DIVISION 25 – INTEGRATED AUTOMATION

Includes the following sections:

See Part II for additional information regarding Indoor Pollutant Reduction and Control, Energy Efficiency, etc.

Also, refer to the following related Sections:

23 08 00	Commissioning of HVAC
23 09 00	Instrumentation and Control for HVAC
23 09 10	Instrumentation and Control for Lab HVAC
23 90 00	Mechanical Rooms

DESIGN DOCUMENT REQUIREMENTS

BAS SYSTEMS STUDIES, SINGLE LINE DIAGRAMS, AND SEQUENCES OF OPERATIONS

The designer shall perform the following and submit in addition to design drawings and specification documents for review:

1. Studies: Before adding new BAS controllers and points to existing BMS systems, the BAS integrator shall study the entire system for current JACE resource utilization performance, age, and suitability for continued use with the additional points. The designer shall confer with UC Engineering staff and Physical Plant BMS Shop for known limitations or problems associated with each existing JACE and temperature control panel that new points are being added. Many older JACES are in poor shape (some are failing), unsuitable for continued use, and maybe on a deferred maintenance list. These issues should be discovered and documented during the design phase to ensure that the new BMS systems are appropriately designed and budgeted before going out to bid.

2. Coordination with Physical Plant BAS Shop: The BMS technicians have a lot of direct experience programming and maintaining existing BAS systems on Campus. They have design and equipment specification preferences that change regularly based on challenges encountered post-construction on other projects. The BMS Shop should be engaged early in the design process to take advantage of lessons learned and identify designs and specifications of equipment they specifically don't want to have to maintain.

3. Controls Network Security: Any vendor-provided devices must adhere to UCSC minimum network connectivity standards. Refer to https://policy.ucsc.edu/policies/its/it0004.html#appa

4. Single Line Diagrams Required:

    a. CONTROLS NETWORK ARCHITECTURE DIAGRAM: Diagram shall illustrate all DDC systems control equipment including communications via internet web browser at remote location workstation, Ethernet cabling to routers and switches, operator workstation server (if used on site), JACE BMS control panel(s), LON cabling to field controllers, MODBUS RS-485 cables to equipment gateways (boiler managers, chiller managers, split system managers), communications wiring to remote XI/O) panels, and for each

JACE indicate notated “120V power provided by Division 26” and ITS “Data cabling and hot jack provided by Division 27”.

b. NETWORK RISER DIAGRAM FOR EVERY JACE: Diagram shall illustrate all DDC system controls equipment and communications cabling connected to the JACE via the LON network (all local controllers for boilers, exhaust fans, air handlers, variable frequency drives, variable volume terminal devices, etc.), BACnet MS/TP for fume exhaust air valves, MODBUS for electrical meters, and BACnet IP for variable refrigerant gateways, etc.

c. Division 25 designers shall coordinate with the Division 26 and Division 27 designers to ensure these other designers know the power and data requirements for each JACE and all terminal devices such as variable air volume boxes or lab air control valves.

d. Coordination of power requirements to each JACE: if the JACE controls any equipment on standby power, the JACE must also be on standby power. If the JACE manages any equipment on emergency power, the JACE also must be on emergency power. Note that JACES on emergency power is rare (only for special applications such as vivarium or seawater systems with livestock; otherwise, the BMS system does not control life safety equipment). The BAS Integrator should discuss this with the UC Engineering staff.

5. Points Lists: Provide a list of all control points by name and signal type (AI, AO, DI, DO). Coordinate with Physical Plant to integrate specific equipment PLC read/write points that the BMS Integrator needs to map onto the BAS.

6. Sequences of Operation: Provide sequences of operations for each controlled system, including setpoints and alarms.

7. Zone Maps: provide a scaled zone map for each floor, including what central equipment and terminal devices serve each zone. Indicate all BAS control panel locations.

8. Mechanical Rooms: Refer to 23 90 00 for BIM Modeling Requirements. BMS control panels with NEC clearances shall be shown and coordinated with other trades equipment and required access clearances.

9. Legacy of Single Line Diagrams: The University’s intent for the Single Line Diagrams to be the building’s perpetual living model documents continuously modified and updated for future construction remodels, alterations, etc. For this reason, single line diagrams shall be updated and submitted by the Engineer of Record at the end of the project to reflect as-built conditions. In addition, as-built CAD and spreadsheet calculations shall be presented in native AutoCAD .DWG file format, Excel spreadsheet, and Acrobat PDF file formats. Before generating single line diagrams or measures, the Design Engineer should confer with Archives to determine if AutoCAD single line diagrams and Excel spreadsheet files are available to modify. The newer buildings on campus should have them, but the older ones won’t. If Archive does not have them, the Design Engineer will need to generate them from scratch. The Design Engineer’s responsibility is to ensure they have included the appropriate time and fees in their proposal to create and deliver these as-built single line diagrams and calculations.

DESIGN RECOMMENDATIONS

The following is a list of Building Committee Suggestions compiled by Physical Plant BMS Shop based on many years of lessons learned on past projects on campus and is provided herein to help the designer

not repeat these lessons. Please note that most of these suggestions are mandatory and are somewhat redundant to the above design guidelines, but there may still be some pearls of design wisdom to mine. Also, this list will grow over time.

Building energy management systems

- Adhere to Tridium resource management limitation guidelines
- Follow campus ITS security guidelines
- No Beta testing of software or equipment & SOO strategies
- Use Tridium BAS systems on the Niagara network
- Fully utilize LON Modbus or BACnet devices on HVAC systems
- ITS infrastructure activated, emphasizing BAS data port connections for system commissioning.
- ITS switches and BAS equipment should be on standby power

Building energy management systems

- Always provide a third-party commissioning agent
- Use demand-controlled ventilation strategies by measuring Co2 levels.
- Use motion occupancy detectors to reset VAV supply airflow & zone setpoints for DCV
- Use motion & Co2 detectors in lecture halls and classrooms to reduce operating hours for DCV
- Differential Pressure Alarm from the filter bank to the front end
- Design building HVAC / BAS to meet LEED certification level
- Use supply air static set-point reset.
- Use chilled / heating water D.P setpoint reset.
- Provide start-up commissioning and change of season retro-commissioning
- Consider SkySpark or other persistent commissioning software
- Provide alarm if VAV can’t meet supply airflow set-point
- Utilize VAV DAT sensor and alarm SAT to zone
- Utilize building optimum start stop
- Utilize building Night purge
- Utilize OSA free cooling

The following standard specification is intended to be edited according to the specifics of the project. Brackets [] and areas shaded in gray [e.g., format] indicate requirements that are optional depending upon the type of system being provided or per instructions associated with the [] and project requirements. Consult with University's Representative and campus stakeholders.

DOCUMENT UTILIZES TRACK CHANGES TO RECORD YOUR CHANGES AS YOU EDIT. DO NOT CHANGE THE FOOTER OF THE DOCUMENT

SECTION 25 00 00

BUILDING AUTOMATION SYSTEMS

PART ONE - GENERAL

A. SUMMARY

1. This section describes the scope of work for the Building Automation System that must be installed by a qualified BAS Contractor and integrated into the UCSC Campus Supervisor Server by the BAS Contractor Developer.

2. The Building Automation System (BAS) as provided in this Division shall be based on the NiagaraN4 Framework, a Java-based framework developed by Tridium.

3. Provide a Building Automation System (BAS) incorporating Direct Digital Control (DDC), energy management, and equipment monitoring consisting of the following elements:

4. Microprocessor-based remote-control panels interfacing directly with sensors, actuators, and environmental delivery systems to provide complete standalone DDC/EMS functionality. (i.e., HVAC equipment, lab monitoring, energy metering, etc.).

5. Communication network allows data exchange between remote panels and central servers.

6. Associated operator station(s) and software functioning as the primary operator interface for BAS. The system shall utilize a graphics front end.

7. Pneumatic, electric, and electronic control for all items indicated, including dampers, valves, panels, and pneumatic and electrical installation.

8. Human Machine Interface (HMI) control:

    a. Controls installer shall interface the BAS systems with the BAS panel provided by the equipment manufacturer. Control installer shall provide integrator panel and all wiring from BAS to equipment panel and from equipment panel to other equipment. Equipment panel communications protocol shall be LONWORKS,

BACnet MSTP, or Modbus RTU to a JACE. BACnet/Modbus IP must be a separate network communicating through the JACE secondary IP port.

b. Any vendor-provided devices must adhere to UCSC minimum network connectivity standards. Refer to https://policy.ucsc.edu/policies/its/it0004.html#appa.

9. Provide submittals, installation, data entry, programming, startup, test, and validation of BAS, instruction to UCSC PPDO representative on maintenance and operation of BAS, as-built documentation, and system warranty.

10. Completely coordinate with work of other trades.

11. UCSC's goal is to implement an open system that will allow products from various suppliers to be integrated into a unified approach to providing flexibility for expansion, maintenance, and service. University of California, Santa Cruz shall be the named license holder of all software associated with incremental work on the project(s).

12. All labor, material, equipment, and software not explicitly referred to herein or on the plans required to meet the functional intent shall be provided without additional cost to UCSC.

B. DEFINITIONS

1. BACnet:

   a. An open communications protocol for building automation and ASHRAE 135 control networks. It is an ASHRAE, ANSI, and ISO standard protocol developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

2. FOX:

   a. Tridium's TCP/IP-based protocol is used for communication between network-level controllers and supervisor servers.

3. LonTalk:

   a. An open communications protocol for building automation and LonWorks control networks. It is a LonMark International, ANSI, and ISO standard protocol initially developed by Echelon Corporation.

4. Low Voltage:

   a. As defined in NFPA 70 for circuits and equipment operating at less than 50 V or for remote-control, signaling power-limited circuits.

5. Modbus:

   a. An open communications protocol for building automation and Modbus control networks. It is a standard protocol supported by the Modbus Organization, Inc.

6. Niagara-AX:

a. A software framework and development environment that solves the challenges of building Internet-enabled products, device-to-BMS Supervisor applications, and distributed Internet-enabled automation systems. The older version, phase-out started in 2015, is still compatible with the newer version, Niagara.

7. Niagara N4:

    a. A software framework and development environment that solves the challenges of building Internet-enabled products, device-to-BMS Supervisor applications, and distributed Internet-enabled automation systems.

8. TCP/IP:

    a. Short for Transmission Control Protocol/Internet Protocol. A protocol for communication between computers is used as a standard for transmitting data over networks and as the basis for standard Internet protocols.

C. SCOPE OF WORK

1. The Building Automation System (BAS) shall comprise Java Application Control Engine or Controllers (JACE) within each facility. Integration with the Tridium NiagaraN4 Framework shall be accomplished through a BAS contractor installed Tridium NiagaraN4 JACE 8000. No legacy JACEs will be permitted.

2. Each copy of Tridium Niagara software shall include a 5-year Niagara Software Maintenance Agreement.

3. Niagara Supervisor software and JACE network controllers are required for the supervisor and network levels of the BAS. Communication at these levels shall be FOXS, Tridium’s Secure TCP/IP-based protocol. The WEB Service (Port 80 and 443) on each JACE is to remain disabled. Access to the system, locally in each building, shall be accomplished using a technician’s laptop with Workbench. Remote access to each JACE should be established using Tridium’s Workbench over a FOX's connection, from a technician’s laptop or pc through UCSCs VPN.

4. Field level controllers to be configured or programmed using wizards. The BAS Integrator shall provide integration wizards free of charge and compatible with the current published versions of the network Automation tool supplied as part of this project. The wizard software shall be available for public access from the manufacturer’s website. These wizard programming tools shall be compatible with at least three other network Automation tools.

5. Each JACE shall communicate directly to LonMark/LonTalk (LWC), BACnet MSTP (BNC), MODBUS RTU devices, and other open and legacy protocol systems/devices provided under this Division. UCSC aims to eliminate any gateway or redundant (redundant to the JACE functionality) device(s).

6. Multiple entities shall perform the work provided in this specification. The BAS Contractor shall have overall responsibility for the Division work.

7. BAS Contractors shall provide overall management, coordination, and responsibility for delivering integrated BAS systems. The BAS Contractor shall review work performed by other Specialty Contractors such as low voltage, IT, security, and control system

subcontractors and coordinate the connection of these systems to UCSC's IT infrastructure in conjunction with UCSC IT staff.

8. All materials and equipment used shall be standard components. All systems and components shall have been thoroughly tested and proven in actual use for at least two years.

9. The electrical contractor or BAS Installer shall wire everything following all local and national codes.

D. DIVISION OF WORK

1. This section contains specifications about the (new/expansion of existing) Tridium-based Building Automation System controls at "Project Name"

2. All work, including the provision of materials and installation, is to be performed by the BAS Contractor with input from the UCSC BAS Department

3. System programming [Designer to confer with Physical Plant BMS Shop to select one of the following Options]

    a. [Option #1] Contractor provides system programming and graphics per UCSC BAS Department Standards.

    b. [Option #2] UCSC BAS Department to provide system programming and graphics per UCSC BAS Department Standards.

4. Functional Acceptance Testing

    a. Contractor or Third-Party Commissioning Agent will provide proof of point-to-point documentation for all hardware and terminations. The contractor and the Sequence author shall provide written Functional Acceptance Test Scripts based on the Sequence offered before the actual functional test date. (Provide a minimum of16 hours of assistance time by a qualified technician.)

5. The BAS Contractor shall be responsible for all communicating thermostats, any miscellaneous (LonWorks (LWC) and BACnet (BNC) controllers, control devices, control panels, controller programming, and controller programming software, controller input-output, and power wiring and controller network wiring.

6. The BAS Contractor shall be responsible for the Java Application Control Engine(s) (JACE), software and programming, graphical user interface software (GUI), and connection of the JACE to the local or wide area network. BAS Contractor shall also be responsible for developing all graphical screens, Web browser pages, setup of schedules, logs, alarms, and network management for all LWC or BNC devices.

7. LWC or BNC devices not provided by BAS Contractor shall be configured and commissioned by the appropriate contractor and later managed in the JACE and integrated by the BAS contractor.

8. For reasons of security and consistency, it is UCSCs intention to divide the work defined in this section into two sections:

a. A qualified BAS Contractor Systems Integrator shall perform all work at the JACE level and below.

    1. UCSC BAS Department will provide access to the Campus Construction Server for graphics development

b. UCSC BAS Department shall supply all work provided at the Supervisor Server and between the Supervisor Server. IF APPLICABLE, UCSC BAS Department shall also be responsible for all Security integration at the Supervisor Server level.

9. All work on global strategies across sites and other intelligent building systems, including between the JACE and other subsystems, shall be by the BAS Contractor.

E. QUALITY ASSURANCE

1. DDC System Manufacturer Qualifications:

    a. Tridium Vykon, Distech Controls, Honeywell.

2. All new DDC controllers shall be Tridium based and programmed utilizing NiagaraN4 Workbench as specified and capable of communicating with the campus front end software (Tridium Vykon Supervisor Version 4.9.1.30 at the time of this document) via the campus LAN using FOXS. The BAS Integrator must follow all Supervisor-to-JACE software version hierarchies.

    Licensing of controllers must be an open license allowing complete admin abilities to the end-user.

3. Proprietary devices, licensing, and networks are not acceptable. All controllers/devices must adhere to “Tridium’s literature guidelines and Best Practices.” For compatibility with existing systems, all facets and units of data must be U.S. standards.

4. Presented points as well as logic points found within the program.

    All electronic equipment shall conform to the requirements of FCC Regulation, Part 15, and Governing Radio Frequency Electromagnetic Interference and be so labeled.

5. The electrical contractor or BAS Installer shall install a UPS for 120v feeding power supply and battery backup option for JACE.

6. System to be installed by competent technicians, with full responsibility for proper operation of BAS, including debugging and adequate calibration of each component in the entire system.

7. Codes and approvals:

    a. Complete BAS installation according to national and local electrical codes. All devices designed for or used in line voltage applications must be UL listed.

