SMART BUILDINGS

WINTER EDITION

CONSULTING - SPECIFYING engineer eBOOK

Reliable controls

Contents

3 — Five steps to BAS replacements

12 — Engineering with automated fault detection and diagnostics

26 — The Art of Building Sustainability

36 — Deliver smart buildings using CSI Division 25, commissioning

51 — Tap into a building automation system's data and maximize investment

56 — VIDEO: Designing smart buildings with Aaron Szalaj

Five steps to BAS replacements

Replacement of building automation systems can follow the process and precision of medical surgery

A building owner or facility team may be interested in fully replacing the facility's building automation system, but the engineering consultants and owner have concerns and fears surrounding potential complete facility shutdowns or interruptions of critical processes. A surgical BAS replacement can help allay these concerns and keep a facility operational while the automation infrastructure is modernized.

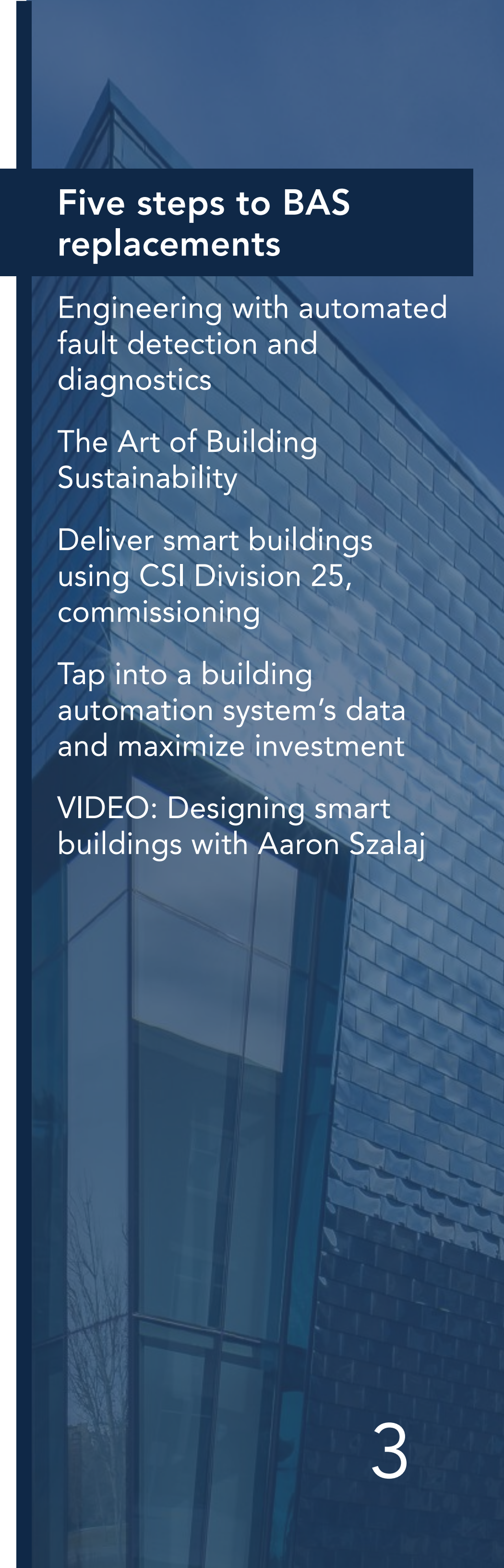
Similar to a delicate organ transplant, a BAS replacement requires a surgical level of precision to be successful. Facilitating the transition from an outdated, problematic system to a modern and sophisticated system while managing (or even eliminating) downtime of the controlled equipment should be the goal.

Here are some design considerations and approaches that can be used to support the next BAS replacement.

1. Vision for the building automation system

Before planning, it is essential to determine the overall vision for the facility and commit to this vision. What long-term goals do the stakeholders have for the facility? What is the current culture and/or mindset as it pertains to energy management and maintenance? What is the current culture surrounding information technology and cybersecurity?

Similar to how an organ replacement can fail if habits of misuse aren't supplanted by healthy patterns of behavior, poor maintenance and management can sabotage even



Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

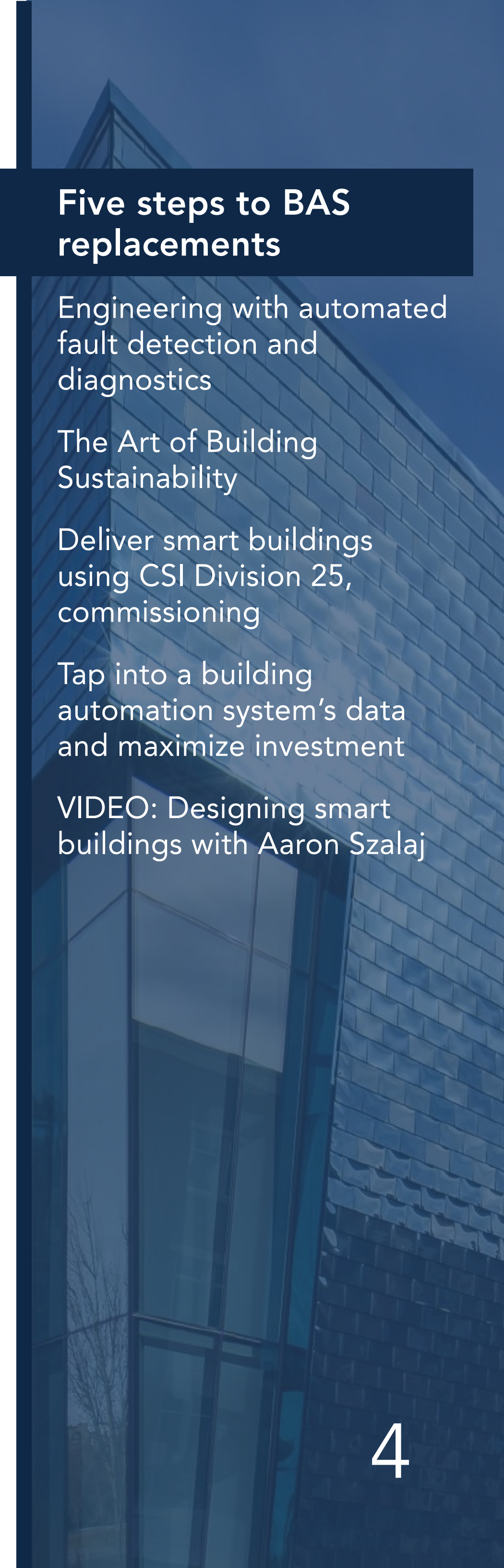
the most advanced and skillful BAS installations and replacements. Vision should begin with an honest assessment of the present before looking to the future.

It is estimated that approximately 40% of a commercial building's energy usage comes from its HVAC system. Currently, the United States has a goal of reaching net zero carbon emissions by 2050. A BAS replacement in and of itself will not lead to achieving higher efficiencies.

That said, synergy does exist between better energy management and BAS replacement upgrades. Newer hardware with IP connectivity allows for interfacing with more data points using the "internet of things," which, in turn, creates opportunities for more precise monitoring and control. Properly programmed analytics and fault detection diagnostics also help steer a BAS toward improving and maintaining energy metrics. The vision of a facility should not stop at avoiding penalties within the next five years, but for decades to come.

Embracing standards makes planning out the vision for the facility easier over time. If these standards are functions of expected business outcomes and key performance indicators, then they make future installations, upgrades or optimization opportunities seamless, regardless of which BAS vendor is chosen to execute the work. Information on how to get started on these efforts is readily available.

For example, after evaluating lessons learned from the existing installation (with input from in-house engineers), consider how the team will incorporate opportunities to improve upon future graphics that will make training next year's operator easier and steer the organization closer to the goals set.



Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

Many patients perform extensive research on the characteristics of the surgeon set to orchestrate their procedure. This mindset should also be applied when gauging a company's ability to perform a BAS replacement. The evaluation process should dig deep into details such as: How readily available is the new hardware the company supports? What are the average lead times for supervisory controllers? How many vendors locally and abroad support the product? What is the size and longevity of the company in question to facilitate the BAS replacement? Pay close attention to the operating system requirements of more modern BAS hardware as well as server requirements.

An insurance commercial comes to mind where the doctor approaches a patient sitting on a hospital bed and asks, "Are you nervous?" The patient shakingly replies, "Yeah." The doctor then replies, "Me too. Good luck out there," and pats the patient on the shoulder.

To avoid this kind of scenario, as part of the project bid, a facility owner should request references to prior projects with similar or greater complexities and scope. Keep in mind that a surgical replacement for a commercial office building comes with a very different set of challenges and consequences than one for a data center or hospital.

