SMART BUILDINGS

SPRING EDITION

CONSULTING - SPECIFYING engineer eBOOK

ABB

Contents

Integrating building systems through controls

By considering updated controls architecture, integrating building systems together becomes much more attainable and streamlined

Commercial buildings consume nearly 36% of electricity in the United States. Mechanical systems, lighting and plug loads consume a majority of commercial building electricity. Information technology, audiovisual, security and fire systems also consume electricity to meet building demands and codes. Building energy use is managed and can be curtailed through the various control systems implemented.

Major electricity consumption through heating, ventilation and air conditioning systems are managed by the building automation system. Historically, the BAS controls mechanical systems, while lighting and plug loads are managed by separate systems, typically provided by a lighting controls manufacturer. IT, AV, security and fire systems are typically controlled by separate manufacturers.

Control requirements vary to support the project goals, comply with the codes enforced and to control building operation costs and energy consumption. Within the United States, most states adopt energy codes for commercial buildings.

The International Energy Conservation Code is recognized as code, with compliance paths through ASHRAE Standard 90.1: Energy Standard for Buildings Except Low-Rise Residential Building, currently the 2019 edition, though this edition is not accepted by many jurisdictions.

Beyond the state level, local jurisdictions and federal requirements may deviate or exceed the state adopted energy requirements. Multiple codes, versions and compliance paths governing energy use through control systems — combined with client project goals — necessitate coordination through trades to provide value to the client.

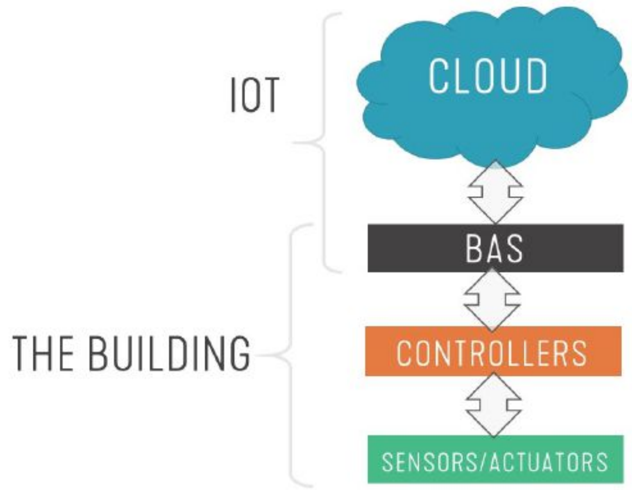

Figure 1: "Internet of things" relates to the building through the cloud and building automation system. The cloud and BAS take information from the building controllers and sensors/actuators to compute and send commands for effective building operation. Courtesy: SmithGroup

Currently, codes and requirements for mechanical controls only describe how the control system should operate and does not provide the associated sequences of operation. For instance, in the 2018 edition of the International Mechanical Code Section C403.6.5, multiple-zone HVAC systems are mandated to have automatic supply temperature reset in response to building loads or outdoor air temperature. The code then describes the requirements for the temperature reset and provides exceptions but it does not list any sequences of operation for designers to use.

Recently, ASHRAE published Guideline 36: High-Performance Sequences of Operation for HVAC Systems, which standardizes advanced sequences of operation for the use of mechanical designers and controls contractors. In future code editions, this will be referenced to provide a verified and streamlined way to write and implement new sequences of operation into different BAS architecture.

Defining the controls architecture

Typical BAS architecture is designed through building automation and controls network (BACnet) over internet protocol, referred to as BACnet/IP, at higher level BACnet building controllers with master-slave token-passing at room-level BACnet application specific controllers (see Figure 2). B-BCs generally have higher computational power than B-ASCs to run complex sequences of operation for the overall building system, which is why IP connections are used because data can be communicated much faster than with MS/TP connections.

The B-BCs then send or request data to the B-ASCs, which then, in turn, enact simpler sequences of operation on a specific device. In addition to these two levels of controllers, BACnet advanced application controllers can be used as a steppingstone between the B-ASCs and a B-BC. B-AACs are usually connected using MS/TP and provide additional computational power to the BC to run overall system sequences of operation.

B-ASCs and B-AACs that are connected on the same MS/TP trunk are daisy-chained together and can only communicate with another device by passing a "token" down the line. After a controller requests and receives a token, the controller is then allowed to open an application layer message using an application protocol data unit. This then allows the device to pass/communicate the token on to other controllers or back to the master controller. The only exception to this process is the master device, which can have the token and request or send the token without being specifically asked to.

MS/TP connections inherently add delays in communication to and from the BAS because each individual token must be passed through the chain of controllers until it

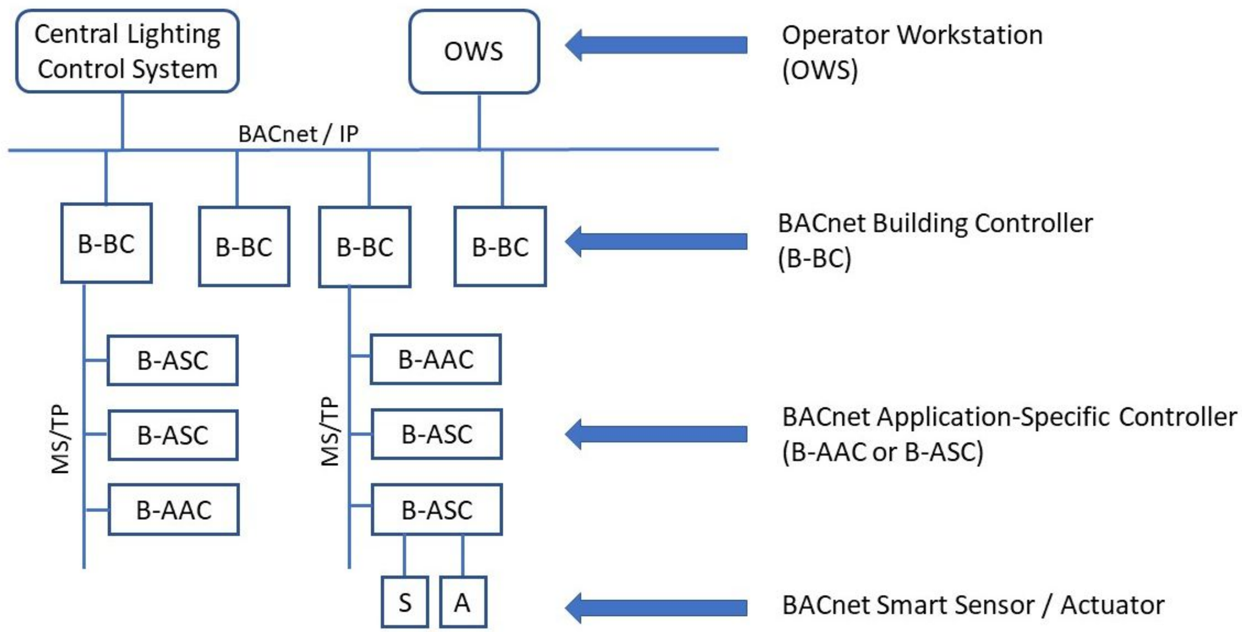

Figure 2: Typical building automation system architecture uses master-slave token-passing connections at lower level controllers and BACnet over internet protocol for higher level controllers. MS/TP connections cause inherent delays in communication between controllers and the BAS. Courtesy: SmithGroup

finds the correct device. To prevent excessive network backup, it is best practice to place application specific controllers that receive greater traffic closer to the master controller and keep high traffic devices on separate MS/TP trunks.

Meanwhile, upstream of the B-ASCs and B-AACs, the B-BCs are connected with BACnet/IP to the main BAS. In this network, each device is assigned its own unique IP address, which allows the BAS to know exactly where each device is in the network. The IP addresses let the BAS send commands and information directly to the device in question through ethernet cables, rather than going to each device along the way like with MS/TP. BACnet/

IP is not often used throughout the system architecture because of the complexity and cost of installation from programming/assigning each device with its own unique IP address.

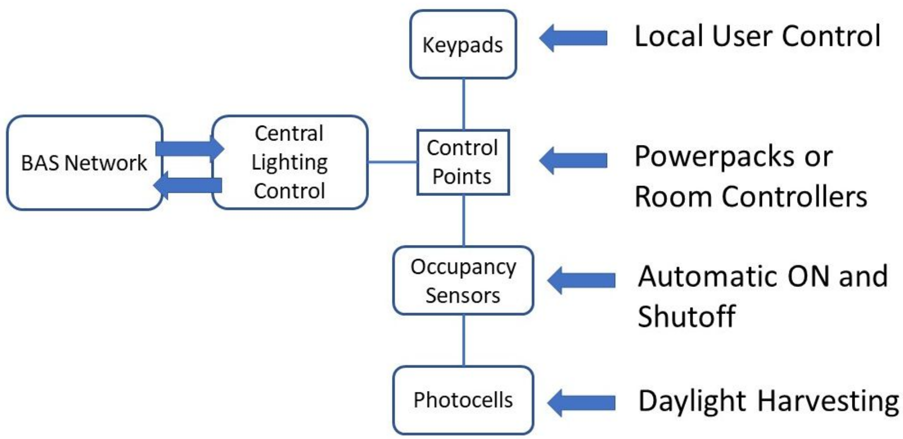

Figure 3: The building automation system network communicates to the central lighting control panel for distribution to the individual space control points. Keypads, occupancy sensors and photocells separately communicate to the control points for programmed response. Courtesy: SmithGroup

Controlling equipment

In a typical commercial building, devices such as variable air volume boxes and fan coil units are controlled by B-ASCs (room-level controllers). These devices can handle simple sequences of operation such as maintaining temperature requirements and relaying commands from the B-AACs and B-BCs. Because B-AACs and B-BCs have the most computational power in the BAS, they perform intensive sequences like supply temperature reset, hot water reset and other overall system commands. Typically, chilled/hot water plants and larger pieces of equipment, like air handling units, have their own dedicated building controllers to handle the amount of sequences required to effectively execute commands to the system.

The building controllers also report sensing data and other computed results to an operator workstation and/or to a cloud network depending on the client's needs. Because all sensing data must go from room-level controllers all the way up to building-level controllers and then back for some commands, the amount of traffic on a network can be extremely high. At times when multiple computationally intensive sequences are trying to be executed, delays in the network can be minutes long.

In addition to mechanical control architecture, lighting and plug load control architectures also are implemented to reduce energy consumption and the associated costs, while supporting space functions. Because illumination levels and plug load energization are critical in supporting effective space use, it is important for the control system to prioritize supporting the functions within each space and to reduce energy without impacting functionality of the space.

Codes and standards

Client-specific space use requirements are typically evaluated in conjunction with code analysis for control requirements to achieve code compliance. Lighting, control and energy codes/standards analyzed include but are not limited to:

- ASHRAE Standard 90.1.
- International Building Code.
- Illuminating Engineering Society: The Lighting Handbook, 10th Edition.
- NFPA 70: National Electrical Code.
- NFPA 101: Life Safety Code.

Each code and standard is intended to provide minimum requirements for the electrical design. The IBC and NFPA 101 provide minimum emergency egress illumination requirements. NFPA 70 contains requirements for most electrical systems and specifically addresses emergency systems within Article 700. IECC and ASHRAE 90.1 provide minimum energy-related requirements for electrical systems. IES is a reference for average and uniformity illumination targets, while also providing recommendations for various lighting applications.

The most recent energy codes are designed to consider typical space type requirements and to provide options for achieving compliance. The options provided by code allow design professionals to tailor control systems to space use goals, while ensuring energy reduction.

Where the ASHRAE 90.1-2010 edition (or more recent) are adopted, designers are required to analyze each space type and provide a variety of control methods within. In general, ASHRAE 90.1 requires user controllability through local lighting bilevel controls. While local control and bilevel control requirements vary by space, the intent is to provide user controllability within each space. Local bilevel controllability provides users opportunities to reduce electricity consumption and to customize the visual environment to support the user task. Beyond user control, most spaces are required to adjust the lighting and plug loads based on occupancy and vacancy.

Lighting and lighting controls

ASHRAE 90.1 allows for occupancy to fully energize lighting fixtures in select spaces. Many spaces are permitted to partially energize the lighting load in each space when occupancy is detected and others energize lighting loads only when initiated by a user. The code intent is to adjust light output when a space is vacated, either by fully or partially de-energizing the lighting fixtures depending on the space.

Certain spaces are permitted to allow system schedules to override vacancy and maintain illumination in vacated spaces. Nearly all spaces are required to reduce light output in determined daylight zones when daylight contributions are sufficient to support the task in the daylight zone. Plug load control requirements are generally tied to occupancy/vacancy and time schedules, with scheduled overrides to occupancy control permitted in select spaces.

To support the user, occupancy/vacancy, daylight harvesting and scheduling requirements within each space, multiple control points are required. The control points for lighting controls are often referred to as zones; it is common economical practice to share line voltage power circuit wiring across multiple spaces and zones without impacting controllability.

Within a space, multiple sensors are installed to react to user input, occupancy/vacancy status and daylight contribution. User keypads respond to user action, to energize or de-energize lighting fixtures, signal programmed scenes or adjust light output via an electrical signal. Occupancy/vacancy sensor technologies can detect ultrasonic (sound) waves within a space, passive infrared (heat) energy or both and transmit an electrical signal to the system.

A photosensor comprises a light-responding circuit element that converts incident light into an electrical signal. The signal transmission through the system can be achieved through a variety of methods, but 24-volt analog and digital systems are most common to control the zones described. The signals are received by controllers of various complexities. The quantity of zones and programming requirements can determine whether a digital or analog control system is best suited for a space.

Most analog control signals are 24 volts direct current and universally compatible with varying frequencies and power voltages. Typically, analog systems control components are more cost-effective as compared to digital components. The analog system typically requires three-wire circuiting by the contractor between all control devices, which can increase installation costs and programming issues in complicated spaces across a large building. Many building maintenance personnel can troubleshoot malfunctioning analog wiring configurations over time or adjust as needed for new space uses.

Digital systems

Many digital load managers are proprietary technologies using manufacturer-developed software to manage the digital signals through proprietary cabling. The digital systems provide programming advantages aiming to take implement schedules and added logic into the control system.

Digital Addressable Lighting Interface can be effective for spaces designed for flexibility to support frequent space alterations or where several control zones are required. The DALI systems provide separate controllability to each fixture driver within the system. DALI cost savings can be seen within the lighting control package; however, the cost is typically transferred to the addressable lighting fixture drivers provided to each controllable fixture segment.

The digital system simplifies installation, standardizing a single control cable between daisy-chained devices. The system can be delivered preprogrammed or be programmed by the manufacturer in the field. With digital systems, it is common for the owner and maintainer to place service calls to the manufacturer for modifications to the system. Warranties and maintenance contracts between owners and manufacturers become valuable for digital systems.

Many new lighting control systems incorporate load management from centralized locations (see Figure 3). The control network typically is established through proprietary digital software and cabling. The network interconnects spaces benefiting from centralized software control.