8. All system components shall be fault-tolerant.

    a. Provide satisfactory operation without damage at 110 percent and 85 percent of rated voltage and +/- 3-hertz variation in line frequency.

b. Provide static, transient, short circuit, and surge protection on all inputs and outputs. Communication lines to be protected against incorrect wiring, electrostatic transients, and induced magnetic interference. Bus-connected devices will be AC coupled or equivalent so that any single device failure will not disrupt or halt bus communication.

F. QUALIFICATIONS

1. Detailed design & installation of the Building Automation System shall be by a BAS Contractor that meets the following requirements:

   a. Contractor's primary personnel working on this project will have one year of completed the Tridium Niagara N4 Certification training at the bid. Contractor to provide proof of mechanics/technicians having completed this training as part of submittals. These mechanics/technicians are designated as the primary designers/installers/integrators. They will be responsible parties to be on-site during the installation. In addition, they are required to attend all pre-construction, construction, and post-construction meetings, including acceptance testing and training.

   b. Experience installing at least three networked BAS systems utilizing Niagara N4-based control systems integrating controls using the LonWorks or BACnet communications protocol in the last three years. The minimum point count of these systems shall be 50 points. Submit information documenting this experience, including contact information of client representatives familiar with the contractor's work on each project.

G. BASIC BAS REQUIREMENTS

1. Panel Locations:

   a. BAS panels should be covered and centrally located relative to controlled equipment.

   b. BAS panels (including JACE and remote I/O) shall be protected from pipe leakage, dust, and other hazards and shall have a minimum 36" working clearance in front of each panel.

   c. BAS panels will be located as indicated on mechanical project drawings. The exact panel location will be determined by the Contractor and the University's Representative before the installation process.

   d. All panels shall be fully accessible without space restrictions to allow easy service and troubleshooting. The contractor shall obtain University approval of panel locations before proceeding with the work.

2. DDC controllers and remote IO shall provide the capability to manually override both digital and analog outputs at the BAS panel.

   a. Interface Relays: BAS output points shall not be used to switch motor control circuits directly. Provide an interface relay between the DDC controller and motor starter or equipment at the BAS panel. The interface relay should have a manual override leveler.

1. Interface relay, Automation Direct 781-1C-24A or similar
2. Relay socket, Automation Direct 781-1C-SKT

b. Status Monitoring: Electric current sensor switches shall be used for BAS status monitoring. (As opposed to differential pressure switches or flow switches). These shall be in the motor starter panel.

3. Start-Up Testing (Commissioning):

a. BAS Commissioning shall consist of 2 phases. The Contractor shall include BAS commissioning in the construction schedule. The BAS commissioning phases shall be:

1. Pre-Functional Testing: Point-to-point testing of all points and controllers. UCSC BAS Department must receive and sign off on the pre-Functional test script developed by the Contractor or Third-Party Commissioning agent at least 14 days before Final Functional testing. The testing shall be completed in advance of program installation and Functional Acceptance Testing. The contractor shall submit signed-off testing scripts verifying that this testing has been completed before the commencement of Functional Acceptance Testing.
2. Functional Acceptance Testing: This will be line-by-line testing of the operation sequences. This testing shall be conducted by the BAS Contractor Systems Integrator and the author of the sequence, with equal support from both UCSC BAS Department and BAS Contractor.

H. SUBMITTALS

1. Shop Drawings: Provide individuals experienced with the installation and startup of this type of integration equipment.

a. One copy of shop drawings of the entire BAS shall be submitted. It shall consist of a complete list of equipment and materials, including manufacturers' catalog data sheets and installation instructions.

b. Complete system design information, including:

1. Data entry forms for initial parameters. The BMS Shop needs to approve all text and graphics before data entry.
2. Valve and damper schedules showing:
    a. Size.
    b. Configuration.
    c. Capacity.
    d. Location.
3. Wiring and piping interconnection diagrams, including panel and the device power and sources.
4. Equipment lists (bill of materials) of all proposed devices and equipment.

5. Software design data including:
    a. Flow chart of each DDC program showing the interrelationship between inputs, PID functions, all other functions, outputs, etc.
    b. Sequence of operation relating to all flow chart functions.
6. Control sequence.
7. DDC installation, block diagrams, and wiring diagrams for each piece of equipment.
8. DDC panel physical layout and schematics.
9. The network topology diagram shall indicate all DDC controllers' locations and room numbers.
10. The BAS Contractor shall submit an architecture layout that depicts devices from the JACE down to the device level.
11. The BAS Contractor shall submit an architecture layout that depicts network diagrams for JACE-to-JACE communications and JACE to Server.
12. BACnet specific designs:
    a. The BAS Contractor shall submit a network topology diagram that includes the following on all BACnet devices
        i. TCP/IP Address
        ii. MAC Address
        iii. Device instance number
        iv. BACnet Port
        v. Devices configured for BBMD
        vi. BACnet routers and subnets
13. LonWorks specific designs:
    a. The BAS Contractor shall submit a network topology diagram that includes the following on all LON devices
        i. Neuron IDs
        ii. Routers
14. Sequence of Operations
    a. A complete written Sequence of Operations shall also be included with the submittal package. The BAS Contractor shall coordinate data from other contractors supplying products and systems as part of their package and provide catalog data sheets, wiring diagrams, and point lists to UCSC for proper coordination of work.

b. If a project is considered a renovation project, the BAS Contractor shall update all existing master diagrams to keep as-built drawings entirely accurate for the entire building.

15. Digital Visio updateable drawings should be contained in JACE and Flash drive.

a. A copy of all networks must be drawn on the actual physical daisy chain as installed. The drawings shall be the exact blueprint showing the floorplan, equipment location, and the network's route. The Niagara Network must also be included (i.e., Communications Bldg. communicates to West Remote Parking through JBEB connection on Rm. 252).

2. Product Data:

a. Complete list of product data, including:

1. Datasheets of all products.

2. Valve, damper, and well and tap schedules show all equipment's size, configuration, capacity, and location.

3. Project Information:

a. Certification of installer qualifications.

4. Submittal shall also include a copy of each of the graphics developed for the Graphic User Interface, including a flowchart (site map) indicating how the graphics are linked to one another for system navigation. The graphics are 80% - 90% complete, with the only remaining changes based on review comments from the A/E design team or UCSC. It is expected that the successful BAS Contractor shall utilize the UC Santa Cruz graphic templates as much as possible. UCSC will provide an example of an acceptable graphic template. The Integrator shall create a similar template and gain approval during the submittal process where a particular graphic template does not exist.

5. Upon completing the work, provide a complete set of 'as-built' drawings and application software on a compact disk. Drawings shall be supplied as AutoCAD™ or Visio™ compatible files

6. Contract Closeout Information:

a. Operating and maintenance manuals.

b. UCSC instruction report.

c. Certification that UCSC Training has been provided by BAS installer.

d. As-Built Instrumentation and Control Diagrams.

e. Plan As-Builts at a 1/8-inch scale showing:

1. Upon completing the work, provide a complete set of 'as-built' drawings and application software on a compact disk. Drawings shall be supplied as AutoCAD™ or Visio™ compatible files.

2. Two copies of the ‘as-built’ drawings shall be provided in addition to the documents on a compact disk.
3. Division 23, 25, and 26 contractors shall provide as-builts for their portions of work.
4. The BAS Contractor shall be responsible for as-builts about overall BAS architecture and network diagrams. All As-Built drawings shall also be installed into the BAS server in a dedicated directory.
5. Communication cable circuiting drawing with DDC panels and communication devices labeled.
6. Power-wiring circuiting drawing showing:
    a. 120-volt circuit source and low voltage transformer locations
    b. Identifications and circuits to each controlled device per transformer for the DDC system.
7. Any software needed to program or calibrate the controls system will be provided with any setup, configurations, and data files. Also, any hardware necessary to communicate with the controllers and devices will be included.

I. JOB CONDITIONS

1. Cooperation with other Trades:
    a. Coordinate work of this section with that of other Sections to ensure that the work will be carried out in an orderly fashion. The Systems Integrator shall be responsible for checking the Contract documents for possible conflicts between his work tasks and other crafts in equipment location, pipe, duct, conduit runs, electrical outlets and fixtures, air diffusers structural and architectural features.

J. SOFTWARE LICENSE AGREEMENT

1. It is the UCSC’s express goal to implement an open system that will allow products from various suppliers to be integrated into a unified Tridium Niagara system to provide flexibility for the expansion, maintenance, and service of the system. University of California, Santa Cruz shall be the named license holder of all software associated with incremental work on the project(s). In addition, the UCSC shall receive ownership of all job-specific configuration documentation, data files, and application-level software developed for the project. This shall include:
    a. All custom, job-specific software code and documentation for all configuration and programming generated for a given project and configured for use with the JACE, BAS Supervisor Server(s). Any related LAN / WAN / Intranet and Internet-connected routers and devices.
    b. The BAS Integrator shall provide all required IDs and passwords for access to any component or software program to UCSC.
2. UCSC has signed the BAS software and firmware licensing agreement. Such license shall grant the use of all programs and application software to UCSC as defined by the

manufacturer's license agreement. Still, it shall protect the manufacturer's rights to disclosing trade secrets contained within such software. Systems Integrators that participate in the integration of UC Santa Cruz's direct digital control systems must:

a. Be certified in the use, application, and service of NiagaraN4 software and shall provide documentation from the manufacturer's training center as such.

   However, certification in the above does not automatically qualify an integrator to bid on proposed UC Santa Cruz projects. Only approved integrators listed in this specification are eligible to participate in the project.

b. Agree to use any UC Santa Cruz project, application standards, HTML pages, graphics templates, etc., developed by or for UC Santa Cruz for digital control, scheduling, alarming, graphics, etc.

c. Agree that the application standards, HTML pages, graphics templates, etc., developed only for UC Santa Cruz, are the property of UC Santa Cruz (subject to the manufacturer's license agreement). And shall not be reproduced, etc., for use on any other customer, project, etc., without the expressed written permission of the UC Santa Cruz facilities staff.

d. Agree that certification on the manufacturer's software does not guarantee continued participation in UC Santa Cruz's BAS projects.

e. Agree to provide UC Santa Cruz's staff with the highest level of an administrative password.

f. Agree that UC Santa Cruz staff and other Systems Integrators can use the onsite UC Santa Cruz software tools to modify JACE s, license files, passwords, software maintenance, etc. after the warranty period expires.

g. UCSC requires that all NiagaraN4-based software and hardware on this project have the following Niagara Information Compatibility Statement (NICS). The Existing Ni- agaraN4 Server complies with the requirements below. Organizations without the NICS specified below shall not be allowed to bid.

   1. Brand ID = Vykon or Distech Controls or Honeywell
   2. Station Compatibility In = *
   3. Station Compatibility Out = *
   4. Tool Compatibility In = *

K. WARRANTY

1. Provide all services, materials, and equipment necessary for the successful operation of the entire BAS for two years after acceptance by University Representatives and provide hardware and software upgrade support during that period that corresponds with any upgrades performed by the BAS Contractor Systems Integrator.

2. Within the warranty period, upon notice by UCSC, any defects in the work provided under this section for any reason shall be promptly (within 48 hours after receipt of information) repaired or replaced systems or parts found defective at no cost to UCSC by the BAS Contractor including but not limited to:

a. Building Controls System Server software, project-specific software, graphic software, database software, and firmware updates that resolve known software deficiencies, as identified by the Contractor or UCSC, shall be provided and installed at no charge during the warranty period.

b. Contractor to apply all software updates and security patches immediately (within 72 hours) as they become available, from the start of the project until the end of the warranty period

c. All corrective software modifications made during the warranty period shall be updated on user documentation, and user and manufacturer archived software disks.

d. Include parts, labor, and necessary travel during the warranty.

e. All parts should be replaced with the exact products. If the same components are not available, then the equivalency determination rests with UCSC.

f. Troubleshooting service, preventative maintenance, and scheduled re-calibration of the system are the responsibility of UCSC. Such routine tasks shall not impact Contractor warranty obligations.

3. The system's adjustment requires testing and repair and includes all computer equipment, transmission equipment, and sensors and control devices.

4. UCSC will initiate service calls when the system is not functioning correctly. Qualified personnel shall be available to provide service to the complete system. Furnish UCSC with a telephone number where a service representative can always be reached. Service personnel shall be at the site within 24 hours after receiving a service request.

5. Provide vendor-specific warranty information.

6. At the end of the warranty period, the Contractor shall ensure that every instance of Tridium NiagaraN4 software has the latest Tridium software maintenance release installed.

7. Expiration of the warranty period does not relieve the Contractor of the responsibility for correcting all deficiencies identified during the warranty period. Expiration of the warranty period does not relieve the Contractor of the responsibility for fulfilling all specified obligations during the warranty period.

L. UCSC’S TRAINING

1. In no case shall training be scheduled until all graphics are approved and accepted by UCSC Physical Plant BAS Department.

2. Training shall not proceed until UCSC Physical Plant BAS Department has reviewed and approved the Training Submittal.

3. Provide a minimum of 32 hours of training, organized into eight separate sessions of the 4-hour session.

4. Provide a factory-trained instructor or representative to give full instructions to designated personnel in each piece of equipment or system's operation, maintenance, and

programming. Instructors shall be thoroughly familiar with all aspects of the subject matter. The Contractor shall provide all equipment and material required for classroom training.

5. Qualifications of the proposed training instructor are subject to UCSC approval.

6. The training shall be specifically oriented to the system and interfacing equipment installed.

7. Organize training per user group and into different training sessions. UCSC to provide user groups.

8. Include classroom instruction and field demonstration.

9. Classroom instruction should include, at a minimum:

    a. Detailed review of as-built documentation and conditions with general equipment layout

    b. In-depth discussion of the theory of a sequence of operations

    c. Re-view organization and usability of O&M documentation

    d. Maintenance (preventative, sensor calibration, etc.) procedures and schedules

    e. Pertinent safety requirements

    f. Operator control functions, including graphic operation and navigation

    g. Explanation of adjustment, calibration, and replacement procedures

    h. Explanation of procedures to restore any building level controller or building control server database. The training manual shall include screen captures, including instructional annotation, of each step required to accomplish the task.

    i. Explanation of procedures to restore any local control unit database. Scenarios to ex- plain include restoring a corrupted database in an existing unit; restoring a database in a new unit that replaces an identical unit; and restoring a database in a new unit with a different controller than the failed unit. The training manual shall include screen captures, including instructional annotation, of each step required to accomplish the task for each type of DDC controller installed.

    j. Detailed review of all DDC logic, programming, and programming documentation. Control logic shall be graphical and annotated to describe how it accomplishes the sequence of operations. Annotations shall be sufficient to allow UCSC's BAS Integrators to relate each program component block to corresponding portions of the specified Sequence of Operation. The training manual shall include screen captures, including instructional annotation, of all DDC logic, programming, and programming documentation, for each type of DDC controller installed.

    k. Additional specific topics will be requested by UCSC before the training session. Each custom topic/session will require the Contractor to prepare and submit a training manual with the same level of detail (screen captures, annotation, and written instructions) as described above.

10. Field instruction, if determined by UCSC to be required for this project, should include at a minimum

    a. Normal maintenance procedures

    b. Demonstration of operation

    c. Demonstration of safeties and interlock

    d. Walk-through of the job to locate control component

M. PROJECT MANAGEMENT

1. No later than the project kick-off meeting, the Contractor shall identify in writing:

    a. One employee of the BAS Contractor who has the primary responsibility for managing the project. This person shall be known as the BAS Contractor's Project Manager for scheduling and project management purposes.

    b. One employee of the BAS Contractor who has the primary responsibility for supervising the control system physical installation. This person shall be known as the BAS Contractor's Installation Supervisor for scheduling and project management purposes.

    c. One employee of the BAS Contractor who has the primary responsibility for programming controllers, programming control system database, and developing graphics. This person shall be known as the BAS Contractor's Systems Integrator for scheduling and project management purposes.

    d. Depending on the size of the project, the three above-listed roles may be performed by the same Contractor's employee.

