SECTION 23 09 23

AUTOMATIC TEMPERATURE CONTROLS

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AUTOMATIC TEMPERATURE CONTROLS

PART 1 - GENERAL

1.01 DESCRIPTION

A. The Dartmouth College Design & Construction Guidelines include general administrative, design, product, and installation requirements. It is the intent of Dartmouth College that the consultant incorporates the requirements contained herein with the consultant's specifications to produce a document that is cohesive, coordinated, and non-conflicting. Deviations from these Guidelines must be reviewed and approved by the appropriate DC-FO&M Engineering representative.

B. General provisions and HVAC systems are defined in other Sections of Division 23.

C. The requirements of this guideline shall be contracted directly to the Construction Manager and not through the Mechanical Contractor.

D. This Section covers automatic temperature control systems and equipment. Automatic temperature control system is the building automation system (BAS).

E. The Building Automation System (BAS) contractor shall be responsible for ensuring compliance with this section and Section 25 00 00 – Integrated Automation.

F. This Section includes responsibilities and obligations in support of the performance verification as described and detailed in the Guideline Section 01 91 00 - Commissioning.

G. The BAS includes the network of interoperable, stand-alone digital controllers communicating via network devices, and a server platform.

1.02 REFERENCES AND DEFINITIONS

A. Active Directory (AD) or Single Sign On (SSO) - Authentication and authorization service for users that will enforce security policies associated with Owner IT secure access requirements.

B. Automatic Temperature Controls (ATC) contractor – The contractor responsible for the automatic temperature and control systems and equipment.

C. BACnet - The open ASHRAE/ANSI communication protocol, Standard 135 that allows open communication between building systems and devices.

D. Building Automation System (BAS) - The building controls involved with the operation of all HVAC systems.

E. Building Automation System Contractor (BAS Contractor) – is the contractor that furnishes, installs and integrates the Building Automation System.

F. Building Automation System Controllers (BAS controllers) - field programmable, microprocessor-based type incorporating direct digital control and energy management

functions; same as a field controller NIA or NAC.

G. BAS Licensing - Dartmouth college is the listed owner on all software licenses and toolkits associated with BAS programming.

H. Dartmouth College Controls Vendor Standards for Building Controls Project Documentation and Software Control are minimum requirements for all controls vendors. Reference Appendix B.

I. Edge device – is any device installed in a "Field Setting" that is incorporated into a larger system and intended to provide real-time data and/or control. Edge devices are most commonly IP-network connected and provide connectivity between local building networks and wide area networks.

J. FDD – Fault Detection and Diagnostics is the enhanced analytics system and process that qualifies and quantifies building system information from alarms and alerts into standardized and user-identified categories to efficiently address and resolve building and operational problems.

K. Field controller – is a programmable microprocessor-based device that directly operates field mechanical or electrical equipment using two-way communication.

L. GUI - Graphical User Interface. This is an operational control and monitoring dashboard from which all system and subsystems can be accessed through a single, browser-based system, or "Unified User Interface" (UUI).

M. HVAC - Heating Ventilation and Air Conditioning.

N. Information and Communication Technology Platform consists of network communications infrastructure (wired and wireless) and hosting systems for applications required for the Smart Building Platform that confirms to all Dartmouth Information Security (DISC) Policies.

O. IoT Devices – "Internet of Things" or Edge devices connected to Dartmouth's Operational Technologies network that directly interact in real-time with one another, share data, and allow an action, command, or input from one system or device to produce a response, output, or sequence to another system or device.

P. Machine User Account – A User Account profile intended to allow one system to communicate and transmit information between another system through the access control of a username and password dedicated to the non-human user. This typically used for automated tasks and transactions such as a weather station feed. Machine user accounts do not time out.

Q. M&M – The Measurement & Monitoring Plan describes the criteria established by the Owner for the continuous monitoring of equipment, energy, gas, and water usage.

R. NAC - Network Access Controller is a field device intended for integration between Owner network and BAS field control devices. The NAC provides global supervisory function and control over lower-level controllers in integrated sequences. The NAC operates as a protocol converter for multiple protocols

communicating on both serial and IP.

S. Networks – Dartmouth operates its own converged networks.

T. NIA – Network Integration Appliance is the interface between the building's communications system and the BAS control devices.

U. Open licensed/sourced – Any control device, field controller, NAC, or Server-based platform operating on a license that is "unrestricted" and lists the Owner as the "Named License Holder". This software licensing model ensures ownership of all equipment, software, configurations, data files, code, and documentation associated with the Owner's systems. Any qualified vendor can work on open licensed systems provided they have access to the required BAS system toolkits.

1. For Niagara based licenses, open NICS are required.

2. For Non-Niagara controllers, Dartmouth College shall retain the ability to program, upgrade and manage the controllers.

V. Open protocol – is an industry-accepted Network Standard that is an established set of rules that determine how data is transmitted between different manufacturer's devices on the network (i.e. BACnet MS/TP, BACnet IP, TCP/IP, Modbus, LonTalk in existing integrations only, etc.).

W. OT – Operational Technology includes the hardware and software for monitoring, control, data analytics and visualization for lighting, energy, mechanical systems, security, elevators, space utilization, traffic, transportation, and parking.

X. RAID – Redundant Array of Independent Disks

Y. REST – Representational State Transfer

Z. Smart Building Platform (SBP) – The integrated platform that entails all controlled and monitored building systems and infrastructure including hardware and software for disparate systems. Currently this platform is the same as the BAS front-end platform.

AA. Sub-points – Sub-points are points associated with packaged controls.

BB. Terminal Unit Controller – any controller for thermal equipment, i.e. VAV boxes, Fan Coil Units, Cabinet/Unit Heaters, Radiators, etc.

CC. User Accounts – User accounts are in this context human accounts and not "machine user accounts".

DD. VFD - Variable Frequency Drive

1.03 RELATED WORK AND REQUIREMENTS`

A. See Appendix A for Coordination Matrix for Building Automation Systems (BAS).

B. The installation of motor starters that are not factory-installed, thermal overload switches, and power wiring to motors, starters, thermal overload switches, electric heating coils, electric humidifiers, and contactors, is defined in Division 26. This Section includes the furnishing and installation of controls and wiring for automatic controls, electric damper and valve actuators and motors, terminal unit controllers, interlocks, starting circuits, and 120 V and low voltage power wiring to power consuming control devices.

C. This Section includes wiring fire alarm signal relays, provided and installed under Division 28, to the automatic temperature control systems. See coordination matrix for additional responsibilities.

D. Flow measuring devices are detailed in Guideline Sections 23 05 19 - Meters and Gauges for HVAC Equipment.

E. Switches for Fans serving laboratory fume hoods are provided with the fume hoods under Division 11 - Equipment. This Section includes wiring the switches to achieve the control sequence defined herein.

F. Variable volume for laboratory air control systems are defined in Guideline Section 23 20 00 - Laboratory Airflow Controls. Where defined in Section 23 30 00 - Facility Air Quality Monitoring System, monitoring of temperatures, pressures, airflows, face velocities, equipment status, alarms, and other parameters shall be accomplished by the pressurization controls system and communicated to the BAS. This Section includes relays, wiring, equipment, and connections necessary to accomplish the defined interfaces, and shall include programming of software and color graphics to include the variable volume pressurization control systems into the BAS.

G. The monitoring and data logging capabilities of the BAS shall be available for use in the commissioning process.

H. For environmental air quality, refer to Section 23 30 00 - Facility Air Quality Monitoring System.

I. Division 27 Telecommunication Master Construction Specifications, Guidelines, and Reference Designs https://sites.dartmouth.edu/networkservices/specs/.

J. Open Communications Protocol:

1. The BAS shall provide open protocol communications hardware and software based on IP-based connectivity utilizing TCP/IP, ASHRAE BACnet I/P and BACnet MS/TP, Modbus RTU, Modbus TCP, MQTT, OPC UA, SOAP and SNMP or protocols with open communications such as REST API standards of data exchange.

2. IP-based communications are the required communications protocol. Exceptions are allowed if approved by Dartmouth College Engineering and CSTS. Serial communications that are approved include: BACnet MS/TP and Modbus RTU. Appropriate uses of serial communications are as outlined below:

    a. Terminal units that are installed onto existing serial trunks may use serial protocols.

b. Serial-based equipment that does not support native IP-based protocols. These devices shall be routed to a Dartmouth-approved Serial-to-IP gateway.

c. Old and currently installed VFD's that operate on serial trunks.

d. Isolated equipment that requires distances exceeding 300 feet, but not over 4,000 feet.

3. For all current field devices communicating via serial protocol, coordinate the installation of a serial-to-IP converter adjacent to the serial device or serial trunk head-end device. Coordinate with Dartmouth Network Services for nearest IP-demark. Serial trunks shall be segmented and separated by end-device manufacturer and protocol. Do not mix manufacturers on the same trunk. Serial trunks communicating between VFD loads shall be separate from all other non-VFD trunks. This requirement to be reviewed with Dartmouth College on a case-by-case basis.

K. Removal of existing systems and components must also include removal of those devices from the database and submitting a report that shows all devices disabled and deleted. Coordinate with Dartmouth College BAS Engineering and CSTS. The cost of devices and points removed from the control systems and database is the full responsibility of the Integrator/Contractor of the project.

L. Coordinate with Dartmouth College Engineering for additional scope of work for specific projects.

M. Coordinate with Dartmouth College Engineering for additional design criteria for specific projects.

1.04 QUALITY ASSURANCE

A. Within 30 days after notice to proceed, submit resumes for the project manager, application engineer and field supervisor assigned to the Project. The Owner and Engineer reserve the right to exclude proposed staff not having the experience deemed sufficient for the Project. The proposed staff shall have the following minimum experience levels:

1. Project manager: 5 years' experience, and two projects of similar size and type.

2. Application engineer: 7 years' experience and be manufacturer-certified for the system being provided and understanding of NIST Cyber Security Best Practices.

3. Field supervisor: 5 years' experience and be manufacturer-certified for the system being provided and understanding of NIST Cyber Security Best Practices.

4. Field installers and technicians must be manufacturer certified in the hardware being installed.

B. The BAS Contractor shall be a recognized national manufacturer, installer and service provider of BAS that is regularly engaged in the engineering, programming, installation, and service of total Building Automation Systems.

C. The BAS Contractor shall have, a trained, directly employed and full-time technical staff, spare parts inventory, and all necessary test and diagnostic equipment.

D. The BAS Contractor shall have technicians that are able to respond to jobsite within three (3) hours of receiving a call or emergency call to provide complete maintenance and support services on a 24 hour, 7-day-a-week basis.

E. Conform to the following:

1. NFPA 70-2020 – National Electric Code

F. Installation shall be by technicians trained by the control manufacturer.

G. Controllers and software shall have a current BTL (BACnet Testing Laboratory) listing.

H. Controllers and network devices associated with the smoke control systems shall be UL 864-2014 (R2018)/UUKL listed.

I. Include BAS installer Quality Management Program in project bid documentation.

J. All wiring is to be certified by the installer and certificates submitted to Dartmouth College.

1. MSTP – RS45 per ANSI/TIA/EIA-485-A-1998; https://en.wikipedia.org/wiki/RS-485

2. T1L – 10BASE-T1L

3. Modbus RTU

1.05 SOFTWARE LICENSING

A. The BAS software license shall grant use of all programs and application software to the Owner as defined by the manufacturer's license agreement.

B. The Owner shall be the named license holder of all BAS software associated with the Project. In addition, the Owner shall receive ownership of all Project specific configuration documentation, data files, and application-level software developed for the Project. This shall include all custom, Project specific software code and documentation for all configuration and programming that is generated for this Project and configured for use with the BAS, NACs, and related communications devices. Required usernames and passwords for access to any component or software program shall be provided to the Owner.

1.06 SUBMITTALS

A. Submittals:

1. Submit a single comprehensive submittal package including the items described below. At the Contractor's option, control valves and control dampers may be

submitted in a separate submittal in advance of the other items to maintain project schedule. Submittals process also as described Division 1.

2. Control valve data: including manufacturer's product data and schedule indicating body type, size, flow rate, pressure drop, actuators and motors, end switches, normal (failure) position, and maximum differential pressure at which valve is capable of full closure for each valve.

3. Control damper data: including manufacturer's product data and schedule indicating damper type, size, flow rate, pressure drop, leakage rate, actuators and motors, actuator torque, end switches and normal (failure) position for each damper. Submit size schedule for controlled dampers.

4. Pressure sensor data: including manufacturer's product data and schedule indicating the sensor type, range, and accuracy, and denoted with a discrete tag for each sensor and a description of the associated system and mounting location.

5. BAS data: including control manufacturer's data sheets on BAS controllers, NACs, workstations, sensors, meters, relays, actuators, motors, terminal unit controllers, protection devices, and other devices defined herein. Include data on software.

6. Network data: including switches, converters, routers, broadcast management devices and cabling, as necessary.

7. Graphics: include illustrations of proposed graphics displays, including a flowchart or site map indicating system navigation links.

8. Diagrams: separate field wiring diagrams for each system, including motor starting and interlock wiring, ladder diagrams, control wiring, interior electrical circuits of control instruments with terminal and control device designations, actuators and motors, colors of wires, locations of instruments and remote elements, interfaces with communications equipment provided with equipment defined in other Sections, and normal position of relays. Each diagram shall have terminals labeled as they will be marked on the installed equipment. Each diagram shall delineate between existing piping, wiring or equipment, and new piping, wiring, and equipment.

9. System architecture: provide a drawing of the proposed system architecture showing configuration and locations for BAS controllers, terminal unit controllers, BAS servers, control wiring for each device, and hardware and wiring for connections. Include points list and summary for all physical and virtual points to be installed. Indicate the spare capacity and BACnet instance number or network address for each device. Include networking hardware such as switches, converters, routers, and broadcast management devices, applicable cabling, and applicable terminations. Also provide IP addresses, and VLAN segments, TCP, and/or UDP port numbers, and firewall rules (where applicable). Provide diagrams of the proposed control power infrastructure, including the designation of the electrical panelboards that will be utilized to provide control power, the quantity, configuration, size, and location of controls system transformers, and the distribution wiring to power consuming control devices.

10. Provide floor plans locating equipment coordinated with the work of other trades.

11. The Point List shall be in matrix format and shall indicate each monitored or controlled point, device, and control software. The Point List shall indicate the form of input or output: Digital In, Digital Out, Analog In, or Analog Out. Also, an explanation of the characteristics for each of the inputs and outputs (contact only, pulse, 4-20 mA, third party software, etc.) should be defined. For devices and systems: each input or output point shall have a detailed description of what "sub-point" parameters are available, if they are available for viewing only, and if they are capable of being modified from a workstation. The Point List shall further identify document-required and Owner-selected "sub-points" that are integrated into the Platform and what their functions are:

    a. Point abbreviation / naming convention (shall follow Owner point naming standards).

    b. Point input/output form (DI, DO, AI, or AO). All setpoints, calculated points, and "virtual points" will be listed.

    c. Wire terminations in and out of all controllers and control devices shall be labeled according to the number, I/O name, and location on that device and the corresponding connected field device in accordance with the Owner's naming convention.

    d. System the point is associated with.

    e. Point description (include "monitoring only") if this point is only a monitoring point and doesn't control anything; and/or if it is a "setpoint" and/or calculated point).

    f. Display unit.

    g. Panel address.

    h. Panel ID.

    i. Physical panel location.

    j. Reference drawing number from blueprints.

    k. Intermediate device information.

    l. Field device (temperature sensor, contact, static tip, etc.).

    m. Comments column.

    n. Point trending capabilities and requirements.

12. The BAS contractor shall resubmit any changes to the control design or points list and create a “for the record” final submittal and keep the Commissioning Agent informed of all changes to this list during programming and setup.

13. Project-Specific Submittals: Submit a representative sample, for each of the following, prior to final development of each for the entire project. Once the Engineer of Record and Owner's approval has been obtained for the representative samples, complete submittals for the entire project are to be provided.

    a. Input/output Object Testing: Include copies of all Testing Documentation Forms required to be completed for this project. At a minimum, the following must be included (as applicable): hardware address, object name, device type, transmitter type, signal range, signal formula, and readout formula.

    b. Sequence of Operation Testing: Submit a copy of the Sequence of Operation annotated with the Subcontractor's testing methods. Proposed methods will be performed to prove compliance with the specification.

14. Uninterruptible power supplies: provide wiring diagrams and sizing calculations for uninterruptible power supplies, for all controllers on mechanical equipment that is on Stand-by power. Provide smart UPS for battery monitoring, APC; or equal. Coordinate with Dartmouth College.

15. Sequences of operation: complete detailed sequences of operation, including a narrative of the system operation and interactions and interlocks with other systems, notations indicating whether interlock or interaction is accomplished through software or hard-wired connections, detailed delineation of control between packaged controls and the BAS, and sequences of operation for packaged controlled equipment that interfaces with the BAS.

16. Air compressor: provide calculations indicating air consumption requirements for devices and compressor sizing calculations. Provide manufacturer's product data for air compressor, receiver, refrigerated air dryer, and components.

17. BAS system server data: manufacturer's data sheets on the server equipment including computers, monitors, printers, UPS, communications equipment, other devices defined herein.

18. System implementation requirements: network, workstation, and Web browser requirements for BAS functionality on the Owner's systems. Indicate operating system and other program language requirements for compatibility.

19. Existing BAS system expansion data: proposed system modifications if any are required to support this addition; complete field wiring diagrams showing interconnection with existing controllers, devices, and server equipment; illustrations of proposed graphics displays if defined herein; and proposed database and software additions or modifications, if required.

20. BAS manufacturer shall provide third-party penetration testing documentation to Owner with results, remediation, and hardening guide for all IP-based equipment to be installed.

B. Pre-Commissioning Submittals:

1. Operator's and programmer's manuals: Submit for all operating, user, and application software provided, including all BAS and third-party software furnished.

C. Project Record Documents:

1. Project Record Drawings: Digital As-built versions of submittal shop drawings will be provided as editable AutoCAD, Revit, or Visio compatible files, including 6 prints of each drawing on 11" x 17" paper. All record drawings will be placed on Owner's approved background.

a. Marking of all systems sensors and thermostats on the as-built floor plan and mechanical drawings with their control system designation.

b. Full print out of all schedules, setpoints, and sequences of operation after testing and acceptance of the system.

c. Control equipment component submittals, parts lists, etc.

2. Testing and Commissioning Reports

3. Copies of all check tests and calibrations performed by the Subcontractor (not commissioning tests).

4. Operations and Maintenance (O&M) Manual

5. Engineering, installation, and maintenance manual or set of manuals that explain how to design and install new points, panels, and other hardware; how to perform preventive maintenance and calibration; how to debug hardware problems; and how to repair or replace hardware.

6. Recommended preventive maintenance procedures for system components, including schedule of tasks such as inspection, cleaning, and calibration; time between tasks; and task descriptions.

7. List of recommended spare parts with part numbers and suppliers.

8. Documentation of Changes During Warranty Period

1.07 PROJECT CONDITIONS

A. This section is applicable to existing control systems.

1. Visit the Project before preparing a bid. Except as defined herein or indicated otherwise on the Drawings, existing control equipment, where applicable, may be reused after repairing to place in first-class operating condition. Reused instruments shall bear the same warranty as new instruments. Where new controllers are provided, existing panels and devices shall be disconnected and removed, and existing conduit, wiring, piping, tubing, equipment, and devices that are not reused as part of the renovated control system shall be removed.