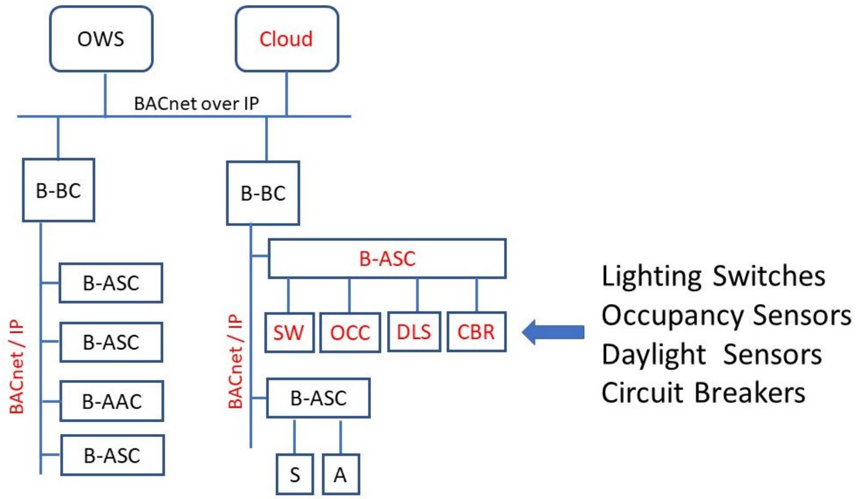

Figure 4: Updating building automation system architecture to be completely connected by BACnet/internet protocol will allow for further integration between mechanical and lighting systems because of the effective communication speeds. Courtesy: SmithGroup

Centralized controllers manage limited quantities of addresses (devices) and larger buildings typically require multiple controllers to support the quantity of devices. The lighting control network architecture is expanded by adding interconnected centralized controllers, which are typically networked to a master control server or processor. The interconnected controllers can be referred to as a distributed digital lighting control network.

Typically, master controllers can connect to the fire alarm control unit, BAS, security system and IT network through shared protocols. FACU, BAS, security and IT signals can be converted to digital signals through the network cabling to the distributed lighting control network to initiate a lighting response in programmed spaces. Emergency, schedules and demand response signals are common applications for tying spaces to centralized control.

Understanding the limits

The current proprietary nature of lighting, plug load and mechanical control systems limit control integration between the systems. Where a central BAS and central lighting control system is implemented, one-way communication from the lighting control system to that BAS is preferred by the manufacturers, which limits the BAS role to monitoring of the lighting and plug load system. Most centralized lighting control systems provide scheduling capabilities for the lighting control system. In some cases, the central lighting control system can be configured to receive scheduled signals from the BAS and translate the signal to proprietary protocol through the lighting control system.

While some room-based digital lighting control systems allow for direct connection into the BAS, the application is mostly used for scheduling and monitoring of spaces. Where room-based controllers lighting controllers are implemented, the BAS controllability of each space is limited. The room-based lighting control appears as a B-ASC within the BAS hierarchy.

Proprietary lighting control protocols limit controllability by the BAS and MS/TP wiring to building controllers limit communication speed between the building controllers and the space. The delay for communication between the B-ASC to control a damper or motor in a space may not be noticeable to the user, however delays in lighting systems can be considered unsatisfactory to the user.

Most control systems share the same basic components. Communication typically occurs between sensors, transmitters and receivers. The communication is supported by power supplies and pathways (conductors for wired solutions and air for wireless solutions). There are opportunities to share the sensors, transmitters, receivers, pathways and power supplies between building systems to react to occupant behavior, environmental conditions and emergencies. Digital communication between transmitters and receivers allows for logic to be integrated into room-based control and separately control mechanical, lighting, IT, AV, security, power and fire systems.

Shared control protocols

If the protocol between the systems within each space were shared, there is an opportunity for a space to be provided a single room controller to support all the space controls. A single, integrated room control allows for fewer user interface locations within a space, sharing of occupancy and daylight control, pathways and connected control modules within a space (see Figure 4).

As control systems become more sophisticated and energy requirements and peak demand load shedding become more attractive for cost savings, a single, fully integrated control system capable of bidirectional communication is required. Communication speed is critical in a system striving to react to room-based occupant behavior and environmental conditions. To implement a fully integrated central control system for all building systems, effective communication speed and a shared communication protocol between systems is required.

Achieving these effective communication speeds is attainable if the entire BAS is connected using BACnet/IP instead of MS/TP at lower level controllers (see Figure 4). BACnet/IP is currently becoming more cost-effective as manufacturers incorporate the technology into their controls systems. By using IP connections, the number of B-BCs can drop (and therefore overall cost) as more B-ASCs and B-AACs can be connected onto one controller due to the increase in communication speeds.

Another benefit to converting to the faster BACnet/IP system is more cloud network capability; a cloud can host computationally intensive analytics that can further help control, react and predict the building systems' needs. The increase in computational analytics will allow room level lighting controls to perform daylight analysis and dimming. However, B-ASCs currently have limited memory and processing power, so connecting the room level lighting controls might be challenging with the current ASCs available on the market.

Beyond integrated room-level control, BAS monitoring of mechanical systems, energy metering, motor status and performance, backup generator status, battery system health, critical electrical system component status and occupancy-based information through the lighting control systems are typical IP addresses that can be tied to a central monitoring system. The centralized monitoring system allows building maintenance to manage the building from a single interface. The centralized system requires building engineers to be proficient in a single software while effectively responding to interruptions or issues within the building.

For building owners implementing demand-response controls, the single monitoring point can provide data to respond to peak signals from the grid and shed load within the capabilities of the system design. Tying several building systems together as IP addresses creates opportunities for system intelligence.

The current state of mechanical and lighting control integration is limited by propriety technology and current BAS communication speeds. However, by updating BAS architecture with complete BACnet/IP, creating one unified controls system becomes much more attainable. A central control system gathering buildingwide data capable of integration has yet to be seen in commercial buildings. Building systems, historically functioning within separate silos, could have opportunities to react to one another through a powerful cloud-based IP network because of IoT (see Figure 5).

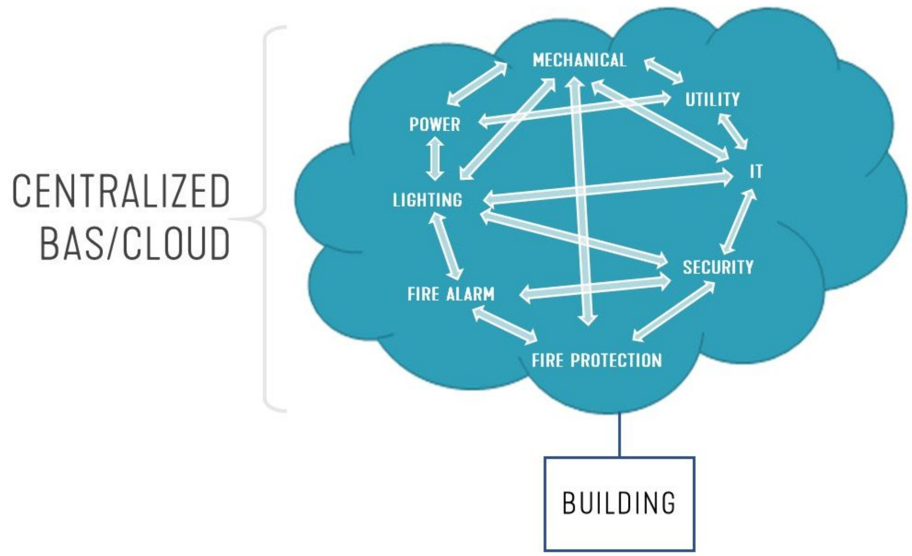

Figure 5: The future of building automation system and cloud monitoring enables a multidirectional, interconnected communication framework between many building systems to make informed decisions during building operation. Courtesy: SmithGroup

A building control system, functioning as cloud-based, can make intelligent building management decisions to optimize energy performance and operational cost beyond capabilities seen in traditional building control systems.

Furthermore, the cloud-based control system that knows the equipment in its building, can make decisions or recommendations that consider the effect of usage on replacement costs and estimated equipment life expectancy. Once a cloud-based, bidirectional, multipathway flow of communication is established in building control systems, the intelligent building will be capable of sharing data via a smart grid that can support sustainability initiatives across cities, states and countries.

Cloud-based building networks

The phrase "internet of things" is often thrown around as a buzzword, but it has revolutionized how technology functions on a day-to-day basis. One basic concept of IoT is cloud-based computation and analysis. In a cloud-based building network, information is sent from sensors/actuators through building controllers and the building automation system to the cloud to be analyzed (Figure 1).

A BAS is a centralized control network that connects many controllers, sensors and actuators throughout a building. The term "cloud" refers to shifting computation from a local server to a remote server. A remote server will have more computational power than a typical local network/computer, which will allow for faster and more effective analysis of building data.

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ABB

Buildings for a Better Tomorrow

ABB acquires Cyclon Controls

How to select a building automation system

Explore the specification of standard, open and proprietary building automation systems

A building automation system, often known as a building management system, is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems and security systems.

As such, a BAS may also include a variety of devices (e.g., controllers, chillers, fans, sensors, lighting controllers, lighting fixtures, heating, ventilation and air conditioning devices, etc.) configured to facilitate monitoring and controlling the building systems.

Considering the available options, specifying a BAS can be a daunting task, even for a seasoned engineer.

Unless a building owner has a specific requirement for a communication protocol, the engineer can select from three options: BACnet, Modbus and LonWorks. The focus of this article is on specifying automation systems that use a BACnet communication protocol.

A standard Construction Specifications Institute specification section has three parts:

- Part 1 — General.

- Part 2 — Products.
- Part 3 — Execution.

CSI master specification, known as MasterSpec, describes the performance requirements and network architecture of the BAS in Part 2 of the specification; however, said paragraphs could also be in Part 1 of the specification. Regardless of where these two main paragraphs are located (Part 1 or in Part 2), they are essential to having a complete and robust BAS specification.

The performance requirements paragraph describes the core requirements that a BAS vendor must meet to be allowed to bid the project. A sample introductory subparagraph may be:

"The BAS direct digital controls shall consist of native BACnet, microprocessor-based, peer-to-peer, networked, distributed devices using the BACnet communication protocol in an open, interoperable system. The BAS also includes operator interface devices, programming and configuration software applications, DDC input/output devices, non-DDC automatic temperature controls, enclosures and interconnecting conduit and wire. The BACnet operating stack must be embedded directly in every device at the board level and in all operator interface software packages."

Similarly, it is important that all BAS controllers are tested, certified, clearly stamped and listed by the BACnet Testing Laboratories; this will allow the engineer to examine the protocol implementation conformance statement for details about the BACnet functionality that the controller can support.

Specifying building automation systems

It is important to note that most of the BAS vendors offer their controllers with preprogrammed generic sequences of operation, typically referred to as "canned sequences of operation." These "canned" sequences are not necessarily preloaded on the controller, but are loaded during programming and system setup.

Although this approach may be suitable for simple BAS designs, most often than not the field technicians end up spending significant amounts of time editing the canned sequences to support the specific conditions of the project. An engineer may insert a paragraph in the specification that prevents a vendor from using canned sequences.

This paragraph could be:

"All BAS DDC devices at all levels shall be fully custom-programmable in the field using the standard operators workstation software. No configurable, canned program controllers will be permitted."

Another performance requirement that should not be omitted from the specification is the behavior of all controllers upon startup after a loss of power. As such, it is important that the BAS prevents all controlled equipment from simultaneously restarting after a power outage. The order in which equipment (or groups of equipment) is started, along with the time delay between starts, should be user selectable.

Lastly but not less important, the specification should require that, at minimum, the BAS manufacturer natively supports the following BACnet data links as defined in the

ASHRAE Standard 135-2016: A Data Communication Protocol for Building Automation and Control Networks:

- Point-to-point.
- Master slave/token passing, known as MS/TP.
- Ethernet (ISO 8802-3).
- BACnet internet protocol.

In addition to ASHRAE Standard 135-2016, the engineer may also specify compliance with the following standards and guidelines:

- National Institute of Standards and Technology NISTIR 6392 Annex B: Profiles of Standard BACnet Devices.
- UL 916: Standard for Energy Management Equipment.
- UL 864: Standard for Control Units and Accessories for Fire Alarm Systems.
- Federal Communications Commission.

The engineer will need to be extremely careful when specifying compliance with UL 864, as this standard will add significant cost to a BAS. Typically, compliance with UL 864 is required when the BAS is used for the control and operation of smoke management systems.

Another important performance criterion that needs to be addressed in the specification is the speed of the BAS as whole. ASHRAE Guideline 13: Specifying Building Automation Systems references the following response time of connected I/O devices/sensors:

- Analog input point values connected to DDC system should be updated at least every five seconds for use by DDC.
- Binary input point values connected to DDC system should be updated at least every five seconds for use by DDC.
- Analog input points connected to DDC system shall begin to respond to controller output commands within two seconds.
- Binary output point values connected to DDC system shall respond to controller output commands within two seconds.

Specifying faster response times will most likely lead to additional cost being incurred by the project. Regarding the display of connected I/O devices, ASHRAE Guideline 13 recommends:

- Analog point change of value connected to DDC system should be updated and displayed at least every 10 seconds for use by operator.
- Binary point change of value connected to DDC system should be updated and displayed at least every 10 seconds for use by operator.

- Alarms of analog and digital points connected to DDC system should be displayed within 45 seconds of activation or change of state.

- Graphic display refresh should update within 8 seconds.

- Point change of values and alarms displayed from workstation to workstation when multiple operators are viewing from multiple workstations should not exceed the graphic refresh rate associated with each I/O.

The network architecture paragraph of the specification describes the primary components of the BAS. At minimum, this paragraph describes the following:

- BACnet advanced operator workstation software, known as B-AWS.

- Remote B-AWS.

- Portable operator workstation software.

- Building controllers.

- Building advanced application controllers.

- Building application-specific controllers.

In some instances, the owner may have a requirement for a web-based BAS or a web-compatible BAS. It is important to note that a web-based BAS is not the same as a web-compatible BAS. Under a web-based BAS, the operators have complete access to the BAS via a web browser. No special software other than a web browser should be required to access graphics, point displays and trends; to configure trends, points and controllers; and to edit programming. Under a web-compatible BAS, the operators, using a standard web browser, are typically able to access control graphics and change adjustable set points.

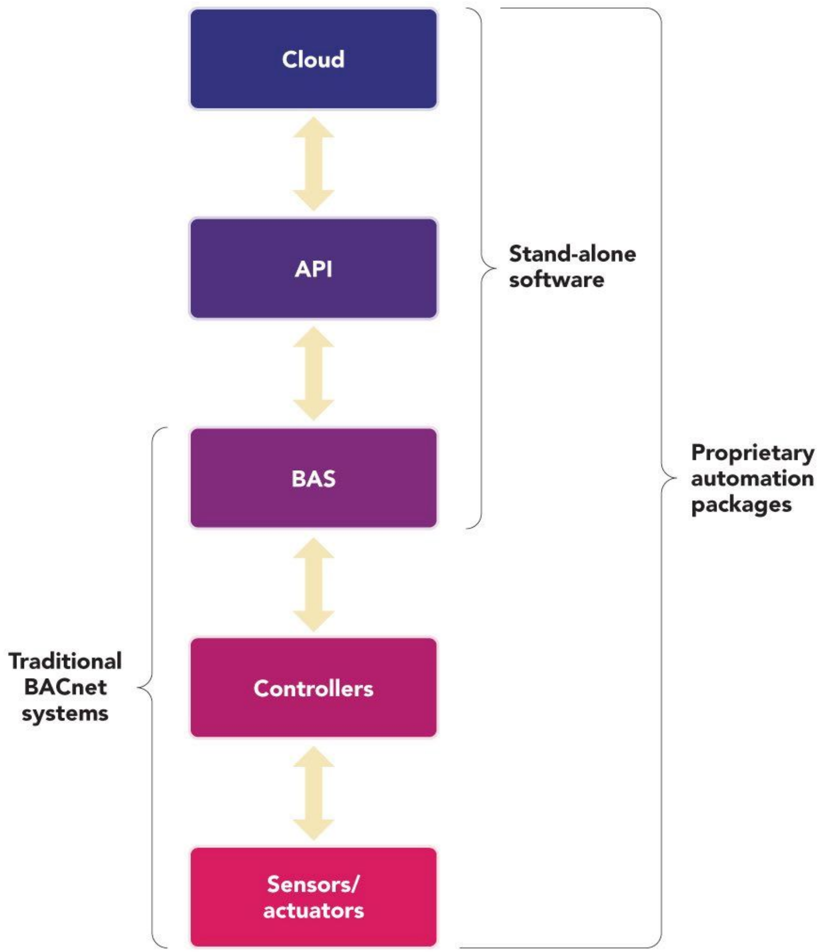


Figure 1: The hierarchical relationship of these solutions compared to traditional BACnet systems can be seen. Courtesy: SmithGroup

Typically, a BAS is comprised of two networks: an enterprise-level communication network and a building-level communication network. The enterprise-level communication network typically consists of high-speed BACnet/IP local area network to host operators workstations, building controllers, building-level communication networks and web-enabled remote connectivity. The building-level communication network typically consists of a BACnet internetwork to host field-level DDCs.