Another key item to consider when documenting the present status of the facility is critical spaces or processes served by legacy control systems. A detailed report by the facility management team should include the exact location of those spaces, schedules of occupation and any special equipment required to heat, cool or maintain pressure in those spaces should the control system be inactive. The contingencies within this report should be revisited every time changes are made to these critical spaces. Where redundancy exists with cold standby (N+1) or hot standby (all equipment running),

Five steps to BAS replacements

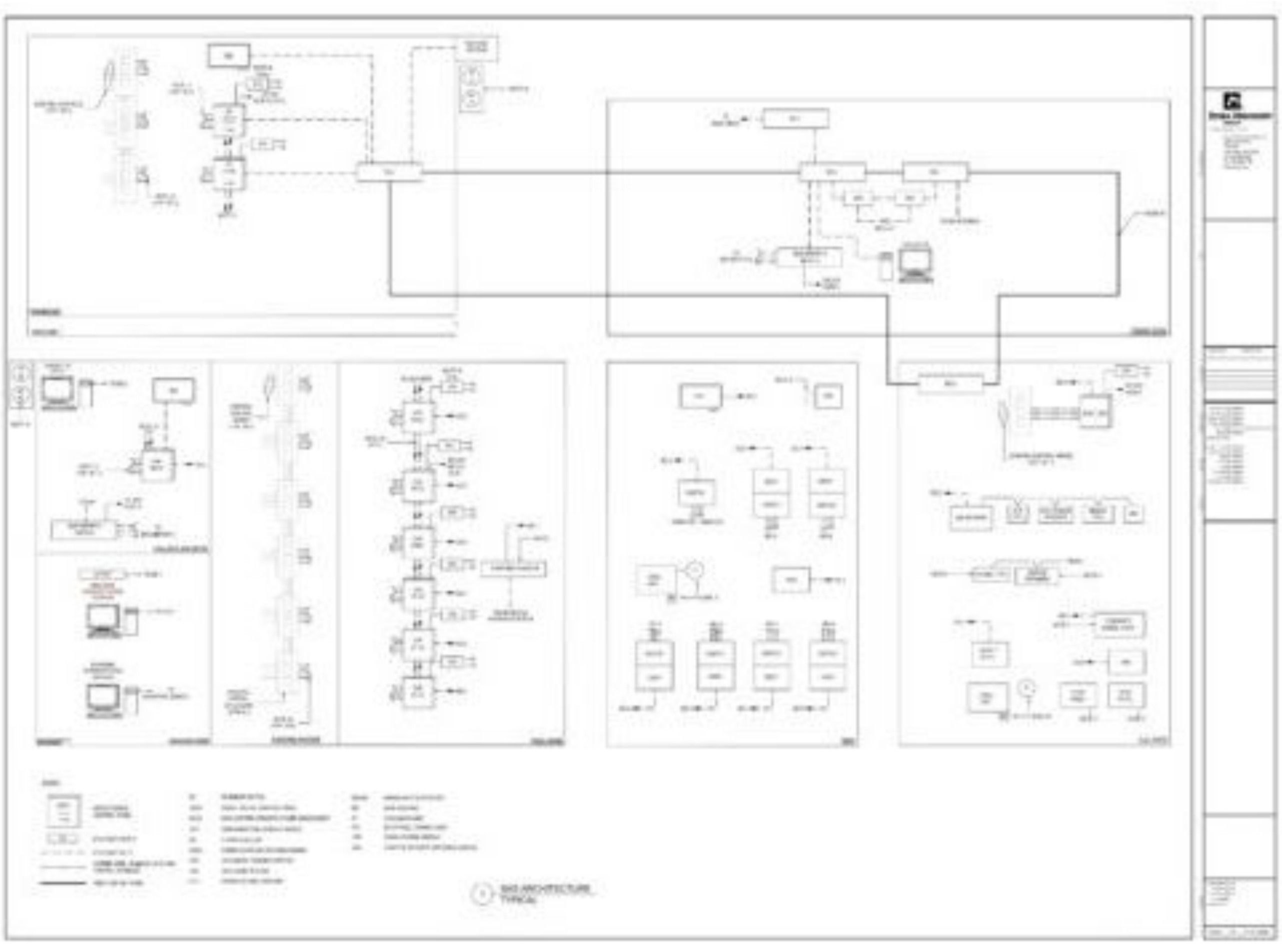
Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj



Building automation system surgical replacement design. Courtesy: Syska Hennessy Group

rotations and failure scenarios should either be part of a maintenance program, or their functions should be witnessed from the existing BAS in automatic mode.

The vision should also encompass the expected involvement of a facility's IT department. This would include provisions for cybersecurity screening of the installing contractor's current product line as well as its corporate cybersecurity standards. The IT

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

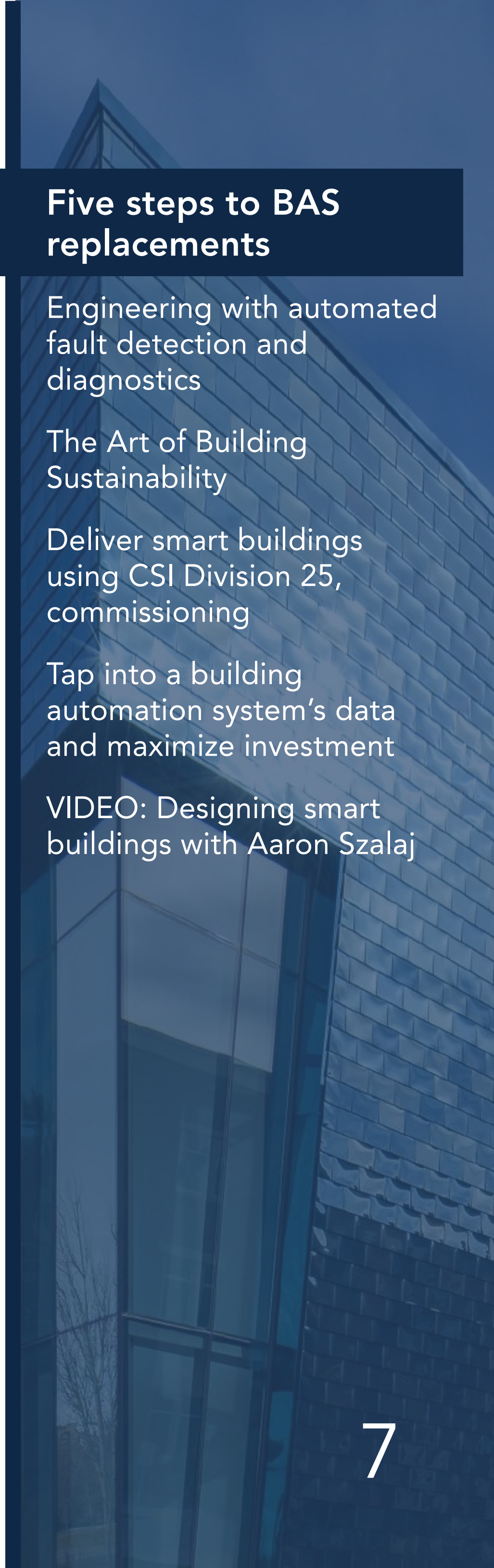
company's involvement should also aim for coordination with any future vendors so that a new building automation server can be installed and set up alongside the existing legacy equipment server before any new controllers are installed. A separate network for the operational technology devices should be created and internet protocol addresses should also be prepared in advance.

As part of the standard, supervisory and terminal unit controllers should be expected to be preprogrammed before arrival on-site. An opportunity may exist to have programming updated to the latest ASHRAE Guideline 36: High Performance Sequences of Operation for HVAC Systems. Graphics and simulation bench-test reports for controllers set to replace those serving critical processes should be provided for review by the operations team.

2. The BAS checkup

Universally, before a surgical procedure, a series of checkups and evaluations are required to understand the overall health of an individual and subsequently decrease complicating factors that could negatively impact the effectiveness of surgery. Similarly, the overall health and condition of the BAS should be assessed to document and consider correction to issues that could cause more harm than good for the new system.

Safety: Safety should be the No. 1 priority when evaluating a site for a BAS replacement. Do sensor cables exist in the same troughs or conduits as high-voltage wiring? What is the current condition of the control panel, starter and variable speed drive enclosure real estate? These questions must be addressed: Electrical hazards cause 30,000 non-fatal shock incidents and 1,000 deaths each year among the U.S. workforce alone.



Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

From the consultant's perspective, an opportunity exists to have hazardous panels replaced in alignment with a building standard that formalizes performance expectations and protects operating personnel from bodily harm. This goes beyond a typical "reuse existing" design keynote and should be part of a due diligence walkthrough.

As-built documentation: Poor as-built documentation can serve as a barrier to the successful execution of a surgical BAS replacement. Which control panels serving critical equipment have their dedicated power sources? Which ones have redundant power sources? Do sensors exist that are broadcast across the automation network? If so, would taking their associated panels down for a replacement create a ripple effect of issues for other equipment that must remain in operation? What are the current sequences in place?

Inaccurate as-builts make these questions difficult to answer and can create unanticipated change orders. It is not uncommon to find the answers to key questions on as-builts taped to the interior door of an existing panel enclosure.

Stability: The condition of the existing instrumentation made available to a surgeon is of paramount importance. The consultant's approach to using either existing sensors, existing cabling or some combination of the two, must be taken very seriously. In addition to probable deterioration of the incumbent equipment due to age, legacy BAS installations tend to come with legacy sensors, some of which have antiquated control signals not used by modern control systems. Some additional items to take into account:

- The verification of current wiring integrity (Is solid core wiring in place for sensors?).

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

- Will the controlled equipment accept standard 0 to 10 volts direct current, 2 to 10 volts DC, 4 to 20 milliampere or 0 to 20 milliampere control signals?

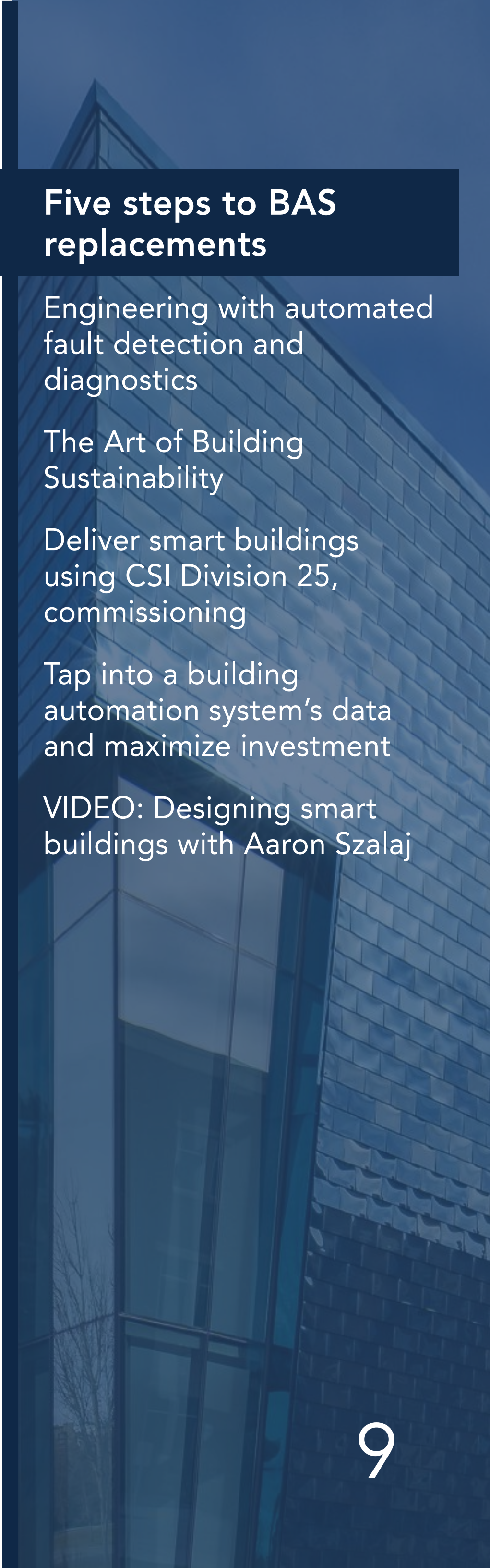
- Integration in place: Some legacy systems use discontinued protocols that may require the use of a protocol conversion gateway to access. The same can be said for variable frequency drives.