2. For scheduling and project management purposes, the project shall generally be divided into 3 phases.

    a. Installation Phase

        1. Shall be the period from project start until the physical installation of all controllers, appurtenant devices, and computers is complete

    b. Database/Graphics Finalizing Phase

        1. Shall be the period from the completion of the Installation Phase until the Contractor has completed all system programming and graphics development.

    c. Project Closeout Phase

        1. Shall be the period from completing the Database/Graphics Finalizing Phase until UCSC has accepted the project.

3. The Contractor shall attend all project meetings and provide meeting minutes and action items to all attendees within three working days of each session.

a. During the Installation Phase, project meetings shall occur weekly at a regularly scheduled meeting time. BAS Contractor's Project Manager and BAS Contractor's Installation Supervisor shall attend all sessions. If requested by UCSC, BAS Contractor's Systems Integrator shall participate in any meeting during the Installation Phase. BAS Contractor shall furnish an updated project schedule with all applicable milestones at least one day before the meeting.

b. During the Database/Graphics Finalizing Phase, project meetings shall occur as determined by UCSC. UCSC will give 1-week advance notice of any project meetings during this phase. BAS Contractor's Project Manager and BAS Contractor's Systems Integrator shall attend all sessions during the Database/Graphics Finalizing Phase. If requested by UCSC, BAS Contractor's Installation Supervisor shall participate in any meeting during the Database/Graphics Finalizing Phase. BAS Contractor shall furnish an updated project schedule with all applicable milestones at least one day before the meeting.

c. During the Project Close-Out Phase, project meetings shall occur as determined by UCSC. UCSC will give 1-week advance notice of any project meetings during this phase. BAS Contractor's Project Manager and BAS Contractor's Systems Integrator shall attend all sessions during the Project Close-Out Phase. If requested by UCSC, BAS Contractor's Installation Supervisor shall participate in any meeting during the Project Close-Out Phase. BAS Contractor shall furnish an updated project schedule with all applicable milestones at least one day before the meeting.

4. Meeting minutes shall represent a true and accurate record of the meeting. Corrections or clarifications to the meeting minutes shall be by a written request for correction within seven days of the meeting minutes' issuance.

5. BAS Contractor accepts that UCSC may rely on third-party consultants, i.e., Commissioning Authority, to complete independent tests and review project deliverables from BAS Contractor during the Project Close-Out Phase.

6. The BAS Contractor shall maintain a "red-lined" copy of the as-built drawings on-site

7. The BAS Contractor shall have a Functional Performance Test and always start up sheets available on-site.

N. SCHEDULING

1. The BAS Contractor must provide a schedule of activities and continually update the plan as the project progresses. Clearly distinguish between commissioning activities performed solely by BAS Contractor and commissioning activities involving the Commissioning Authority.

2. During the Installation Phase, the BAS Contractor shall update the schedule weekly, at least one day before the project meeting, to provide a 3-week look-ahead plan with a list of construction impacts for occupants.

3. Project Schedule shall include, at a minimum, with at least three weeks' advance notice, the following project milestones:

a. BAS Contractor starts the physical installation.

b. Any Utility Shut Down required by the project.

c. BAS Contractor ready to connect Building Automation System to UCSC Campus Controls Network.

d. BAS Contractor completes all physical installation.

e. BAS Contractor complete and ready for Commissioning (Cx) network points.

f. BAS Contractor ready for preliminary controller FPT and programming review (1 of each controller or controller application type

g. BAS Contractor ready for final zone terminal unit controller FPT and programing review (10% of each type of controller).

h. BAS Contractor ready for air handler FPT (Verifies AHU reset strategies and occupancy schedules are functioning correctly).

i. BAS Contractor ready for building heating/cooling, central plant, or whole building FPT (as applicable).

j. Controller programming and entire Niagara database ready for UCSC Physical Plant BAS Department to review.

k. Graphics ready for UCSC Physical Plant BAS Department review.

l. BAS Contractor ready for Cx trend review.

m. Contractor submits Training Agenda and Training Binder for UCSC Physical Plant BAS Department review. Note: Graphics, Training Agenda, and Training Binder must be reviewed and approved by UCSC Physical Plant BAS Department before the scheduled training.

n. Training sessions.

4. Included in this project are connections to equipment provided by others. Coordinate deliveries, final locations, factory mounting, and various inter-shop connections required.

5. Coordinate activities with the contract project schedule.

   a. Ensure integration activities are incorporated into the project schedule.

   b. Communicate requirements to prevent potential damage from paint, dust, water, weather, etc. Monitor and take measures to assure protection for all equipment.

6. Coordinate all IT requirements with UCSC and contract project schedule.

O. SYSTEM ARCHITECTURE

1. GENERAL

a. The Building Automation System (BAS) shall comprise a network of interoperable, stand-alone digital controllers, a computer system, graphical user interface software, network devices, and other devices.

b. This specification intends to provide a peer-to-peer networked, stand-alone, distributed control system with the capability to integrate the most current ANSI/ASHRAE Standard BACnet, LonWorks technology, MODBUS, existing OPC if applicable, and other existing open and proprietary communication protocols if applicable in one open, interoperable system.

c. The supplied Building Automation System shall employ component-based technology to represent all data and control devices within the system. In addition, adherence to industry standards, including the most current ANSI / ASHRAE™ Standard, BACnet, and LonMark, ensures interoperability between all system components. For each LonWorks device that does not have LonMark certification, the device supplier must provide an XIF file and a resource file for the device. The device supplier must give a PICS document showing the installed device's compliance level for each BACnet device. Minimum compliance is Level 3, with the ability to support data read and write functionality. The physical connection of BACnet devices shall be via RS-485 (BACnet MSTP) or Ethernet (BACnet Ethernet/IP) only by exception with prior UCSC BAS Department approval and only through the JACE's secondary IP port.

d. All components and controllers supplied under this Division shall be true "peer-to-peer" communicating devices. Components or controllers requiring "polling" by a host to pass data shall not be acceptable.

e. The supplied system must incorporate the ability to access all data using standard Web browsers without requiring proprietary operator interface and configuration programs. An Open Database Connectivity (ODBC) or Structured Query Language (SQL) compliant server database is required for all system database parameter storage. This data shall reside on a supplier-installed server for all database access. Systems requiring proprietary database and user interface programs shall not be acceptable.

f. A hierarchical topology is required to assure reasonable system response times and manage the flow and sharing of data without unduly burdening UCSC's internal Intranet network. Systems employing a "flat" single-tiered architecture shall not be acceptable.

    1. Maximum acceptable response time from any alarm occurrence (at the point of origin) to the moment of annunciation shall not exceed 5 seconds for network-connected user interfaces.

g. The installed system shall provide secure password access to all features, functions, and data contained in the overall BAS.

h. System architecture shall consist of two levels of LAN or communication busses.

    1. Level one – Campus Supervisor level

        a. Consists of JACE 8000 controllers acting as gateway devices to share data between buildings and the supervisor server, where

Campus NiagaraN4 Supervisor software resides. UCSC BAS Department oversees the Supervisor Server. All modifications must be pre-approved and coordinated. BAS Department System Integrators access supervisor using client-provided workstations, connected to the Client LAN/WAN using preferred web browser software. According to the Niagara Product Model, JACE controllers must be installed throughout Client buildings connected to Client LAN/WAN for communication between the supervisor server and the specific building controls.

The communication protocol between the supervisor and JACE controllers shall be FOXS, Tridium's Secure TCP/IP-based protocol.

2. Level two - Field level

    a. Consists of general-purpose programmable controllers to provide stand-alone control of terminal units. Terminal units include VAV boxes, fan coil units, heat pumps, induction units, unit heaters, smaller rooftop units serving a single zone, etc. Field level controllers are configured or programmed using the manufacturer's programmable controller tool. The programmable controller tool shall be capable of connection to field controllers via Client LAN/WAN routed through the JACE controllers. Communication at the field level shall be open protocol; BACnet MS/TP or LonWorks. For new xio (inputs/outputs) point requirements, BACnet IP controllers are the preferred integration method (Distech ECY-303) or similar.

P. NETWORK ACCESS AND SECURITY

1. Remote Access

    a. For Local Area Network installations, UCSC shall connect to the Internet to enable access via the customer's Intranet to a corporate server. BAS Contractor shall connect to IP drop provided by the UCSC IT is utilizing a minimum of Category 6 grade of patch cabling

2. JACE IP Communications

    a. BAS Contractor will use DHCP and DNS for IP communications.

        1. No static IPs or "hardcoded" IP addresses (except for secondary port, see below) in the JACE will be accepted.

        2. The BAS Contractor shall request from UCSC IT Department all required primary port TCP/IP network configuration settings for all JACEs via standard RFI. The BAS Contractor shall not assign any of the following configuration settings without UCSC BAS Department approval.

            a. Domain name

            b. Hostname

            c. Station Name

d. Secondary port

i. For troubleshooting purposes, The BAS Contractor shall configure the JACE's secondary port to a static IP address of 192.168.1.14X, where X is equal to the last digit of JACE's serial number.

ii. The subnet mask shall be configured to 255. 255. 255.0

b. SSL requirements

1. All communications between Niagara devices and the Supervisor server or user interface software, i.e., IDE, shall be secured using SSL encryption.

2. The following ports shall be used for SSL communications

Software Interface	Protocol	Specified Port
Browser	HTTPS	443
Niagara Station IDE	FOXS	4911
Niagara Platform IDE	TLSv1	5011

Q. JAVA APPLICATION CONTROL ENGINE (JACE)

1. The BAS Contractors Systems Integrator shall supply one or more Java Application Control Engine (JACE) as part of this contract to manage devices/points in all specification sections. The number of JACEs provided by the BAS Contractor is dependent on the type/quantity of devices and points. It is the responsibility of the BAS Contractor to coordinate with all Division contractors to determine the quantity and type of JACEs needed to fulfill the operating sequences.

2. Java Application Control Engine (JACE) shall provide the interface between the LAN or WAN and the field control devices and provide global supervisory control functions over the control devices connected to the JACE. It shall be capable of executing application control programs to provide:

a. Calendar functions

b. Scheduling

c. Trending

d. Alarm monitoring and routing

e. Time synchronization

f. Integration of LonWorks controller data and BACnet controller data

g. Network Management functions for all LonWorks-based devices.

3. The Java Application Control Engine must provide the following hardware features as a minimum:

    a. TI AM3352: 1000MHz ARM® Cortex™-A8

    b. 1GB DDR3 SDRAM

    c. Removable micro-SD card with 4GB flash total storage/ 2GB user storage

    d. Wi-Fi (Client or WAP)
        1. IEEE802.11a/b/g/n
        2. IEEE802.11n HT20 @ 2.4GHz
        3. IEEE802.11n HT20/HT40 @ 5GHz
        4. Configurable radio (Off, WAP, or Client)
        5. WPAPSK/WPA2PSK supported

    e. USB type A connector
        1. Backup and restore support

    f. Isolated RS-485 with selectable bias and termination

    g. (2)10/100MB Ethernet ports

    h. Secure boot 24VAC/DC power supply

    i. Runs Niagara-4.1 and later

    j. Real-time clock

    k. Battery-less

    l. Any Expansion Modules and IO Configurations needed for the project.

    m. The JACE must be capable of operation over a temperature range of -22 to 140°F

    n. The JACE must be capable of withstanding storage temperatures of between -40 and 185°F

    o. The JACE must be capable of operation over a humidity range of 5 to 95% RH, non-condensing.

4. The JACE shall support standard Web browser access via the Intranet/Internet. It shall provide support for a minimum of 32 simultaneous users.

5. JACE Data Collection and Storage.

    a. The JACE shall have the ability to collect data for any property of any object and store this data for future use. The maximum number of records stored should be 250. See points list for required logs.

    b. The data collection shall be performed by log objects resident in the JACE that shall have, at a minimum, the following configurable properties:

        1. Designating the log as interval or deviation.

2. For interval logs, the object shall be configured for the time of day, day of the week, and the sample collection interval.
3. For deviation logs, the object shall be configured for the deviation of a variable to a fixed value. This value, when reached, will initiate the logging of the object.
4. For all logs, provide the ability to set the maximum number of data stores for the record and to set whether the log will stop collecting when full or roll over the data on a first-in, first-out basis.

c. Each log shall have the ability to have its data cleared on a time-based event or by a user-defined event or action. All log data shall be archived in a database in the EnergyN4 Server, and the data shall be accessed from a standard Web browser. When accessed from a server, all log data shall be capable of being manipulated using standard SQL, BQL & NQL statements.

d. All log data shall be available to the user in the following data formats:
   1. HTML
   2. XML
   3. Plain Text
   4. Comma or tab-separated values

e. Systems that do not provide log data in HTML and XML formats at a minimum shall not be acceptable.

f. The JACE shall have the ability to archive its log data remotely to a server on the network. Provide the ability to configure the following archiving properties at a minimum:
   1. Archive on time of day
   2. Archive on a user-defined number of data stores in the log (buffer size)
   3. Archive when the log has reached its user-defined capacity of data stores
   4. Provide the ability to clear logs once archived.

6. JACE Audit Log

a. Provide and maintain an Audit Log that tracks all activities performed on the JACE. Provide the ability to specify a buffer size for the log and the ability to archive the record based on time or when the log has reached its user-defined buffer size. Provide the ability to archive the log to a server. For each log entry, provide the following data:
   1. Time and Date
   2. User ID
   3. Change or activity: i.e., Change the setpoint, add, delete objects, commands, etc.

7. JACE Database Backup & Storage

a. The JACE shall have the ability to automatically backup its database. The database shall be backed up based on a user-defined time interval.

b. Copies of the current database and, at the most recently saved database, shall be stored in the JACE. The age of the most recently held database is dependent on the user-defined database save interval.

c. The JACE database shall be stored, at a minimum, in XML format to allow for user viewing and editing, if desired. Other configurations are acceptable as well if XML format is supported.

8. JACE Time Sync

    a. Use the NtpPlatformServiceQnx in the Station/Services/PlatformServices/ NtpPlatformServiceQnx. Use Time Servers ntp1.ucsc.edu: 128.114.129.77, ntp2.ucsc.edu: 128.114.1.77, ntp3.ucsc.edu: 128.114.103.81

9. JACE Weather Station/OA Temperature

    a. The Web Supervisor has a dedicated weather station available through the Niagara Network. While the JACE is not on the UCSC Network and for backup purposes, all buildings must have their own Outdoor Air Temperature sensor for economizer and other requirements. The Web Supervisor Outdoor Air Temperature can also override it.

    b. Outdoor Humidity, Dew point, and Wet Bulb are also available from the Web Supervisor.

    c. The weather station in the Services of the Station should also be enabled and set for KWVI Watsonville Municipal Airport.

    d. Air Quality is not enabled due to conditions beyond our control. Therefore, this property should be set to False.

10. JACE Loading

    a. The Systems Integrator is to properly design the system to be load-balance across multiple JACEs. I.e., UCSC does not want 1 JACE operating at 80%, and another is running at 20%

11. JACE Mounting

    a. The manufacturers recommended environmental and mount requirements shall be followed. In addition, a minimum clearance of 6 inches all around the JACE shall be maintained for local connections to the JACE.

R. INTEGRATED DEVELOPMENT ENVIRONMENT (IDE)

1. UCSC intends to manage and maintain all Niagara devices on the BAS network to the same Niagara-approved version. The BAS Systems Contractor’s responsibility is to check the currently installed/supported version of Niagara on campus (N4.9.1.30 at the time of this document) and to attain and perform any deployment with the current UCSC-approved version.

2. An integrated development environment for the development of graphic screens, control logic, security, alarm notification, and data storage has been established using the Niagara Workbench Tool and currently resides on the EnergyN4 Construction Server. All graphical development will be done on UCSC’s EnergyN4 Construction Server. The server and JACE IDE tools shall be identical; however, it shall be possible to limit views and commands via a unique user profile and password in either. The system shall automatically monitor the operation of all workstations, modems, network connections,

building management panels, and controllers. The failure of any device shall be annunciated to the operator.

S. WEB BROWSER CLIENTS

1. The system shall also allow an unlimited number of clients to use a standard Web browser, including Chrome and Firefox™, Explorer Edge(preferred). The system shall be capable of providing a rich user experience (including full use of the engineering toolset) using java applets or a simple user interface using only HTML, CSS, and JavaScript. Refer to Sequence of Operations for the client-side display types required on this project.