2. Advise, in writing, of any malfunctions or inoperative control apparatus or instruments that become apparent during the course of the work in portions of the temperature control system that are not directly affected by this Project.

B. Coordinate with Dartmouth College Engineering for additional requirements that apply for new projects.

1.08 ROLES AND RESPONSIBILITIES

A. See Appendix A Coordination Matrix for Building Automation System (BAS).

B. Dartmouth is responsible for network coordination and configuration for authentication utilizing SSO (Active Directory (AD)) per Owner's IT requirements.

C. The use of any portion of the IT infrastructure by any building sub-system must meet the Owner's IT standards and policies.

D. The BAS Contractor shall be responsible for all mechanical BAS and DDC-level controllers (both new and existing, and both serial and IP-based controls), control devices, control panels, controller programming, controller programming software, controller input/output and power wiring and controller network wiring. The BAS contractor is responsible for programming all mechanical Sequences of Operations (SOO's).

E. Network Jacks and/or other telecommunications demarcation points needed to support BAS systems must be coordinated with and appear on the Telecommunications set of drawings for the project. Network Jacks that are not properly indicated on the Telecommunications Construction Drawings may not be installed or activated.

F. All IP-based cabling between Dartmouth network switches and the demark location of the BAS controllers is the responsibility of the Division 27 contractor. All IP cabling between BAS controllers and the demark is the responsibility of the BAS contractor.

G. The BAS contractor is responsible for installing all mechanical equipment cabling and building/floor-wide serial trunks through established building cores between BAS communications modules.

H. The BAS contractor is responsible for complete installation and automatic temperature control of specialty systems including precision terminal units and air sampling systems.

I. The BAS Contractor shall install all communication wiring on separate communication trunks,-from the VFD's to the BAS communications modules. The BAS Contractor will integrate all fieldbus communications from the VFD. Electrical power serving the VFD is installed by the Division 26 contractor. Controls wiring and sequences of operation programming is the responsibility of the BAS contractor.

J. The Division 23 mechanical contractor shall be responsible for the complete installation of all thermal utility and, per Section 23 05 20 - Thermal Utility Meters, and water flow meters per Section 23 05 19 - Meters and Gauges for HVAC Equipment. The BAS contractor shall be responsible for power and low-voltage (e.g. 4-20 mA) communication

wiring between the thermal utility meters and the inputs onto the BAS field controls. All serial-to-IP gateways shall be installed and configured per Dartmouth IT standards, including coordination with Dartmouth's Division 27 contractor for cabling and demark locations and network equipment.

K. For terminal unit power including fans and electric reheat, the electrical contractor and BAS contractor shall coordinate power requirements to provide adequate spare electrical capacity and circuits.

PART 2 - PRODUCTS

2.01 ACCEPTABLE MANUFACTURERS

A. Honeywell EBI, Johnson Controls Metasys

B. The manufacturers' product lines defined above shall be a complete system of NACs, BAS controllers, and terminal unit controllers used consistently throughout the Project. BAS and terminal unit controllers shall be programmable from the NACs and server. Products provided shall be the most current version that is compatible with Dartmouth College's current version. Programming tools and license shall be open and provided to the Owner (see definition of Open Licensed/Sourced in section 1.02 of this guideline).

C. All equipment and terminal units shall be controlled through the ATC with controls provided by the BAS contractor. Equipment that comes with packaged controls is prohibited without prior review and acceptance by Dartmouth College Engineering and BAS shop.

2.02 SYSTEM ARCHITECTURE

A. Provide a complete peer-to-peer networked, stand-alone, distributed BAS to perform the controls functions and monitor the points defined herein and on the Drawings.

B. The BAS shall be engineered, and equipment selected by the manufacturer as required to meet the performance defined herein.

1. The BAS shall be comprised of a network of interoperable, stand-alone digital controllers communicating via the BACnet communication protocol with one or multiple NACs.

2. Lower-level networks utilizing BACnet over MS/TP shall only serve terminal units and small applications.

3. The BAS shall interface with the electric, and electronic systems to provide control outputs and monitoring inputs to the BAS as defined herein and as indicated on the Drawings.

4. Provide communications media, connectors, repeaters, bridges, switches, and routers necessary to provide a fully functional BAS network.

5. Complete electric control systems shall be provided to perform sequences not indicated to be performed by the BAS.

6. The location and quantity of BAS controllers shall be as determined by the BAS manufacturer except that, as a minimum, a separate stand-alone controller shall be provided for each refrigeration plant, heating plant, air handling unit over 3 hp, and as indicated on the Drawings. Sensors and control points for each system shall be connected to its associated stand-alone controller.

7. Each BAS controller shall be designed to allow for the future addition of at least 20% of the number of connected input/output points; it is acceptable to achieve the 20% spare capacity with 10% spare on the BAS controller with capability of adding input/output expansion modules with an additional 10%. Include inputs from all virtual and imported points from other control software including innate software on equipment controls (e.g. Yorktalk, Trane Intellipak). BAS controller spare capacity shall apply to both analog and digital control points.

8. The BAS, including the system servers, the network components, and network area controllers (NACs), shall be designed to allow for the future addition of at least 100% of the number of control objects connected to the components or systems.

9. An alarm condition shall be reported to the appropriate operator device no more than 10 seconds following the occurrence of that condition. Sensor and control values displayed to the operator in graphics displays shall be dynamically updated within 10 seconds of significant change of value, with a typical response time of 1 second or less.

C. Lower level networks serving terminal units, such as BACnet over MS/TP, shall be connected to the associated air handling unit controller. When multiple lower level networks are required for a single air handling unit, those networks shall be divided in an orderly method, such as by floor or wing. Remote sensors shall be wired to the controller associated with that sensor, unless defined otherwise.

D. The system shall have the capability to integrate ASHRAE 135-2016, BACnet, LonWorks, MODBUS, OPC, and other open and proprietary communication protocols into one open, interoperable system.

E. The following functions shall be performed at the server or NAC:

1. Calendar functions.

2. Scheduling.

3. Trending.

4. Alarm monitoring and routing.

    a. Alarms should have API end point for integration.

    b. Alarm generation shall be selectable for annunciation type and acknowledgement requirements including, but not limited to:

        1) In alarm.

        2) Return to normal.

        3) Fault condition.

    c. Provide for the creation of a minimum of 8 alarm classes.

    d. Provide time scheduled routing of alarms by class, object, group, or node.

    e. Provide alarm generation for equipment runtimes and other event counts for equipment maintenance. The user shall be able to reset runtime or event count values with appropriate password control.

    f. Controller and network failures shall be treated as alarms and annunciated.

    g. Alarms shall be annunciated in any of the following manners as defined by the user:

        1) Screen message text.

        2) API-based alarming (for devices that support API's)

        3) E-mail of the complete alarm message to multiple recipients via the Owner's e-mail service. Provide the ability to route and e-mail alarms based on:

            a) Day of week.

            b) Time of day.

            c) Recipient.

            d) Pagers.

            e) Graphics showing flashing items in alarm.

            f) Printed message, routed directly to a dedicated alarm printer.

    h. The following, at a minimum, shall be recorded:

1) Time and date.

2) Location (building, floor, zone, office number, etc.).

3) Equipment (air handling unit number, access way, etc.).

4) Acknowledge time, date, and user who issued acknowledgement.

5) Number of occurrences since last acknowledgement.

i. Alarm actions may be initiated by user-defined programmable objects created for that purpose.

j. Defined users shall be given proper access to acknowledge any alarm, or specific types or classes of alarms.

k. A log of all alarms shall be maintained by the NAC and/or a server (if configured in the system) and shall be available for review by the user.

l. Provide a "query" feature to allow review of specific alarms by user defined parameters.

5. Time synchronization.

6. Web browser access via an intranet and the internet, supporting a minimum of 32 simultaneous users.

7. The following additional logs shall be included and made available to the user:

a. System alerts, such as controller and network failures.

b. Errors, such as invalid property changes or commands.

F. This Project may involve expansion of an existing BAS including new BAS equipment, software, programming and controls. In such cases, any new BAS controllers shall comply with this guideline and be connected to the existing BAS.

1. Updates to the existing BAS including programming and graphics, as required to perform the work defined herein shall be included. This work shall include updates to campus maps, building floor plans, and associated links, lists or associated data trees.

2. New system components shall be 100% hardware and software compatible with the existing systems and shall be by an approved manufacturer. Programming logic, database definition, and point identifiers shall conform to, and be a logical extension of, the existing systems.

2.03 CONTROLLERS

A. Network Area Controllers (NACs):

1. The Contractor shall supply one or more NACs. The quantity and location of NACs is dependent on the type and quantity of control points and devices, and the functionality defined herein, and shall be determined by the Contractor.

2. NACs shall provide the interface between the building's communications system and the BAS control devices and provide global supervisory control functions over the control devices connected to each NAC. It shall be capable of executing application control programs. It shall perform the following functions:

    a. Integration of legacy LonWorks (where applicable) and BACnet controller data.

    b. Network management functions for control devices.

3. NACs shall have the following hardware features as a minimum:

    a. Two ethernet ports - 100/1000 Mbps.

    b. Two RS-485 ports.

    c. Battery back-up and flash memory for long term data backup, with minimum 1 gigabyte storage capacity.

4. Digital displays are not required on BAS controllers and NAC's. Reference Dartmouth's VFD guidelines for digital display requirements for VFD's.

5. Local UPS battery backup shall be installed within NAC Enclosure. Provide smart UPS for battery monitoring, APC; or equal. Coordinate with Dartmouth College Engineering for specific length of time for battery back-up.

6. NACs shall be capable of operating under a temperature range between 32°F to 122°F and a humidity range between 5% to 95% RH, non-condensing, and of being stored under a temperature range between 0°F and 158°F.

7. NACs shall provide multiple user access to the system and support for ODBC or SQL. A database resident on the NACs shall be an ODBC-compliant database shall provide an ODBC data access mechanism to read and write data stored within it.

8. Alarm Notifications and Actions:

    a. NACs shall provide alarm recognition, storage, routing, management, and analysis to supplement distributed capabilities of equipment or application specific controllers.

9. NACs shall be able to route any alarm condition to any defined user location whether connected to a local network, or remote via dial-up telephone connection or wide-area network. BAS controllers: field programmable, microprocessor-based type incorporating direct digital control and energy management functions. Each BAS controller shall perform its assigned control and energy management functions as a stand-alone unit and shall comply with FCC Part 15, Subpart B 2019.

a. Provide a communication interface for communication with the BAS.

b. Controls shall be performed in a digital manner using the digital signal from the microprocessor-based controller, converted through electronic circuitry for modulation of actuators.

c. Each BAS controller shall be expandable by adding additional input/output modules that operate through the processor of the BAS controller. Each BAS controller shall be designed to allow for the future addition of at least 20% of the number of connected input/output points; it is acceptable to achieve the 20% spare capacity with 10% spare on the BAS controller with capability of adding input/output expansion modules with an additional 10%. Include inputs from all virtual and imported points from other control software including innate software on equipment controls (e.g. Yorktalk, Trane Intellipak). BAS controller spare capacity shall apply to both analog and digital control points.

d. The master processor in the BAS controller shall be able to manage remote field interface units thereby expanding its control loop and energy management point capacity.

e. The BAS controller shall be supplied with a minimum of 8 hours of battery back-up for the clock operation and memory retention with an automatic battery charger.

f. Provide interface for valve and damper actuators. BAS controller hardware shall provide relay or solid-state isolation on each contact input circuit and each output circuit to prevent high voltage surges from entering the logic circuits.

g. Digital displays are not required on BAS controllers and NAC's. Reference Dartmouth's VFD guideline for digital display requirements for VFD's.

h. Provide manual hand-off-automatic (HOA) override switches and means for manually adjusting the analog output of outputs connected to each BAS controller. HOA switches and manual adjustments shall be either of a key operated design with switches keyed alike and utilizing the same keying system used for other outputs, or otherwise protected from unauthorized access by a key locked enclosure. An auxiliary set of contacts rated for at least 120 V AC, 1 A shall be provided as an integral part of each switch.

i. BAS controllers shall be arranged as indicated on the Drawings and installed to allow controllers to share global data. This global data shall include, but not be limited to: time-of-day, outside air temperature and humidity, and electrical meter and demand information. If BAS controllers are not configured in a communication network to share this data, then each BAS controller shall be provided with sensor inputs to implement sequences indicated on the Drawings when operating in a stand-alone mode.

B. Terminal Unit Controllers:

1. Control of terminal units shall be accomplished by microprocessor-based stand-alone terminal unit controllers utilizing direct digital control.

2. An individual terminal unit controller shall be provided for each terminal unit and shall interface to the BAS.

3. Terminal unit controllers may be the wireless communications type utilizing ZigBee technology or other technologies as defined. Refer to Section 33 83 00 – Wireless Communications Transmission and Distribution, https://dartgo.org/DartmouthNetworkMasterSpec and confirm with Owner for location and application of wireless sensor prior to installation.

4. Terminal unit controller components shall be furnished to the terminal unit manufacturer by the BAS for factory mounting and calibration.

5. Terminal unit controller power shall be 24 V AC.

6. Each terminal unit controller shall contain resident programs which are field-selectable for a specific application. Resident programs shall be contained in nonvolatile memory using EEPROM, EPROM, or RAM. Systems that employ volatile (RAM) memory shall provide 72-hour battery back-up for each terminal unit controller.

7. Temperature setpoints for heating and cooling and night setback shall be independent of each other and shall provide a zero-energy band between heating and cooling modes.

8. Each terminal unit controller shall be accessible for purposes of control parameter and setpoint adjustment and monitoring from the BAS. An operator's terminal connected to any BAS controller on the network shall have access to all terminal unit controllers. Terminal unit controllers shall also be accessible through a communications port at the space sensor.

9. Terminal units shall not have virtual point capacity limitations including field objects.

C. Packaged Equipment Controls

1. Controls shall be provided by the BAS contractor for all equipment on the project. Use of packaged controls from equipment manufacturers to be approved by Dartmouth College.

2.04 SERVERS

A. Central Server:

1. The central servers are existing and provided by Dartmouth, and shall be modified to support all NACs and BAS controllers connected to the customer's network whether local or remote.

2. Local connections shall be via the Owner's IT LAN on a dedicated Energy Management VLAN.

    a. Systems and device which communicate inter-building shall not rely on being connected to the same VLAN. OSI Model Layer 3 (Routed IP) communication is required for all inter-building traffic.

    b. Systems and devices which communicate intra-building can directly communicate at OSI Model Layer 2 (Ethernet).

3. Remote connections will be available via a virtual private network (VPN) through a Web interface. VPN will be provided and operated by Dartmouth IT. It shall be possible to provide access to NACs via a single connection to the server. In this configuration, each NAC can be accessed from a remote graphical user interface (GUI) or from a standard Web browser by connecting to the server.

4. The server shall provide the following functions, at a minimum:

    a. Global data access: the server shall provide complete access to distributed data defined anywhere in the system.

    b. Distributed control: the server shall provide the ability to execute global control strategies based on control and data objects in any NAC in the network, local or remote.

    c. The server shall include a master clock service for its subsystems and provide time synchronization for NACs and with Dartmouth’s Network Services Department.

    d. The server shall accept time synchronization messages from trusted precision atomic clock internet sites and update its master clock based on this data.

    e. The server shall provide scheduling for NACs and their underlying field control devices.

    f. The server shall be capable of providing demand limiting that operates across all NACs. The server shall be capable of multiple demand programs for sites with multiple meters and or multiple sources of energy. Each demand program shall be capable of supporting separate demand shed lists for effective demand control.

    g. The server shall implement the BACnet Command Prioritization scheme (16 levels) for safe and effective contention resolution of commands issued to NACs.

    h. Each NAC supported by the server shall have the ability to archive its log data, alarm data and database to the server, automatically. Archiving options shall be user-defined including archive time and archive frequency.

i. The server shall provide central alarm management for NACs supported by the server. Alarm management shall include:

1) Routing of alarms to display, printer, e-mail and pagers.

2) View and acknowledge alarms.

3) Query alarm logs based on user-defined parameters.

j. The server shall provide central management of log data for NACs supported by the server. Log data shall include process logs, runtime and event counter logs, audit logs and error logs. Log data management shall include:

1) Viewing and printing log data.

2) Exporting log data to other software applications.

3) Query log data based on user-defined parameters.

5. Server hardware requirements: the Contractor shall coordinate the server hardware requirements with the Owner and provide software and programming necessary.

6. Server hardware requirements: the server shall include the following, at a minimum, and include software and programming necessary for the BAS.

a. Server System Minimum Requirements:

1) The server/storage systems shall include sufficient capacity to meet the trending requirements defined herein. The system shall be able to store historical data for the most recent (1) year.

2) The BAS software shall be installed on systems which meet or exceed the manufacturer's requirements as well as the requirements defined herein.

2.05 COMMUNICATIONS

A. The BAS communications shall comprise control products, communication media, connectors, repeaters, hubs, and routers. Controller and operator interface communication shall conform to ASHRAE 135-2016. Install new wiring and network devices as required to provide a complete and workable control network. System shall be expandable to at least twice the required input and output objects with additional controllers, associated devices, and wiring.

B. Each NAC and BAS controller shall have a communication port for temporary connection to a laptop computer or other operator interface. Connection shall support memory downloads and other commissioning and troubleshooting operations.

C. System shall support Web services data exchange with any other system that complies with REST, XML (extensible markup language) and SOAP (simple object access protocol) standards defined by the Web Services Interoperability Organization (WS-I) Basic Profile

1.0 or higher. Web services support shall as a minimum be provided at the workstation or web server level and shall enable data to be read from or written to the system.

1. System shall support Web services read data requests by retrieving requested trend data or point values (I/O hardware points, analog value software points, or binary value software points) from any system controller or from the trend history database.

2. System shall support Web services write data request to each analog and binary object that can be edited through the system operator interface by downloading a numeric value to the defined object.

3. For read or write requests, the system shall require username and password authentication and shall support TLS 1.2 (at minimum), TLS 1.3, or equivalent minimum data encryption.

4. System shall support discovery through a Web services connection or shall provide a tool available through the operator interface that will reveal the path/identifier needed to allow a third-party Web services device to read data from or write data to any object in the system which supports this service.

2.06 SOFTWARE

A. Web-Based Graphical User Interface (GUI):

1. The system shall be capable of supporting an unlimited number of clients using a standard Web browser such as Microsoft Edge, Google Chrome, Mozilla Firefox, or Safari. Systems requiring additional software to be resident on the client machine, or manufacture-specific browsers, are not acceptable. User Interfaces that require software installation on the client device (e.g. Microsoft Silverlight®, Adobe® Flash®), or software downloads from an online app store shall not be acceptable for these purposes.

2. The Graphical User Interface (GUI) will support HTML5 enabled browsers without requiring proprietary operator interface and configuration programs or browser plug-ins.

3. Graphic screens shall be capable of supporting Scalable Vector Graphics (SVG) or equivalent ability to zoom in and zoom out of a graphic.

4. The Graphical User Interface (GUI) shall inherently adapt to mobile displays i.e. smartphones and tablets. The mobile user interface shall provide system operators with a simple location-based navigation approach to finding information, including the ability to search for any location by name and to bookmark a location in a standard browser.