Understanding the BAS platform

Part 2 of the specification typically includes the performance requirements for all hardware, software, sensors and actuators that will be a part of the BAS, including the performance requirements for the BAS controllers and the operator workstation.

The B-AWS platform provides complete configuration, monitoring, modification and operation of the entire DDC system by advanced building operators and technicians; it typically resides on the enterprise-level communication network. In addition to specifying the hardware requirements for the B-AWS, the engineer will also need to specify the software requirements.

Typically, the B-AWS is provided as a complete engineering tool for the configuration of the system; this approach will allow for future system changes under proper password protection including dynamic creation, deletion and modification of all configuration parameters, programs, graphics, trend logs, alarms, schedules and every BACnet object used in the installed system.

Further, the engineer should require that the BACnet advanced operator workstation software shall comply with the minimum requirements of ASHRAE Standard 135 for a B-AWS and shall be certified and listed by the BACnet Testing Laboratories as a B-AWS.

BACnet building-level controllers typically are used to control major mechanical equipment (e.g., chilled water plants, heating hot water plants, large air handling units, etc.) and execution of BAS global strategies for the BAS based on information from any object in the internetwork. Building-level controllers typically support local hardware I/O by the use of onboard I/O and/or I/O expansion modules.

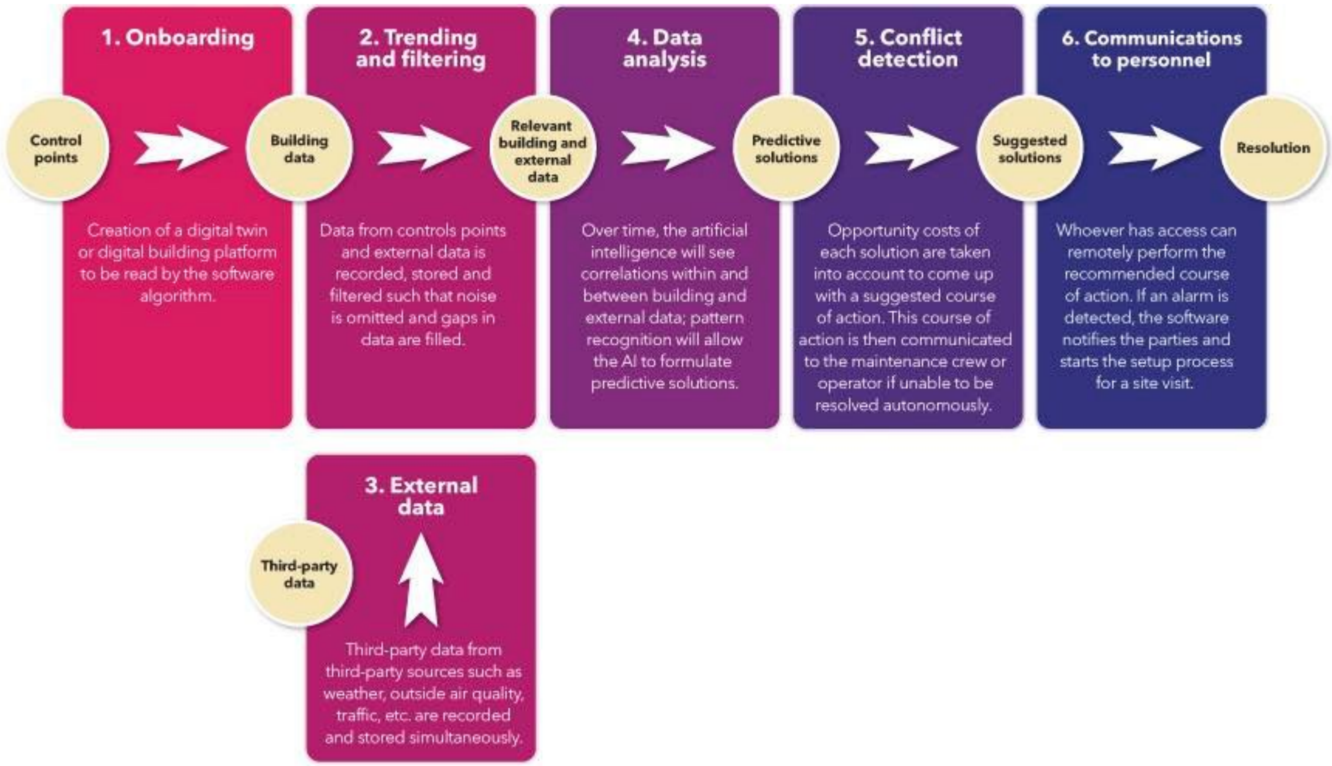


Figure 2: The flow of data flow using cloud software solutions is outlined. Courtesy: SmithGroup

It is important to note that for small heating hot water plants, one does not need a BACnet building-level controller. Typically, and in addition to the controls sequences internal to the boiler, the onboard boiler controllers can also control pumps, boiler isolation valves and makeup air dampers. Further, one of the boiler controllers is designated as the master controller while the other boiler controllers are designated as slave controllers. In this scenario the BAS needs only to send enable/disable commands to the master boiler controller for the plant as a whole to operate. All other points (i.e., boiler inlet and outlet temperatures, alarms etc.) could be mapped via a BACnet MS/TP or IP connection.

BACnet advanced application controllers have slightly fewer capabilities than building-level controllers; they are typically used for small- or medium-sized mechanical systems.

Recognizing that there is no formal definition of what constitutes a large, medium or small air handling unit, the engineer should specify when a BACnet building controller or a BACnet advanced application controller should be us

For example, a specification paragraph that addresses these potentially conflicting requirements could be:

"Provide one building-level controllers with expansion modules to control the chillers and chilled water pumps. Provide one building-level controllers with expansion modules to control the cooling towers and condenser water pumps. Provide one building-level controllers for each air handling unit with a capacity equal to or larger than 20,000 cubic feet per minute and one BACnet advanced application controllers for each air handling unit with a capacity less than 20,000 cfm."

BACnet application specific controllers are typically used to control terminal devices such as but not limited to variable air volume air terminal units, series and parallel fan-powered VAV ATUs, unit heaters, unit ventilators, fan coil units and individual fans.

Specifying open BAS

For the purposes of this article, an open BAS is defined as a peer-to-peer networked, stand-alone, distributed control system using open protocols to create an automation infrastructure. An open BAS supports a multivendor environment/network architecture and requires all equipment furnished by all vendors be fully programmable and from a single software tool such that only one software license is required to program and control the entire multivendor network. An open BAS should be specified in a very similar manner to a standard BAS, but with modifications as described in this section.

An open BAS can provide value to an owner by allowing for more competitive bids on controls for new work, renovations and service contracts, due to the fact that proprietary controllers, user software tools and their associated license fees, which typically allow an entrenched vendor with an existing presence in the building or campus to create a noncompetitive bidding environment are prohibited.

An item to note is that an open BAS is not entirely open. It allows for multiple vendors to coexist in a controls network; however, the controllers from each vendor must all tie into a single high-level framework with an associated user interface and software licenses — this high-level framework and user interface will be referred to as the "head end" system.

An overall standard defining the requirements for controller programmability, user tools and license requirements does not exist in the industry; therefore, to create a multivendor environment each head end vendor must define these requirements for themselves and create a unique specification to dictate the compatibility requirements of vendor controllers with the head end system through strength of brand.

When specifying an open BAS, it is important to require that any controller used in the building comply with the head end vendor's specifications. In addition, the head end vendor will likely require that one or more proprietary controllers, often classified as building-level controllers, serving an integration function be provided. The specification for the devices serving an integration function should be coordinated with the head end vendor.

In some regions, open BASs are less commonly specified than standard BASs and, as a result, local vendors may be hesitant, not adequately incentivized, not adequately trained or even lack the controller hardware required to provide an open system in compliance with the head end vendor's specification.

The current building controls market is extremely competitive with most jobs being awarded based on low bid. As a result, many vendors bid jobs at razor thin or nonexistent profit margins with the knowledge that, once their equipment is implemented in the building, money will be earned through license fees and service contracts for many years to come.

For a project with an open BAS specification, the license fee and service contract incentive for the non-head end vendors is smaller, which can lead to higher first costs as compared to a project with a standard BAS specification. Before specifying an open BAS, at least three local vendors should be capable and willing to bid the specification.

Specifying proprietary BAS

One of the more recent developments in proprietary HVAC controls is the ability to create a controls system that is predictive instead of reacting with preset sequences. Predictive controls enable HVAC systems to quantify and anticipate relationships between equipment and factors external to the building systems.

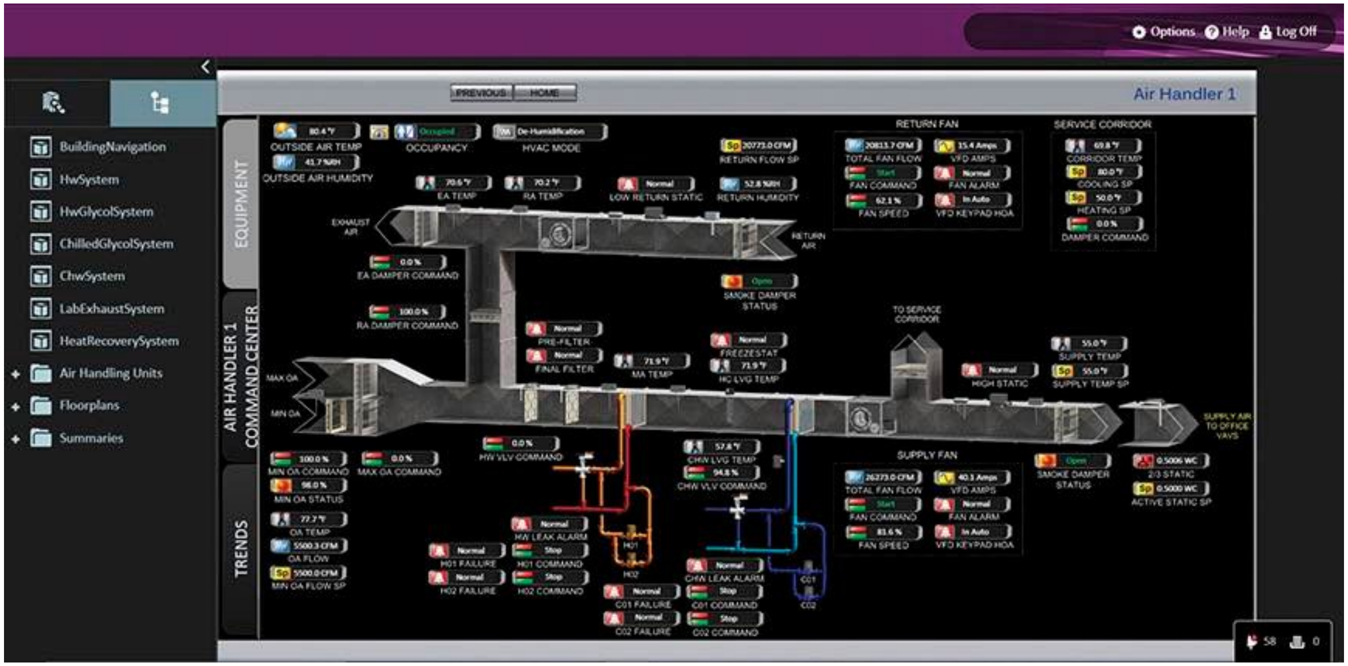


Figure 3: This provides an example of web-based, visual representation and reading of air handling unit points. Courtesy: SmithGroup

For example, a predictive controls system could, in conjunction with reading space data, trend sun pathing throughout the day and preemptively change temperature setpoints of a VAV box depending on whether the zone it serves will be under daylight or shade. This predictability allows the controls system to function as an autonomous building control system. In this instance, autonomous building controls are defined as systems that use various artificial intelligence algorithms to control the building systems. Said systems are capable of self-learning and self-adjusting with minimal or no interference from operators.

In contrast, traditional, sequence-driven BAS are automated with little flexibility to operate outside their sequences of operations. If a traditional sequence of operation is not optimized by design or during coding, this could lead to an unnecessary waste of energy. As international and local climate goals are set, there is a call to look at the energy wastage of the built environment and the waste of energy caused by a poorly optimized BAS. The easy access to digitalize the built environment and the need for more efficient systems is why there is a movement from automated rule-based building controls to autonomous building controls.

How stand-alone software works

The method by which the data are aggregated, how the trends are analyzed and dashboarding (user interface) is where software vendors can differ, but the general process is largely the same. The software process of predictive controls is:

1. First, all the sensor data of a building is "onboarded." All controls points are recreated into a "digital twin," or digital replica of the building model on the cloud that can be read by the computing software. For building systems, a digital twin is a virtual, living model of the building that trends, saves and locates all of the building's data components such as sensors, equipment feedback and meter readings. Within this reconstructed model, many companies in this stage offer a live dashboard to easily view the raw data, history and location of the sensors. This digital twin is where physical data is transformed into an "internet of things" system.

2. After all the controls points have been recreated, readings from all the points are trended and filtered. This happens simultaneously with step 3.

3. Third-party data such as weather, air quality, sun pathing, traffic, etc. are downloaded into the system from the internet.

4. The artificial intelligence algorithms, created by the manufacturer, examines these building and external values for trends within and between the two sources to create optimal solutions. For example, the algorithm can determine an ideal temperature setpoint for a room based on correlations between weather data, sensor trends or occupant input via temperature setpoint adjustment.

5. If any solutions conflict with one another or causes financial or energy efficiency trade-offs, the algorithm takes this into account and can come up with a compromise. Some vendors work with the user to fine-tune the threshold for these trade-offs.

6. After compromises are considered, the software communicates solutions with the operator (or any party who has access to view and change the controls system). The operator can remotely take any of the recommended course of action for the BAS using the software. Many software vendors provide a secure application programming interface to facilitate this communication process. An API is the communication between commands sent by the software and/or operator to the physical equipment in the BAS. If there is a larger issue, such as an alarm is detected, if equipment is approaching end of life or if a filter needs to be replaced, the software will notify all associated parties and facilitate the process for an on-site maintenance visit.