2. The Web browser shall provide the same view of the graphics, schedules, calendars, logs, etc., as is provided by the Graphical User Interface and match the look and feel of graphics in the Web Supervisor. Systems that require different views or other means of interacting with objects such as schedules or logs shall not be permitted.

    a. The Web browser client shall support, at a minimum, the following functions:

        1. User log-on identification and password shall be required. If an unauthorized user attempts to access it, a blank web page shall be displayed. Security shall be implemented using Java authentication and encryption techniques to prevent unauthorized access.
        2. Graphical screens developed for the GUI shall be the same screens used for the Web browser client (unless clearly stated in the sequence of operation). The Web browser interface shall support any animated graphical objects supported by the GUI. The UCSC BMS Shop shall provide a BAS Contractor with a basis of performance/expectation for GUI. BAS Contractor shall use this standard graphic template or modify the graphics slightly to achieve the desired specification requirement/outcome.
        3. Storage of the graphical screens shall be in the UCSC EnergyN4 Construction Server, and these graphics shall be “learned” by the Energy N4 Construction Server andEnergyN4 Server via Export tagging.
        4. Real-time values displayed on a Web page shall update automatically without requiring a manual “refresh” of the Web page.

    b. UCSC shall have administrator-defined access privileges. Depending on the access privileges assigned, the user shall be able to perform the following:

        1. Graphically modify most used application objects, such as schedules, calendars, and setpoints.
        2. Schedule times will be adjusted using a graphical slider without requiring any keyboard entry from the operator.
        3. Holidays shall be set using a graphical calendar without requiring any keyboard entry from the operator.
        4. 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 entry of text shall be required.
        5. View logs and charts
        6. View and acknowledge alarms
        7. Setup and execute SQL queries on a log and archive information.

c. Graphic screens on the Web Browser client shall support hypertext links to other locations on the Internet or Intranet sites by specifying the Uniform Resource Locator (URL) for the desired hyperlink.

d. Navigation page will follow this layout:

    1. Home page – Main landing page with menu and a picture of the building.
    2. Floor Plans, underfloor plans folder are the individual floor plans and under them the individual VAVs (meters and lighting to be shown on a floor plan with layers and a legend.)
    3. Systems
    4. Equipment
    5. Meter
        a. Power
        b. Water
        c. Gas
    6. Miscellaneous
        a. Schedules
        b. Sequences
        c. Network Arc
        d. Notes
        e. Histories

e. Tagging is required on all projects. Points shall be tagged appropriately with Haystack and Niagara tag libraries.

f. All PID setpoint adjustments on a secure/hidden graphic. The system administrator will restrict this file
    1. Autotune is not acceptable and will be disabled

g. Legends to show what the different colors are

h. All floorplans must be in an SVG or Scalable Vector Format.

i. VAV summary Page - Room Temp, Act temp, setpoint, damp position, reheat valve position, supply air temp, override the color

j. Page for Max Terminal Box used for Setpoint Calculation to allow airflow up or step down. Ability to disable and enable VAV boxes in the calculation

k. Show what points are in override, down, stale, Alarm, and fault.

l. Label units (AHU) to show what they feed

m. Network diagram to show JACE network inter-connectivity

n. JACEs to use outside air temp and campus weather station for temperatures

o. Valves need to be labeled and the position shown

p. All flow meters and temperatures need to be trended

q. Page definitions with standards - AHU, CHW, Floorplan, VAV pages, DHW summary page, VAV summary page, water and gas meter page, electric meter

r. Insert maps (critical plan) when zoomed in on floor plans

s. Thermostat box on VAV page

t. Show where meters are in the building, show the icon on the floor plan and link back to the summary page.

u. Floorplan zones - don't use conflicting colors

v. The control diagram must show network addresses for each device

w. Control valve Tuning is required on the graphics

3. Campus Navigation Bar on the left side of the page

4. JACEs shall be on Niagara 4.9.1.30 at a minimum or at the latest Niagara N4 version that UCSC runs on the Web N4 Supervisor. Check with UCSC BAS Department.

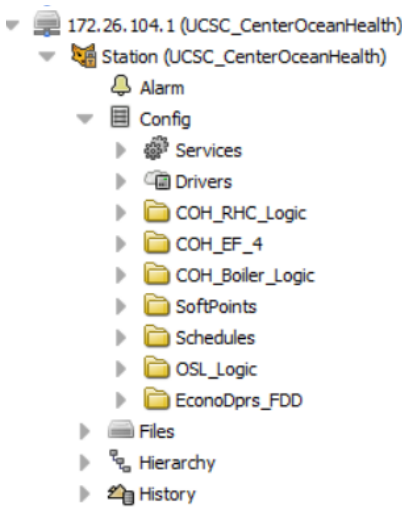
T. PROGRAMMING

1. Renovation work will require the contractor to communicate directly with the UCSC BAS Department to coordinate access for system programming and interface to existing building system operation. Remote access to Construction N4 Supervisor will be approved once the contractor understands system complexity. Project requirements may require programming and graphic generation to be completed on-site.

2. UCSC has a general programming standard. For programming file structure NavTree layout, see below.

   a. Logic folder naming and location should follow the naming standard used by the UCSC BAS Department. All logic should reside in folders named "Equipment Name_Logic" under Config.

   b.



3. Network architecture (Lon, Modbus, BACnet).

4. Programming Methods:

a. Power Fail Protection - All System set points, proportional band, control algorithms, and other programming parameters will be stored. A power failure does not necessitate reprogramming the ASC (Application Specific Controller) JACE.

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

c. Configuration of each component through the component's properties sheet view. Requiring custom programming, scripting language, or a manufacturer-specific procedural language for every component configuration will not be accepted.

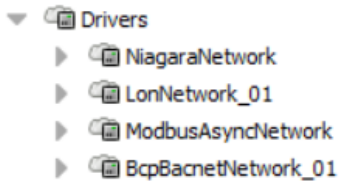
d. The software shall provide the ability to view the logic in a monitor mode. When online, the monitor mode shall offer the ability to quickly diagnose the logic execution and consider the logic in real-time. When off-line (debug), the monitor mode shall allow the user to set values to inputs and monitor the logic for analyzing performance before applying it to the system.

e. The system shall support component duplication within a customer's database. An application, once configured, can be copied and pasted for easy re-use and replication. Other than the hardware, all links shall be maintained during duplication.

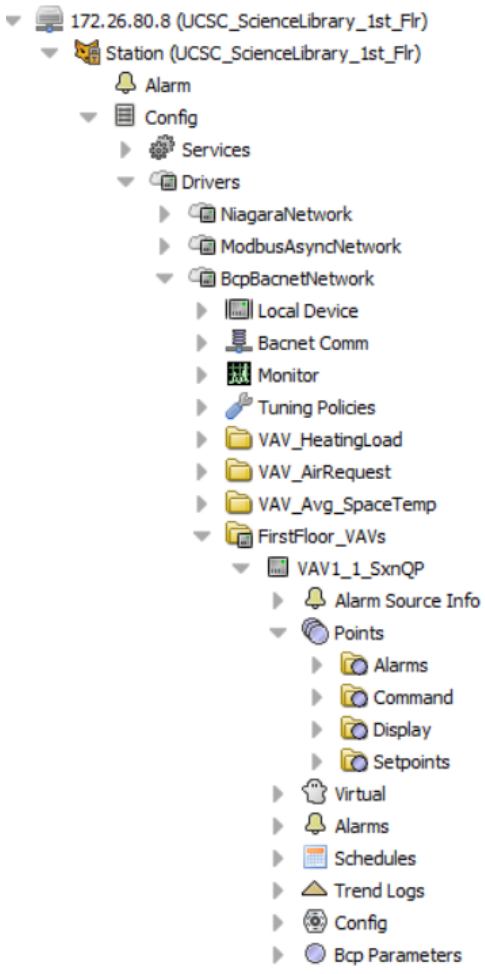
f. All PIDs shall have an adjustable set point on a secure/hidden page exposed to the graphic.

5. Network, Device, and Control Panel Naming Conventions.

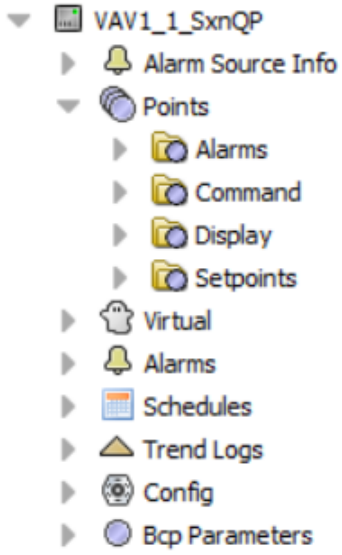
a. All Network names will not have spaces. Underscores are only acceptable when more than one network of the same protocol is integrated. I.e., BACnetNetwork or LonNetwork_01 is acceptable. BACnet Network is not.



b. Device names will not have spaces; underscores are acceptable. VAVs must have a room name associated with them. I.e., VAV1_1_Rm126. The #1 attached to the VAV corresponds with the VAV Number; the second #1 correlates with the floor it is on.



c. Each network device should have three folders named Alarms, Command, Display, and Setpoints, where all integration points should reside.



d. All Network and Device names must be kept to a minimum and subject to UCSC BAS Department acceptance.

U. COMPONENTS LIBRARIES

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

2. The components 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 components created in their application and store the new instances of these components in a user-defined library.

3. The Contractor will use the Niagara template station file provided by UCSC BAS Department. The template station will be available to the BAS Contractor upon request via standard RFI.

4. Contractor shall not use any "non-standard" or OEM JAR files unless approved by UCSC BAS Department. A JAR is considered "non-standard" if not included in Tridium's "Niagara N4 Developer" release made available to developers and OEM partners. An example of a non-standard JAR is "jcigrahicssmall.jar." A current list of approved JARs will be available to the BAS Contractor upon request via standard RFI. Source codes are made available to UCSC BAS Department to store and use.

5. Any approved non-standard JAR files become the property of UCSC with a copy of the source code to store and use

6. All control components shall conform to the control component specified in the BACnet specification.

7. The component library shall include components to support integrating devices connected to the Java Application Control Engine (JACE). At a minimum, provide the following as part of the standard library included with the programming software:

8. LonMark/LonWorks devices. These devices shall include, but not be limited to, devices for control of HVAC, lighting, access, and metering. Provide LonMark manufacture specific components to facilitate simple integration of these devices. All network variables defined in the LonMark profile shall be supported. Information (type and function) regarding network variables not defined in the LonMark profile shall be provided by the device manufacturer.

9. For devices not conforming to the LonMark standard, provide a dynamic component that can be assigned to the device based on network variable information supplied by the device manufacturer. The device manufacturer shall provide an XIF, resource, and documentation to facilitate device integration.

10. For BACnet devices, provide the following components at a minimum:

    a. Analog In

    b. Analog Out

    c. Analog Value

d. Binary

e. Binary In

f. Binary Out

g. Binary Value

h. Multi-State In

i. Multi-State Out

j. Multi-State Value

k. Schedule Export

l. Calendar Export

m. Trend Export

n. Device

11. For each BACnet component, provide the ability to assign the component a BACnet device and component instance number.

12. 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 Write Property

    g. Write Property Multiple

    h. Confirmed Event Notification

    i. Unconfirmed Event Notification

    j. Acknowledge Alarm

    k. Get Alarm Summary

    l. Who-has

    m. I-have

    n. Who-is

    o. I-am

p. Subscribe COV

q. Confirmed COV notification

r. Unconfirmed COV notification

s. Media Types

t. Ethernet

u. BACnet IP Annex J

v. MSTP

w. BACnet Broadcast Management Device (BBMD) function

x. Routing

V. LONWORKS NETWORK MANAGEMENT

1. The Graphical User Interface software (GUI) shall provide a complete set of integrated LonWorks network management tools for working with LonWorks Networks. These tools shall manage a database for all LonWorks devices by type and revision and provide a software mechanism for identifying each device on the network. These tools shall also be capable of defining network data connections between LonWorks devices, known as “binding.” Systems requiring third-party LonWorks network management tools shall not be accepted.

2. Network management shall include the following services: device identification, device installation, device configuration, device diagnostics, device maintenance, and variable network binding.

3. The network configuration tool shall also provide diagnostics to identify network devices, reset devices, and view health and status counters within devices.

    a. These tools shall provide the ability to “learn” an existing LonWorks network, regardless of what network management tool(s) were used to install the existing network so that existing LonWorks devices and newly added devices are part of a single network management database.

    b. The network management database shall reside in the Java Application Control Engine (JACE), ensuring that anyone with proper authorization always has access to the network management database. Systems employing network management databases that are not resident, always, within the control system shall not be accepted.

    c. All Lon Networks must be installed to industry standards and not exceed a max length of 3500 ft. The wire must be installed in a separate conduit if the non-plenum is unestablished following proper LON specifications, no more than 60 devices, and no LON repeaters, point, and trend count to assure appropriate polling of devices and points. Plenum cable is allowed without conduit with University’s approval. All points and devices must update correctly and not go into a fault, stale, or offline. Proof of network reliability using but not limited to Lon

Network Scan tool, Oscilloscope, and Polling Service. Copies of these operations must be submitted to UCSC before the warranty period.

W. BACNET/MSTP NETWORK MANAGEMENT

1. The Java Application Control Engine shall support integrating device data from BACnet TCP/IP or BACnet MSTP system devices. The connection to the BACnet system shall be via an RS485 or Ethernet IP as required by the device before UCSC approval for IP/Ethernet controls and only through the secondary IP port of the JACE.

2. Provide the required components in the library, included with the Graphical User Interface programming software, to support the integration of the BACnet system data into the BAS. Components provided shall consist of at a minimum:

    a. Read/Write BACnet AI Points

    b. Read/Write BACnet AO Points

    c. Read/Write BACnet AV Points

    d. Read/Write BACnet BI Points

    e. Read/Write BACnet BO Points

3. Read/Write BACnet BV Points; all BACnet system devices' scheduling, alarm, logging, and global supervisory control functions shall be performed by the Java Application Control Engine.

4. The BAS supplier shall provide a BACnet system communications driver. The equipment system vendor that provided the equipment utilizing BACnet shall provide documentation of the system's interface and shall provide factory support at no charge during system commissioning

5. BACnet Conformance:

    a. Logic controllers shall support MS/TP BACnet LAN type as a minimum. They shall communicate directly via this BACnet LAN at 9.6, 19.2, 38.4, and 76.8 Kbps as native BACnet devices. Logic controllers shall be of BACnet conformance class 3 and support all BACnet services necessary to provide the following BACnet functional groups:
        1. Files Functional Group
        2. Reinitialize Functional Group
        3. Device Communications Functional Group
        4. All proprietary services shall be thoroughly documented and provided as part of the submittal data. All necessary tools shall be supplied for working with proprietary information.

    b. All BACnet Networks must be installed to BACnet Network industry standards with attention to the number of devices, routers, and overall length, point, and trend count to assure proper polling of devices and points. All points and devices must update correctly and not go into a fault, stale, or offline. Using the BACnet Network Scan tool, Oscilloscope, and Polling Service, provide proof of network reliability. Copies of these operations must be submitted to UCSC before the warranty period.

X. ALARM MANAGEMENT

1. It is required that a logical and consistent alarm strategy be used. The alarm strategy described here must be used. The typical alarms listed here show everyday situations; it is expected that additional alarms be added when applicable.

2. Additional, non-typical alarm extensions shall be added for specific situations described within the control sequences in the drawing set.

3. Alarm handling shall always be active to ensure that alarms are processed even if an operator is not currently signed on to the DDC system.

4. Full point name shall be included in every alarm message; refer to “Point Naming” in this specification section.

5. These steps must be taken to prevent nuisance alarming. False alarms can quickly fill alarms logs causing actual warnings to get overlooked.