- Do the current thermistor and/or resistance thermal device (RTDs) types conform to building standards?

These items can also be packaged as part of a proper due diligence report for review and remediation. Take for example steam boiler burner controls. Some come with modulating actuators that require a 0 to 135 Ω control input to vary the burner firing rate. Typical direct digital controllers do not come with this feature, so a converting module may be required or complete replacement of the actuator should the project budget allow.

3. Building automation system prep

The upkeep and environment of an operating room are set before a surgeon's arrival. With all critical spaces properly identified and contingencies prepared, a sample schedule should be put together in Gantt format for reference as part of a BAS replacement plan. This should include sections for start times, anticipated downtime and any coordination required with the occupants of the space or those affected by its downtime. This allows the facility personnel to be prepared for weekend work or the triggering of the use of process control contingencies outlined above.



Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

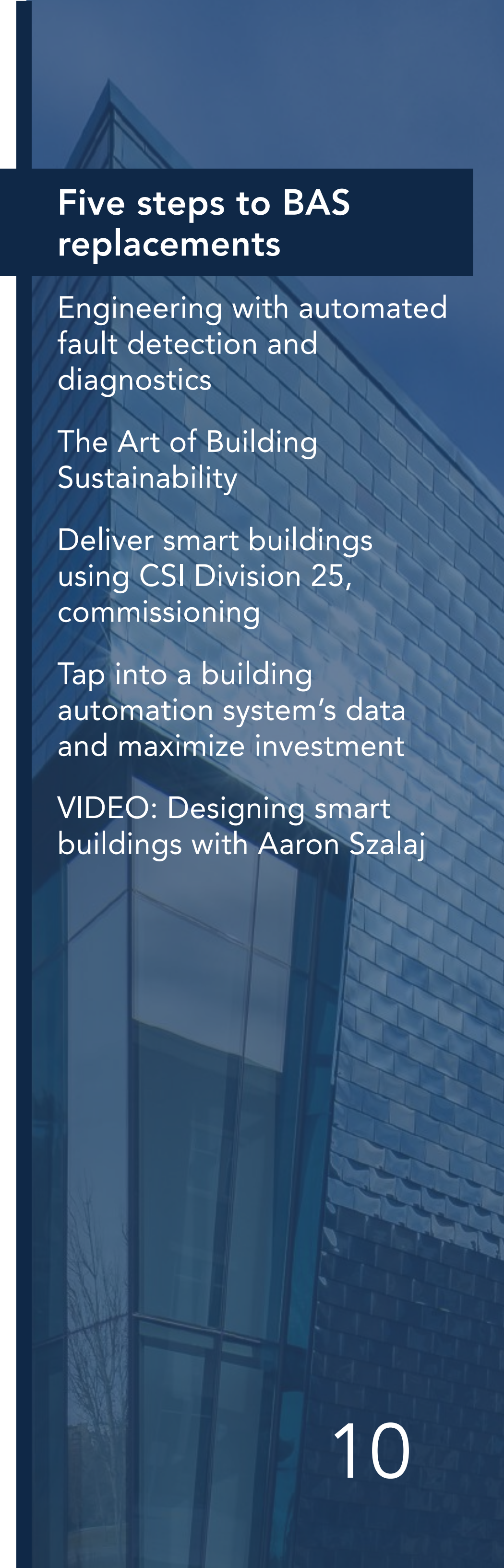
Where applicable, standard documentation should have sections allocated to recording the conditions of the room or process (temperature, pressure, humidity, valve positions, damper positions, etc.) before any work commences. This will provide a baseline for comparison post-replacement.

4. BAS replacement

The BAS replacement process is a very delicate one and requires a peak level of focus. The vendor performing the work must be given the room to operate with minimal interruptions. If there is a service contract in place and other equipment requires attention, a separate technician should be called on to address issues outside of the replacement scope.

Complications during any procedure are a reality that must be accepted and a good technician knows how to communicate when these situations arise. There are certain existing issues that would only be discovered while in the middle of the actual process and some contingencies — no matter how well-thought-out — are not enough to correct them. Dialogue between the technician executing the work and the personnel facilitating it will then cover which matters are critical and must be addressed immediately and which are not.

Upon controller replacement, the point-to-point checkout must be thorough. This process should encompass testing of the instrumentation as well as the sequences (both at the equipment level and the integrated automation level). Once complete, it is up to the facility to decide whether to involve third-party commissioning. Keep in mind that a vendor-agnostic approach to validating the operation of the new BAS hardware provides additional assurance that the surgical replacement was successful.



Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

Updates of the as-built documentation should be verified and include updates to network topology. This information, along with the point-to-point checkout report and commissioning forms, should be filed for review, approval and future reference.

5. Follow-up and analytics

Post replacement, a follow-up should proceed in a fashion similar to a post-surgery checkup. If the new BAS platform has analytics and fault detection capabilities enabled, the activity of comparing performance against the building's standards can become a continual process.

Some say that the BAS acts as the eyes, ears and hands of a facility. Regardless of the organ chosen for comparison, all can agree that proper functionality before and after a replacement is critical. Approaching a BAS replacement with a surgeon's precision can make a procedure once surrounded by fear a process to be embraced with confidence.

Christian Nazon, PE, CEM, Syska Hennessy Group, New York City.

Christian *is a lead building automation systems engineer at Syska Hennessy Group with multifaceted experience in the design, construction project management and installation of environmental controls, energy management and mission critical control systems.*

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

Engineering with automated fault detection and diagnostics

Building engineers and commissioning professionals can use automated fault detection and diagnostics, which has been more commonly used to save building energy and facilitate predictive maintenance

Large commercial buildings are equipped with dozens of air handling units and hundreds of terminal boxes that maintain acceptable indoor air quality and occupant thermal comfort. Building operators are typically buried in the heating, ventilation and air conditioning system data, and mostly react to occupant complaints, equipment/component failure or various levels of building automation system alarms.

Automated fault detection and diagnostics, or AFDD, serves as a promising solution to process the big data flowing from the BAS and efficiently monitor the HVAC system operation with limited manpower.

AFDD has been an active area of HVAC application research and commercial development in the building industry for decades. AFDD is a two-step process that automates the detection of faults and the diagnostics of their causes. Studies have documented and validated the economic benefit of AFDD. Experts from Lawrence Berkeley National Laboratory analyzed the annual consumption data before and after the implementation of AFDD technologies and concluded that 26 organizations that use AFDD across 550 buildings and 97 million square feet achieved median savings of 8%.

Initiated by the Department of Energy, the Smart Energy Analytics Campaign was a four-year public-private partnership to expand the use of energy management and

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

information systems and ongoing monitoring practices in commercial buildings. The campaign participants, including 104 commercial organizations across the United States totaling 567 million square feet of gross floor area and more than 6,500 buildings, achieved a median savings of 9% after using AFDD for only two years, close to the median savings of 8% in the previous research.

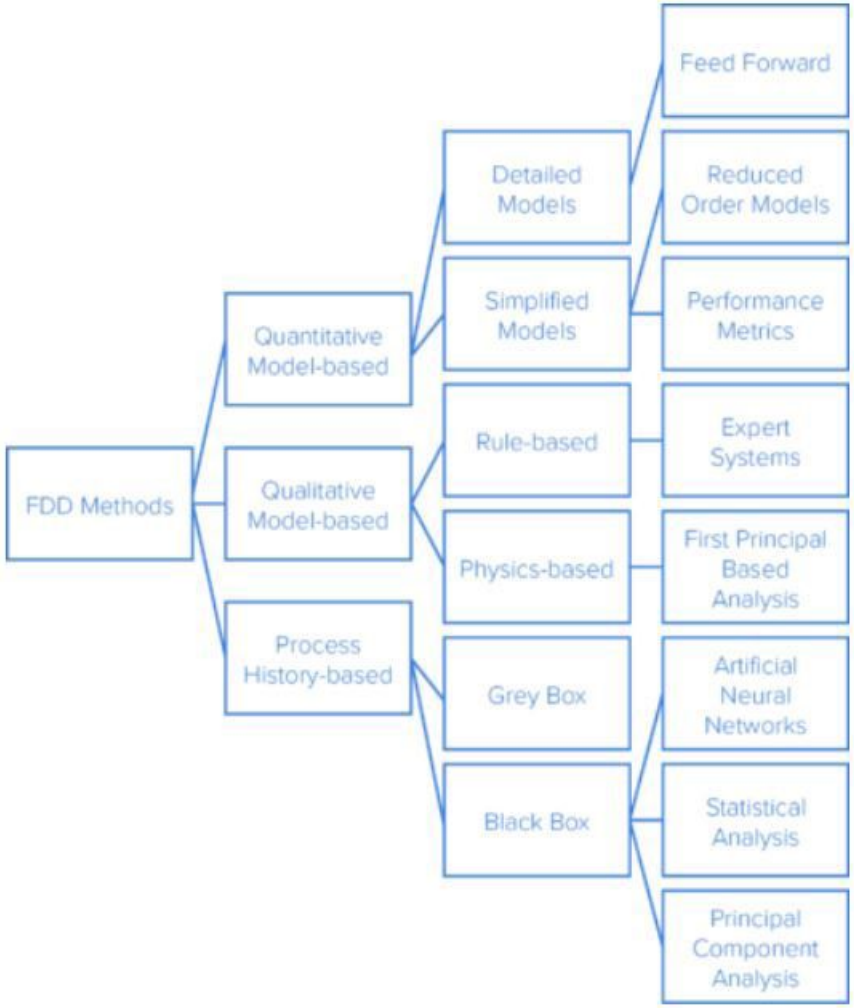


Figure 1: Here is an overview of fault detection and diagnostics methods and algorithms. Courtesy: Smith Seckman Reid

Not limited to energy savings, AFDD technologies can also prevent energy performance degradation over time, support various commissioning processes, improve operational efficiencies and facilitate predictive maintenance, which contributes to increased equipment life, improved reliability and lower labor cost.