5. The Web browser software shall run on any operating system and system configuration that is supported by the Web browser. Systems that require specific machine requirements in terms of processor speed, memory, etc., in order to allow the Web browser to function are not acceptable.

6. Real-time displays: GUIs shall, at a minimum, support the following graphical features and functions:

   a. Graphic screens shall be capable of being developed using any drawing package capable of generating a GIF, BMP, or JPG file format. Use of proprietary graphic file formats shall not be required. In addition to, or in lieu of, a graphic background the GUI shall support the use of scanned pictures.

   b. Graphic screens shall have the capability to contain objects for text, real-time values, animation, color spectrum objects, logs, graphs, HTML or XML document links, schedule objects, hyperlinks to other URLs, and links to other graphic screens.

   c. Graphics shall adhere to the Dartmouth visual identity guidelines, and adhere to the Web Content Accessibility Guidelines (WCAG) established by the World Wide Web Consortium (W3C).

   d. Graphics shall support layering and each graphic object shall be configurable for assignment to a layer. A minimum of 6 layers shall be supported.

   e. Modifying common application objects, such as schedules, calendars, and setpoints shall be accomplished in a graphical manner.

      1) Schedule times will be adjusted using a graphical slider, without requiring any keyboard entry from the operator.

      2) Holidays shall be set by using a graphical calendar without requiring any keyboard entry from the operator.

   f. Commands to start and stop binary objects shall be done by right-clicking the selected object and selecting the appropriate command from the pop-up menu. No text entry shall be required.

   g. Adjustments to analog objects, such as setpoints, shall be done by right-clicking the selected object and using a graphical slider to adjust the value. No text entry shall be required.

7. System configuration: at a minimum, the GUI shall permit the operator to perform the following tasks, with proper password access:

   a. Create, delete, or modify control strategies.

   b. Add or delete objects to the system.

   c. Tune control loops through the adjustment of control loop parameters.

   d. Enable or disable control strategies.

   e. Generate hard copy records or control strategies on a printer.

f. Select points to be alarmable and define the alarm state.

g. Select points to be trended over a period of time and initiate the recording of values automatically.

8. On-line help: provide a context sensitive on-line help system to assist the operator in operation and editing of the system. On-line help shall be available for all applications and shall provide the relevant data for the currently displayed screen. Additional help information shall be available through the use of hypertext. System documentation and help files shall be in HTML format.

9. Security: each operator shall be required to log on to the system with a username and password in order to view, edit, add, or delete data. System security shall be selectable for each operator. The system administrator shall have the ability to set passwords and security levels for other operators. Each operator password shall be able to restrict the operators' access for viewing and/or changing each system application, full screen editor, and object. Each operator shall automatically be logged off the system if no keyboard or mouse activity is detected for a defined time. This auto log-off time shall be set per operator password. System security data shall be stored in an encrypted format. The BAS contractor shall coordinate with Dartmouth IT for configuration of authentication and authorization.

10. System diagnostics: the system shall automatically monitor the operation of workstations, printers, modems, network connections, building management panels, and controllers. The failure of any device shall be annunciated to the operator.

11. Alarm Console:

    a. The system shall be provided with a dedicated alarm window or console. This window shall notify the operator of an alarm condition and allow the operator to view details of the alarm and acknowledge the alarm. The use of the alarm console may be enabled or disabled by the system administrator.

    b. When the alarm console is enabled, a separate alarm notification window will supersede other windows on the desktop and shall not be capable of being minimized or closed by the operator. This window will notify the operator of new alarms and unacknowledged alarms. Alarm notification windows or banners that can be minimized or closed by the operator are not acceptable.

12. Trend

    a. The user interface shall provide the capability to view historical trend data from multiple pieces of equipment in both bar and line formats.

    b. The user shall have the ability to navigate to a selection list of frequently viewed trends.

c. Trend graphs shall have to ability to be smartly auto-generated based on equipment and space relationships.

d. The user shall have the ability to view up to 3 graphs in a single screen and select which data points to plot on each to help with readability.

e. Each graph shall include a dedicated selection icon to export a copy of the graphic and data in .pdf format or the data only as a .csv file.

f. Trend graphs shall allow the plotting of non-trended point's default values.

g. The user shall have the ability to add any trended to point a custom trend graph.

h. The user shall have the ability to save trend graphs for reference later.

i. The user shall be able to specify the duration of time and aggregation period for each trend line.

j. The user shall have the ability to decide whether to show raw or aggregate trend data.

13. The system shall provide the capability to specify a user's (as determined by the log-on user identification) home page. Provide the ability to set a specific home page for each user. From the home page, links to other views, or pages in the system shall be possible, if allowed by the system administrator.

14. Graphic screens on the Web browser client shall support hypertext links to other locations on the internet or on intranet sites, by specifying the Uniform Resource Locator (URL) for the desired link.

15. Graphics: the monitor display format shall be organized to permit the output of displays, and/or summaries defined herein, while concurrently displaying the most recent change-of-state occurrence.

a. The format shall also include in a dedicated and protected area of the viewing screen, the current user of the monitor, date, time, and program day. The monitor shall output advisories in a dedicated and protected area of the viewing screen and an appropriate display in the event of control system hardware malfunction or restoration.

b. Graphic displays for systems and system components shall be provided as indicated in the I/O summaries.

c. The operator shall be capable, upon command entry, of calling for graphic displays of systems or zones.

d. Displays shall contain flow schematics, and schematics of mechanical duct and piping systems, electrical switchgear, electrical distribution systems, pumps, fans, valves, dampers, chillers, boilers, coils, pull stations, smoke detectors, heat detectors, circuit breakers, engine-generator sets, and

cooling towers for systems indicated in the I/O summaries to have graphic display.

e. Displays shall include scaled building floor plans with air handling unit and terminal unit temperature control zones identified and space sensors indicated.

f. User interface shall utilize a location base relationship scheme which summarizes all equipment and spaces related to the operation of each system or device selected for viewing. Displays shall have the capability to navigate to the home page of any related piece of equipment or space with a single click or tap on the desired element.

g. Displays shall indicate values or status of I/O points associated with that system and those shall be dynamically updated at least once every 10 seconds. Software shall be provided to allow operator modification of graphic displays provided with the system and to allow operator creation and storage of new graphic displays.

h. In the instance of a network outage requiring local command and control, for each local air handling unit controller, provide a tabular graphic summary of that unit and its associated air distribution system. Graphics shall contain, at a minimum, the following information:

1) Supply fan's current operating speed and setpoint.

2) Manual adjustment of supply fan speed.

3) Supply air static pressure and temperature.

4) For each associated terminal unit, as appropriate:

a) Minimum, maximum, and current airflow.

b) Current damper position or command.

c) Current associated space temperature.

d) Current reheat valve position or command.

5) A commandable override point to place associated terminal units at maximum airflow.

6) A commandable override point to place associated terminal units at minimum airflow.

i. In the instance of a network outage requiring local command and control, for each local hydronic system controller, provide a tabular graphic summary of the primary equipment for that system and its associated air distribution system. Graphics shall contain, at a minimum, the following information, as required by the system's I/O summary.

1) Supply and return water temperatures and flows.

2) Distribution pump's current operating speed and setpoint.

3) Distribution system controlling differential pressure.

4) Manual adjustment of distribution pump's speed.

5) For each associated air handling unit or consuming equipment, as appropriate:

a) Current valve position or command.

b) Current associated discharge air temperature.

c) A commandable override point to place associated terminal units at maximum reheat flow.

6) A commandable override point to place associated consuming equipment at full flow.

7) A commandable override point to place associated consuming equipment at no flow.

B. System Tools:

1. System Configuration Tools:

a. The workstation GUI software shall provide the ability to perform system programming and graphic display engineering as part of a complete software package. Access to the programming functions and features of the GUI shall be through password access as assigned by the system administrator.

b. A library of control, application, and graphic objects shall be provided by the BAS manufacturer to the owner, without restriction, to enable the creation of applications and user interface screens. Applications shall be created by selecting the desired control objects from the library, dragging or pasting them on the screen, and linking them together using a built-in graphical connection tool. Completed applications may be stored in the library for future use. GUI screens shall be created in the same fashion. Data for the user displays shall be obtained by graphically linking the user display objects to the application objects to provide "real-time" data updates. Any real-time data value or object property shall be connected to display its current value on a user display. Systems requiring separate software tools or processes to create applications and user interface displays are not acceptable.

c. Programming Methods:

1) Provide the capability to copy objects from the supplied libraries, or from a user-defined library to the user's application. Objects shall be linked by a graphical linking scheme by dragging a link from one object to another. Object links will support one-to-one, many-to-one, or one-to-many relationships. Linked objects shall maintain their connections to other objects regardless of where they are positioned on the page and shall show link identification for links to objects on other pages for easy identification. Links shall vary in color depending on the type of link, i.e., internal, external, hardware, etc.

2) Configuration of each object shall be done through the object's property sheet using fill-in the blank fields, list boxes, and selection buttons. Use of custom programming, scripting language, or a manufacturer-specific procedural language for configuration is not acceptable.

3) The software shall provide the ability to view the logic in a monitor mode. When on-line, the monitor mode shall provide the ability to view the logic in real-time for easy diagnosis of the logic execution. When off-line (debug), the monitor mode shall allow the user to set values to inputs and monitor the logic for diagnosing execution before it is applied to the system.

4) Programming shall be done in real-time. Systems requiring the uploading, editing, and downloading of database objects are not acceptable.

5) The system shall support object duplication within a customer's database. An application, once configured, shall be copied and pasted for easy re-use and duplication. All links, other than to the hardware, shall be maintained during duplication.

2. Library:

a. A standard library of objects shall be included for development and setup of application logic, user interface displays, system services, and communication networks.

b. The objects in this library shall be capable of being copied and pasted into the user's database and shall be organized according to their function. In addition, the user shall have the capability to group objects created in their application and store the new instances of these objects in a user-defined library.

c. In addition to the standard libraries defined here, the supplier of the system shall maintain an on-line accessible (over the internet) library, available to registered users to provide new or updated objects and applications as they are developed.

d. Control objects shall conform to the control objects defined in the BACnet standard.

e. The library shall include applications or objects for the following functions, at a minimum:

1) Scheduling object: the schedule shall conform to the schedule object as defined in the BACnet standard, providing 7-day plus holiday and temporary scheduling features and a minimum of 10 on/off events per day. Data entry shall be by graphical sliders to speed creation and selection of on-off events.

2) Calendar object: the calendar shall conform to the calendar object as defined in the BACnet standard, providing 12-month calendar features to allow for holiday or special event data entry. Data entry shall be by graphical "point-and-click" selection. This object shall be "linkable" to scheduling objects for effective event control.

3) Duty cycling object: provide a universal duty cycle object to allow repetitive on/off time control of equipment as an energy conserving measure. Any number of these objects shall be created to control equipment at varying intervals.

4) Temperature override object: provide a temperature override object that is capable of overriding equipment turned off by other energy saving programs (scheduling, duty cycling, etc.) to maintain occupant comfort or for equipment freeze protection.

5) Start-stop time optimization object: provide a start-stop time optimization object to provide the capability of starting equipment just early enough to bring space conditions to desired conditions by the scheduled occupancy time. Object shall also allow equipment to be stopped before the scheduled un-occupancy time just far enough ahead to take advantage of the building's "flywheel" effect for energy savings. Provide automatic tuning of start/stop time object properties based on the previous day's performance.

6) Demand limiting object: provide a comprehensive demand-limiting object that is capable of controlling demand for any selected energy utility (electric, oil, and gas). The object shall provide the capability of monitoring a demand value and predicting (by use of a sliding window prediction algorithm) the demand at the end of the user defined interval period (1-60 minutes). This object shall also accommodate a utility meter time sync pulse for fixed interval demand control. Upon a prediction that will exceed the user defined demand limit (supply a minimum of 6 per day), the demand limiting object shall issue shed commands to either turn off user defined loads or modify equipment setpoints to effect the desired energy reduction. If the list of sheddable equipment is not enough to reduce the demand to

below the setpoint, a message shall be displayed on the users screen (as an alarm) instructing the user to take manual actions to maintain the desired demand. The shed lists shall be defined by the user and shall be selectable to be shed in either a fixed or rotating order to control which equipment is shed the most often. Upon suitable reductions in demand, the demand-limiting object shall restore the equipment that was shed in the reverse order in which it was shed. Each sheddable object shall have a minimum and maximum shed time property to effect both equipment protection and occupant comfort.

f. The library shall include control objects for the following functions. Control objects shall conform to the objects as defined in the BACnet standard.

1) Analog input object: comply, as a minimum, with the BACnet standard for data sharing. Allow high, low and failure limits to be assigned for alarming. Also, provide a time delay filter property to prevent nuisance alarms caused by temporary excursions above or below the user defined alarm limits.

2) Analog output object: comply, as a minimum, with the BACnet standard for data sharing.

3) Binary input object: comply, as a minimum, with the BACnet standard for data sharing. Users shall be able to specify either input condition for alarming. This object shall also include the capability to record equipment run-time by counting the amount of time the hardware input is in an "on" condition. Users shall be able to specify either input condition as the "on" condition.

4) Binary output object: comply, as a minimum, with the BACnet standard for data sharing. Properties to enable minimum on and off times for equipment protection as well as interstart delay shall be provided. The BACnet Command Prioritization priority scheme shall be incorporated to allow multiple control applications to execute commands on this object with the highest priority command being invoked. Provide 16 levels of priority as a minimum. Systems not employing the BACnet method of contention resolution are not acceptable.

5) PID control loop object: comply, as a minimum, with the BACnet standard for data sharing. Each individual property shall be adjustable as well as be disabled to allow proportional control only, or proportional with integral control, as well as proportional, integral and derivative control.

6) Comparison object: allow a minimum of 2 analog objects to be compared to select either the highest, lowest, or equality between the 2 linked inputs. Object shall also allow limits to be applied to the output value for alarm generation.

7) Math object: allow a minimum of 4 analog objects to be tested for the minimum or maximum, or the sum, difference, or average of linked objects. Object shall also allow limits to be applied to the output value for alarm generation.

8) Custom programming objects: provide a blank object template for the creation of new custom objects to meet specific user application requirements. This object shall provide a simple BASIC-like programming language that is used to define object behavior. Provide a library of functions including math and logic functions, string manipulation, and e-mail as a minimum. Also, provide a comprehensive on-line debug tool to allow complete testing of the new object. Allow new objects to be stored in the library for re-use.

9) Interlock object: provide an interlock object that provides a means of coordination of objects within a piece of equipment such as air handling units or other similar types of equipment. An example is to link the return fan to the supply fan such that when the supply fan is started, the return fan object is also started automatically without the user having to issue separate commands or to link each object to a schedule object. In addition, the control loops, damper objects, and alarm monitoring (such as return air, supply air, and mixed air temperature objects) shall be inhibited from alarming during a user-defined period after startup to allow for stabilization. When the air handling unit is stopped, the interlocked return fan shall also be stopped, the outside air damper shall be closed, and other related objects within the air handling unit shall be inhibited from alarming thereby eliminating nuisance alarms during the off period.

10) Temperature override object: provide an object whose purpose is to provide the capability of overriding a binary output to an "On" state in the event a user defined high or low limit value is exceeded. This object shall be linked to the desired binary output object as well as to an analog object for temperature monitoring, to cause the override to be enabled. This object shall execute a Start command at the Temperature Override level of start/stop command priority unless changed by the user.

11) Composite object: provide a container object that allows a collection of objects representing an application to be encapsulated to protect the application from tampering, or to more easily represent large applications. This object shall have the ability to allow the user to select the appropriate parameters of the "contained" application that are represented on the graphical shell of this container.

g. The object library shall include objects to support the integration of devices connected to the NAC. At a minimum, provide the following as part of the standard library included with the programming software:

1) For BACnet devices, provide the following objects at a minimum:

   a) Analog in.

   b) Analog out.

   c) Analog value.

   d) Binary.

   e) Binary in.

   f) Binary out.

   g) Binary value.

   h) Multistate in.

   i) Multistate out.

   j) Multistate value.

   k) Schedule export.

   l) Calendar export.

   m) Trend export.

   n) Device.

2) For each BACnet object, provide the ability to assign the object a BACnet device and object instance number.

3) For BACnet devices, provide the following support at a minimum:

   a) Segmentation.

   b) Segmented request.

   c) Segmented response.

   d) Application services.

   e) Read property.

   f) Read property multiple.

   g) Write property.

   h) Who-has.

   i) I-have.

j) Who-is.

k) I-am.

l) Media types.

m) BACnet IP Annex J.

n) MS/TP.

o) BACnet Broadcast Management Device (BBMD) function.

p) Routing.

C. BAS Software:

1. General: provide global synchronization of BAS controller clocks and global coordination of BAS controller activity. Standard utility software packages shall be contained in memory including self-test diagnostics and on-line memory diagnostics. System displays (hard and soft copy) shall be in plain English. Field selected control and monitoring points shall be capable of being described using operator selected menu penetration techniques. Values shall be described in appropriate units. The system shall have at least 3 user access levels. Menus and screens shall be organized to present orderly information. The system shall perform the following functions:

a. Operator communication with any BAS and terminal unit controller including programming and data acquisition.

b. Full English operator display, including appropriate engineering units for variable data.

c. Power Failure and Automatic Restart:

1) Power failure recovery: when recovering from a failure of the normal power supply, the system shall automatically:

a) Initialize the time of day within the real-time operating system.

b) Adjust time dependent parameters within the monitoring and control software.

c) Automatically restart and output a message indicating that a power failure occurred with the time and date of occurrence. A system restart shall initialize processors and communications, update time programs, and reset equipment to the appropriate operating status for the correct time.

d. System displays shall be capable of being randomly configured with any point assigned to any system for display/logging, independent of its hardware location.

e. Remote status to allow the operator to display on the monitor any point noting point description and engineering value.

f. System function to allow operator to update time and date.

g. Upload/download to transfer database to/from disk or diskette storage to/from BAS or terminal unit controller.

h. Edit/create database to configure, edit, create or delete database information in whole or in part.

i. Database error checking to provide a method of detecting and annunciating discrepancies that would prevent the system from full normal operation.

j. Whenever a field point status exceeds preset limits, or there are other indications of system exceptions, alarms, error or failures, there shall be at least the following indications:

1) Audible tone: the system shall have an integral audible tone. The audio tone shall be capable of being enabled or disabled on operator command.

2) Display: the alarm point identification shall appear on the monitor and print out along with individual point alarm messages. Upon operator command, alarms resident in the CCU shall be hard copy printed along with individual point alarm messages.

3) Automatic dial out: the system shall automatically initiate calls to up to 4 telephone numbers on a rotating basis. Only those alarms selected by the Owner during BAS training shall initiate automatic dial out features.

2. System programming: controller software and custom programming shall be provided to implement control sequences as indicated on the Drawings. Each BAS controller shall contain mathematic, logic, utility functions and standard energy calculations and control functions in ROM to be available in any combination for field programming the unit. These routines shall include but not be limited to:

a. Math Routines:

1) Basic arithmetic.

2) Binary logic.

3) Relational logic.

b. Utility Routines:

1) Process entry and exit.

2) Variable adjustments and output.

3) Alarm indication.

4) Restart.

c. Control Routines:

1) Signal compensation.

2) Loop control.

3) Energy conservation.