6. All indicated alarm threshold, limit, and time delay values to be user-adjustable

7. End-users shall be able to define additional alarms for any point in the system.

    a. Alarm generation shall be selectable for annunciation type and acknowledgment requirements, including but limited to:
        1. To alarm
        2. Return to normal
        3. To fault

    b. Provide a minimum of eight alarm classes (Must contain building name) for routing types and or classes of alarms, i.e., security, HVAC, Fire, etc.

    c. Provide timed (scheduled) routing of alarms by building name and class, object, group, or node.

    d. Provide alarm generation from binary object “runtime” and event counts for equipment maintenance. The user shall be able to reset runtime or event count value with appropriate password control.

    e. Control equipment and network failures shall be treated as alarms and annunciated.

    f. Alarms shall be annunciated in any of the following manners as defined by the user:
        1. Screen message text
        2. Email the complete alarm message to multiple recipients. Provide the ability to route email alarms based on
            a. Day of week
            b. Time of day
            c. Recipient
        3. Graphic with flashing alarm object(s).

    g. The following shall be recorded by the JACE for each alarm (at a minimum)
        1. Time and Date
        2. Location (building, floor, zone, office number, etc.)

3. Equipment (air handler #, access way, etc.)
4. Acknowledge time, date, and user who issued acknowledgment.
5. Number of occurrences since last acknowledgment.

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

i. Defined users shall be given proper access to acknowledge an alarm or specific types or classes of alarms defined by the user.

j. Log of alarms with a maximum of 250 records shall be maintained by the JACE and available for review by the user.

8. Contact UCSC BMS Shop for appropriate Alarm Classes

9. Contact UCSC BMS Shop for an appropriate Alarm Message Library

10. Niagara Bformatting shall be utilized in all offNormal Text, To Fault Text, and To Normal Text. For example, instead of “Space Temp Too High,” use the following Formatting:
    a) %alarmData.sourceName% is at %alarmData.presentValue%, which is above the High Limit of %alarmData.highLimit%.

11. Use the following guidelines for alarms not listed in this schedule. The device name(s), present value(s) and alarm threshold(s) or condition(s) shall be expressed in Bformatting. Hardcoded values shall not be acceptable.

12. All formatting is subject to the approval of the UCSC BAS Department.

13. On each Alarm Extension, the Alarm Source Name shall be correctly BFormatted to automatically prepend the Point Display Name, with JACE Name (Station Name if alarm extension resides in Supervisor). And Controller Name, in the format: JACE Name_ControllerName_PointName, in both the Source and Message Text fields of each alarm record as it appears in any alarm console.

14. Boolean Alarm extensions on analog (Numeric) values are not acceptable.

15. Provide alarms per project I/O table. Coordinate with UCSC points requiring DDC alarming and include the following:

    a) Point Name and Description
    b) Alarm differentials (automatically adjust with setpoints)
    c) Units
    d) Coordinate settings (limits or state) with UCSC
    e) Instrument tag
    f) Priority
    g) Message

16. Include the following Communication alarms:

Point De-scription	Alarm if:	Delay Time	Priority Level	Alarm Class	Alarm Text	To Normal Text
Niagara Network	Any Niagara Station Offline	5 min	10	BMS_Comm_Fail_Alarm	Prepend with BFormat-ting: Building-	Prepend with BFormat-ting: Building-

Heath Alarm	> 5 min. (WBJ-Adj.)				Name_Station Name:	Name_StationName:
LON Network Heath Alarm	Any LON Device Offline > 5 min. (WBJ-Adj.)	5 min	10	BMS_Comm_Fail_Alarm	Prepend with BFormatting: JACEName_DeviceName: if multiple LON trunks on JACE JACEName_LONtrunkID_DeviceName:	Prepend with BFormatting: JACEName_DeviceName:

17. All VAV box alarms shall be inhibited while the AHU serving those boxes is non-functional.

18. Contact UCSC BMS Shop for appropriate priority scheme level

19. Coordinate and implement alarm notifications and routing with UCSC BAS Department. Include:

    a) Paging
    b) Email
    c) Text Messaging
    d) Group and network notifications
    e) Alarm acknowledgment.
    f) Filter and route alarms based on user login.
    g) Alarm reports and messages will be directed to a user-defined list of operator devices

20. Provide hardware or interface required to implement alarm notification and routing.

21. Provide state-based alarming to prevent alarms during specific equipment states.

    a) Interlock equipment status and modes to lockout associated alarms during shutdowns.
    b) Interlock acknowledgment to lockout associated alarm for limited adjustable time.

22. Provide continuous monitoring of network connectivity for all networks. Generate alarm upon any communication failure.

23. Alarms shall be inhibited for a specified time after a change in occupancy or for AHUs that are off.

24. Contractor shall ensure that alarms passed to any remote Station Recipient shall retain alarm class and priority level.

25. Contractor shall use only the exact Niagara alarm class names listed above to ensure compatibility with remote station recipients. Alarm Class Mapping is not acceptable. Note: Niagara object naming conventions do not permit spaces.

26. Alarms report to Localhost Alarm Console on building control systems server. If the project scope does not include a building control systems server, alarms report to the Alarm Console in the building level controller.

27. Alarm Source Name shall be prepended with the following B-Formatting:
    a) %parent. parent. parent.displayName%_%parent.displayName% or as required to produce the format: StationName_ControllerName_PointName
28. Alarm Types
    a) At least four-alarm types as described here shall be programmed.
        (1) Examples are shown here to set the level of expectation to apply these types of alarms to each of these typical situations.
            (a) Supervisory Alarms
                (i) Where the BAS system monitors itself. Programming to issue an alarm when a predicted result is not achieved as a programmed control action typically applies to outputs.
                (ii) Command fail alarm shall be sent to the BAS any time the fan starts/stop, and the status doesn't match for 60 seconds (adjustable).
                (iii) Cooling alarm shall be sent to the BAS anytime a cooling valve is fully open, or the cooling stage is active for 5 minutes (adjustable), and there is not a temperature drop across the coil of at least 5 degrees F (adjustable).
                (iv) Cooling alarm shall be sent to the BAS anytime an outside air damper is fully open. At the same time, the economizer is active for 5 minutes (adjustable), and there is no temperature drop from return air to mixed air of at least 5 Degrees F (adjustable).
                (v) Heating alarm shall be sent to the BAS anytime a heating valve is fully open, or the heating stage is active for 5 minutes (adjustable), and there is not a temperature rise across the coil of at least 5 degrees F (adjustable).
                (vi) Setpoint alarms are only active when control is active. For example, RmTmp alarms shall only alarm when the area is occupied and has been occupied long enough for the temperatures to be average. Setpoint alarms shall be sent to the BAS anytime a sensed value is not within a tolerance of setpoint value within 15 minutes (adjustable).
            (b) Range Alarms
                (i) Where an input sensor is outside of its operating range. Indicates when a sensor or power to the sensor has failed, wiring has been shorted or opened, etc. It is required to determine how every controller reads both an open and short for every input and program a specific range alarm for each.
                (ii) High limit alarm shall be sent to the BAS anytime an input sensor reads near the top of its range, and this value is above its normal control range. For example, outside air temperature reading of 150 Degrees F.
                (iii) Low limit alarm shall be sent to the BAS anytime an input sensor reads near the bottom of its range and this value is below its normal control range. For example, outside air temperature reading of -60 Degrees F.
            (c) Absolute Alarms
                (i) Where an input sensor is above or below a fixed threshold. Or where an alarm contacts close.
                (ii) High limit alarm shall be sent to the BAS anytime an input sensor reads above the high limit threshold. For example, when freezer temperature is greater than 0°F (adjustable) for a minimum of 10 minutes (adjustable). Or when the kitchen cooler

temperature is greater than 37°F (adjustable) for a minimum of 10 minutes (adjustable).

(iii) Low limit alarm shall be sent to the BAS anytime an input sensor reads below the low limit threshold. For example, any room temperature less than 40 degrees F.

(iv) Discrete alarms shall be sent to the BAS anytime a monitored contact changes to alarm status. For example, freeze stat device trips or inhibitor chemical running.

(d) Communication Alarms

(i) When a controller is offline.

(ii) Any controller communication alarm shall be sent to the BAS anytime communication is lost to a controller for 10 minutes (adjustable).

II. HARDWARE

A. Environmental Conditions for Controllers, Gateways, Instruments, and Actuators:

1. Products shall operate without performance degradation under ambient environmental temperature, pressure, and humidity conditions encountered for the installed location.
2. If the product alone cannot comply with the requirement, install the product in a protective enclosure that is isolated and protected from conditions impacting performance. The BMS CP (control panel) shall be internally insulated, electrically heated, cooled, and ventilated as required by product and application.
3. Products shall be protected with enclosures satisfying the minimum requirements specified later in this section unless more stringent requirements are indicated.

B. DDC System Reliability and Redundancy:

1. Design, install and configure the DDC control system to match mechanical/electrical systems and equipment reliability and redundancy design.
   a) For example, if two chilled, the backup chiller will automatically start when the primary chiller fails. Two chillers were installed to ensure cooling remains active if a single device fails. The DDC control system must match this design intent, where the single failure of one DDC controller or DDC component does not prevent the cooling of the building.

C. Electric Power Quality:

1. When a building is equipped with UPS or emergency power, these sources, in respective order, should be used to power all DDC system products if capacity is available.
2. Power Conditioning:
   a) When building UPS power is used to power DDC system products, no additional power conditioning is required.
   b) Provide a UPS with Surge Protection inside the enclosure at each panel requiring 120-volt power. The UPS shall have a minimum capacity of 500 VA and 300W and can digitally monitor normal power and battery condition. (APC SUA500PDR Series with standard battery, or equal). Upsize UPS as required to provide a minimum of 2 minutes of battery backup time at the current load. Provide plug outlet and pigtail as necessary to condition the incoming power on the line side of all panel devices.

c) When a Standby or Emergency power generator powers an enclosure housing a JACE, the building application is not required to maintain control of the DDC devices inside the enclosure other than the JACE. A capacitor-based UPS (PULSUC10.242) will be installed to power the JACE only.

D. Ground Fault:

1. Protect products from ground fault by providing suitable grounding. Products shall not fail due to ground fault conditions. Install grounding wires as shown in the manufacturer's instructions.

E. Backup Power Source:

1. Design, install and configure the DDC control system to match mechanical/electrical systems and equipment reliability and redundancy design.

a) For example, if two chillers are installed, one being a backup, and each powered from separate power panels, it is expected that one chiller will run when power is cut to one power panel. Two power panels were utilized to ensure cooling remains active if a single device fails. Power to the DDC control system must match this design intent, where the single failure of one power source does not prevent the cooling of the building.

2. A backup power source's mechanical/electrical systems and equipment shall have associated DDC system products that control such systems and equipment also served from the same or equivalent backup power source.

F. Continuity of Operation after Electric Power Interruption:

1. Equipment and associated factory-installed controls, field-installed controls, electrical equipment, and power supply connected to building regular and backup power systems shall automatically return equipment and related controls to operating state occurring immediately before loss of normal power. They should revert without the operator's manual intervention when power is restored either through a backup power source or through normal power if restored before backup power is brought online.

III. GRAPHICS

A. SUMMARY

1. Section includes the general requirements for graphic generation and end-user interface with the Building Automation System.

B. SYSTEM DESCRIPTION

1. Provide software and labor for graphical representation of all systems specified.
2. Show all hardware points, setpoints, and integrated points as shown in drawings and as needed to control and monitor systems properly.

C. SUBMITTALS

1. University of California Santa Cruz has developed campus standards, including detailed graphics templates (Px Graphic). Contact the University of California Santa Cruz Physical Plant BAS Department for the latest examples.
2. Submit for Review:

a) Each graphic page shall be submitted for review and requires approval by UCSC BAS Department.

D. GRAPHICS QUALITY ASSURANCE

1. The system shall be capable of supporting an unlimited number of clients using a standard Web browser such as Internet Explorer™, Mozilla Firefox™, or Explorer Edge. Systems requiring additional software (to enable a normal Web browser) to be resident on the client machine or manufacturer-specific browsers are not accepted.
2. Web browser software shall run on any operating system and system configuration supported by the Web browser. Systems that require specific machine requirements in terms of processor speed, memory, etc., to allow the Web browser to function with the BMS shall not be acceptable.
3. The Web browser shall provide the same view of the system in terms of graphics, schedules, calendars, logs, etc., and provide the same interface methodology provided by the Graphical User Interface (if used). Systems that require different graphic views, various means of graphic generation, or that require other means of interacting with objects such as schedules, or logs, shall not be permitted.
4. The Web browser client shall support, at a minimum, the following functions:
   a) All graphics shall be developed on the Construction N4 Server. Graphics on the BAC (JACE) will not be accepted.
   b) User log-on identification and password shall be required. A blank web page shall be displayed if an unauthorized user attempts to access it. Security shall be implemented using Java authentication and encryption techniques to prevent unauthorized access.
   c) HTML programming shall not be required to display system graphics or data on a Web page. HTML editing of the Web page shall be allowed if the user desires a specific look or format.
   d) Storage of the graphical screens shall be in the web-based server application.
   e) Real-time values displayed on a Web page shall update automatically without requiring a manual “refresh.”
   f) Users shall have administrator-defined access privileges. Depending on the access privileges assigned, the user shall be able to perform the following:
      (1) Modify primarily used application objects, such as schedules, calendars, and setpoints graphically.
      (2) Schedule times will be adjusted using a graphical slider without requiring any keyboard entry from the operator.
   g) Text fields, column header labels, button labels, etc., must be a text string. Mapping text strings from Niagara string objects is acceptable; mapping Niagara object names to text fields is not permitted.
   h) Decimal precision. Unless indicated otherwise, point values shall use the following decimal precision:
      (1) Temperatures and temperature setpoints:
         (a) One decimal place.
      (2) Airflow (CFM) and airflow setpoints:
         (a) No decimal places.
      (3) Water flow (GPM) and water flow setpoints:
         (a) One decimal place.
      (4) Duct static pressure (Inches Water Column) and duct static pressure setpoints:

(a) Two decimal places.

(5) Building static pressure (Inches Water Column) and building static pressure setpoints:

(a) Three decimal places.

(6) Humidity (%RH) and humidity setpoints:

(a) One decimal place.

i) All valve and damper output positions should be denoted as % OPEN

j) Provide consistency in measurement units.

k) Graphics for identical mechanical systems shall utilize relative ORDs to minimize the number of graphics. Graphics for identical mechanical systems that utilize absolute ORDs are not acceptable.

l) It is not permitted to have on the graphics, vendor names, logos, hyperlinks to the vendor site, or other vendor identification or promotion.

5. UCSC shall furnish sample UCSC Standard Graphics to ensure consistency of look and feel across all UCSC Niagara N4 sites.
6. UCSC Standard Graphics, furnished to Contractor, are dynamic with programming code embedded in the graphics. The contractor may not modify embedded programming code, variable ORD schemes, color schemes, spectrum binding weighting values, BQL queries, etc., in graphics unless approved by UCSC.
7. Contact UCSC BMS Shop for approved graphics generation guidelines.

E. GRAPHIC GENERATION

1. COMMON FOR ALL GRAPHICS

a) Tridium's kitPxGraphics.jar should be the primary source for images and gifs. Custom non-Tridium jars are not to be used.

b) Each graphic shall include all control points, devices, and user-adjustable setpoints/parameters associated with the system.

c) All points specified in the point's list table shall be displayed and adjustable in graphics.

d) User adjustable points, displayed on any graphic page, shall be identifiable by highlighting (turn blue) upon mouseover.

e) Provide links in a "breadcrumb trail" navigation menu bar that allow a user to navigate all graphics hierarchically and logically.

f) There shall be only one graphic header file used as a "Px Include file" on all graphics required for the project.

g) Operator-specific password access protection shall be provided for each application to allow the administrator to limit access to point control, display, and database manipulation capabilities as deemed appropriate for each user, based upon an assigned password. There shall be four access levels as defined below.

(1) Super User

(a) No restriction. Can set or override adjustable setpoints on graphics.

(2) Operator

(a) Web UI access only. View all graphics and override points only; no set point access can acknowledge alarms.

(b) Can override adjustable setpoints on graphics.

(c) You Can also change your username, password, and email address.