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

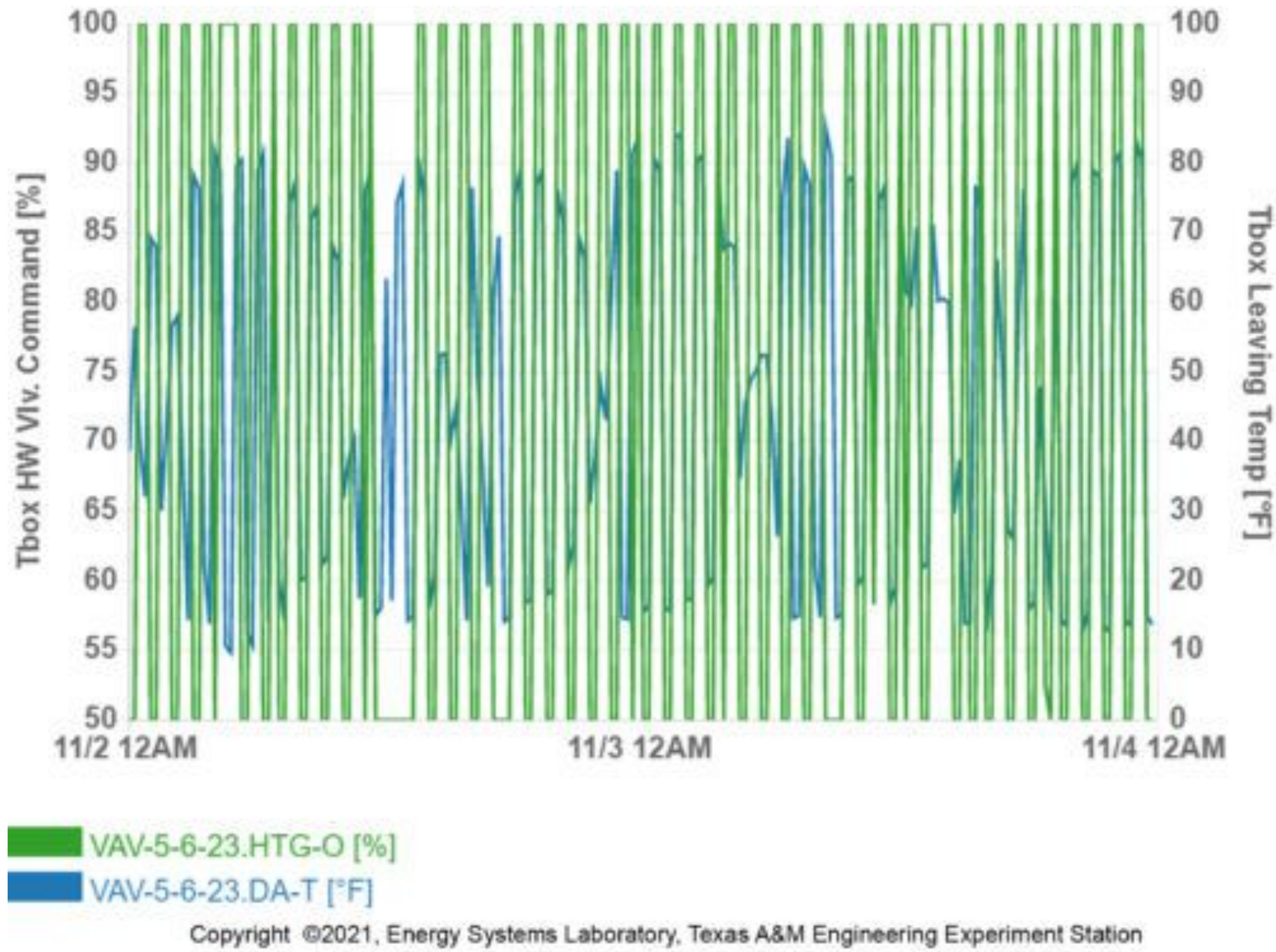


Figure 2: An example of a terminal box hot water valve hunting issue detected by statistical analysis. Courtesy: Texas A&M Engineering Experiment Station

There is agreement about the importance of AFDD in on-going commissioning facilities management to avoid building energy performance drift. But other commissioning activities are currently still performed manually as labor-intensive and undefined processes. As HVAC systems grow more complex, the effort required in commissioning will increase, as well as the cost.

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

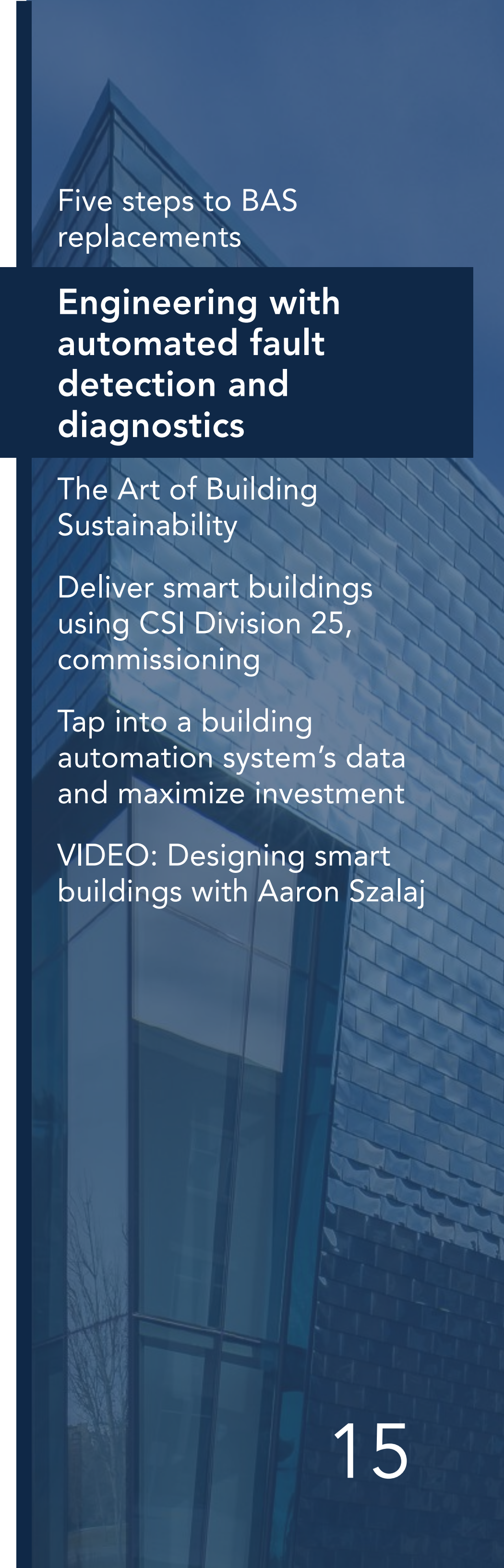
VIDEO: Designing smart buildings with Aaron Szalaj

Eventually, an automated life cycle commissioning process becomes necessary — AFDD technologies could be deployed in all possible commissioning phases, including new construction commissioning, re-commissioning, retro-commissioning and ongoing commissioning or monitoring-based commissioning. Ideally, AFDD tools should be applied at the initial commissioning phase to ensure that the systems are performing optimally, then it should be applied at the on-going commissioning phase to ensure that they continue to do so.

Fault detection and diagnostic methods

A great diversity of techniques adopted in AFDD tools range from those based on physical and analytical models to those driven by analysis of historical trend data. Figure 1 details the main fault detection and diagnostics methods/algorithms and subcategories based on the comprehensive review of FDD applied to HVAC systems. The following criteria are used to determine the feasibility of FDD methods:

- Embedded into existing systems.
- Proven from field/pilot tests on real buildings.
- Minimize the number of false positives to build user trust in the system.
- Rolled out in a cost-effective manner.
- Generic enough to allow for large-scale implementation that is independent of platform/system.



Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

Although rules-based models may require developing complex or bespoke rules, it is relatively easy to develop and implement an effective rule set as well as expanding the ruleset continuously. Analogously, simplified models may require considerable initial analysis, but they can be used for both system and component level analysis effectively. Conversely, process history-based models require a large amount of data to set up and tend to lack accuracy. Therefore, among all FDD methods, simplified models and rule-based models have the highest potential for market deployment in the short to medium term.

Furthermore, it is proven that an effective combination of FDD methods will improve the accuracy and capability of AFDD. Some data-driven techniques, such as artificial neural networks and statistical hypothesis testing, need to be used in conjunction with physics-based models to improve accuracy; expert systems together with simplified physical models cover a larger range of faults. For example, Figure 2 shows an example of a hot water valve hunting issue detected by statistical analysis.

AFDD tools

Today's market offers dozens of full-featured AFDD tools. According to a study on 14 currently available AFDD tools, most of them use limits, alarms and rule-based algorithms with a combination of first principles. The wide variety of AFDD tools available is also a result of AFDD vendors being flexible to develop various features customized to meet market needs. AFDD tools are mostly web-based or cloud-hosted software, which allows scalability and dynamic upgrades.