Understand software, security issues

It is important for mechanical engineers to start considering software-related topics when designing controls systems. Because the technology is so new, there are few standards and codes that govern cloud integration and predictive controls. This is

Figure 4: In this example, a variety of equipment points, trend settings and display options are shown for a single piece of equipment. Courtesy: SmithGroup

made even more complicated by the fact that the analysis software is a black box.

Outside the HVAC industry, ISO/DIS 23247-1 is under development for the digital twin framework in manufacturing processes. Within the HVAC industry, ASHRAE 223P: Designation and Classification of Semantic Tags for Building Data is a proposed standard that outlines the process and requirements for creating a unified naming convention for data and processes within the digital twin. In this instance, a potential best practice as an engineer for now is to specify a digital building platform that uses a nomenclature and data aggregation structure of the proposed standard.

For design guides, ASHRAE Handbook for HVAC Applications mentions little on how

Figure 5: Building automation system control and monitoring software manages a building's various mechanical, electrical and plumbing systems and equipment. Courtesy: SmithGroup

to design HVAC systems around predictive controls, but goes over the different software methods of predictive fault detection. Due to a lack of dedicated predictive controls standards and best practices in the HVAC industry, engineers should pull from numerous sources when writing the specification.

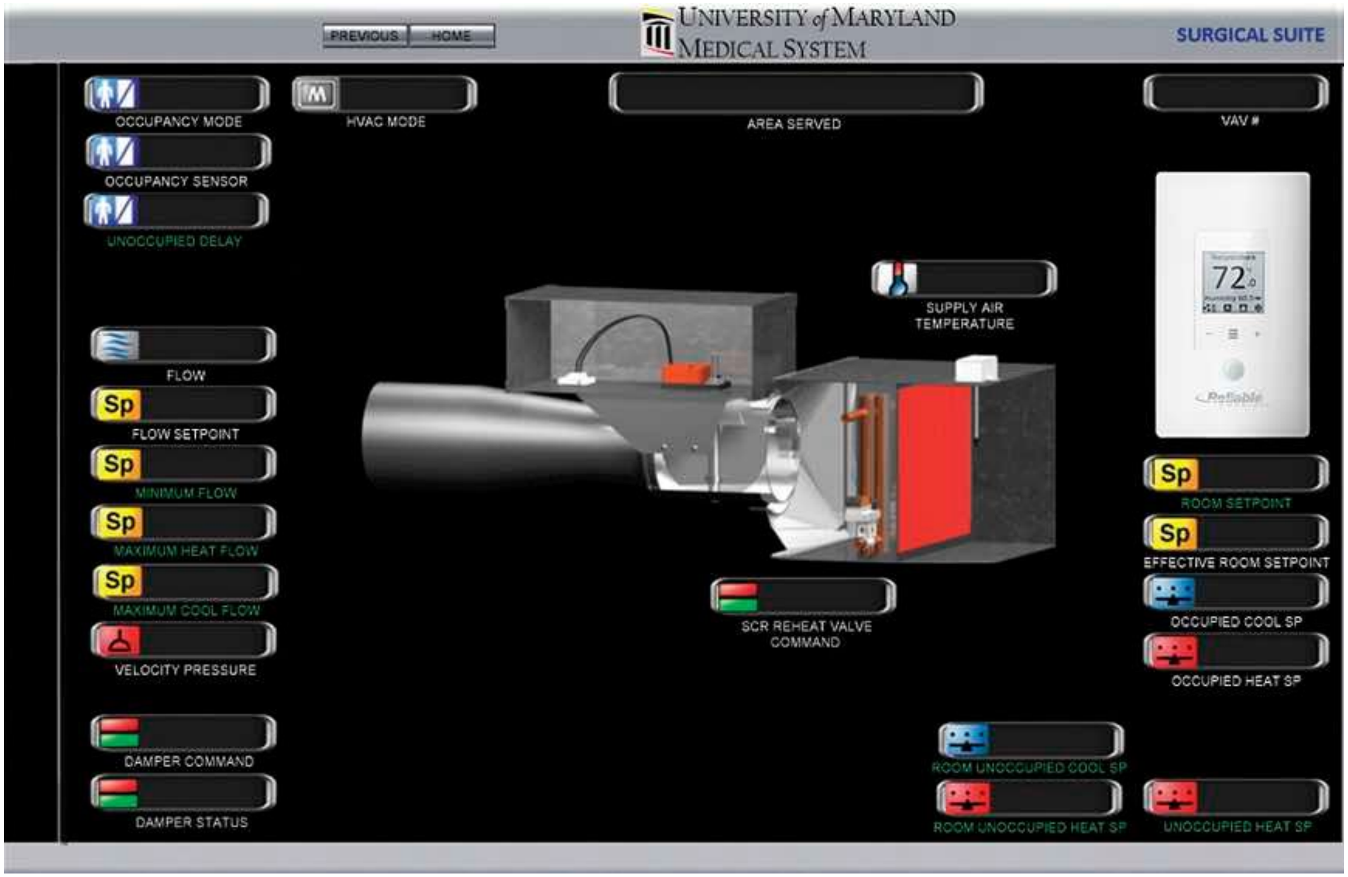
At minimum, the specified cloud software should meet NIST SP 800-82: Industrial Control Systems Security and ISO 16484-5: Building Automation and Control Systems. Users and their information technology departments should be trained in recognizing cybersecurity threats, especially because internet of things framework is not inherently secure to hackers or malware. Cybersecurity should be continuously checked; even adding a small sensor during the construction administration phase of the project and forgetting to change its default encryption can pose a cybersecurity risk.

If the stand-alone software should fail or have bad readings, one mitigation strategy is to take the stand-alone system offline for maintenance or ignore requests if the system. Another pitfall of cloud computing could be the potential for the cloud to go offline. In these instances, it is important to have a backup plan.

The best practice would be to create a failure mode that functions similarly to a standard BACnet sequence. The equipment should not rely on communication with the cloud alone. Additionally, one of the issues with cloud communication is the latency or delay of communication between software to equipment and/or cloud data to computing software. Traditional BACnet systems poll input points for data.

Because stand-alone software reads data from the BAS points via push service, polling data in the cloud is limited by the polling speeds of the traditional BACnet systems. For this reason, it is best to use a peer-to-peer protocol between controllers and avoid slower, traditional MS/TP connections where possible to cut down on polling time.

Additionally, API communication between the cloud and BAS is another point of latency. This cannot be circumvented in a cloud to device system; it is best practice to specify that testing is conducted as soon as possible to assess time delays. For existing buildings that do not have a limited timeline, some vendors provide optional plug-and-play indoor air quality sensors to trend a sample space for several months before digitizing the rest of the building to give insight of the time delays to the cloud, start the digital twin process and create a history of sensor data for analysis.



On this note, specifying design testing and field testing is important for setting clear expectations and documentation of the interface, inputs, outputs, functions and conditions the software vendor should test for. For example, testing of how sensor data is represented/trended, the conditions that automatically call for a maintenance visit and latency between sensors and actuators are variables that can be tested and changed accordingly.

Figure 6: Equipment that does not rely on building automation system communication to function, such as the software view of a venturi valve, is another way to lower latency — but is more costly. Courtesy: SmithGroup

Proprietary packaged solutions thrive on the notion that a unified whole is greater than the sum of its parts as they provide hardware that is integrated with its software services. The software works in about the same general way as the stand-alone cloud-based software. It creates a digital copy of the building, filtering, storing and learning trends between the sensors and external sources.

The benefit to these systems is that their hardware can be smarter, more unified and even self-federating. This means some vendors provide sensors that can read multiple types of data, detect each other, read each other's values and determine which one is to function as the master unit autonomously.
Another benefit to this technology is some vendors send commands to actuating devices from integrated local controllers rather than the cloud. This local, edge-based approach minimizes latency between the cloud/device and also means the system can function if the cloud is down. The cloud exists just for data management and dashboarding for the users. Some systems are also physically consolidated by combining electrical panels with communication wiring in the same controller. The controller even can even provide readings for all attached sensors, reducing the number of screens.

Designing for proprietary solutions lacks a unified approach in that each vendor is different. As such, it is important to ensure the project's specifications match the vendor's specifications, and also be open enough for multiple bidders. However, again, there are few standards and codes for packaged systems as well as limited documents from manufacturers.

This can cause issues when specifying a proprietary system because it can be difficult to add on controls provided by other vendors in the future. Other challenges include:

a change in basis of design for a proprietary controls package, the system needs repair/maintenance but cannot be serviced by a third party or if the vendor has a limited selection on devices. As such, it is imperative to communicate with the building owner if you intend to specify a proprietary solution.

Kevin Ricart and Melissa Lim

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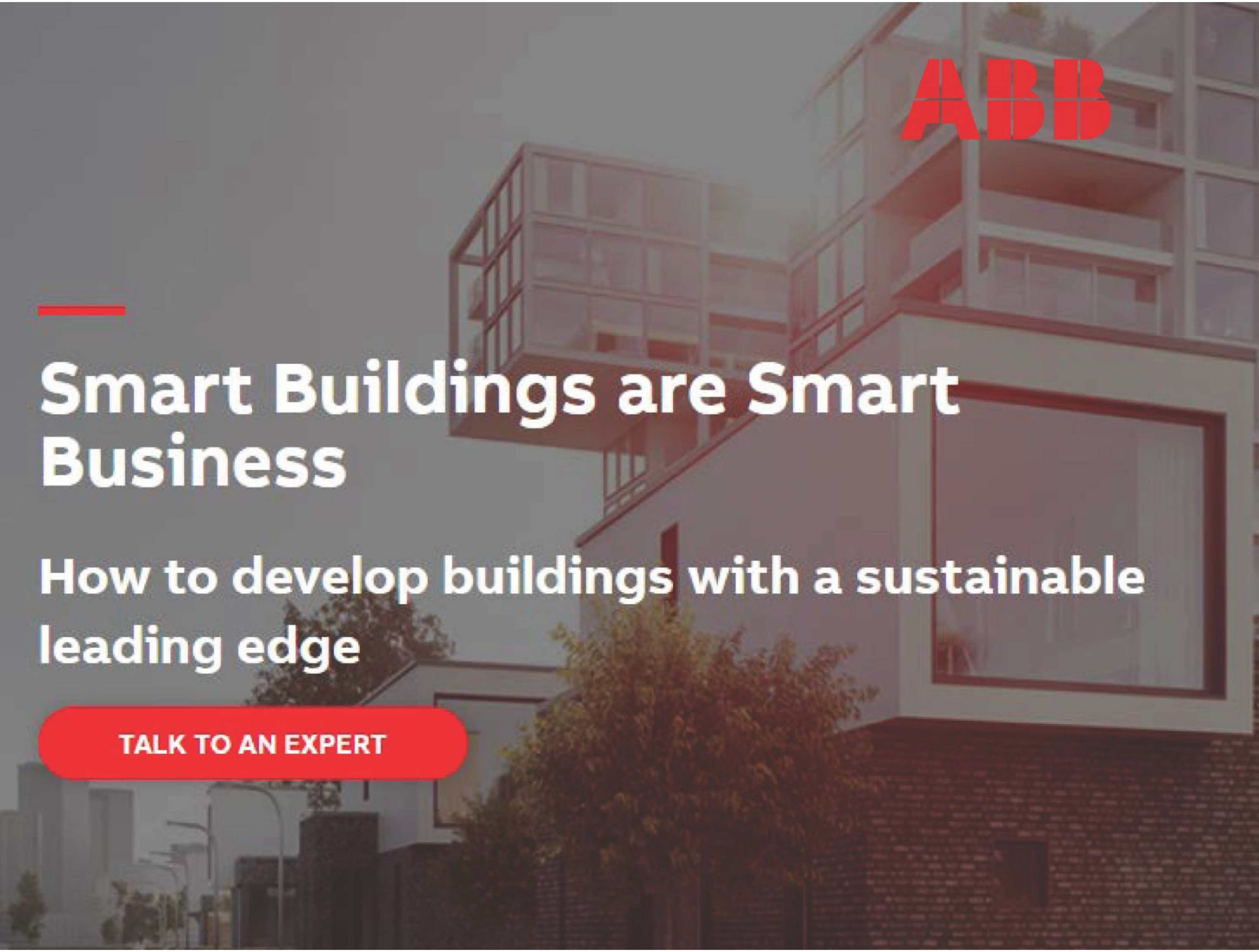
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Smart Buildings are Smart Business
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TALK TO AN EXPERT

Energy Monitoring

"You can't manage what you don't measure."

Management guru Peter Drucker's famous quote is especially meaningful when it comes to industrial electrical systems. Falling cost of sensors combined with cloud-based computing and ever more capability in electrical equipment are putting condition monitoring within reach of more and more businesses.

For most manufacturing and process industries, electric power systems are as vital as the assets they support. Monitoring power system components like circuit breakers can avert problems that could damage valuable assets and bring production to a standstill, but it can also save money over the long term via predictive maintenance.

It's also possible now to monitor, protect and control electrical equipment at the device level without the investment and maintenance of a fully engineered and commissioned system. Coupling that capability with analytics fed by operational data from the assets being monitored brings insight to facility managers and plant operators that they can act on.

Monitoring

Modern circuit breakers, such as ABB's Tmax and EMAX2, often come equipped with onboard sensors that allow the unit to report in real time on several key metrics, including:

- State of devices
- Presence of alerts or abnormal operation
- General parameters (e.g., device type, serial numbers, and rated parameters)
- Maintenance (e.g., latest service operations, contact wear, number of trips, etc.)
- Electronics (e.g., software versions and relay information)

Some devices provide direct links to related device documentation and manuals online. Others offer communications modules to connect breakers to one another and to cloud-based reporting and analysis systems.

With so much capability built into the breaker itself, there is no need for a stand-alone control system or SCADA (though some breakers like ABB's Tmax and EMAX2 can also be controlled via SCADA systems), and no associated cyber security concerns surrounding on-premise software installations.

So, what can end users monitor with such equipment? Basic elements like voltage, current, real/active power, reactive power, power factor, network frequency, energy consumption is all covered. Energy costs can be easily calculated with input rate schemes.

An events log, measurements recording, data logger provide for further analysis of the data streaming from connected devices.

Users determine what circuits and individual assets they want to track based on the attributes of their operations. A shop operating large presses might monitor the breaker inside each machine as well as the one protecting the entire circuit. The facility manager in this case could then devise a protection scheme that can be programmed into the breakers themselves.

Power quality

"PQ" refers to a variety of power system disruptions that can include:

- Deviations of voltage average value from its rated value
- Short interruptions or spikes in power supply
- Short decreases (sags) or increases (swells) in voltage
- Voltage unbalance (i.e., difference in voltage values between different phases)
- Presence of current and voltage harmonics.

The effect of these disruptions can be reduced efficiency in motors, tripped breakers, unplanned downtime and ultimately, damage to primary equipment. The risks can be minimized with the use of power conditioning technologies like power factor correction, harmonic filters, and UPS/backup power supplies, but these solutions are predicated on a robust monitoring regime to provide the data necessary to inform control actions.

Protection

With monitoring in place, the next step is to establish a protection scheme, again based on the unique characteristics of the given business. Users set parameters based on the specific kind of load, equipment, and operating conditions, and can implement protection strategies at the device, circuit, and plant levels.

