database Structure

- Database should be structured so that systems can be easily interpreted by the Internet of Things (IOT)
  - Points separated by equipment, not controller
  - Consistent across systems/floors/buildings
- A well designed BAS opens up the possibility of analytics-driven functional testing.

Trend Analysis and Analytics

Design Phase – Performance Criteria

- Systems Acceptance Testing Criteria for Final Completion
  - The building can control thermal comfort conditions as described in the Basis of Design document (see below). The building is considered in control when all spaces are controlled to their setpoint +/-3F, with 90% of daily 15-minute observations within the control range.
  - All VAV zones can maintain airflow control (supply air flow compared to setpoint within +/- 10% or 50CFM whichever is smaller) throughout the range of load conditions
  - RTUs shall maintain a supply temperature setpoint between 52 degrees and 65 to +/-2F, with 90% of daily 15-minute observations in the control range.
  - RTUs can deliver peak cooling load airflows as defined in the TAB report while maintain a static pressure setpoint between 0.5-1.3" w.g. +/- 10%. with 90% of daily 15-minute observations within the control range.
  - During any hour when outdoor air is below 52F degrees, RTU supply air temp shall meet the supply temp acceptance criteria with no compressor energy used. No compressor starts shall be observed.
  - All RTU economizers are enabled when the OSA temp is below 70F +/-2F and OSA dewpoint is below 55F. Economizers act as the first stage of cooling and compressors are not staged until the economizers are 100% open.
  - The observed fan power as read from the VFD shall be no more than 20% above design values at the conditions specified below:

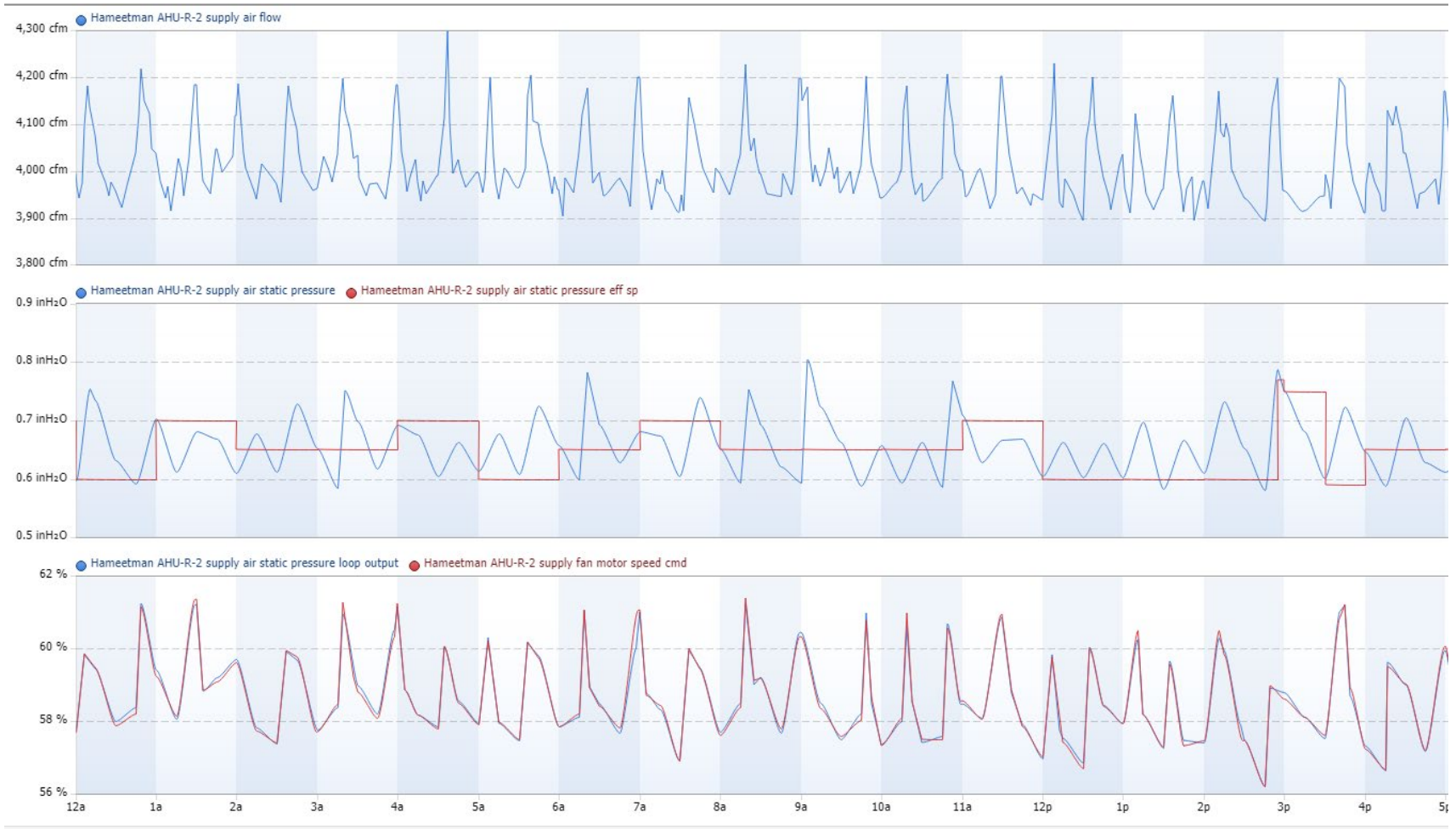
Design Phase – Trends

- Trended histories are vital for verifying system performance
- Create a list of points to be trended
- Trend intervals should be short enough to capture system performance without putting strain on the system.
- Sensors and Numeric Commands
  - 5-minute interval for commissioning
  - 15-minute intervals for continued monitoring
  - Use change of value (COV) only with a threshold (e.g. 5 minutes or 0.5˚ COV)
- Setpoints and Binary Values
  - 4 hour interval plus COV
- Consider storage options – Onsite vs. Cloud. How long to store?

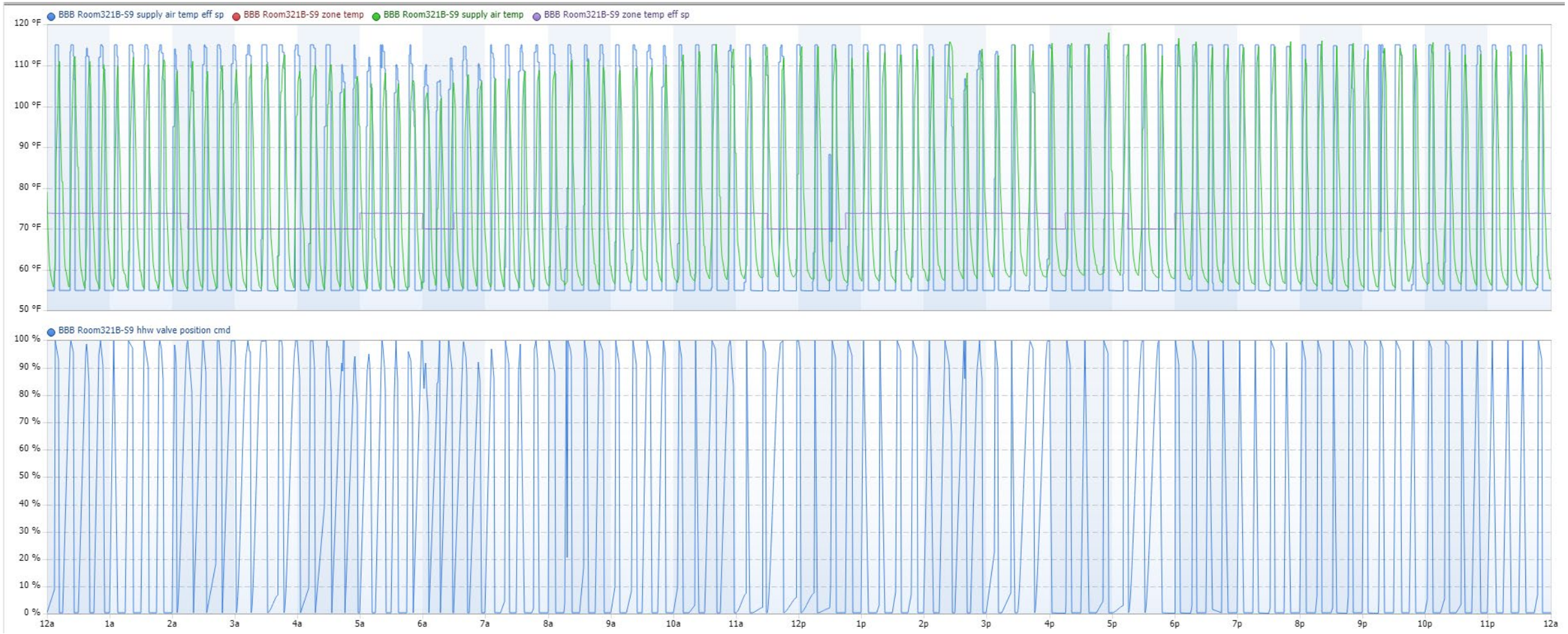
Construction Phase – Trend Analysis

- Capture issues not found though typical FPTs
- Tune PID control loops for stable operation
- Verify how systems effect each other
  - Does the economizer opening affect the static pressure control?
- Verify equipment scheduling
- See how the building responds to sudden changes in occupancy

Construction Phase – Trend Analysis



Construction Phase – Trend Analysis



Construction Phase– Third Party Analytics

- Trend collection and fault detection and diagnostics (FDD)
- Should be considered a tool for commissioning
- 3rd party analytics makes functional testing more thorough
  - Test 100% of equipment, not a sampling
  - Automated test procedures allow for quick issue discovery and easy retesting
  - Easily validate resolved issues
  - Verify performance over time rather than once
- Be more confident that the building works as it should

Conclusion

- Including the BAS/graphics in the commissioning process in necessary as building systems become more complex
- Include the BAS in the OPR/BOD and specifications
- BAS network architecture needs planning and design
- Review BAS submittals before implementation
- Incorporate graphics and trend analysis into functional testing
- Advanced analytics should be the future of commissioning

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