4) Timed programming.

d. Energy Management Routines:

1) Scheduled start-stop and holiday programming.

2) Optimal start-stop.

3) Duty cycling.

4) Demand limiting.

5) Day-night setback.

e. Terminal Unit Control:

1) Volume control in response to temperature.

2) Volume flow limits, minimum and maximum.

3) Occupied and unoccupied operation with associated temperature, and volume limits.

4) Occupant temperature adjustment.

5) Temperature setpoint override.

6) Occupant override.

7) Global reset of temperature and volume limits.

f. Project tailored programs: the library of routines available in firmware shall be capable of generating additional programs for specific Project requirements. These should include but not be limited to:

1) Chiller efficiency.

2) Supply air temperature control.

3) Variable volume supply fan control.

4) Space temperature control.

5) Fire alarm activated sequences.

6) Totalizing.

7) Event initiated sequences.

3. Each BAS controller shall perform its full control and energy management functions, regardless of the condition of the communications link with other system components. These stand-alone capabilities shall be implemented and shall include, but not be limited to, closed loop control functions (P, PI, PID, incremental, floating) and energy management functions. BAS controllers and terminal unit controllers shall be totally stand-alone and independent of other components of the BAS for control applications defined herein. Failure of other components of the BAS shall in no way inhibit the operation or program execution of BAS controllers and terminal unit controllers.

4. BAS controller control algorithms shall be available and resident in the BAS controller to permit proportional, integral and derivative control modes in any combination to meet the needs of the application. Other control modes, incremental, floating or 2-position, shall be available to adapt to the needs of the Project. Adjustment of control variables shall be available at the BAS controller through the display unit. These adjustments shall include, but not be limited to, proportional gain, integral rate, the velocity and acceleration constants associated with incremental control, and on/off values of 2-position control. Each control loop setpoint and control logic threshold shall be programmed as a variable expressed in the appropriate engineering units and shall be displayable and adjustable through the display unit. Modification of BAS software shall not be required to alter those variables.

5. Software, local variables, and data resident in the BAS controllers shall be resident in nonvolatile memory or shall be down-loadable from the BAS.

D. Energy Management Control Strategies:

1. Scheduled start-stop and holiday programs: provide software to start and stop equipment based on the time-of-day for each day-of-week, including holidays. To eliminate power surges and to ensure stable system operation, an operator adjustable time delay shall be provided between consecutive start commands and between consecutive stop commands for electrical loads. Software shall provide for multiple start/stop events scheduled for each output for each day, including holidays.

2. Optimum start-stop program: provide software to start and stop equipment on a sliding schedule based on indoor and outdoor air conditions. The program shall take into account the thermal characteristics of the structure, indoor and outside conditions using prediction software to determine the minimum time of system operation needed to satisfy space environmental requirements at the start of the occupied cycle and determine the earliest time for stopping equipment at the day's end. The program shall automatically modify the calculation constants based on its past performance.

3. Day-Night-Standby setback program: provide software to define the space temperature set points and fan cycling control during unoccupied hours. Whenever the space temperature is above (or below for heating) the unoccupied temperature set point, the system shall be enabled in accordance with the defined sequence of operations until the temperature is within the assigned temperature limit. Include Stand-by temperature settings for systems utilizing occupancy sensors. Standby set points apply when the occupancy sensor detects no occupants during scheduled occupied periods.

4. Power fail-auto restart: on power failure, the BAS controller shall shutdown without damage to the BAS controller or connected systems, and without loss of programmed information. If power is restored within the time defined herein for battery back-up of BAS controller clock operation, the BAS shall automatically restart, adjust operating parameters according to the proper time of day, and resume full normal operation within no longer than 5 minutes following restoration of power. Each controlled item of equipment 5 hp or greater shall be sequentially restarted or returned to proper operation as appropriate for the time-of-day.

5. Event initiated sequences: based on programmable values of either digital or analog inputs or outputs, the BAS controller shall be able to open or close any output contacts or combination of contact outputs, and adjust any analog output over its normal range.

6. Terminal unit controller software: provide software for the management and control of the BAS terminal unit controllers. Software shall allow for operator definition of terminal unit controllers as functional groups; monitoring, alarming and reporting of terminal unit parameters on an individual or group basis; after hours terminal unit operation monitoring and reporting on an individual or group basis; and remote setpoint adjustment of terminal unit parameters on an individual or group basis in response to operator commands or through software interaction.

E. Trending and reporting: a utility software data file log package shall be provided that analyzes and formats, into English language, a hard copy printout of hardware and software configurations of the system. This package shall be designed to allow the operator to select individual data file logs defined herein. This software package shall be executable via the BAS to allow site hard copy documentation of current data file caused by system modifications and schedule changes.

1. System configuration log: data file logs shall document basic system parameters, individual channel configuration with listing of type of hardware used with its assigned system address, listing of peripheral device (printer and operator terminals) and address with its associated segregation as to function.

2. Individual point parameter log: this software package shall provide a detailed listing of system points with the following information:

    a. Digital points: point address, assigned engineering units, type of point, listing of which programs the point is used in the system.

    b. Analog points: point address, engineering units, assigned scale factor, offset, decimal position of value, and a listing of which programs the point is used in the system.

3. System program data file log: provide to document details on individual application programs as listed below:

    a. Time program log of programs, or selected programs, listing program number and on and off times assigned for each individual day of the week.

    b. A listing of points grouped by initiating devices causing a change in condition. For example, a listing of points scheduled on by a fixed time schedule.

    c. Printout listing individual calculation address with its assigned operators and parameters. Also, a listing of other calculation points using its results.

4. Alarm summary: an alarm summary shall be provided which contains the point status of points in the alarm condition.

5. Trend log: a program shall be provided which outputs a log on a time interval basis. This program shall provide the operator with the ability to place a minimum of 16 points on trend logs and the ability to assign the trend interval from 1 second to 99 minutes. Adding, changing, or deleting a trend point, assigning the trend log period, or outputting the trend log shall be performed without any loss of change-of-state reporting on the designated hard copy device. Trend log report information shall be listed in vertical columns. A directory of columnar placement shall appear in the heading of the trend log.

6. Historical data file storage: the system shall provide software to allow operator designation of point values or status to be automatically stored in historical files on the hard disk of the BAS central computer. Software shall allow operator designation of which point data is to be stored, at what frequency it is to be stored, when to start and when to stop storing the data, and shall allow a minimum of 50 points to be assigned to the historical data function at one time.

7. Field generated reports: the system shall have the capability, as installed, to develop custom management report logs. The software shall be capable of displaying, organizing, and editing the historical data files of point data.

8. Custom reports: software and programming shall be capable of generating the following reports, for example:

    a. Chiller operation: for each chiller, report the number of chiller start commands, the total hours of operation, total chiller kWH consumption,

average chiller kW input per ton for the report period, peak chiller tons, peak chiller kW demand and time of peak, and the number of chiller safety shutdowns. The chiller tons shall be calculated using the chilled water flow rate and evaporator entering and leaving water temperatures.

b. Boiler operation: for each boiler, report the consumption of gas, oil, and electricity (where applicable) for the report period. Gas consumption shall be measured using a transducer to monitor the gas burner manifold pressure while the burner is in operation. Oil consumption shall be obtained by monitoring and totalizing the pulse contacts of the existing fuel oil meter pulse initiators and subtracting the fuel return meter value from the supply meter value. Electricity shall be measured through the use of CT's.

1) Calculate the number of 65ºF based degree hours during the period while the boilers were enabled, and report the average building heating energy consumption in Btu/(ºF·h), using an energy value of 1050 Btu/ft³ for gas and 140000 Btu/gal for fuel oil.

c. Smoke control system verification: for each smoke control system, a weekly test sequence shall verify the presence of power downstream of disconnects, positive confirmation of actuation, and confirmation that the system has not been manually overridden. Abnormal conditions shall be communicated via audible and visual alarms and a printed report.

2.07 SENSORS

A. BAS Sensors:

1. Sensors – General:

a. Analog Sensors: Compatible with systems defined, selected for required span:

1) Preferred Signal Types: 2-10 VDC, 4-20 mAmps.
2) 20K NTC

b. All Sensor Wiring; Analog or Digital, Input or Output:

1) Capable of sharing single conduit runs without affecting signal performance.
2) Comply with Division 26.

2. Provide sensors, controls, instruments, and control interfaces to meet the performance defined herein. Sensors shall be high quality precision electronic type, selected to be compatible with the BAS controllers and appropriate for the service defined herein. Accuracy values defined herein include sensor, wiring, signal conditioning and display accuracies for overall end-to-end performance. Sensors shall be selected to place the expected value in the middle third of the device's range.

3. Temperature sensors: 100 or 1000 ohm platinum or Nickel resistance temperature device (RTD), Deutsches Institut für Normung (DIN) 43760, with an average percent change in resistance per degree (α) of 0.00385 ± 0.00002 ohms/ohm/ºC, selected for normal range of media sensed with accuracy of ±0.5ºF at 70ºF except chilled water sensors used for Btu calculations or control as indicated on the I/O summaries shall have an accuracy of ±0.25ºF at 32ºF. Sensors used for Btu calculations shall be matched pairs at the calibration point. Temperature sensor stability errors shall not exceed 0.25ºF cumulative over a 5 year period. Provide thermowells and insertion type sensors for water temperature sensing. Air temperature sensing shall be provided by duct insertion type sensors for supply or return duct temperatures and by extended element averaging type for plenum, and coil entering or leaving temperatures. RTD transmitters shall be a 2-wire, loop-powered device, producing a linear 4-20 mA output corresponding to the temperature span of the connected sensor. The output error shall not exceed 0.1% of calibrated span. Transmitters shall include noninteracting offset and span adjustments and RFI shielding and rejection circuitry to prevent disruption from ambient signals. Transmitter drift shall be less than 0.1ºF per year. 20K NTC Thermistor.

    a. Every AHU coil shall have an averaging temperature sensor located downstream of the coils.

    b. Duct Temperature Sensors: RTD type.

        1) Mounted in main airstream as required for best temperature control.
        2) Hole and plug to permit insertion of 1/8 inch test thermometer of length appropriate to situation. Sensors used on coils to have extended length.
        3) Sensor Location:

            a) Locate at reheat coils such as VAV boxes, terminal boxes, lab control valves, etc.
            b) Locate at discharge of fan coil units.

    c. Pipe Immersion Temperature Sensors: Stainless steel immersion well and accessories.
        1) On inlet and outlet of heat exchangers, air handling unit coils, and mixed temperature water streams.
        2) Temperature Sensors for Energy Meters: Refer to Section 23 0519 Meters & Gauges.

4. Space temperature sensors: RTD type, with space temperature type with setpoint adjustment range of 45ºF to 85ºF.

    a. Hardwired space temperature sensors are preferred.

    b. Wireless space temperature controls may be provided (not preferred) for space temperature controls associated with terminal units and as approved by Dartmouth College Engineering and BAS Shop. Wireless space temperature controls systems shall be comprised of a wireless network utilizing ZigBee technology, with multiple pathways of communication to/from each controller. The systems shall be designed by the Contractor

so as to provide the functionality defined herein. Refer to Section 33 83 00 – Wireless Communications Transmission and Distribution, https://dartgo.org/DartmouthNetworkMasterSpec and confirm with Owner for location and application of wireless sensor prior to installation.

c. The setpoint adjustment shall be locked out, overridden, or limited as to time or temperature in software from a central or remote operator's terminal. Precision thermistors may be used in space temperature sensing applications below 200ºF. Sensor accuracy over the application range shall be minimum 0.5ºF between the range of 32ºF to 150ºF including sensor error and A/D conversion resolution error. Sensor manufacturer shall utilize 100% screening to verify accuracy. Thermistors shall be pre-aged and inherently stable. Stability error of the thermistor over 5 years shall not exceed 0.25ºF cumulative. Sensor element and leads shall be encapsulated. Bead thermistors shall not be used. Space temperature sensors shall include a communications port for local connection of a portable test/terminal device for communications/programming access to the associated BAS controller.

d. Space Temperature Sensors Control and Readout: temperature readouts on all models.

1) Unless Otherwise Noted:

a) Classrooms, Offices, Lounges, Conference and Computer Labs -
b) NO: Temperature Display Reading, unless otherwise defined and approved by Dartmouth College.
c) YES: Slider temperature. ±2 °F adjustment, total ±4 °F (adjustable).
d) YES: Occupancy overrides.
e) Tuck, Cummings, Med School, provides full adjustment capabilities.

2) Public Spaces; Hallways, Toilet Rooms, Vestibules, etc:

a) NO: Temperature Display Reading.
b) NO: Slider temperature adjustment.
c) NO: occupancy override.
d) Sensors only.

3) Offices, Conference and Classrooms with Operable Windows: Provide with space sensors and local display (LED) for natural ventilation signal.

5. Humidity sensors: bulk polymer type, with self-contained 4-20 mA transmitter and replaceable element. Accuracy shall be ±2% RH in the range of 20% to 90%. The transmitter shall include noninteracting zero and span adjustments with an output error not exceeding 0.1% of calibrated span. Saturation shall not alter calibration.

Sensors for space humidity shall have same appearance as space temperature sensors.

6. Dewpoint Measuring Instrument:

   a. Dewpoint and calculated dewpoint setpoint shall be included as points in all required applications (e.g. chilled beams) as a read/write point in all applicable field-controllable system components.

      1) Alarms for dewpoint and temperatures approaching dewpoint shall be configurable in field-controllers and included in all applicable BAS and NAC routines and SOO's.

      2) Communication protocol: Modbus or BACnet, hardwired options shall be 0-10V, or 4-20mA.

      3) Accuracy and Ranges:

         a) Measuring range temperature 0.0 … 50.0 °C

            (1) Resolution 0.1 °C

            (2) Accuracy ±0.5 °C

            (3) Response 10 seconds

         b) Measuring range humidity 0.0 … 99.9 % RH

            (1) Resolution 0.1 % RH

            (2) Accuracy ±3 % RH

            (3) Response 10 seconds

   b. Dewpoint measurement and calculation in Dartmouth facilities that operate a Facility Air Monitoring System shall adhere to requirements defined in guidelines section 23 30 00 Facility Air Quality Monitoring System and be reviewed with Dartmouth College Engineering.

7. Pressure sensors: 2-wire strain gauge type, designed for media sensed for static pressure or differential pressure. The span shall be continuously adjustable from 0% to 125% of the expected full pressure or full flow differential pressure. The zero shall be continuously adjustable on outputs. Transmitters shall produce a 4-20 mA signal with an accuracy of ±1.0% of the upper range limit for 6 months from calibration. Instruments shall be capable of withstanding an overrange pressure limit of 300% normal. Pressure sensors measuring water differential pressure at chillers shall be furnished with NEMA 4 cover and digital pressure differential readout.

   a. Differential Pressure Transmitters – Air:

      1) Dedicated DP sensor

a) For air differential pressure (such as air static or velocity pressure in ducts)
b) For air static pressure (such as pressure in ducts up to 3" w.g.).
c) Not Acceptable: Using two pressure sensors and calculating the pressure differential.

2) Air flow Switches: Provided to monitor filter differential pressure.

a) Adjustable Set Point Range: 0.05 to 5.00 inch W.C.
b) Signal the operator's workstation (where applicable) of supply, return, and/or exhaust fan status for every AHU (supply, return, and exhaust fans independent).

3) Fan Status: Monitored by differential pressure switches.
4) Size Transmitters for the application Range:

a) Combined static error (RMS of non- linearity, non-repeatability and hysteresis) to be less than ±1% of full range output.

5) Manufacturers: Modus, Ashcroft, Setra, Robinson-Halpern, Johnson Controls, Mamac, or acceptable equivalent.
6) Mounting: On surfaces isolated from fan vibrations.

b. Differential Pressure Transmitters – Hydronic:

1) Differential Pressures for hydronic systems for critical control on plant systems., to control campus hydronic system pressures.

a) Pressure Differential transmitter shall be Endress Hauser Deltabar S PMD75 or equivalent Honeywell, Rosemount, ABB or Yokogawa.
b) Rosemount Model 2051 with HART Protocol or equal; including capabilities to calibrate with in-house technicians.

2) Pressure Transmitters for Liquid Differential Pressure:

a) Ranges: As necessary. Ensure proper system control without exceeding transmitter sensing range.

(1) Static Pressure Sensors: Selected as appropriate for application.

(a) Static Pressure Readings: Reported to operator's workstation.

b) Accuracy: ± 0.25%.
c) Capacity: Withstand system pressure applied to one port with no pressure on other port.
d) Manufacturers: Setra, Mamac, or Robinson-Halpern.

e) Three-valve manifold to simplify calibration.
f) Mounting suitable to relieve stress on tubing and sensing transducer.

8. High Pressure Transducers: For water or air.

   a. Analog signal transmitter, temperature compensated, with integral signal conditioning, full range span and offset adjustments.

   b. Manufacturers: Ashcroft, Setra, Mamac or acceptable equivalents with ±0.5% accuracy for lab areas and ±1% accuracy for other areas.

9. Liquid Flow Switch: Vane-operated or disc-operated with SPDT contacts.

   a. Switch sealed from liquid with magnetic linkage.
   b. Components exposed to liquid shall be non-corrosive.
   c. Switch to be full pipe size.
   d. Not Acceptable: Mercury switches.
   e. Models:

      1) W.E. Anderson "Model V6 Flotect".
      2) Thomas Products "Model 1100".

10. Liquid Level Sensor:

    a. Continuous output signal indicating liquid level.
    b. Appropriate range, zero, and materials suited to the application.
    c. Accuracy: ±0.75 inch.
    d. Temperature: Compensated from 32 to 110 degrees F.
    e. Programmer/Calibrator Unit: If unit is required to set zero and span.
    f. Types: Submersible pressure type, ultrasonic type, RF type, capacitive probe type, or other type acceptable to Engineer.

11. Water Differential Pressure Switch:

    a. Working Pressure Range: 10-350 psig.
    b. Adjustable setpoint on increasing differential of 10-300 psi.
    c. Models: Mamac, #XXXXX; Honeywell #P606A, or acceptable equivalent.

12. Duct Static Pressure Probe:

    a. Models:

       1) Air Monitor "Stat-Probe I",
       2) Paragon #PE-5000,
       3) Setra DPT 264
       4) Acceptable equivalent.

    b. Space Static Pressure Sensors: For recessed ceiling mounting.

1) Capable of sensing pressure in sensor's vicinity to within 1% of actual pressure value, when subjected to airflow rate of 1000 fpm from 360 degree radial source.
2) Multiple sensing ports
3) Pressure impulse suppression chamber
4) Air velocity shielding
5) Casing: 12-gauge stainless steel.
6) Models:

    a) Air Monitor "Type S.A.P./3"
    b) Acceptable equivalent.

13. Current sensing relays: current sensing relays shall provide an adjustable setpoint normally open contact rated at a minimum of 50 V peak and 0.5 A or 25 VA, noninductive. There shall be a single opening for passage of current carrying conductors. Relays shall be sized for operation at 50% rated current based on the connected load. Voltage isolation shall be a minimum of 600 V.

14. AC Current Sensor & Switch:

    a. Current transformer with built in Transducer.

        a) Transducer: 4-20 ma, 0-10 Vdc, for variable speed motor loads or switch with setpoint adjustment for constant speed loads with. Accuracy: ±2.0%.

    b. Models: Veris Industries Inc, Hawkeye sensor, switch, Rib Devices, or acceptable equivalent.