Modern electrical components offer a great deal of flexibility, too. Plant operators can set up customized trip parameters for monitored values with several options such as:

- Trips with or without an alarm
- Verification of automatic control actions (i.e., alarm triggered if actuator does not confirm trip)
- Zone selectivity (separate from protection parameters)
- Confirmation that two voltage sources are synchronized before connection

As with monitoring, all of this can be tested and modified remotely via a communications module and secure access to the local network serving the equipment being monitored.

Control

Historically, control actions like opening and closing breakers were managed via a SCADA or other centralized control system. Today's field devices can perform basic control actions automatically based on pre-programmed logic to isolate certain loads, switch to backup power and flag potential problems (e.g., voltage fluctuations). It's also possible to add functions like load shedding (based on economic or operational triggers) and automatic transfer switches (ATS) using common communications protocols.

There's an important safety aspect here, too, as technicians can implement a wide range of actions remotely, without exposure to energized equipment. Even the HMI on the devices themselves is isolated from the energized lines, significantly enhancing operator safety.

Forecasting and optimization

The safety of people and equipment is paramount, and these objectives make up the foundation of any condition monitoring scheme. However, the same monitoring capability can be leveraged to perform load forecasts and overlay operational data with energy costs specific to the given facility. Plant managers can then optimize their energy use while observing operational constraints, production targets and utility pricing parameters.

Real-time monitoring is also the cornerstone of condition-based maintenance, which can have a dramatic impact on opex spending. So, the value of modern circuit breakers and related equipment derives from two use cases: avoiding costly downtime and reducing the cost of normal operations.

Both are made possible by cloud-based software solutions that record, analyze, and optimize energy flow within the energy supply system. Plant operators can retrieve the data anytime, anywhere via smartphone, tablet, or PC.

"I can see, in a very detailed and with graphic visualization, where and how much electrical energy is consumed throughout the entire plant," says Stefano Aimi, responsible for production, technology and logistics at rice processor Riseria.

In a completely different application, the world's tallest building, the Burj Khalifa, can reduce operational costs by up to 30 percent using real-time sensor data and condition monitoring with ABB's Electric Distribution Control System (EDCS), replacing routine maintenance work.

By now, the benefits of condition monitoring and predictive maintenance are well known. As more intelligence and capabilities are pushed down the control hierarchy to the devices themselves, the easier it becomes to implement effective monitoring, protection and control schemes. Today's field devices, coupled with cloud-based analytics and reporting tools, make for a compelling business case.

How to get started designing a smart building

What is a smart building, and how can engineers design integrated building systems?

Owners, operators and occupants expect more from the built environment, and rightfully so. Technology continues to evolve at an exponential pace and there are many more tools, systems and services available to the average customer.

Terms like "internet of things," "smart" and "open solution" are used as vague buzzwords to grab attention, but leave owners overwhelmed and unsure of which technologies or sensors to choose. Questions engineers and designers may be asked include:

- What is a smart building?
- What technologies will enable it?
- How do I ensure these systems can "talk" to each other and offer interoperability?
- What information technology or data security systems do I need to consider?
- How can I connect my systems to the cloud via the internet of things?
- Should I select vendor A or vendor B?
- What will my smart building look like in the future?
- What do I even do with all this data?

According to the Building Efficiency Initiative, a smart building is broadly defined as a building that delivers useful services that make occupants productive at the lowest cost and environmental impact over the building's life cycle.

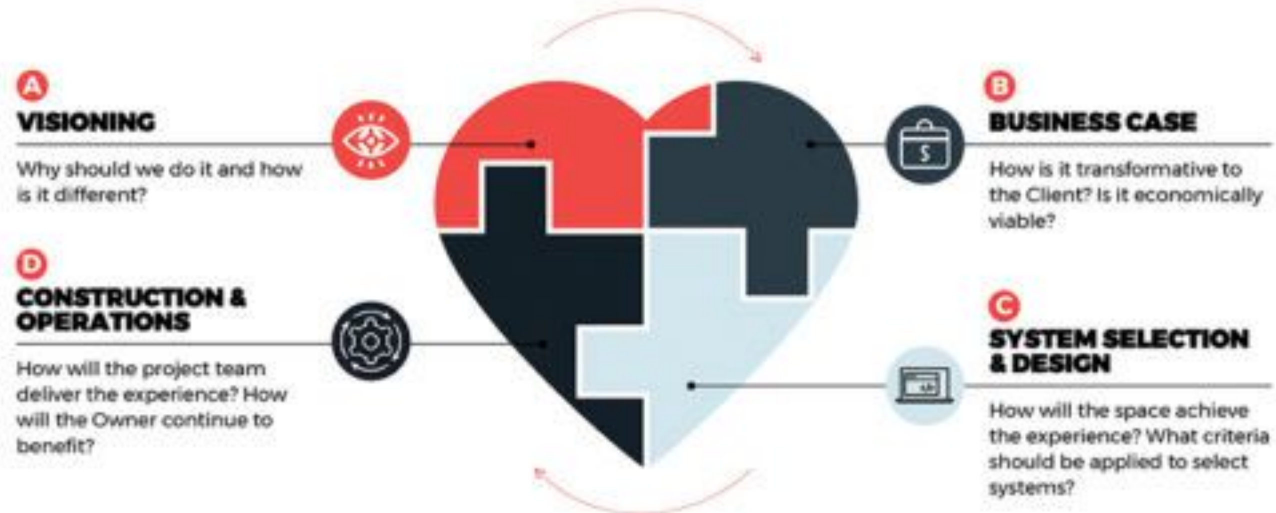

Figure 1: The smart building consultant's role is evolving to guide conceptual visioning sessions, develop the foundations to support integrated building systems and to select systems to meet the owner's operational and organization goals. Courtesy: WSP USA

A smart building requires adding intelligence from the start of the design phase to the end of the building's useful life. Smart buildings use converged networks during operation to connect a variety of subsystems, which traditionally operate independently, so that these systems can share information to enhance total building performance.

Instead of focusing on systems and sensors first, smart building consultants are leading discussions to define client goals and help reduce the noise of continuously evolving sensors and solutions. It is important to remember that we build buildings for people; technology should not complicate, but enable, a better building experience.

To meet the demands of modern tenants, owners are turning to their trusted consultants earlier in their design process, often even before any specific project is in mind to define their smart building. Consultants' roles are evolving to guide conceptual visioning sessions, develop the foundations to support integrated building systems and to select systems to meet the owner's goals.

How is this changing the way consultants approach projects? Two ways:

- In general, it is important that consultants have a deep understanding of the clients' business and goals before thinking about design solutions (smart or not) to meet those needs.

- Some smart designs, systems or products are new or novel and may create significant added costs. To generate a truly accurate justification or return on investment, it is important to understand how such solutions may provide value to a business in categories consulting engineers may not traditionally be used to consciously impacting through design, such as occupant productivity.

Developing a vision

The first phase of client engagement for smart building projects is visioning. This is important because the term smart building has different meanings to different clients. The purpose of visioning is to learn or develop, alongside the client, the aspirations and operational pain points for their organization — not just their building or employees, but the business as a whole.

Most clients' goals fall roughly into three categories: energy and water optimization, real estate efficiency and occupant or employee productivity. Ultimately, most clients are interested in the bottom line, which is some combination of these three categories. These categories are proportionally related to each other by orders of magnitude.

If, for an office space, annual energy and water costs are $x per square foot, then lease costs are roughly 10 times more per square foot and employees who work in that space have combined salaries of 100 times more per square foot (see Figure 2). This is also known as the "3-30-300 rule," coined by Jones Lang LaSalle. These numbers vary widely depending on location and other factors, but the general proportional relationship is true for most businesses; energy costs are only a fraction of total annual operating costs.

Focusing on delivering spaces in which employees are happier, more comfortable and more productive can be orders of magnitude more impactful on the bottom line than just reducing and optimizing energy consumption. There are also nonmonetary reasons to focus on all three categories, as they can provide data to support corporate sustainability plans or core values. The key is determining where the client's focus and attention lays among these three categories and where the consulting engineer's responsibilities can make an impact.

Once some general areas of focus are established, the next step in visioning is to define specific metrics that can be measured throughout the life of their business or a project and used to assess ongoing performance (or lack thereof, and how to correct it). The visioning phase of an engagement is an important part of any project. Therefore, it is important that scope for this visioning phase is included in any consultant's client engagement, especially for discussions around smart technologies.

The final step is to perform financial modeling of metrics that quantify the owner's business goals. This is not just calculating these based on projected energy savings year-over-year, but also incorporating real estate efficiency (e.g., density of workstations) and metrics surrounding occupant comfort. Some clients may not be large enough or focused enough to have the expertise to perform this in-house; this can be a growth area for well-rounded consulting engineering or advisory services firms with specialization in studies like this.

With space and anonymized employee salaries included in the financial model, smart technology solutions that may seem expensive at first can demonstrate their complete value. Even with conservative estimates of improvements in these categories, the payback period can come out to an astonishingly short amount of time.

This is exactly what resulted from a financial model and analysis for a leading global investment banking corporation. Although it did take some convincing and time to earn this client's trust with some internal financials (lease costs and salaries, which were anonymized and summed from real data), this information was essential to the accuracy of the financial model. The resulting payback period was so low that some assumptions had to be tweaked to extend the period to make it more credible to their leadership.

Smart design

With a clear vision and financial analysis in hand, the design phase can commence. At the essence of design for connected buildings and smart solutions is the ability to share data between building systems. A few foundational infrastructure pieces are required to support integrated building systems and collection of smart metrics.

Converged network

A converged network provides efficiency increases by centralizing management of IT resources and reducing the amount of hardware, as well as creating a system with the flexibility and performance to scale. Convergence is also the basis for cost-effective and efficient analysis of data at scale.

Even within the building space, a consultant's role has increased to require a fundamental understanding of the network and typically help with design to support the speed and resiliency necessary for real-time building data. Partnerships have grown between IT departments and consultants as more devices become connected to the network, increasing security concerns and the need to solve them collaboratively.

IT provides its specialized knowledge of systems, including network equipment, fiber and duct bank utility infrastructure provisions, enterprise web-based services supporting campus operations and integration of data sources. In addition, IT defines policies for device management and cybersecurity and may want to perform hands-on testing of sample devices before implementing across a campus.

Accessible and available data

Additionally, traditional mechanical, electrical and plumbing systems are capturing massive amounts of data every day. How, as owners, can this data be mined and leveraged to produce actionable insights? While the answer relies on those goals defined in the visioning phase, data from all systems needs to be accessible and available. Data can no longer be stored only within the building management system or lighting control system databases; it must be exposed to a central point capable of ingesting, storing and overlaying data from disparate systems. This means that data storage must

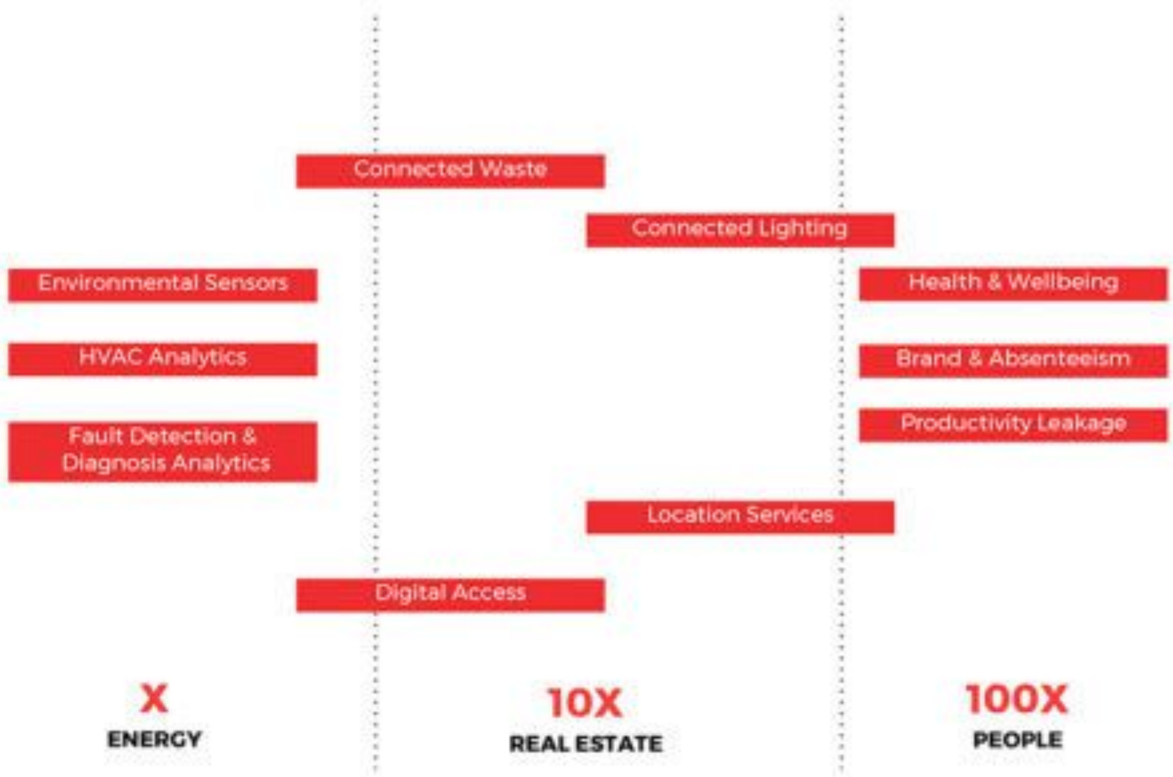

Figure 2: Energy and water costs are only a fraction of total annual operating costs. At $x per square foot for energy and water costs, lease costs are roughly 10 times more per square foot and employee costs are roughly 100 times more. Courtesy: WSP USA

be designed to manage unstructured and time-series data for multiple disparate sources efficiently.

The solution for data storage will vary with each project, and consultants can advise on the best model to meet specific project needs. Regardless, a single database needs to be identified as the "source of truth" to ensure data integrity and accuracy. With these foundational infrastructure pieces in place, the consultant can start to consider system selection criteria.

System selection

To meet local or state building codes, most of the systems that enable a smart building already are required, or soon will be. Thus, the initial cost for a fully integrated smart building is not substantially more. For example, many energy codes require occupancy sensors to turn off lights when the space is unoccupied. Depending on what is important to the owner in their smart building, as discovered and defined in a visioning phase, more granular occupancy sensors could be as little as $0.02/square foot more. Choosing the best system solution for an integrated building is based on several considerations: cost, flexibility, control and convenience, meaningful feedback, real-time metrics and common tagging and communication protocols.

Each system should have the flexibility to be reconfigured or expanded as required to meet future needs. It is no longer acceptable to be limited or locked into a single, stagnant solution. As more is learned about systems, spaces, operations and performance, owners should be able to add features and/or systems to meet their evolving goals.

Control and convenience

Two key traits of any smart building solution designed for occupants are control and convenience. Without one or both traits, long-term adoption will be low. Interoperability among building systems also is important, both in the short- and long-term, so that future needs can be met without having to reconfigure or replace all smart systems.

Users of most smart building solutions can be categorized as occupants (employees or visitors) or operators (maintenance staff, building engineers, landlords, property managers or owners). Both user groups must be able to affect control at some level and have convenient access to the data that is most relevant to them. A well-designed mobile phone application can be an effective way to provide this. However, care must be taken to make it simple and intuitive, while still providing control and convenience. There are millions of mobile apps available on numerous marketplaces now, but only a select few provide true control and convenience and even fewer meet corporate IT's robust network and data security requirements.