(3) Read Only

(a) Read-only Web UI access.
(b) Can change your username, password, and email address.
(4) Scheduler
(a) Read-only Web UI access with the ability to modify equipment schedules as required.
(b) Can change your username, password, and email address.
h) All overrides are globally limited to a maximum of 8 hours.

F. REPORTS

1. Standard Reports:
a) Standard DDC system reports shall be provided, and the operator shall be able to customize reports later.
b) All I/O:
a) With live status and values
c) All I/O in a manual override state:
a) With live status and values
d) Alarm:
a) All current alarms
e) Disabled I/O:
a) All I/O points that are disabled
f) Logs:
a) Alarm history
b) Audit history, displaying all operator-initiated events
c) System messages
d) System events
e) Trends
2. Custom Reports:
a) Operator shall be able to easily define any system data into a daily, weekly, monthly, or annual report. Reports shall be time and date stamped and shall contain a report title.
3. Custom Trends:
a) Operator shall be able to define a custom trend log for any I/O point in the DDC system.
b) Each trend shall include interval, start, and stop time.
c) Data shall be sampled and stored on the DDC controller, within storage limits of the DDC controller, and then uploaded to the archive on server hard drives.
d) Data shall be retrievable in spreadsheets and standard database programs.

IV. DDC CONTROLLERS

A. DDC CONTROLLERS

1. DDC system shall consist of JACE network controllers, programmable application controllers, and application-specific controllers to satisfy the performance requirements indicated.
2. DDC controllers shall perform monitoring, control, energy optimization, and other requirements indicated.
3. DDC controllers shall use a multitasking, multiuser, real-time digital control microprocessor with a distributed network database and intelligence.

4. Each DDC controller shall be capable of total and complete operation as a completely independent unit and part of a DDC system-wide distributed network.
5. Environment Requirements:
   a) Controller hardware shall be suitable for the anticipated ambient conditions.
6. Power and Noise Immunity:
   a) Controller shall operate at 90 to 110 percent of nominal voltage rating and perform an orderly shutdown below 80 percent of nominal voltage.
   b) Operation shall be protected against electrical noise of 5 to 120 Hz and from keyed radios with up to 5 W of power located within 36 inches of the enclosure.
7. DDC Controller Spare Processing Capacity:
   a) Include spare processing memory for each controller. RAM, PROM, or EEPROM will implement requirements indicated with the following extra memory:
      (1) Network Controllers:
         (a) 15 percent spare. The average operating CPU% shall not exceed 85 percent, and the “heap used” value shall not exceed 85 percent of the “heap total.”
      (2) Programmable Application Controllers:
         (a) 15 percent spare.
      (3) Application-Specific Controllers:
         (a) 15 percent spare.
8. Memory shall support the network controller’s operating system and database and shall include the following:
   a) Monitoring and control.
   b) Energy Automation, operation, and optimization applications.
   c) Alarm Automation.
   d) Historical trend data of all connected I/O points.
   e) Maintenance applications
   f) Operator interfaces.
   g) Monitoring of manual overrides.
9. DDC Controller Spare I/O Point Capacity:
   a) Include spare I/O point capacity for each controller as follows:
      (1) Network Controllers:
         (a) Room in the panel shall be allocated to allow for additional I/O devices and associated wiring to achieve 25 percent added extra point capacity. The anticipated point mixture shall be planned at approximately 6-1/2 percent of each point type, AI, AO, BI, and BO.
      (2) Programmable Application Controllers:
         (a) When applied to equipment other than a zone terminal unit, spare capacity requirements shall follow the network controller.
         (b) No spare capacity is required when applied to a zone terminal unit.
      (3) Application-Specific Controllers:
         (a) Spare capacity requirements shall be identical to programmable application controllers.
10. Maintenance and Support:
    a) Include the following features to facilitate maintenance and support:
       (1) Mount microprocessor components on circuit cards for easy removal and replacement.
       (2) Means disconnecting the controller quickly and easily from the network.
       (3) Means to connect to field test equipment quickly and easily.
       (4) Visual indication that controller electric power is on, of communication fault or trouble, and that controller is receiving and sending signals to the network.

11. Input and Output Point Interface:
    a) Hardwired input and output points shall connect to network controller I/O devices, programmable applications, and application-specific controllers.
    b) Input and output points shall be protected so shorting to itself, to another point, or ground will not damage the controller.
    c) Input and output points shall be protected from voltage up to 24V so that contact will not damage the controller.

B. NETWORK CONTROLLERS

1. General Network Controller Requirements:
    a) Tridium Niagara framework JACE 8000 controllers with open NiCS (open Niagara Implementation Conformance Statement).
    b) Include an adequate number of controllers to achieve the performance indicated.
    c) System shall consist of one or more independent, standalone, microprocessor-based network controllers to manage global strategies indicated.
    d) Controller shall have enough memory to support its operating system, database, and programming requirements.
    e) Data shall be shared between networked controllers and other network devices. The controller's operating system shall manage input and output communication signals to allow distributed controllers to share accurate virtual object information and central monitoring and alarms.
    f) Controllers that perform scheduling shall have a real-time clock.
    g) Controller shall continually check the status of its processor and memory circuits. If an abnormal operation is detected, the controller shall assume a predetermined failure mode and generate an alarm notification.
    h) Controllers shall be fully programmable.
    i) Controllers shall be capable of routing necessary configuration software tools to attached level three controllers.
2. Communication:
    a) Network controllers shall communicate with other devices on DDC system level one or two networks.
    b) Network controller also shall perform routing if connected to a level three network of programmable applications, application-specific controllers, or integrated equipment. Level three network shall be open protocol: BACnet MS/TP. The use of other open protocols, including LonWorks or Modbus, is acceptable when integrating third-party devices.
    c) A different level three network is required for each unique device manufacturer type. For example, a single level three network connecting several different size BACnet VAV controllers and FCU controllers from a standard manufacturer would be acceptable. Still, adding a BACnet chiller to this same network would not be permitted. A separate level three network would be required to connect the BACnet chiller or chillers. The only exception to this requirement would be for level three networks connecting less than (10) devices with UCSC approval.
3. Serviceability:
    a) Controller shall be equipped with diagnostic LEDs or other local visual indication of power, communication, and processor.
    b) Wiring and cable connections shall be made to field-removable, modular terminal strips or a termination card connected by a ribbon cable.
    c) Controller shall maintain BIOS and programming information in the event of a power loss for at least 96 hours.

C. PROGRAMMABLE APPLICATION CONTROLLERS

1. General Programmable Application Controller Requirements:
   a) Include an adequate number of controllers to achieve the performance indicated.
   b) Controller shall have enough memory to support its operating system, database, and programming requirements.
   c) Data shall be shared between networked controllers and other network devices. The controller's operating system shall manage input and output communication signals to allow distributed controllers to share real and virtual object information and central monitoring and alarms.
   d) Controllers that perform internal scheduling shall have a real-time clock.
   e) Controller shall continually check the status of its processor and memory circuits. If an abnormal operation is detected, the controller shall assume a predetermined failure mode and generate an alarm notification.
   f) Controllers shall be fully programmable with configuration software tool connected via the attached network controller or with embedded programming tools within the network controller.
2. Communication:
   a) Programmable application controllers shall communicate with other devices on the level three network.
   b) Communication at this third level shall be open protocol; BACnet or LonWorks
3. Serviceability:
   a) Controller shall be equipped with diagnostic LEDs or other local visual indication of power, communication, and processor.
   b) Wiring and cable connections shall be made to field-removable, modular terminal strips or a termination card connected by a ribbon cable.
   c) Controller shall maintain BIOS and programming information in the event of a power loss for at least 72 hours.

D. APPLICATION-SPECIFIC CONTROLLERS

1. Description:
   a) Microprocessor-based controllers are dedicated to controlling a specific piece of equipment through hardware or firmware design. Controllers are not fully user-programmable but are configurable and customizable for operating the equipment they are designed to maintain.
   b) Capable of standalone operation and shall continue to include control functions without connecting to the network.
   c) Data shall be shared between networked controllers and other network devices.
   d) Controllers shall be configured or programmed using the configuration software tool connected via the attached network controller or with embedded programming tools within the network controller.
2. Communication:
   a) Application-specific controllers shall communicate with other application-specific controllers and devices on level three network and to programmable application and network controllers. Communication at this third level shall be open protocol; BACnet or LonWorks.
3. Serviceability:
   a) Controller shall be equipped with diagnostic LEDs or other local visual indication of power, communication, and processor.
   b) Wiring and cable connections shall be made to field-removable, modular terminal strips or a termination card connected by a ribbon cable.

c) Controller shall use nonvolatile memory and maintain all BIOS and programming information in the event of power loss.

V. POINT NAMING – TYPICAL

A. GENERAL

1. It is required that a logical and consistent point naming strategy be used. The point naming method described here may be used, or an alternative approach may be submitted for the engineer's approval before implementation.
2. Actual point names of Boolean, Numeric, Enumerated, and String points shall be simple short names repeated as much as possible throughout the system to take advantage of batch commands. For example, there should be many points throughout the system with the name "ZnTmp" The key is that these repeat points are all in different, uniquely named folders. The real point name shall be derived from folder structure naming and extracted as needed automatically by the BAS.

a) For example, when a point alarms and is issued to the alarm log, the entire point name extracted from the folder structure shall be included in the alarm message, so it is known precisely which ZnTmp of all the ZnTmps throughout the system is in alarm.

3. Title-case is used in this naming strategy to efficiently group abbreviations without using several separator characters. When it is prudent to use a separator character, the use of the underscore character is preferred. The total character count in point naming is limited.
4. Provide a BMS points list to UCSC BMS Shop for appropriate Naming Convention

VI. HISTORY TRENDING – TYPICAL

A. GENERAL

1. It is required that a logical and consistent history trend strategy be used. The history trend strategy described here may be used, or an alternative approach may be submitted for the engineer's approval before implementation. The typical history trends listed here show everyday situations; other historical trends are expected to be added when applicable.
2. History trend extensions shall be added and configured for all typical situations described here. This includes every hardware point and every calculated software point those changes automatically by way of program logic.
3. Full point name shall be included in every trend name; refer to "Point Naming" on this specification.
4. All history trends shall store at minimum (3) years' worth of data before rolling to overwrite data. It is understood that change of value (COV) type trend sizes will have to be estimated. History trend data shall be stored on the EnergyN4 Supervisor server.
5. Change of Value (COV) trends are where a sample is logged whenever the value changes by a specified amount.
6. Boolean and Enumerated point COV trends shall log a sample for every state change.

   a) Examples of Boolean or Enumerated points are fan command, fan status, and HVAC Mode.

b) For Boolean and Enumerated points, Interval trends are not recommended; use COV trends instead.

7. For Numeric points, COV trends are not recommended; use Interval trends instead.
8. Interval trends are where a sample is logged according to a preset regular time interval.
9. Numeric point Interval trends log interval times shall be set as:
   a) 15- mi nut e intervals for slower variables such as outside temp, room temp, return temp, discharge air temp, heating valve signal, building static pressure, etc.

VII. CONTROL LOGIC FUNCTIONALITY

1. Building and energy management application software and logic
   a) Shall reside and operate in system controllers. Applications shall be configurable through the operator workstation, web browser interface, or engineering workstation.
2. Memory and System Time
   a) All controllers shall have a Non-Volatile Memory providing indefinite application and configuration data storage. The system must have the ability to maintain time and automatically correct for daylight savings time and leap year adjustments. In the event of power failure or user-generated power cycle, all system components must automatically update with the current time and date from a network Time Sync device.
3. Stand-alone capability
   a) All controllers shall be capable of providing all control functions of the HVAC system without using a computer. The controllers shall include the inherent capability to access the system control selections and monitor system performance utilizing a communicating network with a PC and EMS software program.
4. Sequencing
   a) Include application software based on operation sequences indicated to properly sequence chillers, boilers, and other applicable HVAC equipment.
5. Control Loops
   a) Support any of the following control loops, as applicable to the control required:
      (1) Two-position (on/off, open/close, slow/fast) control.
      (2) Proportional control.
      (3) Proportional plus integral (PI) control.
   b) Include PID algorithms with direct or reverse action and anti-windup.
   c) Algorithm shall calculate a time-varying analog value used to position an output or stage a series of outputs.
   d) Controlled variable, setpoint, and PID gains shall be operator selectable.
6. Staggered Start
   a) Application software shall sequence chillers, boilers, and pumps as specified in Sequence of Operations for HVAC Controls.
7. Anti-Short Cycling
   a) Binary Output points shall be protected from short cycling.
   b) Feature shall allow minimum on-time and off-time to be selected.
8. On and Off Control with Differential:
   a) Include an algorithm that allows a BO to be cycled based on a controlled variable and set point.
   b) Algorithm shall be direct or reverse-acting and incorporate an adjustable differential.
9. Zone Control

a) Zone system compatible with a constant volume air source (Variable Volume/Variable Temperature) (VVT). The zone system shall be compatible with a constant volume air source and consist of programmable, multiple communicating Zone Controllers and a Bypass Controller. The system shall also include a complete array of input and output devices. The system shall fully control HVAC heating and cooling equipment in a multiple zone application. The zone system shall be capable of operating as a stand-alone system or network with various systems to communicate with their source controllers.

b) Zone control. Each zone shall be capable of monitoring space conditions and providing the correct amount of conditioned air to satisfy the space load. Each area shall be capable of the following:

(1) Space temperatures control. To maintain individual heating and cooling setpoints.

(2) Relative Humidity/Air Quality (DCV). Each zone shall be capable of maintaining space relative humidity set point or air quality set point (zone-level demand control ventilation).

(3) Demand coordination. Each zone shall be capable of zone demand data coordination with other zones in the system.

c) Static pressure control. The zoning system shall be capable of maintaining a user-adjustable supply air duct static pressure setpoint.

(1) The Bypass controller shall also provide the capability to increase system airflow during conditions when the supply air temperature from the equipment is approaching the operation limits. In these cases, the Bypass controller shall raise the static pressure setpoint to a user-configurable maximum limit to increase the system airflow during these conditions.

(2) The Bypass control shall contain the ability to monitor the bypass damper movement (or VFD speed) and automatically adjust the setpoint control band and hysteresis to provide stability and prevent premature actuator failure.

d) Air source control. Shall control all associated HVAC rooftop equipment functions and be capable of stand-alone or networked operation. The resident algorithms shall use error reduction logic designated in ASHRAE standard 90.1 to provide temperature control and lower energy usage. The Air source shall be capable of zone demand data coordination with the associated zones.

e) System Terminal Modes. Each air terminal mode shall be based on the current air source mode, terminal type, space temperature, and the current temperature set points.

(1) Off:

(a) All terminal dampers will maintain a 65% open position. Fans shall be disabled.

(b) If the zoning requirement is heating, all single duct terminals shall maintain their damper position at 65%. Any zone controller servicing a parallel box shall fully close their dampers while the fan is operating. If local heat is available, the parallel fans shall start, and local heat shall be enabled to maintain its unoccupied heating setpoint. The damper shall be modulated open to 65% after heating is no longer required.

(2) Cooling and Nighttime Free Cooling (NTFC):

(a) If the zone requirement is none, the zone controllers shall modulate their dampers to maintain their minimum cooling damper position or damper ventilation position if the supply air temp is between 65 and 75 F. During the NTFC mode, the zone controller shall control its occupied heating and cooling

setpoint. The controller shall modulate its damper to its appropriate (occupied or unoccupied) cooling setpoint during the cooling mode.

(b) If the zone requirement is cooling, the zone controllers shall modulate their air dampers between their minimum and maximum cooling damper position to maintain their cooling set point. Parallel fans shall be disabled unless the damper has closed below the user-adjustable fan-on minimum damper position (optional). In that case, the fan shall be energized to mix return air with the cold primary air to prevent “cold air dumping” from the diffusers.

(c) If the zone requirement is heating, the zone controllers shall modulate their dampers to maintain their minimum cooling damper position. Any zone controllers servicing single duct units with reheat capability shall maintain the greater of either the minimum cooling damper position or the specified reheat damper position. Zone controllers servicing parallel units shall enable their fans while the damper shall maintain its minimum cooling damper position.