15. Filter status: filter status shall be sensed by contact closures or 4-20 mA input, depending on application from differential pressure gauges across each filter, as defined in all Mechanical Equipment Guidelines.

16. Water flow meters: Refer to Dartmouth's guidelines section 23 05 19 Meters and Gauges for HVAC Equipment.

17. Non-Revenue Water Flow Energy Meters: Refer to Dartmouth's guidelines section 23 05 19 Meters and Gauges for HVAC Equipment.

18. Thermal Utility Meters: Refer to Dartmouth's guidelines section 23 05 20 Thermal Utility Meters.

19. Building electrical meter: Refer to Dartmouth's guidelines section 26 16 00 Electric Metering.

20. Hydrogen sensors: industrial type housed in a cast aluminum or heavy plastic enclosure complete with automatic calibration microprocessor and display. Sensor and transmitter shall provide a 4-20 mA analog output proportional to gas concentration. Standard range shall be 0% to 4%. Drift shall be less than 2% per month. Average sensor life shall be not less than 2 years.

a. Manufacturer: Analytical Technology, Mine Safety Appliances, or Quatrosense Environmental.

21. CO_2 sensors: dual channel infrared type, with 10-micron filter to prevent particulate contamination of sensing element. Sensor shall have an accuracy of ±5% of reading up to 10000 ppm, with a repeatability of ±20 ppm and a maximum drift of ±10 ppm per year, and a recommended calibration interval of 5 years. Sensor shall have a response time of no more than 2 minutes to a 90% of full-scale change. Sensor and transmitter shall provide a 4-20 mA analog output proportional to gas concentration.

    a. Manufacturer: Telaire.

22. CO sensors: electrochemical or solid-state sensing elements, adjustable or selectable sensing range of at least 200 ppm. Sensor elements shall have a minimum operating life of 5 years in normal service, a maximum drift of no more than 0.5% per month, and a response time of no more than 30 seconds to a 90% of full-scale change. Sensors and transmitters shall provide a 4-20 mA analog output proportional to sensed gas concentration.

    a. Manufacturer: Senva, INTEC Controls, or Mine Safety Appliances.

23. Multipoint gas detection control system: self-contained panel for monitoring and reporting up to 25 gas detection sensors. Control panel shall include local display of monitored conditions, a minimum of 10 relay contacts for local interlocking of equipment and signaling of alarm conditions, and a communications port designed for connection to the BAS (LON, ethernet, or other interface as appropriate for the BAS installed). Controller shall operate from 120 V AC and be designed for wall mounting in an environment of 32°F to 120°F up to 95% RH, noncondensing.

    a. Manufacturer: Senva, INTEC Controls PolyGard CO DT5-1110

24. For environmental air quality, refer to Section 23 30 00 Facility Air Quality Monitoring System and be reviewed with Dartmouth College Engineering.

2.08 MATERIALS

A. Damper Actuators: All new and replacement actuators shall be electric actuated, not pneumatic. Dampers actuators for all plant, outside and outdoor air applications shall be NEMA 4 rated housings. Actuators for use in entirely interior, non-plant applications do not require NEMA 4-rated housings.

1. BAS terminal unit actuators: 24 V non-stall (spring return where defined) type, providing complete modulating control for the full range of damper movement. Actuators shall be de-energized when the damper has reached the operator or system determined position. Where defined, actuators shall be supplied to the terminal unit manufacturer for factory mounting and calibration. Actuators shall be removable for servicing without removing the terminal unit. Actuators shall be provided with transformers for proper operation from the terminal unit controller power source.

a. Quarter Turn Operators: Using floating control signal of VAV box volume damper, with torque required by the box manufacturer by BAS contractor.
b. Minimum stop adjustments shall be set or reset via software.

2. Other actuators: 24 V electric worm-gear type, sized to provide required starting torque and control the driven apparatus smoothly. Higher voltage actuators are acceptable for specific applications where 24 V actuators are not adequate. Provide adjustable end switches for valve and damper open/closed monitoring where required by the control sequences or as defined herein. For control valves 4" and larger, provide actuators with visual position indicator, self-regulating heater for condensation control, motor thermal protection, and hand-wheel for manual override.

    a. Actuators for outside air, exhaust air, and other openings to the outside shall have spring return.

    b. Emergency and Stand-by Generator Dampers: Normally open, spring return, and on the emergency power system.

3. Meet selection requirements defined for damper size and type.

    a. Non-overloading motors.

    b. Direct drive.

    c. Furnished with end switches and adjustable zero and span where required.

    d. Manufacturers: Johnson Controls, Honeywell, Belimo or acceptable equivalent.

    e. Actuators Associated with Outdoor Air: Fail-closed devices and reversible rotation.

    f. Actuator Damper Operator Mounting Arrangements:

        1) Outside the airstream. Otherwise as approved by Owner, based on accessibility restrictions.

    g. Actuator Sizing and Quantity: To be determined by control manufacturer.

        1) As Needed To:

            a) Meet system requirements.

            b) Provide sufficient power for smooth modulation over entire range.

            c) Be able to open or close damper without binding or damage, at pressure differential up to 4 inch w.g. for low pressure systems and up to 8 inch w.g. for medium and high pressure systems.

4. Provide actuator for each damper over four feet in length or height.

5. Assembly shall include necessary mounting hardware and brackets.

B. Thermostats: line voltage type and shall have adjustable throttling range with an accuracy of ± 0.5ºF. Remote element type shall have accessible adjustment knob. Provide separable wells for elements in liquids and extended necks for wells in insulated pipe.

1. Low limit safeties: elements shall respond to the lowest temperature to which any 12" segment is exposed; minimum length 8'.

2. Averaging type: for use in coil discharge larger than 48” and areas where the is a chance of stratification in mixed air locations.

3. Thermostats shall not contain mercury.

C. Thermostat guards: 22-gauge steel with lockable hinged cover and baked enamel finish.

D. Humidistats: same cover as room thermostats, with an accuracy of ±2%.

E. Sensor piping: seamless copper tubing with sweat fittings, or nonmetallic tubing with barbed brass fittings.

1. Exposed copper tubing shall be hard drawn. Concealed tubing may be hard drawn or annealed.

2. Nonmetallic tubing shall be tested in accordance with UL 1820-2004(R2017) and shall meet NFPA 90A-2018 requirements for use in return air plenums and be approved for plenum use by the code authorities having jurisdiction.

3. Piping used in smoke control systems shall be hard drawn copper tubing, type L, ACR in accordance with International Building Code-2018 requirements for smoke control systems, sized for immediate response. Fittings shall be wrought copper or brass, solder type in accordance with International Building Code-2018 requirements for smoke control systems.

a. Nonmetallic tubing listed by an approved agency for flame and smoke characteristics may be used within control panels and at final connections to devices.

4. Copper pipe applications must comply with one of the following requirements:

a. Use mechanically crimped copper joint systems.
b. All solder joints must comply with ASTM B828 2016 and flux must be ASTM B813 2016 compliant.

F. Occupied/unoccupied switches: stainless steel cover plates with red pilot light. Cover plates shall be engraved with "Occupied/Unoccupied". Pilot light shall be on whenever switch is in the occupied position.

G. Manual push buttons: flush-mounted, in NEMA 1 enclosure with pilot light.

H. Automatic Control Ball Valves: for services as indicated on Construction Drawings.

1. Select size to have turn down to 5 percent capacity.

2. Normally open, normally closed two-way or mixing type, as defined.

3. Manufacturer: Warrant components for 5 years from date of delivery.

4. Normal valve positions unless otherwise defined.

   a. HW Coil or HW Heat Exchanger: Fail Open.
   b. Steam Coil: Fail Open.
   c. Steam Heat Exchanger: Fail Close.
   d. CW Coil: Fail Close.
   e. Terminal Heating Unit: Fail Last Controlled Position.
   f. Terminal Heating Units subject to exposure to outside conditions: Fail Open.
   g. Pressure Reducing Valve: Fail Close.
   h. Steam Humidification: Fail Close.

5. Valves to be as Follows: Unless defined otherwise.

   a. Pressure-Independent 2-way Ball Valves: NPS 3/4 (DN 20) and smaller.

      1) Pressure Rating: 360 psig.
      2) Close-off pressure of 200 psig.
      3) Process Temperature Range:

         a) Between 36 to 212 deg F.

      4) Integral Pressure Regulator:

         a) Located upstream of ball to regulate pressure, maintaining a constant pressure differential while operating within a pressure differential range of 5 to 50 psig.
         b) Internal P/T ports incorporated for differential pressure verification.

      5) Body: Forged brass, nickel plated, and with NPT female ends.
      6) Ball: Stainless steel.
      7) Stem and Stem Extension: Stainless steel, blowout-proof design.
      8) Ball Seats: Teflon PTFE.
      9) Stem Seal: Dual EPDM O-rings (lubricated).
      10) Flow Characteristic: Equal percentage

   b. Pressure-Independent 2-way Ball Valves: Larger than NPS 3/4 through NPS 6 (DN 150).

      1) Pressure Rating for NPS 2 and smaller: 360 psig.
      2) Pressure Rating for NPS 2-1/2 and longer: ANSI 125, Class B.
      3) Close-off pressure for NPS 2 and smaller: 200 psi.
      4) Close-off pressure for NPS 2-1/2 and longer: 100 psig.

5) Process Temperature Range:

   a) Between 14 to 212 deg F.

6) Integrated Flow Meter:

   a) Integrate a characterized control valve with electronic (ultra-sonic or electromagnetic) flow sensor (accuracy +/- 2%) providing analog flow feedback.
   b) Reposition valve to maintain required flow with a +/- 5% accuracy over a pressure differential range of 1 to 50 psig.

7) Glycol Compensation for NPS 2 and Smaller: Incorporate an algorithm to automatically compensate for the glycol concentration and be readable by a local device.
8) Body: Forged brass, nickel plated.
9) End Connections:

   a) NPS 2 and smaller: NPT female ends.
   b) NPS 2-1/2 and longer, pattern to mate with ANSI 125 flange.

10) Ball: Stainless steel.
11) Stem and Stem Extension: Stainless steel, blowout-proof design.
12) Ball Seats: Teflon PTFE.
13) Stem Seal: Dual EPDM O-rings (lubricated).
14) Flow Characteristic: Valve design to allow disassembly of valve top, inspection, and replacement of packing without system shutdown or valve body removal.

c. Pressure-Independent 2-way Energy Valve (where defined for CHW coils):

   a) Equal to Belimo EV.
   b) Same construction and performance as ePICV valves defined under 2.7 A.2.
   c) Components:

      (1) Electronically fail safe actuator with analog input and output.
      (2) 2-way control valve.
      (3) Ultrasonic or electromagnetic flow meter with glycol compensation
      (4) Supply and return temperature sensors.

   d) Provide BACnet IP communication.
   e) Controls: Allow valve operation in Delta T Manager ON or OFF mode.

d. Pressure-Independent 6-Way Ball Valves: NPS 3/4 (DN 20) and Smaller:

1) Pressure Rating: 232 psig.
2) Close-off pressure: 50 psi.

3) Process Temperature Range: Between 43 deg F to 180 deg F.
4) Integrated Flow Meter:

a) An integrated characterized control valve with an electronic (ultra-sonic) flow sensor (accuracy +/- 2%). Includes one piece containing 5 times the pipe diameter to maintain the tolerance and providing analog flow feedback.
b) The valve is to reposition to maintain the required flow with a +/- 5% accuracy over a maximum pressure differential of 15 psig.

5) Glycol Compensation: Incorporate an algorithm to automatically compensate for glycol concentration and be readable by a local device.
6) Body: Forged brass, nickel plated.
7) End Connection: NPT female ends.
8) Ball: Forged brass, chrome plated.
9) Stem: Forged brass, nickel plated.
10) Ball Seats: Teflon PTFE.
11) Stem Seal: Dual EPDM O-rings (lubricated).
12) Flow Characteristic: Linear.

e. Steam 2-Way Control Valves: NPS 1 ½" and Smaller.

1) Brass Construction Glove Valves,

f. Steam 2-Way Control Valve: NPS 2 ½ " and Larger.

1) Cast Iron Globe valves, with spring return

6. Valve Design: Allow disassembly of valve top, inspection, and replacement of packing without system shutdown or valve body removal.

7. Hot Water Coil Valves & Chilled Water Coil Valves:

a. General: Two-way modulating Type.

1) Pressure Drop: Between 4 and 6 psig at maximum design flow (approximately equal to coil pressure drop).

b. Where Indicated: Three-way modulating type, equal percentage valve with throttling ball.

1) Pressure Drop: Between 2 and 5 psig at maximum design flow.

c. Close-off Rating: Suitable for minimum differential pressure of 50 psig.

1) Insofar as possible, valves on same pump system shall have approximately same pressure drop.
2) Higher-pressure drops are permitted on valves nearest to pump. Up to 50% of system pressure drop on systems with total pump head over 45 feet.

d. Chilled Water Valves: Linear characteristic.
e. Valve to fail in the position defined.

I. Automatic Controls Valves – Butterfly Type

1. Industrial grade control valves, supplied by control manufacturer.

a. Chilled water glycol heat recovery systems and hot water systems: 285 psi pressure rating.
b. Low pressure chilled glycol heat recovery systems or hot water systems: 200 psi pressure rating.
c. Control valves to be modulating valves.
d. Two-position valves shall be line size.

2. Refer to spec 230523 - General Duty Valves for valves construction and accessories.

3. Valve Actuators: Fail to specify position, electrically operated, quarter turn type. Size to provide tight shutoff against differential pressure of 150% of pump head pressure.

a. Manual Override Capability: With handwheel operator.

J. Low Temperature Detection (Manual Reset)

1. Low Temperature Protection Thermostats: In air systems downstream of heating coil.

a. Non-averaging type.
b. Double-pole, double-throw, wire to fan starter and DDC panel.

2. Thermostat Capillary: Sensitive length of 20 feet, and be installed in serpentine fashion downstream from heating coil/upstream of cooling coil.

a. Each square foot of coil shall be protected by a section of thermostat capillary.
b. Where large coil size or multiple coil construction exceeds the limit of coverage of one unit, provide additional units placed in series so that coil area coverage is maintained.
c. Mounted on outside of units, except for roof top units mount inside the control door.

3. Upon Detecting a Coil Leaving Temperature Below Its Setpoint:

a. Thermostat is to stop fan, close outside air damper, and enable heating valves to maintain 100 degree F (adjustable) box temperature via the coil discharge air temperature sensor.

K. Temperature regulators, self-contained: adjustable type with enclosed bellows, cadmium-plated spring, indexed spring adjustment guide, top mounted 3.5" diameter temperature indicator, sensing bulb and copper or stainless steel tubing. Capillary length shall be as required for the installation. Valves up to 2" shall have bronze body, screw pattern, and stainless steel trim, and shall be rated for 145 psig service. Valves 2.5" to 6" shall have cast

iron body, 125 psig flanges, and stainless steel trim. Maximum operating differential pressure is 20 psi.

L. Control dampers: single-blade up to 8" high, multiblade over 8" high; minimum 80% free area based on damper frame outside dimensions.

1. Modulating Dampers shall be sized for design velocities of 1500 fpm through free area of damper at maximum system air flows.

2. Two-Position Dampers:

a. Parallel or opposed blade linkage.

b. Arranged for normally open or normally closed operation as required.

3. Dampers in Air Handling Units: Provided by AHU manufacturer. Actuators to be provided under this Section.

4. Blades: minimum 16-gauge galvanized steel, or extruded aluminum. Blades shall be airfoil shape.

a. Pivot rods: steel, minimum 0.5" diameter or hex, with one rod extended 6" to permit operation of damper from outside the duct.

1) Axle or pivot rod material shall be zinc-plated.

2) Hardware attaching blades to axle or pivot rod shall be zinc-plated.

b. Maximum length 48" unless specifically listed by manufacturer for the applicable duct pressure class and velocity.

c. Maximum width 8".

d. At points of contact: interlocking or overlapping edges, and compressible neoprene or extruded vinyl blade seals, and compressible metal side seals designed for temperature of -40ºF to 180ºF at leakage rate defined herein.

e. Type:

1) Opposed blade: for balancing and modulating applications.

2) Parallel blade: for 2-position, and outside and return air mixing applications. For mixing applications, orient dampers to achieve maximum mixing at throttled conditions.

f. Maximum damper area per motor: 15 ft².

5. Leakage when closed: less than 4 cfm/ft² at 1" wg differential static pressure based on a 48" damper width.

6. Frames: galvanized steel bar minimum 2" wide x 12 gauge for dampers 10" high or less, and 3.5" x 0.875", 16 gauge galvanized roll-formed channel with double-thickness edges or 5" x 1" x 0.125" extruded aluminum channel for 11" high and larger.

    a. Corner bracing.

    b. Full size of duct or opening in which installed.

    c. Provide stiffening or bracing for frame sections over 48 inches high.

7. Bearings: blades shall have suitable bearings for smooth operation.

    a. Weather Exposed Locations: Stainless Steel Sleeve

    b. Interior Building Locations: Oil impregnated bronze.

    c. Thrust bearings: vertically mounted.

    d. Maximum spacing: 42".

    e. Seal off against spring stainless steel blade bearings.

    f. Bearings: Composed of a Celcon inner bearing fixed around a 7/16 inch (11.11 mm) aluminum hexagon blade pivot pin, rotating within a polycarbonate outer bearing inserted in the frame.

        1) This eliminates action between metal-to-metal or metal-to-plastic riding surfaces.

8. Finish on steel parts: galvanized.

9. Damper Construction: Suitable for damper operation at maximum fan pressure, without failure, binding or distortion.

    a. 4 in WG Differential Pressure for low pressure systems.

    b. 8 in WG Differential Pressure for medium and high-pressure systems.

10. Damper Frames: Aluminum, Construct to facilitate field assembly. Openings or mounting clips which allow secure fastening of frame to surrounding ductwork, duct collar or fan housing.

11. Dampers Exposed to Outdoor Air (supply or exhaust): Insulated aluminum construction with expanded polyurethane blades (R=2.2 min.) and a thermally broken, polystyrene filled frame.

    a. Blade & Frame Seals: Extruded silicone.

    b. AMCA Certified Air Leakage Rate: Not to exceed 4.1 cfm/Sq Ft at 4 inches w.g. standard air.

c. Blade End Seals: Stainless steel.

12. E. Manufactured dampers to the actual opening. Do not safe off the opening to use stock sizes.

a. Manufacture: Subject to compliance with requirements.

1) Tamco series 9000 BF

2) Ruskin TED

3) Acceptable equivalent.

13. Damper Seals: To be replaceable.

14. Operating linkage: factory-assembled, concealed in frame out of airstream, steel construction.

a. Linkage must be serviceable without removal of the entire damper.

b. Blade Linkage Hardware: Zinc-plated steel and brass.

M. Firestats: manual reset, remote bulb type in hazardous locations, UL classified, set at 135ºF in return air, and 50ºF above maximum operating temperature in other locations.

N. CONTROL CABINETS

1. Control Cabinets: Fully enclosed, all metal construction with ample room for control device mounting and wiring. Cabinets house control apparatus, relays, I-P transducers, EP and PE switches, gauges and other items defined.

a. Cabinet Openings: Doors or cover plates.

1) Doors: Full piano hinges or heavy duty concealed hinges.