Meaningful feedback

Related to these attributes, for either user group to do their job and make decisions, they need to be provided with meaningful feedback. Everyone in the industry is talking about big data and how raw storage of vast amounts of data are no longer an issue. But big data storage alone is not useful; the system must be able to analyze the data and produce meaningful and actionable information from it.

For example, on the occupant side, app-based solutions can now provide users visibility into current space temperatures, zone heating, ventilation and air conditioning system mode (heating or cooling), lighting level and whether their other colleagues near them are comfortable. Occupants can use this data to choose a space that is more comfortable for themselves or, in open work spaces, help influence setpoints through voting algorithms (for example).

Real-time metrics comparison

As discussed in the visioning phase, all systems and solutions should be justified by playing a role in delivering the client's vision. These systems should be able to provide real-time comparison of key metrics to specific goals or standards developed earlier. Owners, operators and occupants should be able to quickly comprehend the current performance as well as be able to drill down into more specifics to troubleshoot problems.

For instance, operators should have a score or gauge of overall equipment health and performance with a short list of the most problematic buildings, spaces or systems. In an instant, they should be able to assess if overall equipment health is within a predefined range. Then, operators can look at details of problematic buildings, spaces or systems and begin to prioritize how to increase the overall performance score.

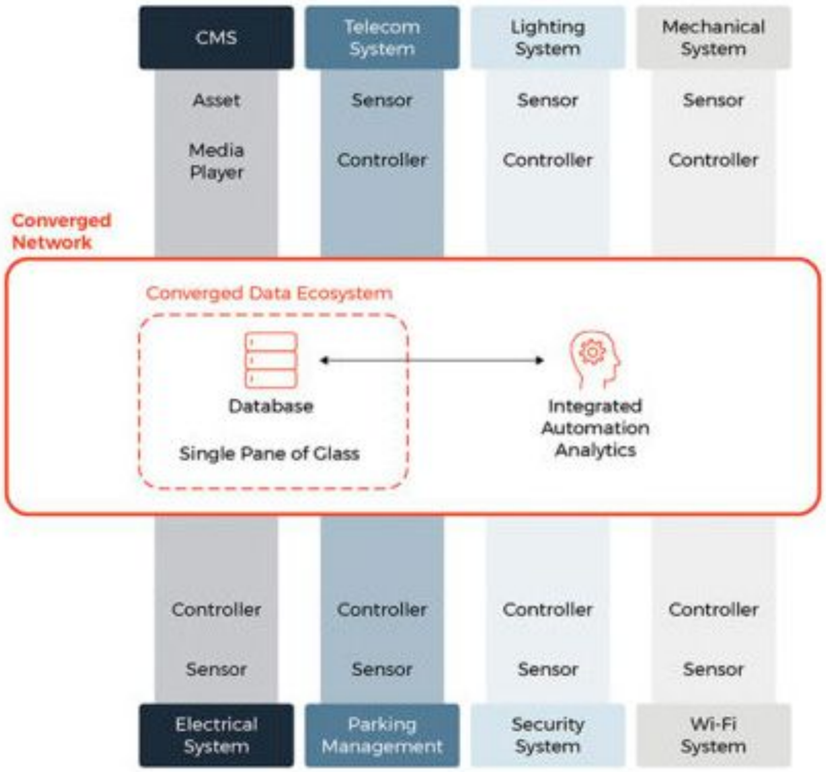

Figure 3: A converged network and common data ecosystem are necessary in smart solutions to share data between all building systems, including media content management systems. Courtesy: WSP USA

Common tagging, communication protocol

To make the above four considerations possible, it is essential that common data tagging and communication protocols be established and adhered to through the life of a strategy. This is the glue that can make or break a project. To integrate the many traditionally "siloed" systems in a building, such as the mechanical building automation systems, electrical power monitoring, plumbing delivery and metering, lighting control systems and life-safety systems, they all need to speak the same language at least at their top levels or head-ends.

But this goes beyond just the typical requirements of ASHRAE Standard 135: BACnet — A Data Communication Protocol For Building Automation and Control Networks. Most of this should be internet protocol-based and use the same converged network. Metadata tagging should be employed within each of these systems to reduce or eliminate the time-consuming and manual process of point mapping.

Emerging industry initiatives such as Project Haystack and Brick Schema, which are being further developed in conjunction with ASHRAE, should be followed. Properly tagged data can be more effectively used and manipulated by analytics platforms. Application programming interfaces could be used as part of the solution, and these must be well documented, robust and maintained. Many available smart building or analytics platforms claim to have an API, but a quick look under the hood often reveals it has been developed for show only and in reality, the API does not provide all expected or advertised functionality.

Delivering any smart building project requires close management of scope and active involvement throughout the process. For some contractors and construction managers, all this new technology and interconnectivity is overwhelming and can be subject to the process of value engineering.

For example, if the right consultant is not in the room, a significant first-cost savings for a converged network deletion may be offered up and accepted by the owner. Without understanding the design implications of the overall integrated solution and how it aligns with owner goals and expectations, the real value of the smart building and the comparison metrics developed during visioning may be lost. This drastically effects the ROI found in the original all-inclusive financial modeling.

Design teams need to include specifications with industry-accepted standards and guidelines to provide guidance to the contractors to ensure quality control and standardization, versus one-off solutions that do not offer interoperability.

In any smart building project, no matter the scale, it is important to spend the time in the beginning to learn about the client's business goals and develop metrics that can be used to show progress toward or compliance with them. Supporting the vision with a comprehensive financial model demonstrates the true value of smart and interconnected systems. Foundational infrastructure to enable this functionality includes converged networks and a common data ecosystem.

The main criteria for system selection are flexibility, control and convenience, meaningful feedback, real-time metrics and common tagging and communication protocols. It is important to include scope for the management of the client, design team and contractor throughout a smart building engagement to provide periodic reminders of the client's objectives and how the smart solutions support their vision and cost expectations.

Codes, standards, guidelines to consider

It's a bit of the wild west with regard to smart buildings, with every vendor indicating they have the best single solution. Owners are best served if they are not pigeonholed into one solution where they are held hostage with licensing agreements and proprietary solutions that others cannot bid on. Some aspects to consider are:

- ANSI/BICSI-007-2017: Information Communication Technology Design and Implementation Practices for Intelligent Buildings and Premises.
- ASHRAE Standard 135: BACnet — A Data Communication Protocol For Building Automation and Control Networks.
- Brick Schema: Uniform Metadata Schema for Buildings.
- EN ISO 16484-1 Building Automation and Control Systems.
- ISO/IEC 18598-2016: Information technology — automated infrastructure management systems — requirements, data exchange and applications.
- Project Haystack: Standardized Semantic Data Models.
- Telecommunications Industry Association Smart Building Program.

What about network security?

Cybersecurity and network security are topics that every client must consider when mixing disparate networks, some with better security protocols than others. Smaller companies may not have a concern. Large, multinational corporations with high-tech product development and subject to regular hacking attempts will be extremely reluctant to open untested building automation systems to their product development, financial and other corporate networks. Cyberattacks that pop up in the daily news cycle should concern any building owner or manager with a networked smart building system. This is a growth area for all built environment consulting and specifying engineers, to be able to advise clients on these issues, especially if the network engineering expertise is available in-house.

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Case study: Integrating an intelligent campus

A flexible and adaptable solution enabled future expansion for this campus

WSP USA has followed these best practices — goal-setting and metrics development, design of foundational infrastructure to support integrated building systems and system selection based on the aforementioned criteria — to enable an intelligent campus with connected building systems across the combination of commercial, industrial and transportation buildings.

A large client wanted a tool to manage operations for building management systems and campus-level utilities. The owner's desire was to understand, manage and improve energy consumption data to meet sustainability targets, including net zero energy. Across its campus of 90-plus existing buildings, 35 disparate building management systems existed, as did 1,500 meters that monitored gas, water, thermal and electrical consumption. Many were legacy, outdated systems that could not share data in their current state and were connected to various, unmanaged and disconnected networks.

The two biggest challenges for this client were:

- The associated high cost to upgrade the entire campus to meet sustainability and performance goals while maintaining 24/7 operations.
- The selection of new systems and/or devices to improve energy performance, occupant experience, operational efficiency and equipment performance.

WSP USA led visioning sessions to understand and define stakeholder expectations and establish workflow organization. These sessions brought together stakeholder groups that usually worked in silos — such as facility managers, sustainability organizations and information technology — to improve the overall operations of the campus and identify a common vision.

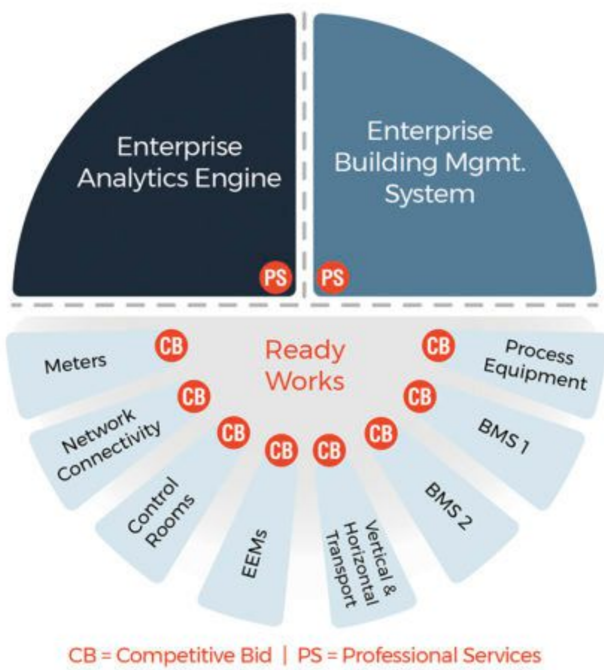

Figure 4: This workflow and procurement diagram simplifies the case study into three manageable parts: enterprise analytics engine, enterprise building management system and ready works. Other typical energy-efficiency measures projects and upgrades also were rolled into this project. Courtesy: WSP USA

In smart building projects like this one, IT stakeholders had a crucial role as more existing and new systems were connected to fewer common networks. WSP USA also advised the owner on best practices in implementing a smart building by using Lawrence Berkeley National Lab and U.S. Department of Energy research initatives such as the Better Buildings Initiative.

A detailed site assessment was necessary to evaluate the existing systems and infrastructure across the campus. Campus facility managers were involved in site walks to capture the institutional knowledge of how systems operate. A range of subject matter experts and thought leaders in the areas of technology, sustainability, building utility (mechanical, electrical, plumbing, lighting, acoustics) and financial advisory services were included as part of the team to understand the variety of systems across the campus. The team of consultants advised the stakeholders on the roadmap for upgrading and integrating systems as well as developing future-ready standards for continued operations into the foreseeable future. Phasing of the upgrades was crucial due to the continuous operations and necessary infrastructure improvements.

WSP USA developed a flexible and adaptable solution to enable future expansion for this intelligent campus. All meters and systems were integrated to a converged network to improve IT operational efficiencies and management. Additionally, all existing systems were upgraded to share data using common communication protocols and follow a similar metadata tagging model. Data from every system was stored in a central data repository serving as the "source of truth" and is maintained by IT for availability to different users.

While there was a current market desire for all data to be visible from one central point or system considered a single pane of glass, the solution included multiple applications to meet stakeholder operational, visualization and reporting needs. This enabled the best–in–class applications to be selected for each of the operational requirements or identified goals rather than compromising features for a single application. This design required the outlined foundational infrastructure to support the modular approach and the ability to modify and/or add features or additional applications in the future.

The applications had to be user-intuitive and convenient to ensure long-term use by the stakeholders. In many cases, the applications streamlined the stakeholders' current work processes and reduced the manual labor necessary to produce monthly reports.

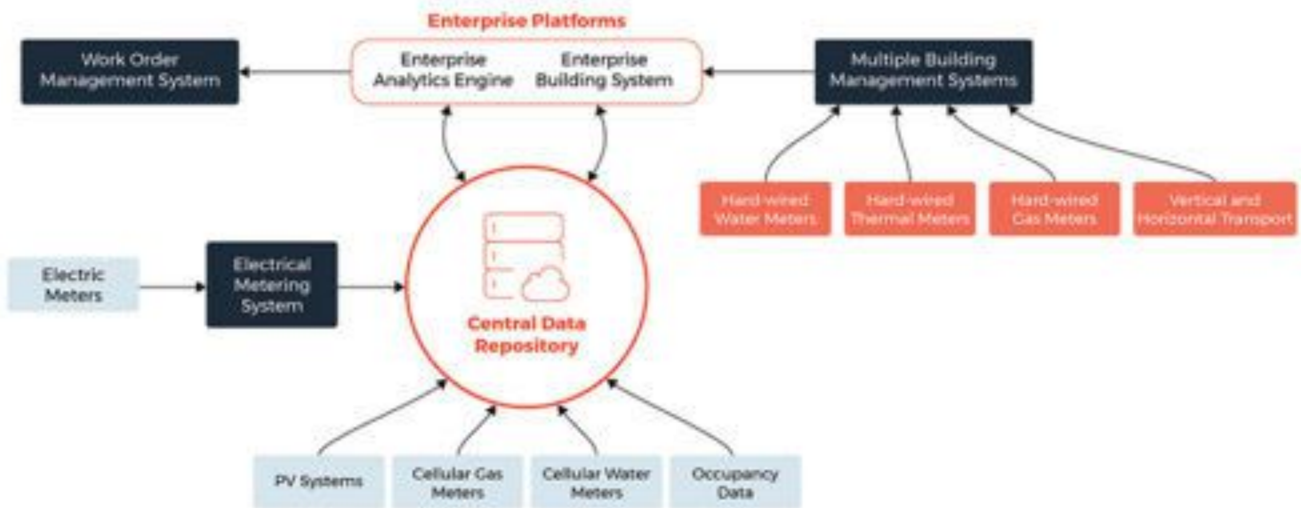

Figure 5: This functional diagram shows flow of data from meters and underlying systems to the enterprise platforms across a large existing portfolio campus. Courtesy: WSP USA

In addition, one application provided a single user-interface for control, giving convenient access to many systems across the campus and significantly improving the stakeholders' ability to complete daily tasks.

Based on the identified sustainability goals and operational efficiency metrics, dashboards and reports were built to compare the real-time performance of each building in meeting these goals. Low–performing buildings were highlighted to easily help stakeholders focus on the worst performers in improving campus performance. The dashboards then provided insights into what actions stakeholders could take to diagnose and correct current problems or information needed to support equipment replacements or future capital projects.

As the campus continues to expand and upgrade, it will need the ability to adapt its tools to meet evolving sustainability goals and improve upon learned performance. Interoperability and flexibility among systems will continue to be important throughout these upgrades.

Benjamin Weerts, PE, and Rachel Kennedy, EIT, WSP USA, Boulder, Colorado
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Smart building consulting: integrating people and systems

Examine the role of a smart building consultant and uncover the tools and processes used to communicate and work with stakeholders to deliver valuable smart building solutions

A smart building project leverages data from one historically siloed system to another historically siloed system to create new and useful insights, savings, efficiencies and other use cases. If an organization's business and building's systems become integrated, the smart buildings project will create the greatest economic impact.

Smart building consultants organize these types of integrations (that share data between systems) into use cases to help communicate what information is being collected, how it is shared and how it can be used in the next system that will benefit from this new information.