(3) Vent:

(a) If the air source equipment operates in a fan-only mode to provide ventilation without mechanical heating or cooling, the zone controllers shall maintain the configured ventilation damper position.

(4) Heat:

(a) If the zone requirement is none, the zone controller shall maintain its minimum heating damper position. Parallel fans shall be disabled, and their air damper shall be modulated to maintain their minimum heating damper position.

(b) If the zone requirement is cooling, the zone controller shall modulate its damper to maintain its minimum heating damper position. Parallel fans shall be disabled.

(c) If the zone requirement is heating, the zone controllers shall modulate their air dampers between their minimum and maximum heating damper position to maintain their heating set point.

(5) Pressurization:

(a) If the zone requirement is none or cooling, the zone controller shall maintain its maximum cooling damper position. Parallel fans shall be disabled.

(b) If the zone requirement is heating, and the zone controller has been enabled to provide local heating, then the zone controller shall modulate its damper to its maximum cooling damper position and allow its auxiliary heat. If local heat is not available, the damper shall still be modulated to maintain its maximum cooling damper position.

(6) Evacuation:

(a) All terminal fans shall be disabled during the Evacuation mode, and all dampers shall close.

f) Air source interface. The zoning system shall be capable of zone demand data coordination with a communicating rooftop. The zones' setpoint and zone temperature information shall be shared with the rooftop controller. The rooftop controller’s error re- duction calculations can determine the correct number of heating or cooling stages to operate to satisfy the system load.

(1) The zoning system shall have the capability of linking up to 32 zones to a single air source and determining system heating and cooling requirements.

(2) The zoning system shall be capable of providing a communication check of all associated controls and display device type and error conditions.

(3) The zoning system shall coordinate and exchange the flowing data as a minimum:

(a) Average zone temperature

(b) Average occupied zone temperature
(c) Average occupied and unoccupied heat/cool setpoints
(d) Occupancy status

g) Space temperature and space temperature setpoints for use by the air source controller shall include a weighted factor proportional to the size of the zone. Only those zones with accurate temperature readings shall be included.

h) The zone system shall provide periodic updates to the air source.

i) The zone system shall obtain and support the following air source modes as a minimum:

(a) Off
(b) Cooling
(c) Heating
(d) Nighttime Free Cooling
(e) Ventilation
(f) Pressurization
(g) Evacuation

j) The air source controller shall bias its occupancy time schedules through the Air Distribution System to provide optimization routines and occupant override. For those zoning systems that do not include inherent air source interface capacity, each zone shall independently determine the operational mode of the equipment through its associated duct temperature sensor mounted in the supply ductwork. If there is an air source controller, then the system will be assumed to be always On.

10. HVAC Equipment Protection

a) The air sources controller shall be capable of monitoring the leaving air temperature to control stages in both the heating and cooling modes. It shall be able to shut down steps based on a rise or fall, leaving air temperature above or below adjustable or calculated values. Calculated supply air temperature requirements shall be based on error reduction calculations from reference zone data to determine the optimum supply air temperature to satisfy space requirements. The system shall protect short cycling of heating and cooling by utilizing time guards and minimum run time configurations.

11. Energy Conservation

a) Load balancing from error reduction calculations that optimize stages.

b) The locking out of mechanical heating or cooling modes based on configurable outside air temperature limits.

c) Staggered start. The system shall intelligently start all equipment staggered after transitioning from unoccupied to occupied modes and power failure to reduce high peak power consumption on start-up.

d) Peak Demand Limiting. Controllers in the system shall be overridden by a separate heating and cooling peak-demand limiting signals. Option/General purpose controller existing on the communications bus shall be able to send a demand limiting broadcast to reduce overall energy consumption and control on and off-peak time kW usage

e) Temperature compensated start. The zone controller shall be capable of supporting temperature-compensated beginning with the air source. Before occupancy, the zone controllers and Air Source shall work together to provide zone-by-zone temperature compensated conditioning. The air source will track the time required for recovery and report the optimal start bias time to the zones before each busy period so that the zone can start conditioning the space before occupancy.

12. Demand Control Ventilation (DCV).

a) The zone shall be capable of reading an analog signal from a CO2 sensor or other sensor measuring volatile contaminants or relative humidity and provide DCV at the area by calculating a DCV damper position and participate in system DCV operation with the air source

b) System DCV (System Level). The zone system shall have the ability to collect the DCV value from any or all the zone controllers in the system. These values may be the average of the highest sensor value transmitted to an air source controller's analog DCV sensor input. The air sources configured DCV routine may perform the appropriate actions to reduce CO2 concentration at the reporting zones. The system shall be capable of maintaining a ventilation setpoint through a DCV algorithm in conjunction with the zone.

c) Local DCV (Zone Level). Each zone shall be capable of reading an analog signal from a CO2 sensor or other sensors measuring volatile contaminants and maintaining a ventilation setpoint through a DCV algorithm in conjunction with the system. Based on an error reduction calculation, the zone shall calculate a DCV damper position for the area. When the DCV damper position value is greater than the temperature control damper position, the system should use the DCV damper position to position the damper. System heating and cooling and supplemental zone heat shall be allowed to operate.

13. Abnormal Conditions

a) The proposed system shall include the ability to detect abnormal conditions and react to them automatically. A return to normal conditions shall also generate a return to normal notification, and the system shall revert to its original control scheme before the abnormal condition exists. The following abnormal terminal conditions shall automatically route an alarm, and the system shall take the following actions:

(1) If the zone controller determines a space temperature sensor, the zone controller shall generate an alarm. During this condition, the system should use the zone damper positioned to either the minimum heating, minimum cooling, or the configured ventilation damper position, based on the air source equipment operating mode.

(2) If the zone controller determines a relative humidity sensor, the zone controller shall generate an alarm.

(3) If the zone controller determines an indoor air quality sensor to be invalid, it shall generate an alarm and disable its IAQ algorithm.

(4) System-level demand coordination. If an air source controller participates in demand coordination with other zones and loses communication with the associated zones, it shall generate an alarm. Likewise, any zone detecting a communication failure will create an alarm notification.

(5) Zone level demand coordination. If the system loses communication with one of the zones associated with that system, the zone system shall remove that zone temperature from its weighted averages. The zone controller shall continue to operate in a stand-alone mode.

(6) If the zone system is configured to interface with the air source for zone demand data coordination and that communication is broken, each zone controller shall determine the equipment operating mode based on the temperature of the primary air. The air source will be assumed to be always on.

14. Run-Time Totalization

a) Include software with the capability to totalize run-times for BI points.

VIII.ENCLOSURES

A. General Enclosure Requirements:

1. Include an enclosure door with a secure latching mechanism.
2. All enclosures containing a DDC controller applied to equipment other than a zone terminal unit shall have a hinged door.
3. All enclosures associated with the DDC control system shall be color/style with a visible label identifying its tag/controlled equipment.
4. Supply each enclosure with a complete set of as-built schematics, wiring diagrams, and product literature located in a pocket inside the door.
5. Enclosure shall be NRTL listed according to UL 508 A.
6. Constructed of steel with factory-applied galvanized coating or paint.
7. Internal panel mounting hardware, grounding hardware and sealing washers. Grounding stud on enclosure body.
8. Internal Arrangement:
   a) Internal layout of the enclosure shall group and protect pneumatic, electric, and electronic components associated with a controller but not an integral part of the controller.
   b) Arrange layout to group-similar products together.
   c) Include a barrier between line-voltage and low-voltage electrical and electronic products.
   d) Factory or shop install products, tubing, cabling, and wiring complying with requirements and standards indicated.
   e) Terminate field cable and wire using heavy-duty terminal blocks.
   f) Install a maximum of two wires on each terminal side.
   g) Include an enclosure field power supply with a toggle-type switch located inside the enclosure to disconnect power.
   h) Include enclosure with a line-voltage nominal 20-A GFCI duplex receptacle for service and testing tools—wire receptacle on the hot side of the enclosure disconnect switch.
   i) Mount products within the enclosure on a removable internal panel/backplane.
   j) All internal panel components to be labeled.
   k) Route tubing cable and wire located inside enclosure within a raceway with a continuous removable cover.
   l) Label controller end of cable, wire, and tubing in enclosure following an approved identification system that extends from field I/O connection and all intermediate connections throughout the length to controller connection.
   m) Size enclosure internal panel to include at least 25 percent spare area on the panel's backplane.
9. Environmental Requirements:
   a) Evaluate each product's temperature and humidity requirements to be installed within each enclosure and locate the panel accordingly.
   b) Outdoors, Type 4X. An additional panel heater is required when components are not rated for outdoor design temperature and humidity levels.
   c) Indoors, Dry Areas: Type 1.
   d) Indoors, Wet Areas, or Areas Exposed to Condensation or Wash-down: Type 4X

IX. ELECTRICAL POWER DEVICES

A. Transformers

1. Transformer shall be sized for the total connected load, plus an additional 25 percent of the connected load.
2. Transformer shall be UL Listed.
3. Transformer shall be at least 40 VA.
4. Transformer shall have secondary resettable breaker.

B. DC Power Supply

1. Output voltage nominally 24-VDC or other voltage within 5 percent.
2. Output power minimum of 14W.
3. Input voltage nominally 120-VAC, 60 Hz. Lower voltage input is not acceptable.
4. Load regulation within 0.5 percent from zero- to 100-mA load.
5. Line regulation within 0.5 percent at a 100-mA load for a 10 percent line change.
6. Stability within 0.1 percent of rated volts for 24 hours after a 20-minute warm-up.

X. CONTROL WIRE AND CABLE

A. Low Voltage Power Wiring

1. Wiring runs less than 150 feet.
2. Wire size shall be a minimum of 18 AWG.
3. Wiring runs of more than 150 feet.
4. Wire size shall be a minimum of 16 AWG. Power/voltage drop calculation must be completed for all longer runs to determine if an even larger wire is required.
5. Conductors shall be twisted soft annealed copper strands.
6. Conductor insulation shall have a nominal 15-mil thickness, constructed from flame retardant PVC.
7. Outer jacket insulation shall have a 300-V, 105-degrees C rating, and Type PLTC cable.
8. Power cabling to have a unique jacket color or striping color.

B. Low Voltage Input/Output

1. Wiring must be shielded.
2. Wire size shall be a minimum of 18 AWG.
3. Conductors shall be twisted soft annealed copper strands.
4. Conductor insulation shall have a nominal 15-mil thickness, constructed from flame retardant PVC.
5. Outer jacket insulation shall have a 300-V, 105-degrees C rating, and Type PLTC cable.
6. Shielding shall be 100 percent type, 1.35-mil aluminum/polymer tape, helically applied with 25 percent overlap, and aluminum side with tinned copper drain wire.
7. Input cabling to have a unique jacket color or striping color.
8. Output cabling to have a unique jacket color or striping color.

C. LAN and Communication Cable

1. Comply with DDC system manufacturer requirements for the network being installed.
2. Cable shall be plenum rated.
3. Cable shall comply with NFPA 70.
4. Cable shall have a unique color different from other cables used on Project.
5. Jacket color: LonWorks - Orange, BACnet - Blue, Modbus – Purple

6. Copper Cable for Ethernet Network:
   a) 100BASE-TX.
   b) TIA/EIA 586, Category 6.
   c) Minimum No. 24 AWG solid.
   d) Unshielded Twisted Pair (UTP).
   e) Thermoplastic insulated conductors, enclosed in a thermoplastic outer jacket, Class CMP as plenum rated.

D. Control Wire Color Code:

XI. PART 3 EXECUTION

A. DDC SYSTEM INTERFACE WITH OTHER SYSTEMS AND EQUIPMENT

1. Communication Interface to Equipment with Integral Controls and Other Building Systems:
   a) DDC system shall have a communication interface with equipment and building systems with integral controls and a communication interface for remote monitoring or control.

b) Perform all steps necessary for integration. These steps may include:

(1) Research and gathering effort to identify how to integrate each piece of equipment and recognize the significance of each integrated point.

(2) Take into consideration the trial-and-error troubleshooting time. It may need time to contact the equipment manufacturer's technical support.

(3) Testing of the interface. Disconnect the communication bus and confirm that points do indeed display as "down." Confirm that values are accurate by comparing them with the onboard equipment display screen. Test writable points and affirm written values are accepted by comparing with onboard equipment display screen and equipment operation.

(4) Create a meaningful graphic screen that displays integrated points logically with an accompanying system schematic diagram.

(5) Add trending and alarming as appropriate and as shown on point lists. Wiring runs less than 150 feet

2. Integration with Existing Campus SupervisorN4 system:
   a) When expanding an existing DDC system and it is necessary to interface with the current Campus SupervisorN4 system, it must adhere to UCSC standards and achieve integration.
   b) Expand existing Campus SupervisorN4 by adding all-new controls matching the process utilized to integrate previous installations. The expanded system shall resemble the existing DDC system, both in appearance and functionality, including graphic layout, navigation, point override, and setpoint capabilities, alarming, reporting, and trending.
   c) Prepare an on-site demonstration mockup of integration of the DDC system to be installed with the existing system before installing the DDC system. Obtain approval from UCSC's control system representative before proceeding with the installation.

B. CONTROL DEVICES FOR INSTALLATION BY OTHER INSTALLERS

1. Deliver selected control devices to identify equipment and systems manufacturers for factory installation and identify installers for field installation.
2. Deliver the following to the duct fabricator and installer for installation in the ductwork. Include installation instructions to Installer and supervise installation for compliance with requirements.
   a) Automatic control dampers
   b) Airflow sensors and switches
   c) Pressure sensors
3. Deliver the following control devices specified in indicated HVAC instrumentation and control device Section 23 09 00 to plumbing and HVAC piping installers for installation in piping. Include installation instructions to Installer and supervise installation for compliance with requirements.
   a) Automatic control valves
   b) Pipe-mounted flowmeters
   c) Pipe-mounted sensors, switches, and transmitters.

C. CONTROL DEVICES FOR EQUIPMENT MANUFACTURER FACTORY INSTALLATION

1. When applicable, as indicated on plans, deliver the following to the manufacturer for factory installation. Include installation instructions to the unit manufacturer.
   a) Programmable or application-specific controller.
   b) Motorized damper actuators when not integral to the controller or applicable.

c) Flow and pressure sensors, transmitters, and transducers when not integral to the controller or as applicable.
d) Unit-mounted temperature sensors when applicable.
e) Unit-mounted relays when applicable.

D. GENERAL INSTALLATION REQUIREMENTS

1. Install room sensors such that they are centered at 60 inches above finished floor A.F.F. unless mounting height is specifically called out on drawings.
2. Install products to satisfy more stringent of all requirements indicated.
3. Install product level, plumb, parallel, and perpendicular with building construction.
4. Support products, tubing, piping wiring, and raceways. Brace products to prevent lateral movement and sway or a break in attachment.
5. If codes and referenced standards are more stringent than the requirements indicated, comply with requirements in regulations and referenced standards.
6. Fabricate openings and install sleeves in ceilings, floors, roofs, and walls required by installing products. Before drilling, punching, and cutting, check for concealed work to avoid damage. Patch, flash, grout, seal, and refinish openings to match adjustable adjacent conditions.
7. Firestop penetrations made in fire-rated assemblies. Contact the University Representative for requirements for “Penetration Firestopping.”
8. Seal penetrations made in acoustically rated assemblies. Comply with requirements in Section 07 92 00 “Joint Sealants.”
9. Fastening Hardware:
   a) Pipe wrenches, pliers, and other tools that damage surfaces of rods, nuts, and other parts are prohibited for work of assembling and tightening fasteners.
   b) Tighten bolts and nuts firmly and uniformly. Do not overstress threads by excessive force or by oversized wrenches.
   c) Lubricate threads of bolts, nuts, and screws with graphite and oil before assembly.
10. If product locations are not indicated, install products in places that are accessible, and that will permit service and maintenance from the floor, equipment platforms, or catwalks without removing any permanently installed furniture and equipment.