2) Cover Plate: Locking latch or bolt-on cover plate.

b. Work light and switch.

c. Finish: Two coats of enamel paint.

d. Indicating Devices and Manual Adjustment Devices Required for Routine Operation of System:

1) Locate on cabinet door or cover plate.

e. Other Devices: Locate on sub-panel within cabinet.

2. Panels and cabinets shall utilize one master key.

O. Wiring: low voltage (Less than 50 Volts) control wiring shall be not less than #18 AWG, 600 V plastic covered, color-coded. Sensor wiring shall be not less than #20 AWG twisted, shielded. For field-installed line voltage wiring, refer to Division 26.

P. Valve tags: as defined in Section 23 05 53 Identification for HVAC Piping and Equipment, Labels: as defined in Section 23 05 53 Identification for HVAC Piping and Equipment,

Q. Thermometers:

1. Water: as defined in Section 23 05 19, Meters and Gauges for HVAC Equipment.

2. Air: 5" diameter, bimetal type.

R. Emergency fan shutdown stations: normally closed toggle switch with brushed stainless steel, single-gang faceplate. Provide key lock transparent plastic guard, and bakelite nameplate engraved "Emergency Fan Stop."

S. Emergency oil flow shutdown stations: aluminum, break-glass switch, surface-mounted, UL listed, with coverplate marking "To Stop Oil Burners."

T. Hazardous storage ventilation system emergency controls: aluminum, break-glass switch, with coverplate marking "Ventilation System Emergency Shutoff."

U. Emergency boiler shutdown stations: aluminum, break-glass switch, flush-mounted, UL listed, with coverplate marking "To Stop Boilers".

V. Thermowells: monel, brass, or copper for use in water piping and stainless steel for other applications. Thermowells shall have threaded plug and chain, retaining nut, and lagging neck to clear insulation. Inside diameter of insertion neck shall accommodate the element being installed.

W. Time switches: 7 day electronic programmable microprocessor type, with a temporary override feature for over calling the off position and operating the system without resetting the program, and a 48 hour battery powered carryover for loss of power.

X. Occupant override timers: 1 hour interval type for overcalling the time switch off position and operating the system on a temporary basis.

Y. Relays:

1. Control Relays: UL listed. Dust cover and LED "energized" indicator.

   a. Contact Rating, Configuration, and Coil Voltage: Suitable for application.

2. Time Delay Relays: UL listed. Solid-state plug-in type with adjustable time delay.

   a. Delay: Adjustable ±200% (minimum) from set point shown on plans.
   b. Contact Rating, Configuration, and Coil Voltage: Suitable for application.
   c. Provide NEMA 1 enclosure when not installed in local control panel.

3. Relay modules shall contain two or four SPDT line voltage relays (Form C) and Hand-Off-Auto override switches. Each relay shall have a LED to indicate an energized state.

Z. Airflow measurement systems: Provide complete UL listed assemblies to monitor airflow in ductwork at locations indicated on the Drawings. Each system shall be complete with one or more multipoint measuring probes, airflow sensors and a single microprocessor-based transmitter.

1. Probes: aluminum or stainless-steel construction with mounting brackets. Probes shall be supported at both ends.

2. Airflow sensors: designed to operate at velocities of 50 fpm to 5000 fpm, temperatures of 20ºF to 140ºF, and relative humidities of 0% to 99% (noncondensing). Each sensing point shall independently determine the airflow rate which shall be equally weighted and averaged by the transmitter prior to output.

3. The minimum number of sensors for each assembly shall be as follows:

Area, (ft^2)	No. of Sensors
1 to 4	4
4 to 8	6
8 to 12	8
12 to 16	12
>16	16

4. Transmitters: designed to operate at temperatures of -20ºF to 120ºF and provided with LCD display, 24 V AC power connection, and analog output signal (0-10 V DC or 4-20 mA) for connection to the BAS.

5. Accuracy: ±2% of reading over the entire operating airflow range.

6. Manufacturers:

a. Probe-type multi-point electronic sensors.

1) For high turn down applications or pitot tube sensors where 3:1 turndown is adequate.
2) Spacing as required in ASHRAE duct traverse standard.
3) Multiple Probe Pitot Type Sensors: Manifolded to provide a single total pressure and single static pressure to a differential pressure transmitter defined above, “BAS Sensors”.

b. Flow Probes

1) For Fan Inlets:

a) Models:
b) Ebtron Gold series or equivalent where 3:1 turndown is adequate. Flow Probes for Duct Mounting: Same manufacturers duct models with proper turndown range.

2) For Minimum Outdoor Air Dampers:

a) Models:

(1) Ebtron Gold series or equivalent.

2.09 AUXILIARY EQUIPMENT

A. Transient surge suppressors: suppressors shall be solid state, operate bidirectionally, and have a turn-on and turn-off time of less than one nanosecond, and shall provide the protection defined herein, either as an internal part of the BAS controller or as a separate component. Suppressor manufacturer shall have available certified test data confirming a fail short failure mode.

1. Communication or Signal Conductor Transient Suppressors:

a. Maximum single impulse current conductor-to-conductor or conductor-to-ground: 10000 A, 8 x 20 µs waveform.

b. Pulse life rating: 3000 A, 8 x 20 µs waveform, 2000 occurrences.

c. Maximum clamping voltage at 10000 A, 8 x 20 µs waveform, with the peak current not to exceed the normal applied voltage by 200%.

B. Uninterruptible power supply (UPS): provide a self-contained UPS designed for installation and operation at each BAS controller and NAC sized for at least 125% of the peak demand, and to provide a minimum of 15 minutes of full operation of the controller and input/output expansion modules connected to that controller.

1. Equipment connected to the UPS shall not be affected in any manner by a power outage of a duration less than the rated capacity of the UPS.

2. Each UPS shall be wired such that primary power to the controller will be maintained upon failure of the UPS, including either a relay switch upstream of the UPS or two UPSs in parallel.

3. UPS shall be complete with necessary power supplies, transformers, batteries, and accessories and shall include visual indication of normal power operation, UPS operation, abnormal operation and visual and audible indication of low battery power and shall provide a normally open alarm contact for monitoring by the BAS.

C. Wind Speedometer: Digitar of Hayward.

1. Range: 5-190 mph.
2. Accuracy: +/-5%.
3. Threshold: 1-2 mph.
4. Operating Temperatures: -60 to 140 degrees F.

D. Outdoor Static Pressure Probe: Probe will serve as a reference for space static pressure sensors.

1. Accuracy: To 1% when subjected to 360° radial wind velocities of up to 80 mph.

2. Models:

   a. Air Monitor #SOAP.
   b. Ultratech #ORS
   c. Vaisala WXT530
   d. Acceptable equivalent.

E. Snow Detector with Slab Temperature Sensor:

1. Model:

   a. Tekmar (094) and a BACnet controller (m/n 680),
   b. Viega
   c. Acceptable equivalent.

2. Mounting Socket for Sensor Installation: By pavement contractor.
3. Back-Up Sensor: For redundancy. Install in an alternate location.

F. Outdoor Air Dewpoint Sensor: High accuracy; 2% or better.

1. Manufacturers:

   a. Viasala.
   b. General Eastern.
   c. Acceptable equivalent.

G. Weather shield enclosures: NEMA 3R rated with transparent cover, sized for the device enclosed.

H. Spot Leak Detectors: Secured to the floor or a drain pan.

1. Detection: Microchip controlled energized probes.
2. Operate on 24 Vdc or less.
3. SPDT contacts to be inside a watertight enclosure.

PART 3 - EXECUTION

3.01 GENERAL

A. Where control devices are installed on insulated piping or ductwork, provide standoff brackets or thermowells sized to clear insulation thickness. Provide extended sensing elements, actuator linkages, and other accessories as required.

B. Wiring and tubing shall be identified with the same numbers and symbols as used on the corrected, approved record diagrams.

C. Label control apparatus with nameplates or tags bearing the functional designations shown on approved control diagrams.

D. Where control devices are exposed outside the building, provide weather shield enclosures.

E. When installing new controls wiring or replacing existing, all unused controls wiring shall be removed in full.

3.02 BUILDING AUTOMATION SYSTEM (BAS)

A. BAS Failure Mode:

1. BAS controls and interfaces shall be arranged so that equipment controlled by the BAS operates as indicated on the I/O summaries on failure of the BAS controller for any reason, including logic power supply failure, CPU lock-up, or interposing relay failure. Safety and operational interlocks shall remain in effect.

B. Control sequences for fire alarm system signal responses shall be independent of the BAS controller and its outputs.

C. Modify the BAS front-end to include new systems defined herein. Provide graphic displays for systems and systems components as indicated in the I/O summaries.

D. Transient surge suppressors: install on low voltage signal or communications conductors entering the building from exterior locations, including those conductors from devices mounted on the exterior of the building. In addition, provide AC voltage power transient suppressors for BAS equipment power supplies.

E. BAS Sensors:

1. Hydrogen sensors: install in an accessible location at the highest point of the room.

2. Liquid temperature sensors: fill sensor wells with thermally conductive material to assure accurate readings.

3. Current sensing relays: fan and pump status shall be sensed by a current sensing relay wired on the load side of each fan and pump. For constant speed fans and pumps, the current sensing relay trip setpoint shall be set at the motor's normal operating speed. For variable speed fans and pumps, the current sensing relay trip setpoint shall be set for the lowest operating speed, as determined by the commissioning process (typically 20%).

4. Proper calibration of sensors shall be demonstrated and documented as part of the commissioning process.

5. Sensor calibration: calibration of sensors shall be included as part of the prefunctional checklists according to the following procedures:

a. General: verify that sensors with shielded cable are grounded only at one end.

b. Sensors without external transmitters: take a reading with a calibrated test instrument within 6" of the sensor installation and verify the sensor

reading is within the defined tolerance. If not, install offset, calibrate, or replace sensor to obtain required accuracy.

c. Sensors with external transmitters: disconnect sensor from transmitter input and connect a signal generator in place of sensor. Using manufacturer's data, simulate minimum measured value. Adjust transmitter potentiometer zero until minimum signal is read. Repeat for the maximum measured value and adjust transmitter until maximum signal is read. Reconnect sensor. Make a reading with a calibrated test instrument within 6" of the sensor installation. Verify that the sensor reading is within the defined tolerance. If not, repeat process until defined accuracy is achieved, or replace the sensor and repeat process.

d. Paired sensors: for sensor pairs that are used to determine a temperature or pressure difference, calibrate both sensors to a common measurement and verify they are reading within ±0.25ºF for temperature and within a tolerance equal to ±2% of the sensor reading for pressure.

F. BAS Start-up and Check-out:

1. Provide the services of control technicians at start-up to check-out the system, verify and calibrate sensors and outputs, input data supplied by the Owner, and place the system in operation. Verify proper operation of each item in the sequences of operation, including hardware and software.

2. Check-out each system for control function through the entire sequence. Check actuator travel on dampers and valves for action and extent. Verify that control dampers and valves open and close completely. Check calibration of instruments. Calculate and verify instrument setpoints.

3. Calibration and testing: calibrate sensors and monitoring inputs and verify proper operation of outputs before the system is placed on-line. Check each point within the system by making a comparison between the operator console and field device. BAS control loops, failure modes, interlocks, sequences, energy management programs, and alarms shall be debugged, tested, and stable operation verified. Control loop parameters and tuning constants shall be adjusted to produce accurate, stable control system operation. Before obtaining permission to schedule the functional test, acceptance test, provide written documentation of system calibration and certification that the installed complete system has been calibrated, verified, and is ready to begin testing.

G. BAS Acceptance Conditions:

1. Acceptance test: conduct final acceptance test, with the Owner on site, on the complete and total installed and operational system to demonstrate that it is functioning in accordance with requirements defined herein. Demonstrate the correct operation of monitored and controlled points as well as the operation and capabilities of sequences, reports, specialized control algorithms, diagnostics, and software. This may be done separately or in conjunction with functional testing by the project’s Commissioning Authority.

2. System shall demonstrate the following minimum acceptable levels of performance, within the physical limitations of the controlled equipment:

    a. Control loops shall maintain stable, nonhunting, nonoscillating control, with minimum overshoot in response to transient and upset conditions.

    b. Space and air temperatures shall be maintained within ±1ºF of setpoint.

    c. Humidity shall be maintained within ±5% RH of setpoint.

    d. Chilled and hot water and other hydronic system temperatures shall be maintained within ±0.5ºF of setpoint.

    e. Duct static pressures shall be maintained within ±0.05" wg of setpoint.

    f. Hydronic system pressures shall be maintained within ±2 psig of setpoint.

    g. Air and water quantities shall be maintained within ±5% of setpoint.

3. Final system acceptance will be based upon the completion of the following items:

    a. Completion of the installation of hardware and software items. Demonstrate complete operation of the system, including hardware and software, with no failures during a 10 consecutive day period. Obtain receipt from the Owner acknowledging no failures within the test period. Submit a daily log documenting failures.

    b. Satisfactory completion of functional performance testing including deferred testing as defined herein.

    c. Satisfactory completion of the record drawings, and operating and maintenance manuals.

    d. Satisfactory completion of training programs.

4. Upon final acceptance, the warranty period shall begin.

H. BAS Training:

1. Provide the Commissioning Authority with a training plan for review 4 weeks before the planned training.

2. Provide designated Owner personnel training on the control system. The intent is to clearly and completely instruct the Owner on the capabilities of the control system.

3. The training shall be tailored to the needs and skill-level of the trainees.

4. The trainers shall be knowledgeable on the system and its use in buildings. The Owner shall approve the instructor prior to scheduling the training.

5. The standard operating manual for the system and any special training manuals shall be provided for each trainee, with a copy included in each copy of the operation and maintenance manual. In addition, copies of the system technical manual shall be demonstrated during training and a copy included in each copy of the operation and maintenance manuals. Manuals shall include detailed description of the subject matter for each session. The manuals shall cover control sequences and have a definitions section that fully describes relevant words used in the manuals and in software displays.

6. Copies of audio-visual materials used in the training program shall be delivered to the Owner.

7. Training shall be tailored to the size and scope of each individual BAS project, as approved by the BAS Shop. BAS contractor shall provide separate line-item training modules in bid response. Provide formal training sessions. Each session shall be conducted by factory-trained personnel:

    a. Training I: the first training session shall consist of 24 cumulative hours of actual training. This training may be held on-site or in the supplier's facility. If held off-site, the training may occur prior to final completion of the system installation. Provide materials and training for up to 6 persons to be designated by the Owner. Upon completion, each student, using appropriate documentation, should be able to perform elementary operations and describe general hardware architecture and functionality of the system. If the Dartmouth BAS Shop is already trained on the operation of the installed control system, this Training may be reduced or deleted.

    b. Training II: Building Systems: the second session shall be held on-site for a period of 24 hours of actual hands-on training after the completion of system commissioning. Provide materials and training for up to 6 persons to be designated by the Owner. The session shall include instruction on:

        1) Specific hardware configuration of installed systems in this building and specific instruction for operating the installed system, including HVAC systems, lighting controls, and any interface with security and communication systems.

        2) Security levels, alarms, system start-up, shut-down, power outage, and restart routines, changing setpoints, and alarms and other typical changed parameters, overrides, freeze protection, manual operation of equipment, optional control strategies that can be considered, energy savings strategies and setpoints that if changed will adversely affect energy consumption, energy accounting, and procedures for obtaining vendor assistance.

        3) Trending and monitoring features (values, change of state, and totalization), including setting up, executing, downloading, viewing both tabular and graphically and printing trends. Trainees shall actually set-up trends in the presence of the trainer.

4) Every screen shall be completely discussed, allowing time for questions.

5) Use of keypad or plug-in laptop computer at the zone level.

6) Use of remote access to the system via networks.

7) Setting up and changing a terminal unit controller.

c. Training III: the third training session shall be conducted on-site 6 months after occupancy and consist of 24 hours of training. Provide materials and training for up to 6 persons to be designated by the Owner. The session shall be structured to address specific topics that trainees need to discuss and to answer questions concerning operation of the system.

d. Supervisory training: provide a separate training course for supervisory personnel. This training shall briefly cover the material of the operator training session but shall address the more advanced features of the system with emphasis on the energy conservation strategies and reporting capabilities of the system and how to implement them. The training session shall be conducted by factory-trained personnel and shall be a minimum of two 8-hour days, for a total of 16 training hours. Provide materials and training for up to 6 persons to be designated by the Owner.

I. In addition to the defined BAS training, provide technically competent technicians to attend training sessions for systems and equipment that are monitored or otherwise interfaced with the BAS, to discuss the interaction of the control system to the equipment being discussed.Control System Operation and Maintenance Manual Requirements:

1. In addition to documentation defined elsewhere herein, including part 1.06: Submittals, compile and organize operation and maintenance manuals in labeled 3-ring binders. The manual shall be organized and subdivided with permanently labeled indexed tabs, containing at minimum:

a. Full as-built sequence of operations for each piece of equipment.

b. Full as-built set of control drawings, including the marking of system components, sensors, and thermostats, and power sources on the as-built floor plans and mechanical drawings, identified with their control system designations.

c. Full point list. In addition to the as-built points list for the major equipment identified in the I/O summary, provide a listing of rooms served by BAS terminal controls, with the following information for each room:

1) Floor.

2) Room number.

3) Room name.

4) Air handling unit identification.

5) Reference drawing number.

6) Terminal unit tag identification.

7) Heating and/or cooling valve tag identification.

8) Minimum cfm.

9) Maximum cfm.

d. Controller/module data shall include specific instructions on how to perform and apply functions, features, and modes defined herein and other features of this system. These instructions shall be step-by-step. Indexes and clear tables of contents shall be included. The detailed technical manual for programming and customizing control loops and algorithms shall be included.

e. Control equipment component submittals and parts lists.

f. Thermostats, sensors, switches, and timers, including maintenance instructions and sensor calibration requirements and methods by sensor type.

g. Valves and valve actuators.

h. Dampers and damper actuators.

i. Full as-built documentation of software programming, including commented software program printouts, and a full print out of all schedules and setpoints after testing and acceptance of the system. Provide an electronic copy of programming and database information for this facility.

j. Warranty requirements.

3.03 THERMOSTATS AND ENVIRONMENTAL SENSORS

A. Mount space humidity sensors, humidistats, space CO_2 sensors, space temperature sensors, and thermostats at 48" above the floor, or per architect direction or RESET Certification requirements.

B. Align horizontally with adjacent light switches.

C. Final locations shall be accessible and shall be coordinated with the furniture layout and architectural layout.

D. More than 2 sensors in a single location shall be installed with a common faceplate to minimize wall space.

E. Remote element type: mount on a vibration free surface 5' above the floor, unless defined herein to be mounted on a control panel. Provide 1 linear foot of element to sense the temperature of each ft² of the coil face. Install in a serpentine arrangement across the entire face of the coil.

F. Averaging and low limit safety type elements: install in a horizontal sine curve manner to sense temperatures across the entire face of the coil, and support independently from the coil by stainless steel bands or multibulb holders. Provide 1 linear foot of element for each ft² of coil area. Provide 0.5" metallic raceway or 0.375" hard copper rails for support of elements, both top and bottom, for plenum or duct width greater than 36".

G. Under window fan-coil unit thermostats: mount so that adjusting knob is accessible through access panel.

H. Provide guards on thermostats and space temperature sensors where subject to damage, such as in warehouses Gymnasiums, storage rooms, and equipment rooms.