To integrate building systems, which have historically been siloed and separate, the smart building consultant first needs to integrate people, who are also historically siloed and separate. It is often more challenging to integrate people by effectively communicating than it is to detail and integrate a system using technical means and methods. The true feat is securing alignment with these separate groups of people, who are used to doing separate things in separate ways, to deliver something new together.

Who is the smart building consultant?

Historically, there have been building control "integrators" in the industrial era of building design and construction; they primarily dealt with the physical integration of building systems. Their scope was mainly limited to integrating building systems together, often to enable more useful methods of control for occupants and operators.

This entity has evolved to meet the needs of the digital age and can be understood as the smart building consultant. The term "smart building consulting-specifying engineer" makes more sense for this role because the framework that smart building consultant works in, along with their tools and the methods of delivery, all stem from the proven model of a consulting-specifying engineer. The smart building version of this engineer is the response to our increasingly digital world. By nature, the role of the smart building consulting-specifying engineer is different and is something that some stakeholders on a project might not be used to yet.

Designing smart buildings

The smart building consultant looks at how an organization communicates, both within the actual business of the organization and within the building. The portions of the project that relate most to the consulting portion of the smart building consultant's role is the planning stage and the operation stage, which are at the beginning and end of a project.

During design, they work as a peer review and regulatory entity, responsible for ensuring the core systems specified by traditional engineers adhere to the specifications and intent of the overall smart building solution. Because smart building solutions leverage data between previously unrelated systems, the smart building consultant needs to act as an oversight entity to ensure that traditional engineers act in more advanced, integrated ways.

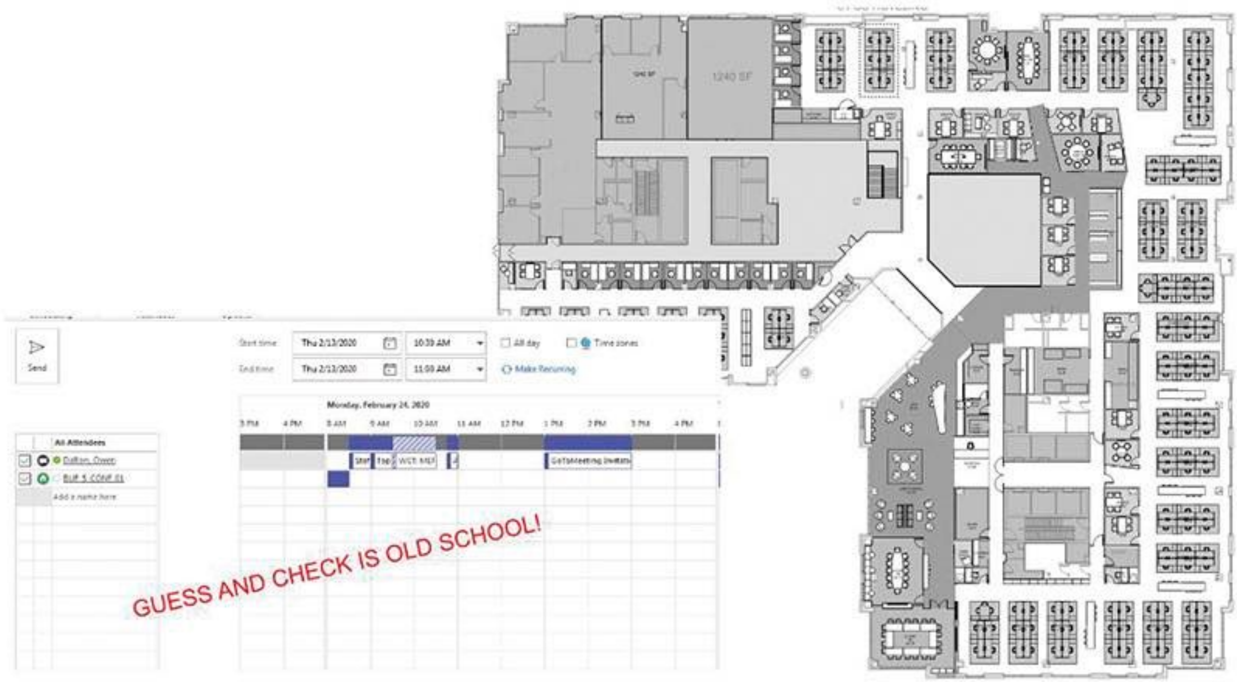

Figure 1: The organization's employees currently schedule a conference room by guessing and checking to see if something is available in the native room scheduling software on a room-by-room basis. Courtesy: CannonDesign

In construction, the smart building consultant also acts in an oversight role, ensuring submittals adhere to specifications, which should adhere to the smart building consultant's direction for digital capabilities and functionalities of the core engineering systems.

The smart building consultant acts as a specifier and an engineer during the design and construction portion of the project. They issue drawings and specifications that trigger a master systems integrator on the construction team to implement the integration sequences as well as provide the smart building software platform. The engineering specification triggers both a service (custom integration) and a product (smart building platform) generally provided by a master systems integrator (service) and a manufacturer (product).

Scope, role and tools

The overall job of the smart building consultant is to help the owner achieve newfound efficiencies, productivity, wellness, communication and connection between the organization in ways that were previously not possible. The smart building consultant helps unleash the power of the inherent data that systems within an owner's building and business are already generating, can generate and inevitably will generate in the future.

Using a true consultant-based approach, the smart building consultant begins by understanding how the organization functions, communicates and operates, by talking through use cases to help communicate sequences and ties between systems as they currently exist, do not exist or could be improved by shared data between one another. As a trusted adviser to the owner, the smart building consultant will help identify, realize and optimize solutions that stem from technology integration between building and business systems.

Planning: The initial stage of a project is led by the consulting portion of the smart building consultant. The goal is to analyze how an organization currently communicates and operates, propose solutions made possible by data interaction and secure alignment around achieving use cases that will enable bottom-line savings. Smart building consultants must have the ability to effectively communicate with different types of people. The tools described below have been developed to assist with communicating the same information to dissimilar people from multiple backgrounds with varying agendas.

Observation: Consultant to the owner's organization as a "fly on the wall" for a period. The goal is to understand the owner's operational structure of the organization. Create communication diagrams that help explain how the organization interacts within the business and within their building systems. Organize findings by energy, real estate and people. Tools include:

- Organizational communication diagrams (people).
- Business system communication diagrams (digital systems).
- Building system communication diagrams (digital systems).
- Use case diagrams (systems and people).

Visioning: Articulate observations to owner. Help envision how these could be improved by leveraging data between systems. Goal is to secure buy-in from owner's stakeholders. Tools include:

- Division 25 master specifications (systems and people).
- Use case diagrams (systems and people).
- Network and system architecture diagrams (digital systems).
- Return on investment analysis (systems and people).
- Integration master plan (systems and people).

Metrics: Define specific metrics and key performance indicators that can be generated from each use case. Keep in mind return on investment as an ultimate measure of success. Depending on the project, metrics will sometimes fall within to the buckets of energy, real estate and people. Tools include:

- Energy model (usage and savings).
- Workplace satisfaction surveys (data and metrics from multiple sources).
- Productivity metrics (clicks to a task or time).

Financial modeling: Energy modeling, real estate appraisals, workplace strategy and space use modeling are all methods to help predict the financial gains seen by increased efficiencies and optimization in energy, real estate and people for an organizations for specific iterations and use cases, as defined by the team.

Design: The smart building consultant's role during the design phase of a project is to ensure the building is designed with the integration goals in mind. Their job is to implement the integration solutions envisioned and agreed upon with the owner during planning. They work alongside the other mechanical, electrical, plumbing and technology engineers as another design consultant on the project, hired in any number of ways; direct by owner is best. As the owner's advocate for the integration vision, the smart building consultant works as an owner's representative, commissioning agent, peer-review and a consulting-specifying engineer in design.

Their scope of work can touch all low-voltage power and digital control systems typically in a building, as well as the enterprise level business systems that help an organization operate. Although they do not typically specify these systems, they provide detailed reviews, direction, control features and sequencing.

As a design engineer focused on data and information exchange, the smart building consultant may need to interact with the enterprise software and management tools governing an organization. Their scope does do not include software development or programming, but it does provide the required direction and specification to support the smart building platforms and subcontractors necessary for programming or development work to bring the integration use cases to reality.

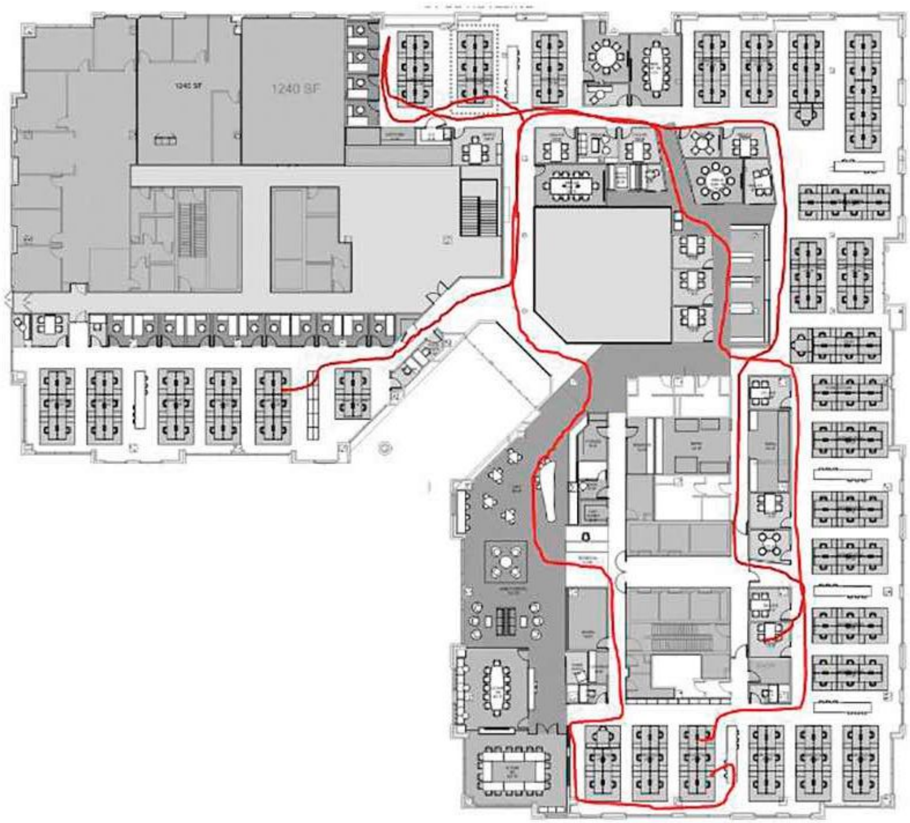

Figure 2: While employees may find a room available for scheduling a meeting in the native room scheduling software, they tend to spend on average 5 to 15 minutes per week searching for a new room to meet in because they walk to the room they have scheduled only to find out someone is using the meeting room who did not schedule it. Courtesy: CannonDesign

They specify in-between or "scope-gap" devices/controllers/hardware/software necessary for added integration capabilities by issuing integration automation drawings and Division 25 specifications. If a necessary hardware component should be grouped into another division, such as electrical or mechanical, the smart building consultant will manage and direct the documentation of the device on the other discipline's documents.

For the smart building consultant to be effective, they need to be involved in the project from all angles.

Therefore, a multidisciplinary integration team helps develop a more holistic understanding of the building and business systems that are being tied together. This diverse team then creates innovative ways to solve digital communication roadblocks.

Use case document

Communication tool: This is a way for multiple people from many different backgrounds interpret the same information. It needs to be simple enough to speak to everyone but detailed enough to convey what is happening, how it happens, why it's important and how it might affect things.

It organizes ideas into specific sequences of operation that can be discussed by dissimilar people so that it is easier for everyone to refer to specific integration instances.

MEPT drawings and specifications review by the consultant: Guidelines are issued to each MEPT discipline regarding control requirements and information exchange criteria. Design reviews of Divisions 22, 23, 25, 26 and 28 ensure criteria is being met through specifiers that are not the smart building consultant. Many of the integration use cases hinge on the success of the relationship between smart building consultant and design team. It helps if the traditional design team has someone dedicated to the control portion of their scope so that they can work as a member of the integration team and serve as a point person for control reviews and collaboration.

Integration automation drawings by the specifier: These can be considered integrated-automation sheets or "I-Sheets" and are used to communicate network architecture, enterprise level integrations and sequence of operations that support the integration use cases. These drawings include:

- Division 25 specifications (specifier).
- Sequence of operations.
- Triggers the who (master systems integrator).
- Specifies the how (execution).
- Specifies the what (master system integrator service and smart building platform products).

Construction: Integration begins as data between previously dissimilar systems begins to exchange. The smart building consultant's scope is Division 25. Their role is to ensure that the sequences and specifications laid out in the bid and construction documents are met and that the building begins to collect, share and use its data in ways that enable the use cases.

The bid review and master systems integrator selection role entails:

- Help the owner, design team and or general contractor interpret and vet Division 25 bids.
- Interview Division 25 contractors.
- Review value engineering process and protect integration critical systems/components.

Construction administration responsibility includes:

- Review building control submittals.
- Review of Division 25 required submittals.
- Conduct regular construction integration team meetings to ensure that integration

use cases and construction related activities, hand-offs and processes are occurring.

Commissioning agent duties are:

- Performance and verification testing.

The owner's representative role is:

- Ensure schedule, budget and functionality are met and delivered.
- Conduct user group meetings within the owner's organization.
- Provide feedback and meaningful actions for use cases made possible through integration.
- Assist in hand-off between manufacturer, representative/support networks, contractors and owner's facilities management team

Helpful tools include:

- An active list of team members and their role and responsibility on the project.
- The schedule of construction-related activities.
- Selection criteria developed for master systems integrator selection.
- A process map issued to the team with integration-specific activities.

Other stakeholders

Depending on the project delivery method, stakeholders can vary. The following can be considered on a typical integration project: owners, designers, builders and manufacturers.

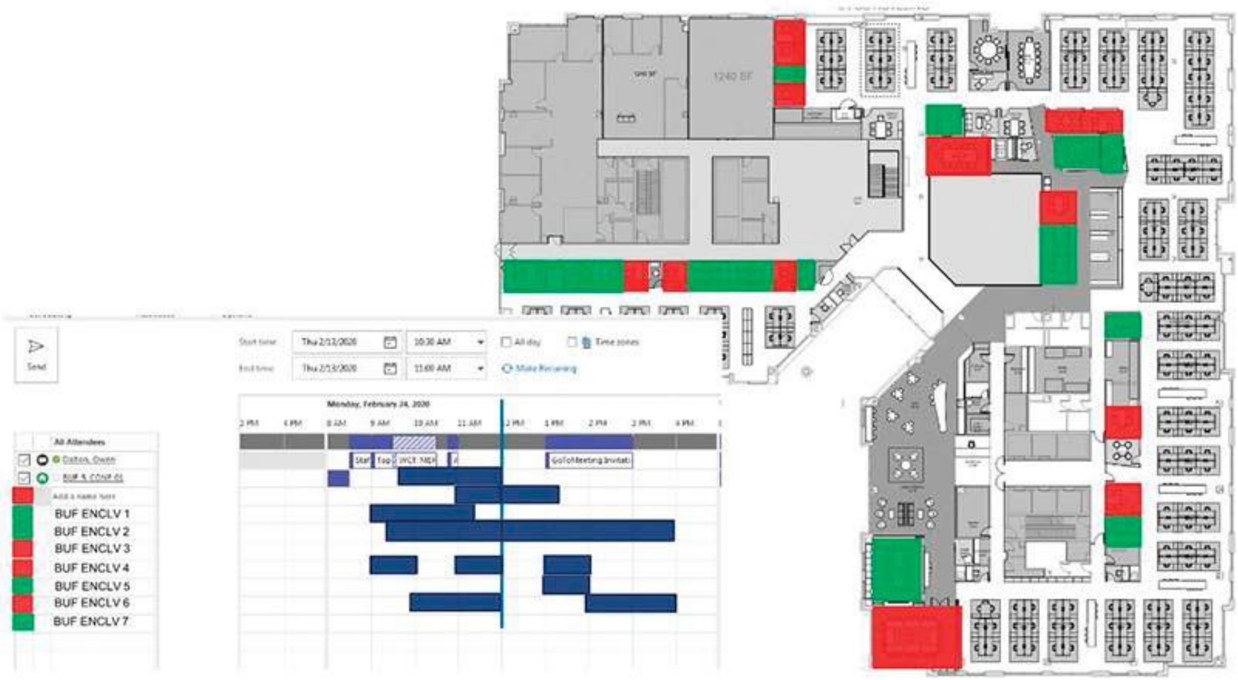

Figure 3: Employees are now presented with an organized view of all potential conference rooms with their current occupancy status, this allows the rooms to be scheduled based on the occupancy information available for ad hoc use. Courtesy: CannonDesign

Owner: Overall entity that owns and operates the building, campus or facility. The owner is responsible for:

- **Business systems:** These are the departments within an organization that are responsible for everyday operations to support the business itself.