The majority of the AFDD tools cover most of the HVAC components and systems including central plants, AHUs and terminal units, and a wide range of faults, such as

Five steps to BAS replacements

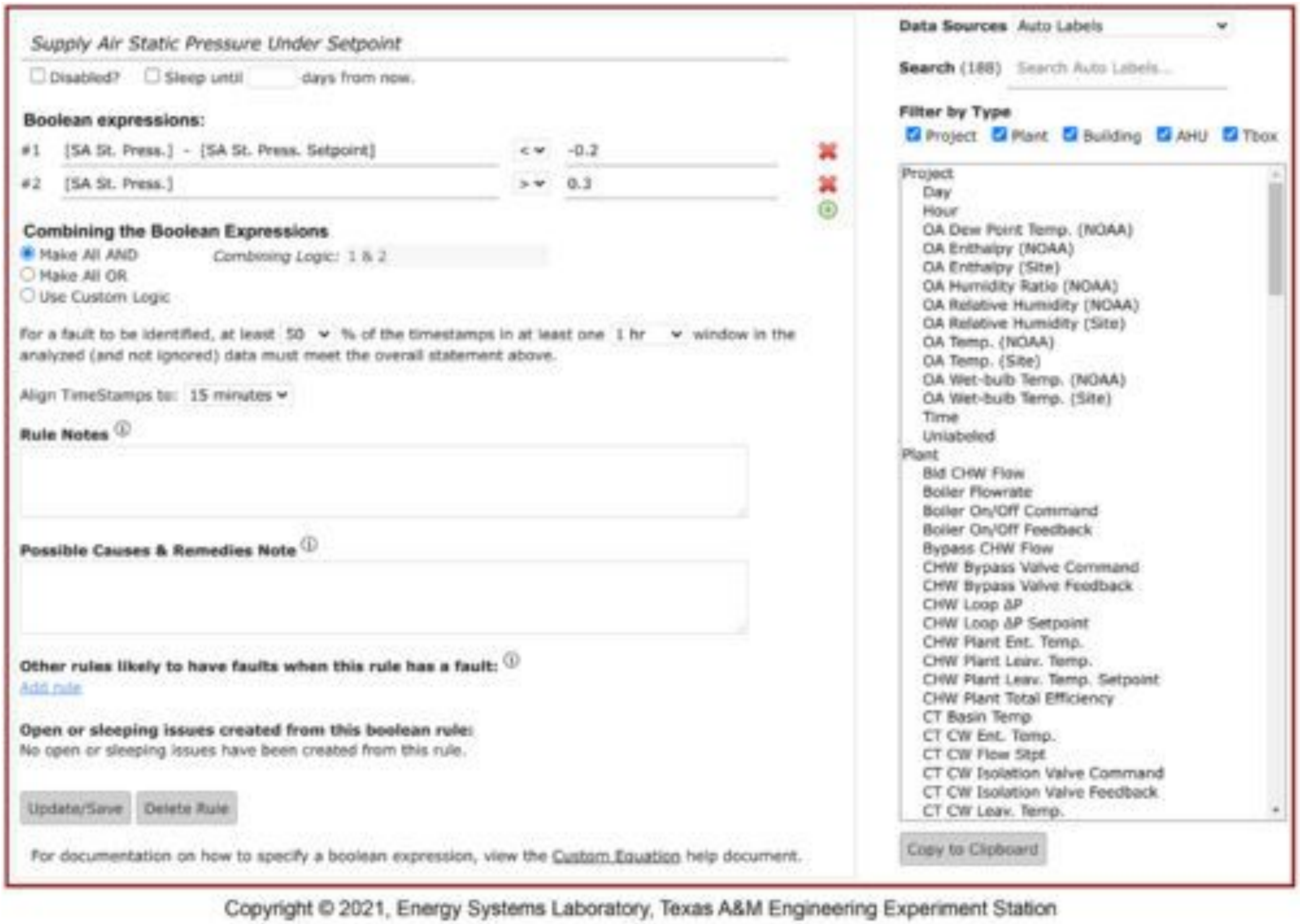
Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj



sensor error, valve hunting, simultaneous heating and cooling, deviation from setpoints, etc. Studies show that the coverage of systems and faults is driven more by building trend data availability than by AFDD product offering Also, while rule-based methodologies are still the norm, vendors are beginning to adopt process history-based techniques.

Figure 3: Here is a snapshot of the Implementer rule creation page where the rule of "supply air static pressure under setpoint" is created using Boolean equations. Courtesy: Texas A&M Engineering Experiment Station

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

Take Implementer, an AFDD tool designed by the Energy Systems Laboratory at Texas A&M Engineering Experiment Station to be part of the Continuous Commissioning process, for example. Rules are created to confirm the proper operation of the HVAC systems.

Figure 3 shows that a rule is created to check if supply air static pressure meets its setpoint. Once the FDD rules are executed, the triggered rules are listed separately in the spreadsheet for review. Figure 4 shows the triggered rule of "supply air static pressure under setpoint." Among the useful hyperlinks available in the AFDD spreadsheet, the time series plot of relevant trends can be used for further analysis. Figure 5 provides a snapshot of the time series plot interface where the users can add/drop various trends and view the plot in different dates.

The costs of AFDD projects are modest compared to capital projects. The Lawrence Berkeley National Laboratory report summarizes the ranges and median of the base cost, annual recurring tool cost and annual labor cost (internal staff or contracted) across 27 organizations using FDD. The median base cost for FDD software installation and configuration was $0.05/square foot and the median annual recurring software cost was $0.02/square foot. The median annual labor cost was $0.05/square foot. A median total cost would be roughly $0.12/square foot for a one-year AFDD service contract and the average annual cost goes down for a multiyear contract.

AFDD tools are commonly delivered with many additional functionalities. Typical features are time series visualization and plotting; quantification of energy impacts and cost management and fault prioritization; and automated work order request system integration, metered data analytics, etc. These supplementary features are "free" and add extra value to AFDD tools.

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

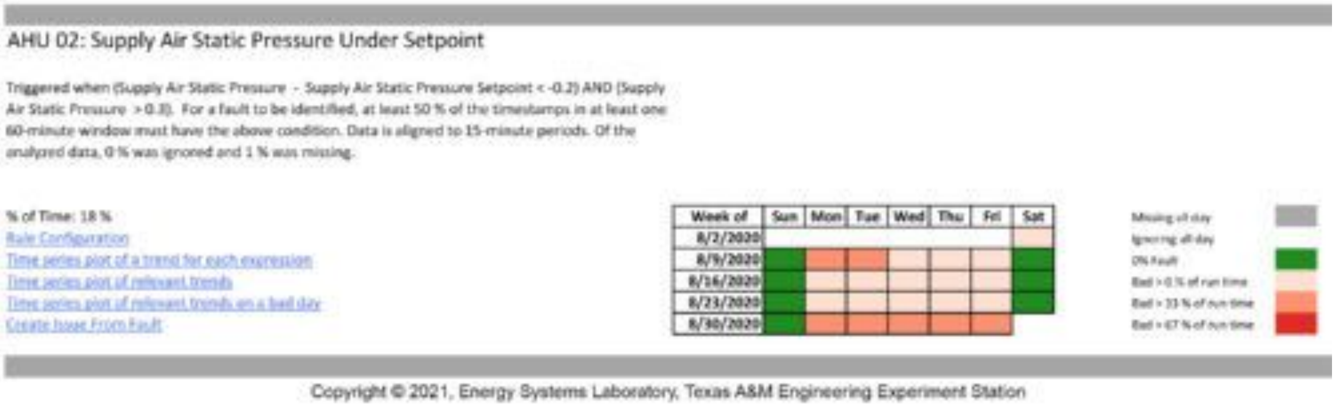


Figure 4: The rule of "supply air static pressure under setpoint" is triggered because the static pressure is under setpoint during weekdays. Courtesy: Texas A&M Engineering Experiment Station

The Smart Energy Analytics Campaign shows the median savings for participants with AFDD in percentages and dollars per square foot per year. AFDD helped achieve median savings of $0.17 to $0.24 per square foot per year. Comparing the AFDD project cost and savings per square foot, it is evident that using AFDD results in high savings and rapid return on investment, not to mention its noneconomic benefits and additional features.

AFDD project scheme

As Charles E. Gulledge, 2020-2021 ASHRAE president said, "Digital transformation is not simply associated with adopting new technical solutions. Knowledge needs to be captured and linked in such a way that ALL relevant stakeholders' benefit. Doing so requires understanding of how to collect, store and analyze data; so that it is insightful and actionable."

It is crucial to use the AFDD tools wisely and effectively. The majority of AFDD tools

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

are configured and used by some combination of facility staff, control vendor, tool vendor and third-party service providers. In most cases, the vendor plus a third party does the configuration, working from owner requirements.

Figure 6 lists a typical AFDD project scheme as part of the fault management workflow. Firstly, an AFDD user should collect interval historical HVAC system trend data from the BAS, local to the equipment or controller, external sensors and meters or a combination of these data sources.

Second, the user should set up the AFDD portal based on the trends and HVAC system configurations, which can be obtained from BAS and mechanical drawings. Some of the AFDD tools may require additional setup depending on the adopted FDD methods.

For example, for AFDD tool rule-based models, a library of existing rules may be offered by the AFDD tool provider and the user may also need to create bespoke rules specific to the HVAC systems and the sequences of operation. Once the AFDD setup is completed, the user will be able to run AFDD to output faults and diagnoses. The process generally relies on analytical or physical redundancies to isolate faults during the diagnostic step.

Lastly, the user can evaluate the faults and the possible causes and validate the issues considering multiple factors including energy efficiency, economic loss, comfort impediment, safety concerns or environmental impact.

The validated issues should be listed based on their relative significance and prior-

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

itized to focus effort where most valuable. This ensures that over-stretched maintenance resources are used in the most beneficial and cost-effective manner.

Trend data collection surprisingly presents the most challenges in the entire AFDD project. Typically, the AFDD user provides the list “format” of the trend data to the control vendor and the control vendor creates daily trends through the BAS. Here are some common issues and solutions.

- Most modern BAS platforms can send scheduled emails that contain trend reports to the AFDD portal. However, many facilities are regulated with high-security precautions on both the BAS and the local computer and ban email communications. Multiple methods have been developed to import the trend data into the AFDD portal through the FTP site, HTTPS POST, API script, etc.

- Trending all available BAS points may cause long processing time and low memory space on the field panels, while trending insufficient points may hinder the AFDD tool capacities. A general rule of thumb is to trend all critical control points for HVAC equipment such as chillers, boilers, AHUs, pumps, etc. with a data interval of 5 to 30 minutes. Also, breaking down big trend files generated by the BAS can reduce the BAS processing time.