I. Provide insulated bases for thermostats and temperature sensors installed on exterior walls or walls to unconditioned spaces.

3.04 SENSOR PIPING

A. Tubing shall be concealed except in mechanical rooms.

B. Fasten tubing with clips at regular intervals and run parallel to building lines. Attach concealed tubing above suspended ceilings to structure.

C. Copper bends shall be tool made. Provide unions at final connections to apparatus. Provide separation between dissimilar metals.

D. Nonmetallic tubing run in mechanical rooms and concealed in inaccessible locations shall be run in metallic raceways. Make connections to hot equipment with copper tubing.

E. Tubing installed inside control panels and equipment enclosures, and above ceilings shall be tied and supported.

F. Provide sleeves where tubing passes through concrete or masonry.

G. Test tubing at 30 psig for pressure loss of not more than 1 psig in 1 hour.

H. Nonmetallic tubing used in smoke control systems, and connected devices, shall be completely enclosed within a galvanized or paint grade steel enclosure having a minimum 22 gauge thickness. Entry to enclosures shall be by copper tubing with a protective grommet of neoprene or Teflon or by brass compression to male barbed adapters. Tubing shall be identified by appropriately documented coding. Tubing shall be neatly tied and supported within the enclosure. Tubing bridging cabinets and doors or moveable devices shall be of sufficient length to avoid tension and excessive stress. Tubing shall be protected against abrasion. Tubing serving devices on doors shall be fastened along hinges.

I. Changes in direction in copper tubing shall be made with tool bends. Brass compression type fittings shall be used at final connections to devices; other joints shall be brazed using a BCuP5 brazing alloy with solidus above 1,100°F and liquidus below 1,500°F. Brazing flux shall be used on copper-to-brass joints only.

J. Other joints shall be brazed using a BCuP5 brazing alloy with solidus above 1,100°F and liquidus below 1,500°F. Brazing flux shall be used on copper-to-brass joints only.

K. Prior to final connection to devices tubing shall be flushed clean and dry and tested at three times the operating pressure for not less than 30 minutes with no loss of pressure.

L. Tubing passing through concrete or masonry shall be sleeved and protected from abrasion and electrolytic action.

M. Tubing serving other functions shall be isolated from tubing serving smoke control systems by automatic isolation valves or shall be an independent system.

3.05 PANELS AND ENCLOSURES

A. Provide a panel for each BAS controller or each system not controlled by the BAS.

B. Mount the following items in the panels unless otherwise defined herein:

1. BAS controllers.

2. Relays.

3. Switches.

4. 120 V duplex convenience outlet wired from the same circuit as the BAS controller.

5. Wiring and controls.

6. Terminal blocks.

C. Wire controllers, relays, switches, and controls in the control panel to a terminal block. Line voltage and low voltage shall be separated on different terminal blocks with labels indicating voltage. Each sensor or other electrical device shall be wired back to the terminal block in the control panel. Devices in series shall be individually terminated at the terminal block, such that each side of each device is available at the control panel for troubleshooting. In addition to number markings on each conductor, conductor color shall

be the same throughout each wiring run. Wiring shall be neatly tied and routed in the control panel. Shielded wiring shall be terminated neatly, with heat shrink tubing placed over the bare end of the shield. Ground conductors over 4" long shall be insulated with tubing.

D. Provide 6" x 6"trough the width of the control panel, minimum 24" in length, above the control panel to provide an entrance for cabling and tubing into the panel, with 50% spare nipple capacity.

E. Provide 120 V power wiring for control power in the top right corner of each panel, with disconnects, power supplies, and transformers associated with the panel also located in the top right corner.

F. Each item in the panel shall be labeled and the panel labeled as to the system or equipment served.

G. Panels shall be located to avoid conflicts with ductwork, piping, equipment, the work of other trades, and building conditions. Panel locations indicated on the Drawings shall be coordinated prior to installation and adjusted to avoid conflicts.

3.06 STATIC PRESSURE SENSORS

A. Install sensors in the associated air handling unit control panel and use extended sensing lines. Provide taps for calibration purposes. Carefully document locations of pressure sensors on As-Built record documentation.

3.07 HYDRONIC PRESSURE SENSORS

A. Install sensors adjacent to measurement points, with sensing lines extended to accessible locations. Provide test ports equipped with Schrader valves in each sensing line for calibration purposes.

3.08 THERMOMETERS

A. Provide at each remote temperature sensor and element location. Do not duplicate thermometers defined in Section 23 05 19 – Meters and Gauges for HVAC Equipment.

B. Mount thermometers in piping, ducts, and equipment in positions adjusted to be accessible for reading. Use angle and adjustable types where straight type would not be readable.

C. Fill thermometer wells with thermally conductive material.

3.09 CONTROL DAMPERS

A. Refer to Section 23 31 13 – Metal Ductworks, for installation.

B. For outdoor air damper assemblies, stage the opening of each section to prevent stratification and poor mixing of outside and return air.

3.10 SMOKE DETECTORS

A. Refer to Section 23 31 13 – Metal Ductworks, for installation.

3.11 CONTROL VALVES

A. Refer to Sections 23 21 13 – Hydronic Piping and 23 05 23 – General Duty Valves for HVAC Piping, for installation.

3.12 WIRING

A. Materials and installation of wiring and electrical devices shall be in accordance with Division 26.

B. All network cabling for IP-based controls equipment shall be installed by the Division 27 contractor.

C. All network cabling shall be properly labeled.

D. All network cabling color schemes for IP-based controls equipment shall be installed using Dartmouth's uniform color coding requirements for disparate systems and manufacturers.

Dartmouth College to insert color coding appendix when it becomes available.

E. Exposed control and sensor wiring shall be installed in conduits and shall be separate from power wiring. Conduits for ATC control and sensor wiring shall be blue. Plenum rated cable may be used in concealed spaces if supported by cable trays. All cable runs departing cable tray must be in conduit. Refer to Division 27 Telecommunication Master Construction Specifications, Guidelines, and Reference Designs https://sites.dartmouth.edu/networkservices/specs/. Conduits to devices in finished spaces shall be concealed.

F. Provide transformers or filters for operation of automatic temperature controls from building power circuits. Each BAS controller shall be served by a dedicated transformer, and no more than 10 terminal unit controllers shall be served by a single transformer.

G. Provide relays, transformers, fuses and interlock wiring as required to accomplish the sequences indicated on the Drawings.

H. Wiring for emergency fan shutdown stations shall be separate from control and sensor wiring and devices.

I. See Division 26 for 120 V, 20 A electrical branch circuits designated for control power, terminated in junction boxes. Provide power wiring from the designated junction boxes through control power transformers to BAS controllers, terminal unit controllers, smoke dampers, flow measuring devices, and other power consuming control devices. See Division 26 for spare branch circuit breakers for control power in 120 V/208 V electrical panelboards. Provide power wiring from electrical branch panelboards through control power transformers to BAS controllers, terminal unit controllers, smoke dampers, flow measuring devices, and other power consuming control devices.

J. Coordinate needed data jacks for each NAC and BAS controller as required. See Division 27 for communications cabling and outlet requirements. Coordinate the installation of new data outlets with the Owner's Information Technology staff and the Telecommunications

Contractor for the project. All data jacks must be reflected on the Telecommunications drawings for the project.

K. Data wiring shall utilize a star network topology with dedicated data jacks for each device, see Division 27 for cabling requirements. Network architectures such as daisy chain, and ring shall not be installed unless coordinated with Dartmouth College.

L. Power for terminal unit controllers and smoke dampers shall be distributed at 24 V. For terminal units containing fans or electric heat, control power may be obtained from a control power transformer furnished with the terminal unit, except for terminal units used as part of a smoke control system.

M. Branch circuit wiring and conduit furnished under this Section for control equipment power shall be separate from other power wiring. No more than 2 BAS controller installations shall operate from a single 120 V branch circuit.

N. Low voltage control and sensor wiring shall be continuous without splicing.

O. Low voltage serial control and sensor wiring (e.g. twisted pair 18AWG) shall not be bundled with Ethernet or Category 5-5e-6 cabling.

1. Ethernet-Based control cabling may not be bundled with non-controls wiring.

P. Low voltage control and sensor wiring shall be rated for cable tray, and plenum rated when used in plenum.

1. Cable tray ventilation requirements shall conform to guideline for cable trays section 27 05 36.

Q. No line-voltage (120/208/277/480V or higher) is installed in or using cable tray.

R. No zips. Velcro only

3.13 AIRFLOW MEASUREMENT SYSTEMS

A. Install in straight duct sections, in accordance with manufacturer's recommendations and minimum straight duct length requirements.

B. Manufacturer shall provide start-up services, and demonstration testing for the Owner to verify the accuracy of each system and shall submit a certificate indicating same.

3.14 COMMISSIONING SUPPORT REQUIREMENTS

A. Prepare a written plan indicating in a step-by-step manner the procedures that will be followed to test, check-out, and adjust the control system prior to beginning functional testing. Keep the Commissioning Authority informed of progress with the Project and of changes to the proposed installation, programming and test plan. Refer to Guideline section 01 91 00 – Commissioning. At minimum, the plan shall include for each type of equipment controlled by the automatic controls:

1. Step-by-step procedures for testing each type controller after installation, including:

a. Process of verifying proper hardware and wiring installation.

b. Process of downloading programs to load controllers and verifying that they are addressed correctly.

2. Process of verifying proper hardware and wiring installation.

3. Process of performing operational checks of each controlled component.

4. Plan and process for calibrating valve and damper actuators and sensors.

5. A description of the expected field adjustments for transmitters, controllers and control actuators should control responses fall outside of expected values.

6. A copy of the log and field check-out sheets that will document the process. This log shall include a place for initial and final values read during calibration of each point and clearly indicate when a sensor or controller has passed and is operating within the contract parameters. Notification of any equipment failures shall be documented.

7. A description of the instrumentation required for testing, including a certification of calibration for each test instrument.

8. Identify which tests and systems should be completed prior to using the control system for test, adjustment, and balance work.

B. Provide the Commissioning Authority complete system logic diagrams, describing the proposed system programming, with programmed attributes shown. These diagrams shall be updated with field modifications from the start-up, check-out, and prefunctional testing prior to the beginning of the functional testing of the BAS. Provide a copy of each proposed graphical interface screen with interface points shown for the entire system.

C. Prefunctional tests: verify and document the proper installation, addressing, calibration, programming, operation, and failure mode of BAS control points, sequences, and equipment. Provide a signed and dated certification to the Commissioning Authority and Owner upon completion of the check-out of each controlled device, equipment, and system that installation, set-up, adjustment, calibration, and system programming is complete as defined herein and as indicated on the Drawings, except functional testing. Completed prefunctional documentation of the system verification shall be submitted to the Commissioning Authority for review and approval prior to the functional testing of the BAS or its being used in the testing of other equipment or systems, or other purposes. Copies of final field check-out sheets and trend logs shall be provided to the Commissioning Authority for inclusion in the Commissioning Report.

D. Functional tests: conduct and document a functional test of the complete installed BAS, as defined in Section 23 00 90, Performance Verification. Functional testing of the BAS may be conducted in phases or sections, as defined by the requirements of the Functional Test, or as approved by the Commissioning Authority. The BAS, or applicable portions of the system, shall have completed functional testing and be approved by the Commissioning Authority before being used for other purposes, such as test and balance measurements, or in support of the functional testing of other systems.

1. Assist in the functional testing of equipment and systems by implementing trend logs and equipment monitoring as defined herein and as required by Section 23 00 90, HVAC Performance Verification.

E. Meet with the testing, adjusting, and balancing contractor prior to beginning the test, adjustment, and balance process and review the test, adjusting, and balancing plan to determine the capabilities and requirements of the control system in completing the testing, adjusting, and balancing process. Provide the testing, adjusting, and balancing contractor any needed unique instruments for setting terminal units and instruct the testing, adjusting, and balancing contractor personnel in their use. Assist and cooperate with the testing, adjusting, and balancing contractor by providing a qualified technician to operate the controls as required to assist the testing, adjusting, and balancing contractor in performing his work, or alternatively, provide sufficient training for the testing, adjusting, and balancing contractor to operate the system without assistance. Verify the proper operation of affected controls at the completion of the test, adjustment, and balance procedure.

F. Seasonal Adjustment:

1. Assist the Commissioning Authority with the seasonal adjustment process. During this effort the Commissioning Authority will:

a. Check and verify the calibration of temperature control devices and thermostats. Test and verify control sequences for proper operation for the season.

b. Where deficient operation or defective equipment is discovered, provide corrective measures as required by the warranty provisions defined herein.

G. Sequence of Operation Testing: Submit a copy of the Sequence of Operation annotated with the Subcontractor's testing methods. Proposed methods will be performed to prove compliance with the specification.

PART 4 - SEQUENCES OF OPERATION

4.01 GENERAL

A. To be indicated on the Drawings.

END OF SECTION

Appendix A: Coordination Matrix for Building Automation Systems (BAS)

COORDINATION MATRIX				
Work	*Furnish*	*Install*	*Low Volt, Wiring/Tube*	*Line Power*
BMS low voltage and communication wiring (see Note 1 below)	BAS	BAS	BAS	BAS
VAV box controller (see Note 2 below)	Div 23	Div 23/BAS	BAS	Div 26
BMS conduits and raceway	BAS	BAS	BAS	BAS
Automatic dampers (non-factory)	BAS	Div 23	BAS	NA
Automatic valves	BAS	Div 23	BAS	NA
VAV boxes	Div 23	Div 23	BAS	NA
Pipe insertion devices and taps, including thermowells, flow and pressure stations.	BAS	Div 23	BAS	BAS
Air Flow devices, pressure sensors, and temperature sensors.	BAS	Div 23	BAS	BAS
BMS current switches	BAS	BAS	BAS	NA
BMS control relays	BAS	BAS	BAS	NA
All BMS nodes, equipment, housings, enclosures and panels (See Note 1)	BAS	BAS	BAS	BAS
Smoke detectors - duct mounted (see Note 3 below)	Div 28	Div 23	BAS/Div 26	Div 28
Firestats	BAS	BAS	BAS	Div 26
Fire/smoke dampers (see Note 4 below)	Div 23	Div 23	BAS	Div 26
Fire dampers	Div 23	Div 23	NA	NA
Fire alarm shutdown relay interlock wiring	Div 26	Div 26	Div 26	Div 26
Fire alarm smoke control relay interlock wiring	Div 26	Div 26	BAS	Div 26
Thermal Energy Meters (See Note 1)	Div 23/BAS	Div23/BAS	BAS	Div26/BAS
Dartmouth Water Meters (i.e. for Domestic Water)	Div 22	Div 22	BAS	BAS
Variable Frequency Drives (VFD)	Div 23	Div 23	BAS	Div 26

NOTES:

1. BMS low voltage and communications wiring: BMS Ethernet communications cable and IP infrastructure furnish by Div 25 and install by BMS Contractor or Division 26 Electrical Contractor as per options in paragraph above and as approved by Dartmouth College Network Services.

2. VAV box controller factory installation would normally be by Division 23 Mechanical who furnishes the VAV boxes; could be by BMS for field installation of special controllers.

3. Smoke detector also wired to shut down AHU/HVAC by Division 26.

4. Fire/Smoke Dampers: BMS Contractor to provide and ensure OPEN/CLOSE control and monitoring of fire/smoke dampers as coordinated between BMS HVAC systems sequences, controls and overrides, and the Fire Alarm system control status priorities and overrides.

END OF Appendix A

Appendix B: Dartmouth College Controls Vendor Standards for Building Controls Project Documentation and Software Control

Dartmouth College Vendor Standards for Building Controls Project Documentation and Software Control

The following are a list of standards for project implementation and software control for the Dartmouth College Vendor Standards for Building Controls Project Documentation and Software Control. The purpose of these standards is to ensure that vendors coordinate with the College, and provide complete as-builts and proper documentation of issues or software changes implemented.

1. Prior to any project implementation on an existing controls system, selected controls vendor shall perform a "system health assessment" to ensure that the existing system architecture and controllers are capable of supporting the proposed new logic without exceeding the manufacturers recommended configuration guidelines for acceptable amounts of points/devices/memory/CPU usage/etc. on that system. Furthermore, the vendor shall identify if there will be room for continued expansion within the system following implementation. If there are potential limitation issues identified, current system configuration/controllers exceed recommended guidelines, or new hardware or software will be needed, vendor shall make that known in writing to Dartmouth College Project Manager prior to starting any implementation. Conversely, if vendor does not anticipate an issue, that shall be communicated in writing as well.

2. Dartmouth College Building Automation Shop shall make the most current control software for existing systems available to the vendors in order to help them provide an accurate system health assessment.

3. All proposed graphics for a project shall be included as part of the initial project submittals. Failure to include graphics shall be cause for immediate rejection of submittals.

4. All device/controller/point names shall follow the standard “Dartmouth College Control System Naming Conventions” (see attached) unless otherwise requested by Dartmouth College.

5. Vendor shall provide to Dartmouth College Building Automation Shop a digital copy of all software that is currently configured in the system no later than the end of every work week with the understanding that it is to be used in case of emergency and not to be considered a final product.

6. All graphics that are related to equipment that is being worked on shall be in complete and working order before the end of that day so that after hours technicians may have a graphical view of the work that has been accomplished.

7. Vendors should label all thermostats to identify what controller they are connected to.

8. Vendors shall contact the Building Automation Shop on any day that they will be performing demolition or construction work on an existing control system. Also, the vendor shall inform the Project Manager and Building Automation Shop at the end of the work day the status of the controls system and confirm that there are no performance issues on existing systems prior to leaving the site.

9. Upon final completion and acceptance of a project, vendor shall provide a complete digital copy of all software from the project on the day of acceptance. This to include all end devices, building level controllers, graphics, etc. Vendor shall also provide complete construction as-builts and copies of control sequences in both digital and hard copy to appropriate Dartmouth College Shops (Building Automation and/or Electrical), and to Dartmouth Engineering. (As-builts to include electrician's communication bus routing diagram). Note that if project is a partial renovation to existing controls, as- builts shall be an update of original control system as-built digital and hard copy documents.

10. Vendors shall be given access to the control system (not including servers) in order to perform work but access shall be limited to 7:30am-4pm, Mon-Fri, unless an exception is required due to the project schedule.

DAY to DAY work:

11. Vendors that perform service work that is not considered a project may be given a copy of the software that they need in order to perform work that day, and that day only, with the expectation that they will return by disk or e-mail, a digital copy of that project if any changes were made, along with written documentation of changes made. Dartmouth College will then store the changed copy in a separate "working projects" folder until the changes made have been proven to provide the results requested. At that time, the file will be moved to Dartmouth College's secure project folder until a copy is requested again.

12. It is expected that the vendor may keep a copy of work performed in their company archives for reference but will delete said copy from their programming devices upon leaving the premises. Vendor shall request a new copy of software every day that they perform work in order to ensure that they do not use an out of date copy of software.

Dartmouth College Control System Naming Conventions

Note: Building Names/ Room Numbers to be coordinated with Dartmouth Space System

For Controllers:
Building.Floor.UnitName(with location served if a corridor/restroom/mech room).