- **C-suite:** Chief executive, financial, operations and information officers. If consensus within this group can be found early on, everyone's lives will be made easier for the entirety of the project.

- **Information technology:** Responsible for the hardware, software and network architecture to support the organization's business needs. IT departments are more robust than ever and the role IT professionals in an owner's organization that this group is having is increasing on any given project, regardless of how "smart" the project is. Generally, the IT department functions as the main point of decision-making on the owner's behalf to further the overall goals of the organization. During planning, they provide overall picture of existing network architecture and work alongside the smart building consultant to develop an overall integration plan. In design and construction, they serve as an advisory committee to the smart building consultant.

- **Steering committee:** This might include other interested parties, generally referred to as "program," which are the users of the program space: nurses, doctors, clinicians, teachers, faculty, janitorial staff or everyday building users. It is critical that this group sees and weighs in on the use cases discussed in planning and design because their input will create more valuable and useful solutions.

- **Facility managers:** Responsible for ensuring that the organization's building systems ultimately support the business, they ensure that buildings are safe, comfortable, productive and sustainable. The facility managers will weigh in on many of the use cases and will be major players on the decision-making chain of commands for the owner. Most of the use cases in smart building applications directly influence the productivity and usefulness of the tools that facility mangers interact with on a day-to-day basis. They will need to be on board from the beginning of the project and can be a major advocate if engaged correctly.

- **Project manager:** Party responsible for driving a project forward for the owner.

Designers: Generally referred to as the design team on a new construction or building renovation project, designers might include:

- **Architect:** Generally responsible for delivering the overall project. Sometimes the smart building consultant will serve as a subconsultant to the architect in an overall contract with an owner. It is important that the architect sees value in the smart building consultant and honors the requests and needs of the smart building consultant throughout the project. The architect shall help the smart building consultant conduct user group meetings with the owner's steering committee.

- **MEPT consultants:** Traditional scope and roles still apply to the engineering trades during the design and construction of a smart building project. If the smart building scope falls within the framework of a larger building project, the traditional MEPT trades responsible for Division 23, 26, 27 and 28 shall have additional responsibilities to coordinate their designs with the integration team. It is helpful to have a devoted member in each discipline assigned to take point on all building controls related items. They can serve as the discipline representative on the overall integration team. Similar to how the efforts of a U.S. Green Building Council LEED certified project add scope to the engineering team's plate, a smart building consultant on the design team increases the scope of the traditional engineering trades to adhere to control requirements, specify building systems and control systems which comply with the overall integration team's initiatives and use cases. They are then required to see these specifications through during construction.

- **Smart building consultant:** Refer to the overall scope, role and tools of the smart building consultant.

Builders: Generally referred to as the construction team on a building project. This team is usually organized by a general contractor or construction manager who holds subcontracts directly with specialty contractors and installers. If the project is delivered through a design-bid-build approach, the entity holding the contract with the owner shall ultimately own Division 25, unless this division is subcontracted directly by the owner. This group's goal is to deliver the smart building project within the framework of the overall building project.

- **General contractor:** This party is responsible for the overall delivery of the project. If the master systems integrator is subcontracted to the general contractor, the general contractor is ultimately responsible for meeting the integration requirements outlined in the drawings and specifications. The general contractor needs to be on board and in touch with the integration requirements from the moment they receive drawings and specs to bid on. They should engage qualified master systems integrators to submit bids on the Division 25 scope of work and meet with the smart building consultant and owner to discuss the criteria for master systems integrator selection with the team. It is critical that the general contractor and the master systems integrator are aligned, understand each other's scope and can support the needs of one another throughout the construction process.

- **Master systems integrator:** The success of the smart building project being delivered is directly tied to the capabilities and expertise of the master systems integrator. This is the contractor who is triggered by the Division 25 specifications.

These are true integrators who are experts in communication protocols, custom programming, software development, deployment and servicing. Many of them are partnered with a smart building platform or software manufacturer and serve as licensed retailers of the product while also installing, programming and servicing the sequences specified by the smart building consultant. This entity works hand in hand with the smart building consultant and, together, the two parties ensure the design intent is installed and doing its job before construction is complete. Depending on the use cases, the master systems integrator may need to contract out special web development work or custom programming to the manufacturer of smart building software or another entity who may specialize further in programming and web development.

- **Heating, ventilation and air conditioning contractor:** Responsible for delivering Division 23 on the project as a subcontractor to the general contractor. They are usually responsible for providing the building automation system for the project. The HVAC contractor will work closely with the smart building consultant and master systems integrator to define scope split between Division 23 and 25 required products and services. The HVAC contractor's role during construction is to be the link between the manufacturers of their systems and the master systems integrator. When the master systems integrator requests a BACnet or other protocol points list from Division 23 equipment, the HVAC contractor is responsible for coordinating with their reps and manufacturers and producing this information to the master systems integrator for compilation and submission to the smart building consultant.

- **Electrical contractor:** This team is responsible for delivering Division 26, sometimes 27 and 28. Usually responsible for the electrical energy management system as well as the lighting control platform, these two systems are commonly involved in integration sequences and require close coordination with the smart building consultant and master systems integrator. The electrical contractor's role is to be the link between the manufacturers of their systems and the master systems integrator. When the master systems integrator requests a BACnet points list from Division 26 equipment, the electrical contractor is responsible for coordinating with their reps and manufacturers and producing this information to the master systems integrator for compilation and submission to the smart building consultant.

- **Low-voltage contractors:** Responsible for delivering Division 27 and other specialty low-voltage systems, their role is to serve the needs to the master systems integrator and smart building consultant, working in similar ways to link between manufacturers and integrators.

- **Commissioning agent:** Responsibility includes ensuring the design intent is met, both functionally and performance-wise. Can be contracted into the project a variety of ways.

- **Smart building consultant:** Refer to the overall scope, role and tools of the smart building consultant.

Manufacturers:

This group manufacturers the hardware and software products that go into a building.

- **Smart building platform:** Generally, the difference between the building automation system and the smart building platform is that the BAS is designed for and

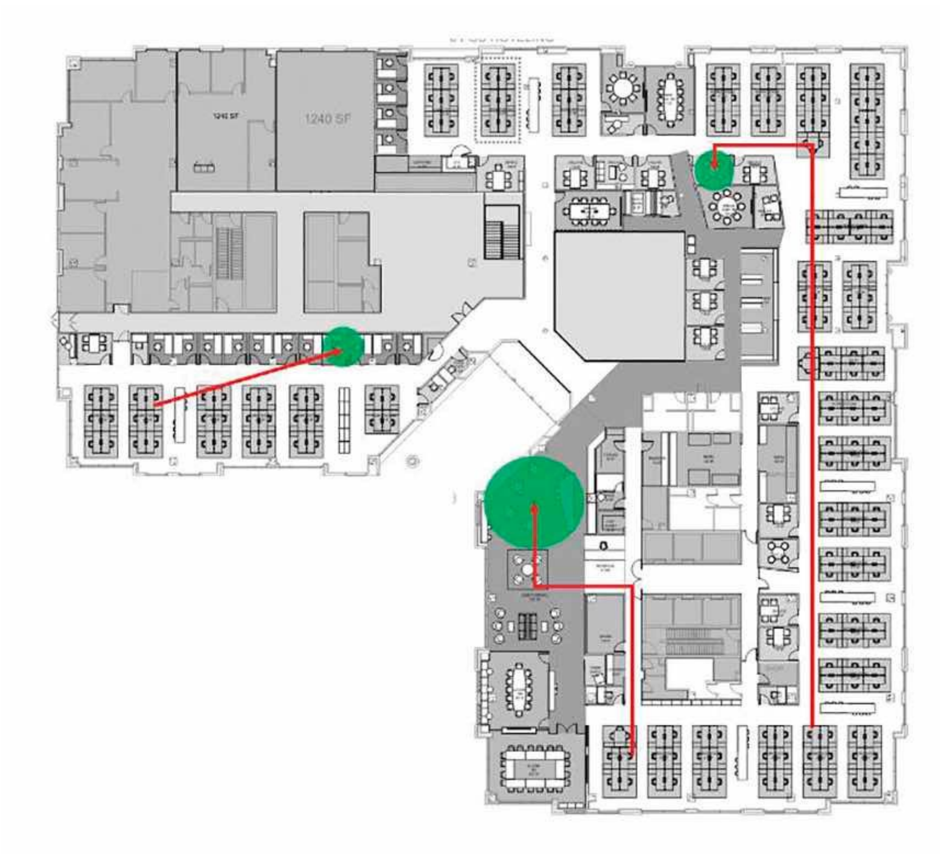

Figure 4: Employees are estimated to save an average of 5 to 15 minutes per week due to the new efficiencies in finding a place to meet and work enabled by the lighting control system working collaboratively to report occupancy status to the native email and room scheduling platform. Courtesy: CannonDesign

works best when used to control and operate the energy management and HVAC systems in a building where as the smart building platform enables more efficient user interfaces and dashboards and provides a space for fault detection diagnostics, advisory controls and building analytics. The smart building platform is the tool that will take a smart building that connects systems to enable integration use cases to an intelligent building that predicts and advises the organization based on machine learning using data tomorrow. Smart buildings are connected systems with sequences written by humans. Intelligent buildings deploy sequences written by machines that learn from historical trends.

- **Building automation system:** This product serves as the main control tool for the owner's facility management team. The BAS consists of distributed digital controllers that communicate using common building communication protocols with one another and other systems through integrations and programming done by the master systems integrator and the HVAC contractor.

- **Lighting, electrical and energy management systems:** These control systems generate a tremendous amount of valuable data and are used and relied on in every day integration sequences. These manufacturers need to have common data tagging abilities, the ability to custom program and offer a variety of storage and data exchange capabilities to keep pace with the demand of an increasingly digital world.

- **Business systems:** These are the makers of the enterprise level software that organizations use every day to operate their core business. They take the form of things like email, company social media platforms, customer relation management software, on-premise data storage platforms, cloud data storage platforms, etc. The master systems integrator shall work closely with the smart building consultant and the owner's IT department to interact together as a team with the business system manufacturers. These manufacturers will be involved in integrations requiring data exchange between their systems and between building native systems.

Owen Dalton and Sal Bonetto

Owen Dalton *is trained as a lighting designer and electrical engineer. He is helping grow Cannon Design Integration Services, a smart building consulting group at CannonDesign.* ***Sal Bonetto*** *leads the technology services group at CannonDesign.*

Case study: Office building's smart potential

An office building renovation project included a host of considerations to retrofit the space into a smart building

Contracted directly by the owner, the smart building consultant was involved in the planning, design and construction of a 30,000-square-foot office renovation project. To provide the best value to the owner, the smart building consultant delivered the smart building project within the framework of the overall construction project.

The concept is simple, shared data between traditionally siloed systems can make the entire ecosystem smarter, more informed and useful. In this project, lighting control data is communicating back and forth to the building automation system and to core business systems, allowing the organization to use data to make their employees happier, healthier and more productive.

Smart building planning

Observation: The consulting arm of the smart building consultant specialized in workplace strategy and took a deep dive into how the organization communicated and worked in its existing physical environment.

Visioning: The organization revisited many of its core values when weighing the commitment to pursue smart building applications. As the owner's values aligned with many of the initiatives that the smart building consultant was proposing, specific use cases were developed based on the observations of the workplace strategy team. Ultimately, the smart building consultant secured buy-in from the owner with the under-

standing that the true return on investment of these solutions would be realized during operation.

Figure 5: Visioning sessions with the owner and design team helped identify the client's goals and helped the smart building consultant identify opportunities for enabling better use cases and smart applications on the project. Courtesy: CannonDesign

Metrics:

- Productivity.
- Efficiency.
- Improvement and learning.
- Wellness.
- Appraisals.

Financial modeling: Cost estimating was performed for each use case. Below is an example of how this was presented for the lighting control informs room scheduling use case.

Design of integrated systems

Use case tool: This tool provided helpful organization of integration sequences and smart building applications that everyone could discuss and discover. It became a guide for the team moving from visioning through design and into construction. Sorting use cases into energy, real estate and people helped the team identify the highest value solutions for the organization.

Energy efficiency (1 times value):

- **Lighting informs heating, ventilation and air conditioning:** Notification of occupancy status from the lighting control system triggers occupied or unoccupied sequence of control in the HVAC system for that room or zone.

Building performance (10 times value):

- **Room scheduling informs HVAC:** The HVAC system preheats/precools room 15 minutes before meetings start time based on accepted number of occupants as load setpoints versus design day setpoints.

People efficiency/human wellness (100 times value):

- **Lighting informs room scheduling:** Occupancy status from the building automation system feeds enterprise-level email and room scheduling application with real-time occupied or unoccupied status. The room scheduler displays real-time status as users interact with room scheduling tool.

- **Circadian rhythm lighting:** The lighting control platform initiates a correlated color temperature shift of tunable white power over Ethernet luminaires in relation to date and time.

- **Space use studies:** An HVAC zoned control adjusts setpoints based on actual occupancy versus design day occupancy conditions. The building automation system collects and stores trend data for every 15-minute interval for at least one year.

Smart building responsibilities

Mechanical, electrical, plumbing and technology drawings and specifications review (consultant):

- PoE lighting: A PoE lighting and control system was determined to be of highest value to support the integration needs of the project; it also aligned with the owner's core values. The smart building consultant helped steer the design team through the entirety of the cross-disciplinary lighting system, with hardware and software specified from both Division 26 and 27.

- Division 23, 26 and 7 review: The smart building consultant coordinated requirements and reviews of these sections to comply with integration criteria.

Integration automation drawings (specifier):

- Integration drawings were issued to communicate design intent.

Division 25 specifications (specifier):

Specifications were issued to communicate products and services required to deliver the smart building solutions.

Construction is currently underway on this project and the smart building consultant is working to help deliver the use cases and smart building solutions identified above.

Owen Dalton and Sal Bonetto

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Smart Buildings

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