- Different BAS platforms may export completely different trend file formats including XLSX, XLS, CSV, TSV, etc. Current AFDD tools are capable of dealing with most data formats. In case where a new data format cannot be read, AFDD tool providers should be able to either add a separate file-based reader or modify the data to fit the tool.

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system’s data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

- It is not uncommon for a building expansion, server migration or BAS upgrade to occur and extra effort is required for setup. Unfortunately, there is no way around this. It is recommended to plan accordingly for a smooth transition and make sure that the trend point names remain the same so that the original AFDD portal setup remains validated.

- Some small facilities cannot generate automatic trend reports or do not have BAS or energy management staff and present much tighter payback constraints due to smaller energy expenditures. The frequency of generating trend reports manually should be lowered as well as delivering AFDD issues reports based on the project budget.

It is worth pointing out that most AFDD tools focus on fault detection but still require a significant level of user knowledge and experience to avoid false-positive faults and validate issues. This knowledge and experience may not always be available in-house, further compelling the expansion of market delivery of AFDD through third-party service providers.

As part of the consulting service, the third-party service providers deliver AFDD issue reports periodically, such as biweekly, monthly or quarterly, as well as troubleshooting specific issues remotely through trends, estimating energy and cost savings and performing optional on-site assessments.

AFDD benchmark

When considering which AFDD tool to use or how well a particular tool works, end-us-

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

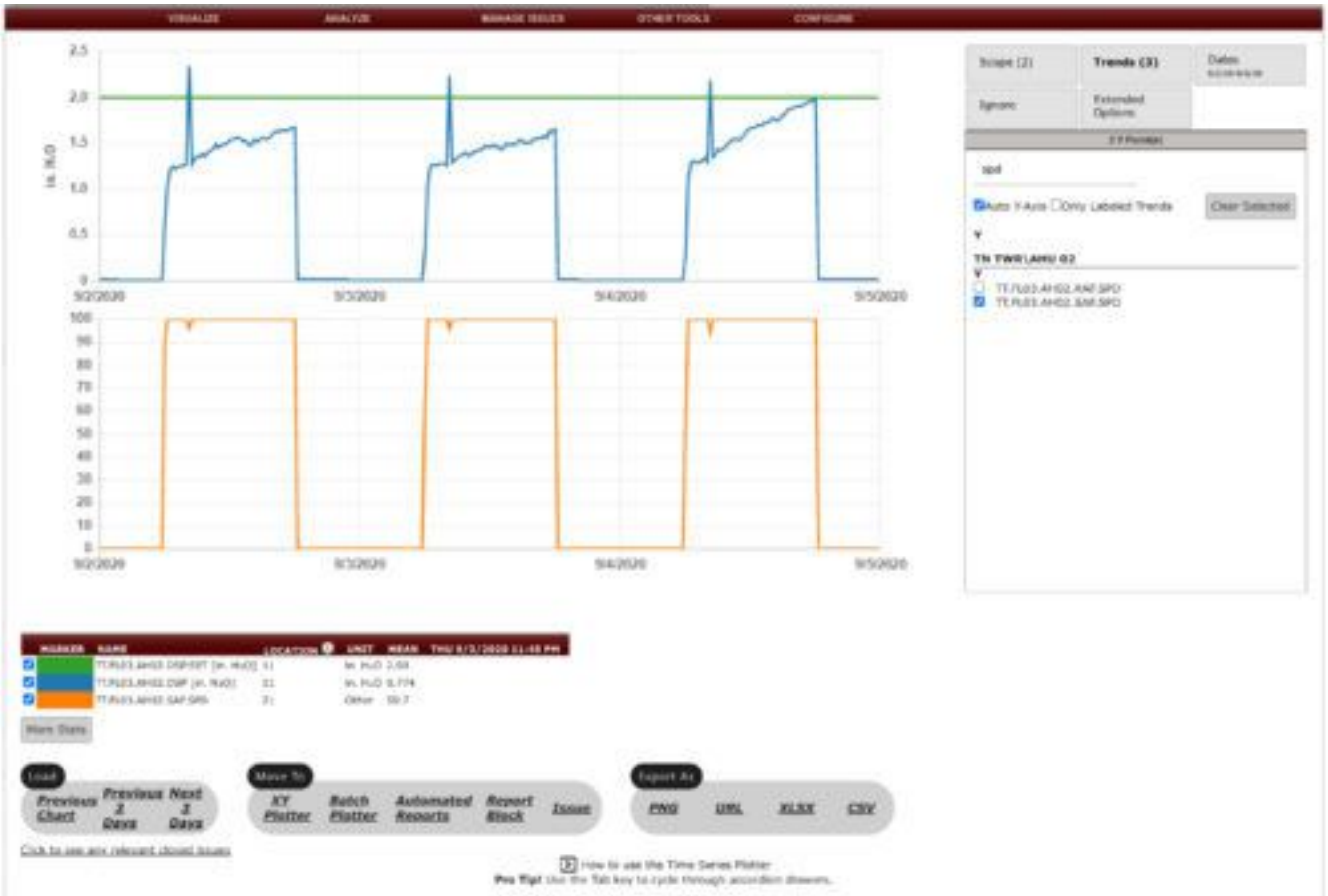


Figure 5: A time series plot of relevant trends in the triggered issue is available for further analysis. Courtesy: Texas A&M Engineering Experiment Station

ers need to be able to benchmark the performance of AFDD. There has been some research about measuring or evaluating the performance of FDD technologies applied in HVAC systems.

However, the process requires manual inputs and needs automation of key steps to improve scalability and repeatability. More importantly, the current dataset input needs

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

to be further expanded toward widespread adoption.

Figure 6: A typical automated fault detection and diagnostics project scheme consists of four basic steps. Courtesy: Smith Seckman Reid

Unfortunately, there are currently no available standards to support the methodology or provide datasets for an AFDD performance benchmark. With the aforementioned methodology being further developed, the users will make informed selections, AFDD tool vendors will further improve the measurable performance and accuracy and regulatory bodies will be able to integrate AFDD to guidelines, standards or technology certifications.

Challenges down the road

Unlike the measurement and verification process that is well-developed to determine the overall building energy performance based on the National Renewable Energy Laboratory's International Performance Measurement and Verification Protocol, AFDD is still in the relatively early stage of adoption nationwide — it is a powerful aid to ensure optimal operational performance. The following barriers are down the road and must be addressed before widespread adoption.

- Information technology and data integration represent one of the largest barriers to scale. Data integration and management need improvements.

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

- AFDD tools require a significant amount of time for initial setup, which has the effect of significantly increasing the labor and overall cost of AFDD projects. The autonomy of the initial setup should be largely enhanced to minimize the manual effort.

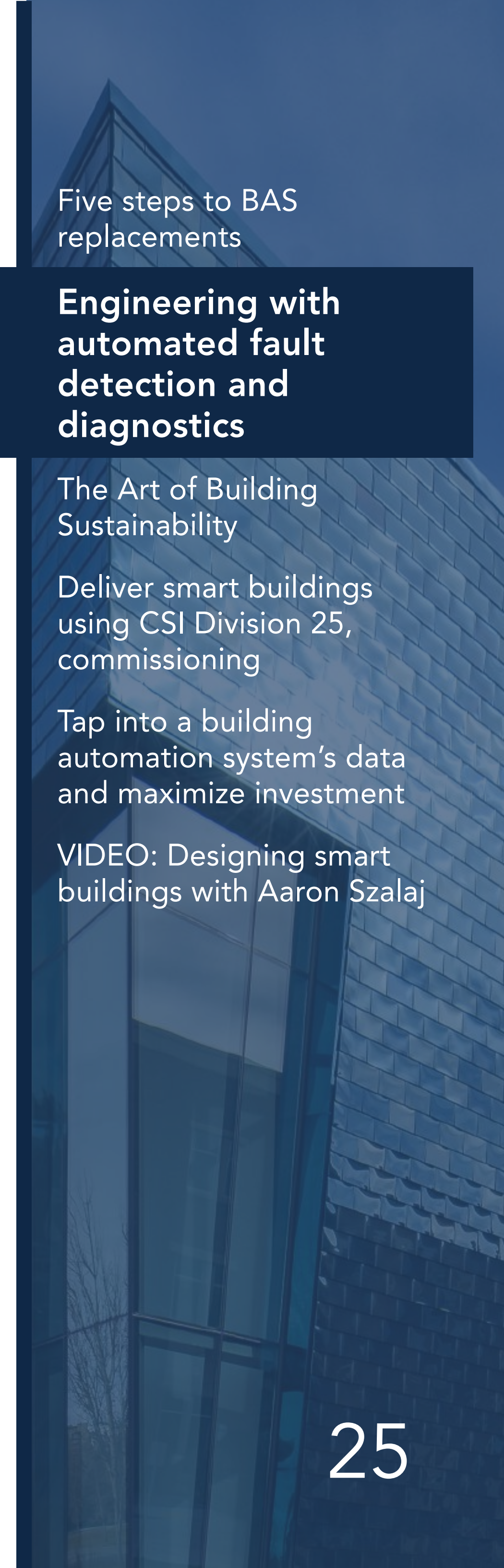
- Currently, AFDD mostly serves as an independent input to energy management practices, such as strategic energy management and monitoring-based commissioning. Ideally, AFDD should be integrated within various commissioning phases.

- There is a lack of standardization of how to evaluate the fault categories, the diagnostic messages and the FDD technical capabilities. Such standardization would require buy-in and agreement from a broad group of developers, vendors and users (both facility staff and third-party service providers).

- Neither widely accepted AFDD evaluation methodologies nor standards/codes addressing AFDD exist. Joint efforts of the entire AFDD community should be spent to formalize the current validated methodology into guidelines or standards.

As the world embraces the new remote norm beyond the COVID-19 crisis, being able to remotely access, visualize and analyze building data becomes an increasingly essential part of remote building management. AFDD is the future.