IE: Wilder.Floor1.FCU1-Men's Room, Wilder.Floor1.AHU1 – Auditorium, or Wilder.Floor3.VAV2

For controller descriptions, please note location served in description if a numbered controller and duplicate in alarm message text.
IE: Name - Wilder.Floor2.VAV3 Description – Serves Rm 201-202-203. Alarm Message Text - Serves Rm 201-202-203.

For Points:

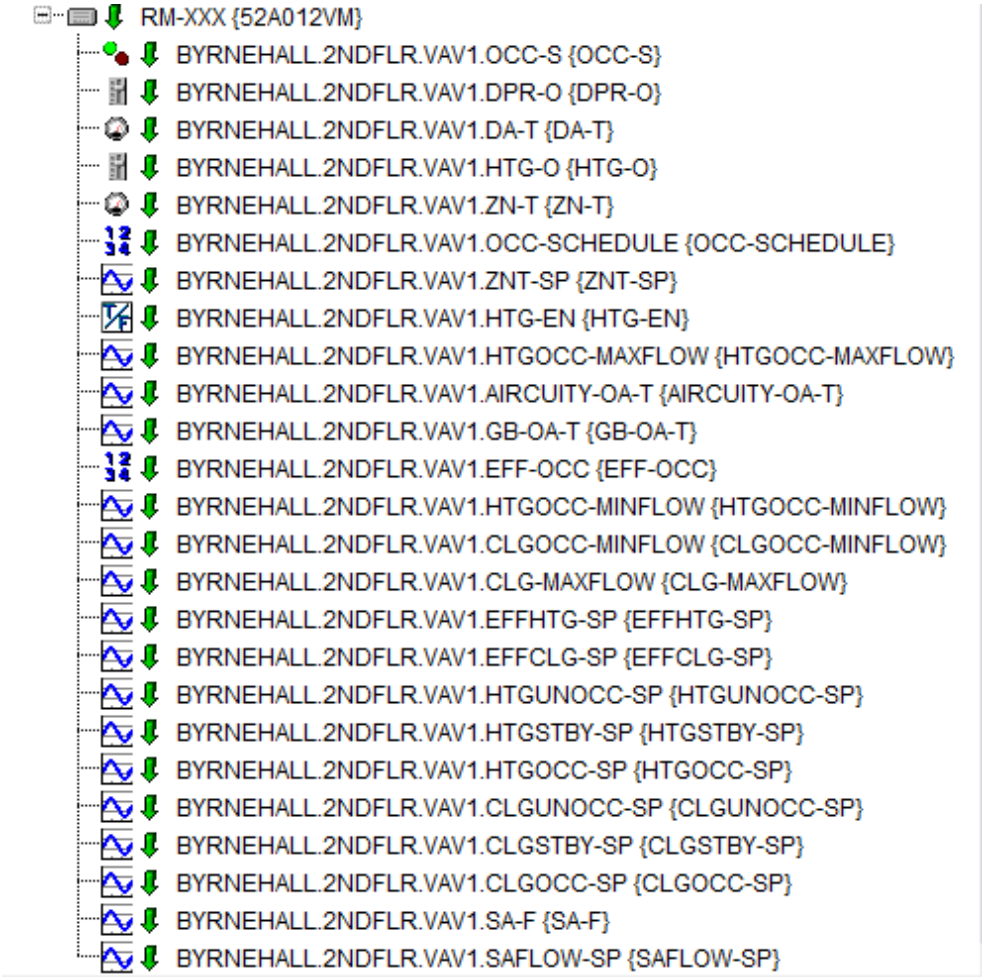
Building.Floor.UnitName.PointName

IE: Wilder.Floor2.VAV4.Room202 RM Temperature or Wilder.Penthouse.AHU3.DA Temperature
In the point description, please use point name, location served and basic description of point.

IE: Description would be …. Wilder.Floor3.FCU12.SF-S - Rm201 Supply Fan Status
Point alarm message texts should give description of alarm such as shown below.

Note: Equipment assigned names should not duplicate names of other equipment in the building, eg. two AHU-1's.

Additional Point Naming examples are given below.



END OF Appendix B

Appendix C: Operational Technology Cybersecurity Policy

Executive Summary

Cybersecurity threats to Operational Technology systems are increasing dramatically with consequences that impact occupant safety, loss of productivity, equipment damage, tenant satisfaction, and access to business data assets.

The cybersecurity policies and procedures contained within this guideline are intended to minimize these risks while preparing the organization to manage risk on an ongoing basis including recovering from a disastrous incident. These policies and procedures represent the minimum effort required to secure the technologies for this project and are intended to be utilized as a starting point for further development between the Owner and the BAS Contractor.

Revision History

General

ROLES AND RESPONSIBILITIES
OWNER and CONTRACTORS

General Responsibilities – Owner and Contractors

•May only access information needed to perform legitimate duties as an Owner employee or contractor and only when authorized by the appropriate information owner or designees.

•Are expected to ascertain and understand the sensitivity level of information to which he/she has access - through training, other resources, or by consultation with his/her supervisor or the information owner.

•May not in any way divulge, copy, release, sell, loan, alter, or destroy any information except as authorized by the information owner and within the scope of his/her professional activities.

•Shall understand and comply with Owner's requirements related to System and Information Integrity.

•Shall adhere to Owner's requirements for protecting any computer used to conduct Owner business, regardless of the sensitivity level of the information held on that system.

•Shall protect the confidentiality, integrity, and availability of Owner and client information - as appropriate for the information's sensitivity level - wherever the information is located (e.g., held on physical documents, stored on computer media, communicated over voice or data networks, exchanged in conversation).

•Shall handle information deemed confidential or highly confidential under this policy in accordance with Owner's requirements for protecting confidential and highly confidential information.

•Shall safeguard any physical key, ID card, or computer/network/system account that allows access to Owner information. This includes creating computer passwords that are compliant with the standards set forth in applicable Owner password policies and procedures.

•Shall destroy or render unusable any confidential or highly confidential information contained in any physical document (e.g., memos, reports) or any electronic, magnetic, or optical storage medium (e.g., USB key, CD, hard disk) before it is discarded in a method that is in compliance with applicable Owner media sanitization policies and procedures.

•Shall report any activities that he/she suspects may compromise sensitive information to his/her supervisor or to the Owner.

•Shall report any incidents as defined in Owner's Information Security Incident Reporting procedures to initiate an incident investigation.

•Shall meet obligations to protect sensitive information even after Owner employment or engagement ends.

•Shall contact the Owner and the Contracts Department before complying with any court orders,

subpoenas, or other compulsory requests from Federal, state, or law enforcement agencies for disclosure of confidential information.

•If performing work in an office that handles information subject to specific security regulations, Shall comply with additional training and documentation requirements (e.g., acknowledge annually that he/she has read, understands, and agrees to comply with the terms of this policy).

Should any conflicting information arise, adhere to Dartmouth Information Security Policy https://policies.dartmouth.edu/policy/dartmouth-information-security-policy

Owner Role

The Owner should familiarize themselves with their responsibilities as it pertains to the policies and procedures outlined in this document.

The Owner should understand that their input will be necessary to complete this implementation in a secure and sustainable manner.

The Owner should understand that the policies and procedures in this document are intended to be the basis for an Operational Technology Cybersecurity Policy, to which will be the standard for implementation of the Division 25 guideline and it is recommended that the Owner augment the policies, should they be properly equipped with knowledgeable personnel.

BAS – Building Automation System Contractor Role

The BAS – Building Automation System Contractor should familiarize themselves with their responsibilities as it pertains to the policies and procedures outlined in this document.

The BAS – Building Automation System Contractor shall adhere to and augment this set of policies by leveraging their qualifications, experience, and industry best practices.

BAS Contractor Responsibilities

The BAS – Building Automation System Contractor is responsible for ensuring that all systems comply with the cybersecurity requirements defined within this guideline.

The BAS – Building Automation System Contractor will be responsible for documenting all devices and related software integrations added outside of the original project design specifications.

Prior to project turnover, commission the Integration Platform and all connected subsystems provided by the Integrated System Contractors based on the defined cybersecurity policies and procedures.

The BAS – Building Automation System Contractor will provide the Owner with a written commissioning report summarizing the compliance findings across all systems.

OWNER POLICY – CYBERSECURITY for DIVISION 25 GUIDELINES

The following policies are to be finalized and updated with the Owner prior to project implementation and again prior to completion in conjunction with the BAS – Building Automation System Contractor. In some cases, the policies apply to post-construction support during and after the warranty period.

End User Account Policy

Encryption Policy

Internet Connectivity Policy

Remote Communications Policy

System Backup Policy

Disaster Recovery Policy

Integrations Platform Host Management Policy

System Component Cybersecurity Configuratin Policy

End User Account Policy

Account Creation

The Owner shall be able to manage and audit all accounts.

The Dartmouth College BAS Shop is the authorized entity to add user accounts to all systems related to the integration platform.

The BAS CONTRACTOR must adhere to the following guidelines:

Account Authorization

Authorization of Users

The Dartmouth College BAS Shop will have the responsibility to manage all user account access.

The Dartmouth College BAS Shop will create user accounts and associate levels of access.

The Dartmouth College BAS Shop will record all user accounts and associated levels of access.

Creation

The Dartmouth College BAS Shop will have the responsibility to create user accounts necessary for system access.

The Dartmouth College BAS Shop will be responsible for assigning the appropriate level of access to the user account.

Removal

The Dartmouth College BAS Shop will have the responsibility to remove user accounts.

The Dartmouth College BAS Shop will remove accounts, either through suspension or deletion, within one business day for individuals who:

No longer employed and require access

Had job responsibilities reassigned and no longer need access.

Audit

The Dartmouth College Campus Services Technology Services (CSTS) will be responsible for performing a User Account Audit no less than every 3 months to ensure that only authorized user accounts remain and that the associated privileges are consistent to their role.

The Dartmouth College Campus Services Technology Services (CSTS) will review the audit results with Dartmouth College BAS Shop.

The Dartmouth College Campus Services Technology Services (CSTS) will securely archive the audit results for a period of 2 years to ensure historical availability.

Administrative Users

The Dartmouth College BAS Shop will ensure that a minimum of 2 Full Administrators and a maximum of 4 with at least one administrator being an Owner employee.

System administration privileges should be granted to individual accounts whose role requires this privilege in order to fully configure and program the system, including creating new accounts.

Guest Users

No Guest user accounts should exist on any system.

The Dartmouth College Campus Services Technology Services (CSTS) will be responsible for disabling or removing Guest user accounts from all systems prior to device installation and after an audit has been performed.

Generic User Accounts

No Generic user account will be used on any system.

Manufacturer Default User Accounts

No Default User Accounts will be used on any system.

All Default user accounts must be deleted or if unable to be deleted, the password must be changed per the Password section of the End User Account Policy and then recorded prior to installation.

Non-User Service Accounts

These may be accounts that allow access between devices or between software platforms and device.

Service accounts or non-user accounts (a.k.a. Machine Accounts) are the responsibility of

the Dartmouth College BAS Shop.

API communications are the preferred method of integration.

The Dartmouth College BAS Shop must configure and manage these accounts according to the Owner's End User Account Policy.

Account Authentication

Passwords

Passphrases shall be utilized in lieu of passwords where permissible by the system being secured.

The Dartmouth College Campus Services Technology Services (CSTS) is responsible for managing and enforcing the Passphrase Policy for user accounts associated with applications and Operating Systems.

Each user account is to have a unique Passphrase

No shared user account Passphrases

Passphrases for user accounts must adhere to Dartmouth Information Security Policy https://policies.dartmouth.edu/policy/dartmouth-information-security-policy

Contain a combination of upper case, lower case, numeric, and special characters.

Passphrases must not be reused.

Passphrases must be changed upon initial end user log on.

Passphrases must be changed at a 90 maximum.

No hard-coded, factory default, or otherwise well-known passwords, passphrases, PIN numbers, or other credentials may remain configured in any system following Commissioning.

Account Accounting

Logging

The Dartmouth College Campus Services Technology Services (CSTS) is responsible for enabling logging for all user account activity on all applications and Operating Systems that comprise the integration solution.

These logs should be remotely collected by a host that should be managed by both the Owner's Backup Policy and Owner's Disaster Recovery Policy.

These logs should be reviewed monthly for suspicious administrative activities.

These logs should be retained for a minimum of 2 years.

Encryption Policy

All communications that transmit system data shall be encrypted. Examples include all GUI

sessions, CLI sessions, endpoint compute devices, APIs, device to device (if feasible), etc.

Encryption standards and methodologies established should align with (b) Cybersecurity Practice Guide Special Publication 1800-16 Securing Web Transactions: TLS Server Certificate Management.

The recommended encryption is TLS 1.2, TLS 1.3.

Obsolete encryption protocols such as SSL 2.0, SSL 3.0, TLS 1.0, and TLS 1.1 shall not be implemented.

Ownership of all certificates comprising the integration solution must be defined.

All device and application certificate expiry dates must be inventoried and a method for renewal must be established.

All device and application certificates must be valid.

Internet Connectivity Policy

Internet connectivity shall be managed by the Owner.

System access to the Internet must be requested of the Owner and will be granted at the Owner's discretion.

Requests for Internet Connectivity must include outbound transmission ports and destination IP Addresses.

Remote Communications Policy

No components of the integration solution will be public facing.

Connections from outside the local area network are to be made through a VPN or other remote access solution (i.e. remote desktop products to a secured, internal workstation; TosiBox, Tempered Networks, etc.)

VPN policy management is by the Owner. Remote access to be coordinated with the Dartmouth College BAS Shop.

Installation and/or use of remote access software such as TeamViewer, Bomgar, VNC, GoToMyPC, or similar is forbidden without formal approval by and coordination with Dartmouth IT Security.

System Backup Policy

All service host platforms (i.e servers that host application, database, domain, syslog, etc.) must have a system image backup performed by an enterprise grade backup service and include daily incremental changes.

Backups are to be stored in a secure location with redundancy.

Backups are to be tested for integrity and restoration capability verified periodically

Systems capable of backing up downstream device configurations are to be configured to do so.

If no system exists to backup downstream device configurations, a manual backup should be made every two months and prior to any device programming change, a backup copy of the current configuration must be preserved.

Backups should be retained for a minimum of 6 months.

Cloud-based hosted solutions are required to provide an outline of data retention and solution backups.

Disaster Recovery Policy

The Owner will work with the BAS CONTRACTOR to establish a Disaster Recovery Plan.

The following topics to be included at a minimum are:

System and system component outage impact

Ownership of each system and each response

Backup and restoration procedures

Manual operations

Communication plan

Failure analysis

Annual testing procedure to include fail-over testing against recorded commissioning procedures.

PRODUCT HARDWARE

Integrations Platform Host Management Policy

The BAS CONTRACTOR and Owner will determine at the onset of the project whether management of the Integration Platform Host (day-to-day, backups, disaster recovery, etc.) is to be the responsibility of the Owner or the BAS CONTRACTOR under a separate service agreement. The BAS CONTRACTOR will follow these guidelines for implementation.

The Host may either be a physical server located onsite or a cloud hosted platform. The following policies will be applied per type:

Local Server

Physical Environment:

The server will be located in a secure environment.

Only intended administrators of the server are to physically access the system.

The server should reside in a lockable enclosure.

Keyboard, mouse, and monitor should not be attached when not in use.

Unauthorized individuals should not be able to plug in any USB device.

The environment should be secured via Key Access (minimum) or Electronic Credentialed Access Control System (recommended).

A recording surveillance camera(s) should be installed to monitor the enclosure and ingress/egress point(s).

Programming:

Anti-virus / anti-malware software will be installed with new signatures and updates applied automatically. Virus updates will be monitored to detect possible negative impacts to the operation of the Integration Server application software.

The operating system (OS) software must be running a fully supported version with all security patches installed with a documented methodology to continue patching as necessary updates are released.

The hardware platform will be monitored for processor, memory and storage performance including real-time alerting.

The only application software resident on the Integration Platform Server will be the Integration Platform Software.*

*Additional Host Server Platforms are recommended for other service functionalities such as Syslog Archive, Domain Services, RADIUS, DHCP, etc.

Cloud Hosted

A Cloud Hosted Integration Platform shall comply with the following policies and procedures:

End User Account Policy

End User Authentication Policy

End User Authorization Policy

End User Accounting Policy

Encryption Policy

PRODUCT SOFTWARE

Product software licensing managed by Dartmouth College BAS Shop in coordination with the BAS Contractor(s).

System Device Cybersecurity Configuration Policy

Purpose:

This policy defines the standards for configuring system hardware devices for standalone installation or integration.

Application of Policy:

This applies to any system that has a user interface (CLI or GUI or Discovery Tool) for modifying the software on the device.

Application Software

The device shall be currently fully supported by the manufacturer and installed to the latest software release level.

Encryption

At a minimum, all device communications must be encrypted using the strongest encryption available on the device. Recommendations include TLS 1.2 and TLS 1.3 (preferred). Obsolete encryption protocols such as SSL 2.0, SSL 3.0, TLS 1.0, and TLS 1.1 must not be implemented.

a. Cyber Security Dashboard (GUI)
    i. The Cyber Security Dashboard shall provide a centralized view of potential cybersecurity related issues or system issues, grouped into critical issues, potential risks, and informational items.
    i. The Cyber Security Dashboard shall identify user account information, including:
        a. Total number of users
        b. Dormant users
        c. Active users
        d. Locked users
        e. Temporary users
        f. Disabled users
        g. Users with Administrator role
        h. Policy related information
    ii. The Cyber Security Dashboard shall indicate out-of-date software and Firmware.
    iii. The Cyber Security Dashboard shall identify when security certificates are set to expire.
    iv. The Cyber Security Dashboard shall provide insight into user activity such as number of successful logins, unsuccessful logins, and locked out accounts.

Securing System Access

If the system provides multiple methods for administrative interaction, it must be configured according to the table below.

GUI - HTTP	GUI - HTTPS	CLI – Telnet	CLI – SSH	CLI – Console

Disable	Enable	Disable	Enable	Via Auto-Logoff

User Accounts

All Administrative User Accounts should be created according to the Owner's End User Account Policy.

Guest Accounts

Must be disabled or removed if option is available per the Owner's End User Account Policy.

Default Accounts

Must be removed or replaced with an Authorized User Account(s) during installation per the Owner's End User Account Policy.

Auto-Lockout

If an auto-lockout feature is available, it must be enabled and configured for no more than 5 login attempts.

Auto-Logoff

If an auto-logoff or "timeout" feature is available, it must be enabled and configured to disconnect an Authorized User Account after 15 minutes of inactivity. This applies to all methods of administrative access.

Activity Logging (SYSLOG)

If the system has the ability to log events, it must be enabled and configured to record all activity (user, system) for a minimum of 1 week and/or be configured to send its log(s) to a remote secure archive.

Multiple Communication Interfaces

If the system has multiple communication interfaces, all interfaces not in use must be disabled. If unable to disable, then the methods should be hardened against discovery and direct connectivity though whatever means is available on the device to do so. I

IPMI management Interfaces

Disable IPMI management when not in use

IF system has IPMI Network interfaces, these must only be connected to dedicated management networks.

EXAMPLE: A system component has the following communication interfaces:

Ethernet port – Primary
Ethernet Port – Secondary
WiFi Radio
Bluetooth or BLE Radio
Console Port

Only the Primary Ethernet port will be used for communications. All other interfaces must be disabled via device programming. Should interface disablement not be an option, then steps must be taken to harden via changing pass phrases, etc.

END OF Appendix C