XII. SUPERVISOR SERVER CONFIGURATION

1. Perform all steps necessary to provide a fully functional supervisor server as specified earlier in this document. Steps include but are not limited to operating system configuration, supervisor software installation and licensing, site-specific supervisor server software configuration, graphics, schedules, trends, alarms, scheduling, operator setup, etc.

XIII.LAN, ROUTER, AND GATEWAY INSTALLATION

1. All LAN/WAN network equipment, including LAN, drops near JACE controllers, is to be furnished and installed near JACE controllers by the UCSC IT department.
2. Install level two LAN network and network equipment if required for the indicated DDC system communication interface requirements.

3. Test LAN and LAN equipment to verify that the communication interface functions appropriately.
4. Locations of all requested LAN drops must be communicated in writing with locations identified on floor plans. Allow at least two weeks from the time of request for LAN drops to be installed.
5. Provide a temporary LAN if required to keep pace with the construction schedule. Permanent Client LAN drops may be delayed, and it is not acceptable to postpone any control work because of these delays. Temporary construction LAN may be abandoned, and permanent Client LAN connected when available. Any necessary JACE reconfiguration must be included.

XIV.CONTROLLER INSTALLATION

A. GENERAL CONTROLLER INSTALLATION

1. Install controllers in enclosures to comply with indicated requirements. Connect controllers to field power supply.
2. Install the controller with the latest version of applicable software and configure it to execute the requirements indicated.
3. Test and adjustable adjust controllers to verify the operation of connected I/O to achieve performance indicated requirements while executing operation sequences.
4. Installation of Network Controllers:
   a) DDC system manufacturer shall determine the quantity and location of network controllers to satisfy the requirements indicated.
   b) Install controllers in a protected location that is easily accessible by operators.
5. Installation of Programmable Application Controllers:
   a) DDC system manufacturer shall determine the quantity and location of programmable application controllers to satisfy the requirements indicated.
   b) Install controllers in a protected location that is easily accessible by operators.
   c) Top of the controller shall be within 84 inches of a finished floor.
6. Application-Specific Controllers:
   a) DDC system manufacturer shall determine the quantity and location of application-specific controllers to satisfy the requirements indicated.
   b) For controllers not mounted directly on controlled equipment, install controllers in a protected location that is easily accessible by operators.

B. ENCLOSURES INSTALLATION

1. Attach wall-mounted enclosures to the wall using galvanized steel struts in dry areas and stainless-steel struts in wet areas:
2. Align the top of adjustable adjacent enclosures.

C. ELECTRIC POWER CONNECTIONS

1. Connect electrical power to DDC system products requiring electrical power connections.
2. Electrical power design to products not indicated with electric power is delegated to the DDC system provider and installing trade. Work shall comply with NFPA 70 and other requirements told.
3. Comply with requirements for electrical power circuit breakers.
4. Comply with requirements for electrical power conductors and cables.

5. Comply with requirements for electrical power raceways and boxes.

D. IDENTIFICATION

1. Identify system components, wiring, cabling, and terminals. Comply with requirements for identification of products and installation.
2. Where a product is installed above the ceiling, also install location identification on the ceiling grid directly below, including all terminal units such as VAV boxes, fan coil units, etc.
3. Include identification on all DDC devices, including room sensors, duct sensors, pipe sensors, relays, power supplies, controllers, control dampers, and valves.

E. NETWORK NAMING AND NUMBERING

1. Coordinate with UCSC to provide unique naming and addressing for networks and devices.

F. CONTROL WIRE, CABLE, AND RACEWAYS INSTALLATION

1. Comply with NECA 1.
2. Comply with TIA 568-C.1.
3. Wiring Method:
   a) Install cables in raceways and cable trays. Conceal raceway and cables except in unfinished spaces:
      (1) Install plenum cable in environmental air spaces, including plenum ceilings.
      (2) Comply with requirements for cable trays specifications.
      (3) Comply with requirements for raceways and box specifications.
4. Wiring Method:
   a) Conceal conductors and cables in accessible ceilings, walls, and floors.
5. Field Wiring within Enclosures:
   a) Bundle, lace, and train conductors to terminal points with no excess and without exceeding the manufacturer’s limitations on bending radii. Install lacing bars and distribution spools.
6. Conduit Installation:
   a) Install conduit expansion joints where conduit runs exceed 200 feet and where conduit crosses building expansion joints.
   b) Coordinate conduit routing with other trades to avoid conflicts with ducts, pipes, equipment, and service clearance.
   c) Maintain a 3-inch separation where conduits run axially above or below ducts and pipes.
   d) Limit above-grade conduit runs to 100 feet without pull or junction box.
   e) Do not install raceways or electrical items on any “explosion-relief” walls or rotating equipment.
   f) Do not fasten conduits onto the bottom side of a metal deck roof.
   g) Flexible conduit is permitted only where flexibility and vibration control are required.
   h) Limit flexible conduit to 3 feet long.
   i) Conduit shall be continuous from outlet to outlet, from outlet to enclosures, pull and junction boxes, and secured to boxes so that each system shall be electrically continuous throughout.
   j) Direct bury conduits underground or install in concrete-encased duct bank where indicated.

(1) Use rigid, nonmetallic, Schedule 80 PVC.

(2) Provide a burial depth according to NFPA 70, but not less than 24 inches.

k) Secure threaded conduit entering an instrument enclosure, cabinet, box, and trough, with a locknut on the outside and inside, such that the conduit system is electrically continuous throughout. Provide a metal bushing on the inside with insulated throats.

l) Locknuts shall be the type designed to bite into the metal or, on the inside of the enclosure, shall have a grounding wedge lug under the locknut.

m) Conduit box-type connectors for conduit entering enclosures shall have an insulated throat.

n) Connect conduit entering enclosures in wet locations with box-type connectors or watertight sealing locknuts or other fittings.

o) Offset conduits were entering surface-mounted equipment.

p) Seal conduit runs by sealing fittings to prevent the circulation of air for the following:

(1) Conduit extending from interior to exterior of the building.

(2) Conduit extending into pressurized duct and equipment.

(3) Conduit extending into pressurized zones automatically controlled to maintain different pressure set points.

7. Wire and Cable Installation:

a) Cables serving a shared system may be grouped in a common raceway. Install control wiring and cable in a separate raceway from power wiring. Do not group conductors from different systems or different voltages.

b) Install cables with protective sheathing that is waterproof and capable of withstanding continuous temperatures of 194°F with no measurable effect on the physical and electrical properties of the cable.

(1) Provide shielding to prevent interference and distortion from adjacent cables and equipment adjustable.

c) Installation of Cable Routed Exposed under Raised Floors:

(1) Install plenum-rated cable only.

(2) Install cabling after the flooring system has been installed in raised floor areas.

(3) Coil cable 6 feet long, not less than 12 inches in diameter below each feed point.

d) Identify each wire on each end and terminal with a number-coded identification tag. Each wire shall have a unique label.

e) Provide strain relief.

f) Terminate wiring in a junction box.

(1) Clamp cable over the jacket in a junction box.

(2) Individual conductors in the stripped section of the cable shall be slack between the clamping point and terminal block.

g) Terminate field wiring and cable not directly connected to instruments and control devices having integral wiring terminals using terminal blocks.

h) Keep runs short. Allow extra length for connecting to terminal boards. Do not bend flexible coaxial cables in a radius less than ten times the cable OD. Use sleeves or grommets to protect cables from vibration at points where they pass around sharp corners and through penetrations.

i) Ground wire shall be copper, and grounding methods comply with IEEE C2. Demonstrate ground resistance.

j) Wire and cable shall be continuous from terminal to terminal without splices.

k) Do not install bruised, kinked, scored, deformed, or abraded wire and cable. Remove and discard wire and cable if damaged during installation and replace it with a new cable.

l) Monitor cable pull tensions.

G. DDC SYSTEM I/O CHECKOUT PROCEDURES

1. Check instruments for proper location and accessibility.
2. Check instruments for proper installation on flow direction, elevation, orientation, insertion depth, or other applicable considerations that will impact performance.
3. Check instrument tubing for proper isolation, fittings, slope, dirt legs, drains, material, and support.
4. Control Damper Checkout:
   a) For pneumatic dampers, verify that pressure gages are provided to each airline's damper actuator and positioner.
   b) Verify that control dampers are installed correctly for flow direction.
   c) Verify that proper blade alignment, either parallel or opposed, has been provided. Verify that the damper frame attachment is properly secured and sealed.
   d) Verify that the damper actuator and linkage attachment are secure.
   e) Verify that actuator wiring is complete, enclosed, and connected to the correct power source.
   f) Verify that damper blade travel is unobstructed.
   g) Verify that any configurable switches on the device are correctly set.
5. Control Valve Checkout:
   a) Verify that control valves are installed correctly for flow direction.
   b) Verify that valve body attachment is properly secured and sealed.
   c) Verify that the valve actuator and linkage attachment are secure.
   d) Verify that actuator wiring is complete, enclosed, and connected to the correct power source.
   e) Verify that valve ball, disc, or plug travel is unobstructed.
   f) After piping systems have been tested and put into service, but before insulating and balancing, inspect each valve for leaks. Adjustable adjust or replace packing to stop leaks. Replace the valve if leaks persist.
   g) Verify that any configurable switches on the device are correctly set.
6. Instrument Checkout:
   a) Verify that instrument is correctly installed for location, orientation, direction, and operating clearances.
   b) Verify that attachment is properly secured and sealed.
   c) Verify that conduit connections are properly secured and sealed.
   d) Verify that wiring is labeled correctly with unique identification, correct type and size and securely attached to proper terminals.
   e) Inspect instrument tag against approved submittal.
   f) For instruments with tubing connections, verify that tubing attachment is secure and isolation valves have been provided.
   g) For flow instruments, verify that recommended upstream, and downstream distances have been maintained.
   h) For temperature instruments:
      (1) Verify sensing element type and proper material.
      (2) Verify length and insertion.
   i) Verify that any configurable switches on the device are set properly

H. DDC SYSTEM I/O ADJUSTMENT, CALIBRATION, AND TESTING:

1. Calibrate each instrument installed that is not factory calibrated and provide calibration documentation. Calibrate according to the instrument instruction manual supplied by the manufacturer.
2. Provide traceable diagnostic and test equipment for calibration and adjustable adjustment.
3. Comply with field testing requirements and procedures indicated by ASHRAE's Guideline 11, "Field Testing of HVAC Control Components," in the absence of specific requirements and to supplement conditions indicated.
4. Control Dampers:
   a) Stroke and adjustable adjust control dampers following the manufacturer's recommended procedure, from 100 percent open to 100 percent closed and back to 100% open.
   b) For control dampers equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.
5. Control Valves:
   a) Stroke and adjustable adjust control valves following the manufacturer's recommended procedure, from 100% open to 100% closed and back to 100% open.
   b) For control valves equipped with positive position indication, check feedback signal at multiple positions to confirm proper position indication.
6. Switches:
   a) Calibrate switches to make or break contact at set points indicated.

I. DDC SYSTEM CONTROLLER CHECKOUT

1. Verify power supply.
   a) Verify voltage, polarity, and protection.
   b) Verify that ground fault protection is installed.
   c) If applicable, verify that power conditioning units are installed.
2. Verify that wire and cabling are secured correctly to terminals and labeled with unique identification.

J. DDC CONTROLLER I/O CONTROL LOOP TESTS

1. Test every control loop to verify operation is stable and accurate.

K. COMMISSIONING, TESTING, AND ACCEPTANCE

1. The calibration and commissioning procedure shall consist of validating field I/O calibration, loop checks, actuator stroking, and integrated system operation validation. Document all commissioning information on commissioning data sheets, which shall be submitted to UCSC for approval before testing. Notify UCSC of the testing schedule so that operating personnel may observe calibration and commissioning.
2. Field I/O Calibration and Commissioning: Before system program commissioning, bring online each control device by:
   a) Performing a single-point measurement validation of all analog devices.
   b) It is not acceptable to use an infrared non-contact thermometer to calibrate temperature sensors.
   c) Verifying instrument ranges.
   d) Verifying and documenting binary switch settings.
   e) Verifying and documenting actuator operating ranges.

f) Verifying and documenting fail-safe position on loss of control signal.

g) Submit calibration datasheets. Datasheets shall include the device designation, the date of calibration, and the name of the person who performed the calibration.

3. Loop checks:
   a) Perform a test of every control device with UCSC personnel.
4. System Program Commissioning:
   a) After calibrating control devices and verifying loop control, each program shall be commissioned online. UCSC shall confirm that the program logic follows the approved software flow chart and sequence of operation. Each control loop shall be adjusted to provide stable control within the specified accuracies.
5. Point to Point Installation Verification Procedure to consist of the following (as a minimum):
   a) Documentation:
      (1) An Excel spreadsheet listing all I/O in the system, including point name, address, Controller ID#, analog range or digital normal-state, engineering units. Provide one signature block per page for BAS Contractor's representative and UCSC's BAS Department Representative to accept the test results.
   b) Digital Inputs:
      (1) Jumper or open the wires at the device and verify state change at controller and GUI. Record results on a spreadsheet.
   c) Analog Inputs:
      (1) Lift the wire at the device to see the state change and record the default value on a spreadsheet.
   d) Digital/Analog Outputs:
      (1) Command the field device from the controller and verify the corresponding state change at the field device—record results on a spreadsheet.
6. Functional Testing and Sequence of Operation Verification Procedures to consist of the following (as a minimum):
   a) Control Loop Tuning:
      (1) Tune all control loops to obtain the fastest stable response without hunting, offset or overshoot—record tuning parameters and response test results for each control loop as part of the O&M package. Except for a startup, the maximum allowable variance from the setpoint for controlled variables under normal load fluctuations shall be as follows for general space conditioning applications. Within3 minutes of any upset (for which the system can respond) in the control loop, tolerances shall be maintained:
         (a) Duct air temperature: ± 1oF.
         (b) Space Temperature: ± 2oF.
         (c) Chilled Water: ± 1oF.
         (d) Hot water temperature: ± 3oF.
         (e) Duct pressure: ± 0.25" w.c.
         (f) Water pressure: ± 1 psid.
         (g) Duct or space Humidity: ± 5%.
      (2) Where the same mechanical system is installed in multiple locations, one system must be tuned, and the same tuning parameters may be used in other controllers. Tuning constants shall be set so that continuous oscillation of actuators does not occur. A steady-state shall be achievable.
      (3) When floating (3-point, incremental) control is used for VAV control, the continual pulsing of the actuator against end stops (end stop fickle) shall not occur when the box is fully open or closed.

(4) Trend logging or other graphical proof of loop tuning stability shall be submitted.

(5) Actuator movement shall not occur before the effects of the previous actions have had sufficient time (minimum one time constant) to have affected the sensor.

(6) A detailed sequence of operations is provided for each system, including instructions for testing the sequence.

(7) A checkout form is provided for each system/sequence. The checkout form is to include areas to check and record each facet of the sequence of operations, including but not limited to the following:

(a) Start/Stop
(b) Interlocks
(c) Safeties
(d) Valve and damper stroke
(e) PID Loops
(f) Modes of Operation

(8) Checkout form is intended to be a function (yes/no/comment) test form.

7. 72 Hour test Procedures to consist of the following (as a minimum):

a) Place Entire System in Automatic Operation.

b) Generate Trends and Trend Logs of all I/O as directed by UCSC's Representative.

c) Review Trend Logs with UCSC's Representative to ensure the system is adequately controlled and that control loops do not exhibit excessive oscillation.

d) UCSC's Representative shall have the right to change set points and verify that the system responds appropriately.

e) Repair any deficiencies found during a 72 Hour test.

f) Re-Execute 72 Hour Test until no deficiencies are found.

L. PROTECTION

1. Protect installation against and be liable for work damage and material caused by Con tractor's work or employees.
2. Maintain protection for work and equipment until inspected, tested, and accepted. Protect material not immediately installed.
3. Close open ends of work with temporary covers or plugs during storage and construction to prevent the entry of foreign objects.
4. Material sensitive to temperature, dust, humidity, or other unprotected elements shall be replaced.
5. Material showing signs of exposure shall be replaced.

END OF SECTION