Jiajun Liao and Victor Saeh
Jiajun Liao *is a project manager with Smith Seckman Reid and serves as a member of several ASHRAE standards/technical committees.* ***Victor Saeh*** *is a principal for existing buildings commissioning services with Smith Seckman Reid. He is primarily responsible for maintaining client relationships, directing the operations of all existing buildings commissioning line of services.*



Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

The Art of Building Sustainability

In social settings I am often asked, "What is it you do again?" I could answer with simple responses about building automation, HVAC, or lighting control, but that often leaves the person wondering what the heck I'm talking about and the conversation at a loss. The best small talk I ever had at a dinner party started with "What is it you do, and why do you do it?" Now I was intrigued and excited, and ready to talk about things that mean something not only to me but also to a genuinely interested audience. "Sustainability," I answered with a grin. I couldn't wait to talk about what it is and why it's important.

Sustainability means different things to many people. To some it means being able to manage the current workload on their desk by delegating work; to others it's reducing burdens on time by picking maintenance-free landscaping. When I think about what sustainability means to me, my mind goes to the buildings we live in, the school I grew up attending, and the projects I participate in year after year. "I am in the business of sustainability" is something I'm proud to say.

For someone who's spent years in the building automation industry, it's easy for me to recognize why we need to talk about sustainability as it applies to buildings and energy. Think back to the grade school you attended. Is it still around, and would it be efficient enough for today's needs? The answer is often no, but why? I remember the need in my school for a fan in the stairway to the basement where the switchgear was kept, just to keep the service on during warmer months. A patchwork solution like this is not only inefficient but also counters the very definition of sustainability.

Every building, including the products and people within and the systems that operate it, is a work of art. Each aspect of a building is selected to perform a task or meet a need, but does that mean every aspect is sustainable? Does it meet the needs of today without compromising the needs of future generations? Sadly, even though the archi-

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

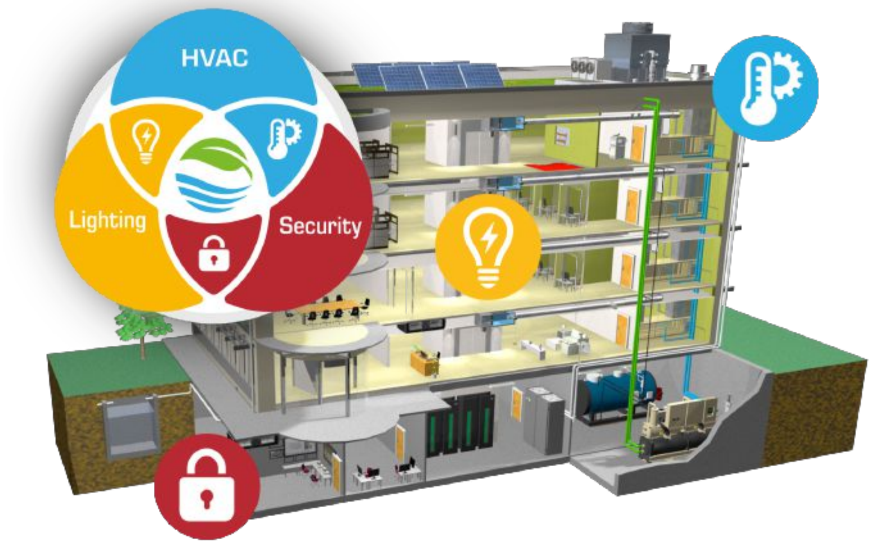
The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

tecture of the school I attended was elegant, these kinds of questions were not considered at the time it was built or during its operation, and it was demolished in 2015 to make room for a new, more efficient building.



The systems that control a building play a large part in how efficient it is, but for it to be sustainable, we must consider how these systems could compromise or promote the ability of the building to meet the needs of the future. Thinking about buildings as living, breathing entities provides a different perspective. Like our bodies, we can make choices about what goes into a building that will help sustain its current quality of life with a mind to quality and longevity.

Sustainability has become a necessity in building design and operation. According to the U.S. Energy Efficiency Administration, "Electricity's share of total energy end-use consumption in commercial buildings increased from 38% in 1979 to 61% in 2012" (EIA 2018).

eia

Approximately two-thirds of that electricity was consumed by end-use solutions that could have been controlled to be more efficient with properly deployed automation systems. Recognizing these opportunities for energy-conservation measures and act-

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

ing on them to maintain a triple bottom line of people, planet, and profit is a great accomplishment for built-environment professionals.

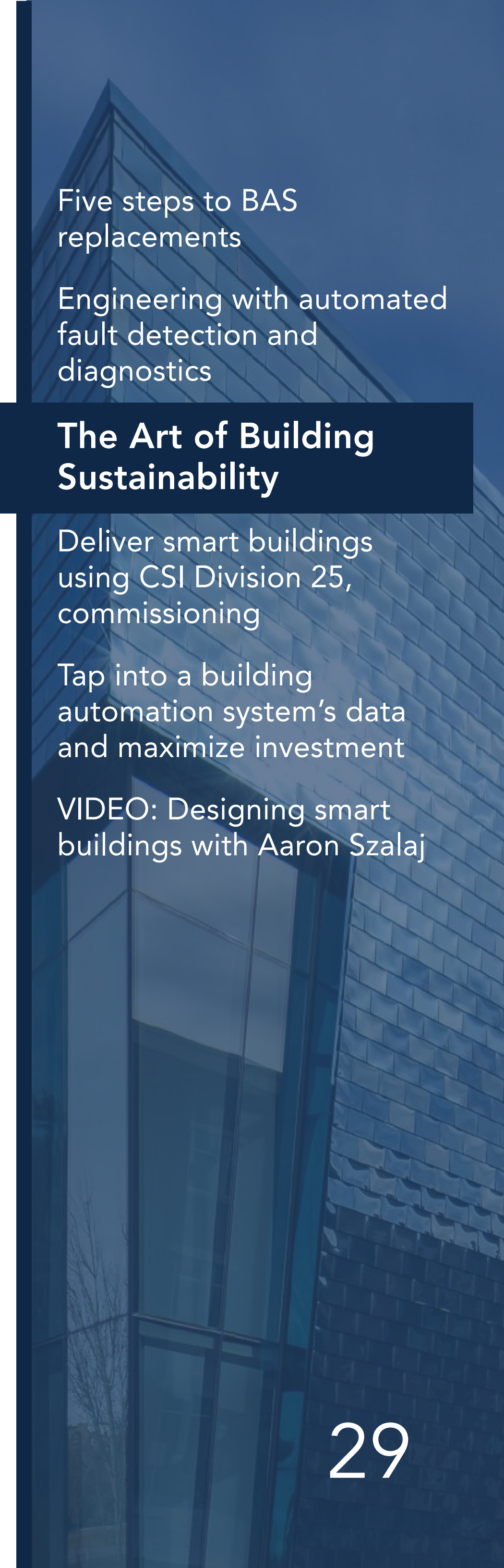
Engineers and others in the engineering community are required to pursue continuing education to maintain a working knowledge of best practices and new solutions. We all make continual efforts to stay informed of new technologies and methods. Even so, applying sustainable practices to designing and specifying for the buildings we influence can sometimes be a daunting task.

Fortunately, some best practices can help. The ART of Building Sustainability, a concept proposed by Reliable Controls, provides a set of technical attributes and supporting services that can guide you in the process of specifying automation technologies. Implementing the following steps ensures a path to sustainability.

1. Specify open communication protocols

During the dinner-party conversation, I could have communicated in a language or words my audience didn’t understand. When you attend functions with a diverse group of participants, it’s important to recognize that the language you use could be misunderstood or not understood at all. This may leave your audience feeling uninterested or as though the conversation was not intended for them. Likewise, the varied systems in a building could face the same communication challenges, where they don’t listen to one another because they speak different languages.

The interoperability of traditionally separate automation systems is key to providing a single, sustainable building automation solution. Protocols that are publicly mandated and backward compatible, such as BACnet, are crucial to ensuring an entire system’s integrity for the foreseeable future. Specifying open protocols and devices that are



Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system’s data and maximize investment

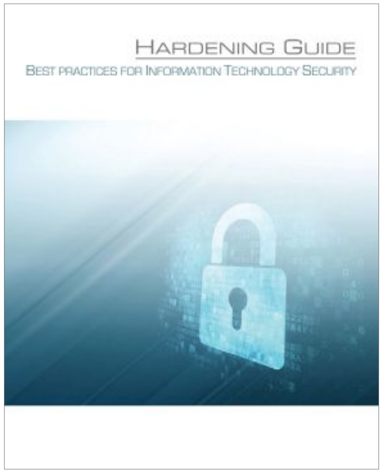
VIDEO: Designing smart buildings with Aaron Szalaj

certified by third parties like BACnet Testing Laboratories ensures that all systems can communicate efficiently and effectively.

When you open a conversation, it's important to consider who can and needs to listen to it. Is it appropriate for everyone in a room? What if the conversation turns to a sensitive business topic or personal information? Considering who is listening and if they should be is crucial. Maybe you should be communicating a topic to an entire room plus a neighboring room. Do you have the capability to communicate securely between rooms, between buildings, or around the world? Can you securely share information with an audience that large?

2. Specify scalable, secure technology

A good building control system design is securely scalable from a single building to a global solution. Using technology like Lightweight Directory Access Protocol and Security Assertion Markup Language enables effective, secure management of credentials. Ensuring communication between devices on a network through secure, encrypted means such as a BACnet Secure Network is key to protecting the integrity of the solution and the customer's assets.



3. Implement real-time fault detection and diagnosis

Once systems in a facility are communicating effectively, information can be shared that impacts how facilities are operating in real-time. Many businesses are reactionary when it comes to energy use or maintenance that affects it. When something breaks,

Five steps to BAS replacements
Engineering with automated fault detection and diagnostics
The Art of Building Sustainability
Deliver smart buildings using CSI Division 25, commissioning
Tap into a building automation system's data and maximize investment
VIDEO: Designing smart buildings with Aaron Szalaj

they look back to what happened, diagnose the root cause, and adjust moving forward. How long should a facility owner wait for action? Is it when they receive their energy bill? Is tomorrow soon enough? By that time the cost of using too much energy during a peak cycle based on a contract could be too late; they may have realized a peak charge for an entire month.

The ability to continuously commission a building control system in real time on an existing network architecture empowers the user with immediate fault detection and provides them with a list of possible corrections. This can mean the difference between meeting peak demand or reacting to the cost of breaking it in an afternoon and not waiting until the next day or month. Knowledge is power for the building owner; immediate information provides efficiencies today instead of waiting to hear about yesterday's costs tomorrow.

4. Provide ownership of analysis

Facility managers and owners can understand and react to inefficiencies in the systems they are responsible for today, but what about a year-over-year comparison? Is the building operating as efficiently in the same conditions today as it did last year or 5 years ago? Data acquisition, storage, and analytics are necessary to answer these questions. Every year the contract for facility controls is renegotiated to ensure costs are kept in line. What happens to a facility's data if the owner chooses a different vendor solution next year? What if they want a different report tomorrow or a report changed to a different layout for a meeting this afternoon?

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

Gaining an understanding of a facility or system is key to empowering the owner to take control and make changes to gain efficiencies. Giving owners and users the ability to design, configure, and run reports on data, either automatically or at will, enables all stakeholders to make informed decisions today or have insight into changes as they are made in day-to-day operations. Retaining ownership of all the data from day one for a facility enables stakeholders to research current efficiencies compared to historical data and identify successful changes and trends for the foreseeable future.

5. Engage occupants with an app-centric culture

Recognizing and reacting to facility efficiencies is only a part of the solution. Engaging with occupants and empowering them to make sustainable decisions for their workspace promotes a holistic approach. Providing an understandable means of engagement via a mobile app allows occupants to feel like a part of the sustainable solution, improves individual feedback on experiences, results in optimized performances, and improves occupant satisfaction.

6. Support minimal waste over a product's life cycle

Just because a product can be a part of a sustainable solution does not mean the manufacturer adheres to the same principles. Provide peace of mind that a building

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

controller is sustainable from cradle to grave. Is the solution manufactured with sustainability in mind? Does the manufacturer adhere to the same sustainable ideas the facility designer and owner are trying to achieve?

Manufacturers of automation systems should have and maintain ISO 9001 and 14001 certifications for quality and environmental management assurances. The systems should support a long hardware warranty of at least 5 years with repair services for life. The manufacturer should follow the Restriction of Hazardous Substances and Waste of Electrical Electronic Equipment directives to support a minimal-waste objective over the life cycle of its products.

7. Specify backward-compatible technology

When a building is designed to be sustainable, planned obsolescence should not be a part of the overall planning. The same should apply to the building automation system. If a solution performs and meets the planned objectives of the overall design, why should it be replaced? To be sustainable, support software and next-generation devices should interact with the products of yesterday, today, and tomorrow.

Sustainability starts with longevity. Each controller in a building automation system should be supported potentially over the life of the equipment it controls. The manufacturer

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

should deliver hardware and software with a proven ability to support working products from previous generations without the need to find older versions of hardware or software. Delivering backward-compatible solutions today optimizes capital and operational expenditures in the future and maximizes return on investment. This also ensures products are not added to the waste stream in the future due to engineered obsolescence.

8. Specify manufacturers who provide comprehensive support

Manufacturing and delivering a product are only part of the solution. Having a sustainable building automation system means having proper support for the installed solution. A complete set of documents and information should be available for the product, in various languages, to support facility staff in their roles. As facility staff changes, information should be continually available, including online operator instruction, 24 hours a day, 7 days a week, to meet the needs of those who interact with the facility every day. Face-to-face training options should also be available to further support staff training requirements if necessary.

9. Specify a manufacturer with a global network of factory-certified service partners

Once a system is installed and the customer is trained to operate it, a global network of factory-trained service partners should be in place to support the solution. Local,

Five steps to BAS replacements
Engineering with automated fault detection and diagnostics
The Art of Building Sustainability
Deliver smart buildings using CSI Division 25, commissioning
Tap into a building automation system's data and maximize investment
VIDEO: Designing smart buildings with Aaron Szalaj

knowledgeable service partners are crucial to the long-term support of a solution. Factory-certified partners who care about their reputation, invest in their people, and want to have satisfied, long-term customers helps operators stand at the helm of sustainability.

True building sustainability emerges when these nine technical attributes and supporting services are combined with a high level of HVAC, lighting, and security integration. Talking about sustainability and encouraging involvement from all parties involved can help move a conversation forward and keep those listening engaged in understanding your excitement about sustainability. For me, discussing sustainability at that dinner party moved the conversation forward into a long-term friendship with people who, as it turned out, are also interested in sustainable solutions.

Following the guidance of the ART of Building Sustainability helps ensure a sustainable built environment for today and for generations to come. For the sake of facility managers and building owners, ensuring that a building automation system meets or exceeds these nine principles should be part of every specified design. Let's create sustainable buildings that will be enjoyed by future generations.

U.S. Energy Information Administration (EIA). (2018). Use of Energy Explained: Energy Use in Commercial Buildings, **https://www.eia.gov/energyexplained/use-of-energy/commercial-buildings.php.**

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

Deliver smart buildings using CSI Division 25, commissioning

The use of CSI Division 25 and commissioning are critical to the successful design and operation of a smart building

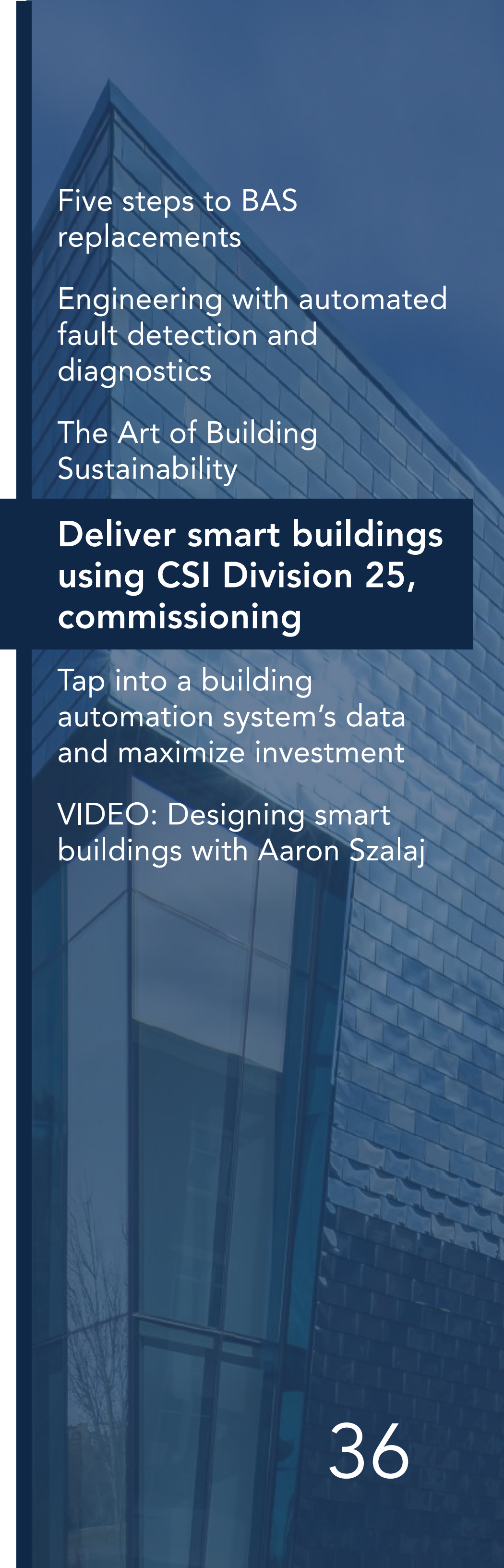
Building automation systems, which are now commonplace with heating, ventilation and air conditioning systems, are used to reduce operator interactions, provide stability and improve the operating efficiency of these systems. The automation industry has now moved from solely controlling HVAC systems into operating a wide range of building systems.

According to a Markets and Markets Research report, the BAS market is expected to grow from $73.5 billion in 2021 to $112.1 billion in 2026.

At the same time there has also been a movement in the buildings industry toward the integration of the "internet of things" into these systems. For buildings, the IoT describes the use of the internet to process of exchanging data between a device (sensor, controller, actuator) and a remote server, which uses the data to create a change in the operation on the devices system.

As the computational power of central processing units and microelectronics has increased, the spread of IoT within a wide variety of building systems has flourished. This technological advancement has created a strong movement toward its use in creating smart buildings.

Smart buildings, which use artificial intelligence and operational technologies, allow



Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

Figure 1: Smart buildings performance is based upon the amalgamation of multiple building systems into a unified building controller to achieve the benefits of remote monitoring and artificial intelligence/operational technology. Courtesy: Stantec

for building systems to be automated in the process of predicting, identifying, analyzing and resolving performance issues. OT is used to monitor building systems and create changes to systems normally within the scope of a human operator. This enhancement to remote operation provides building operators with a wide variety of analytics and visualization.

Likewise, AI can improve energy efficiency, resiliency, indoor air quality and occupant comfort. A cloud-based server allows for the computational power needed to operate these solutions and is quickly being provided by many major control's manufacturers.

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

For engineers designing smart buildings, the use of the Construction Specifications Institute MasterFormat Division 25: Integrated Automation is essential to the success of a project. Complementing this with the implementation of commissioning is critical and works to remove the human errors in design and construction which can cause a smart building to underperform.

The COVID-19 pandemic has had the most unprecedented effect on the global economy and the operation of the built environment. Major weather and seismic related events were once thought of as the primary drivers behind resiliency in buildings until now. Many employees were required to follow shelter-in-place orders from local governments which left the buildings unoccupied and, in some cases, uncontrolled. Regardless of the event, buildings still need to be operated to maintain stable internal thermal and moisture conditions and to avoid damage to equipment if run unattended to for long periods of time.

The pandemic-driven stress test has uncovered weaknesses in remote facilities operations and has alerted the operators of buildings and the industry as whole to the need to create more rigidly defined preparation standards and guidelines that will make these systems more resilient and ready to handle the next major event. It has caused the industry to rethink how we should construct, renovate, operate and maintain buildings. Consequently, it has offered the perfect opportunity to advance the use of cloud-based remote monitoring and operation of building systems, which can be found within smart buildings.

With every opportunity there is always the potential to fail. The same applies to smart building design and construction. It can be the tendency of owners and design teams

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

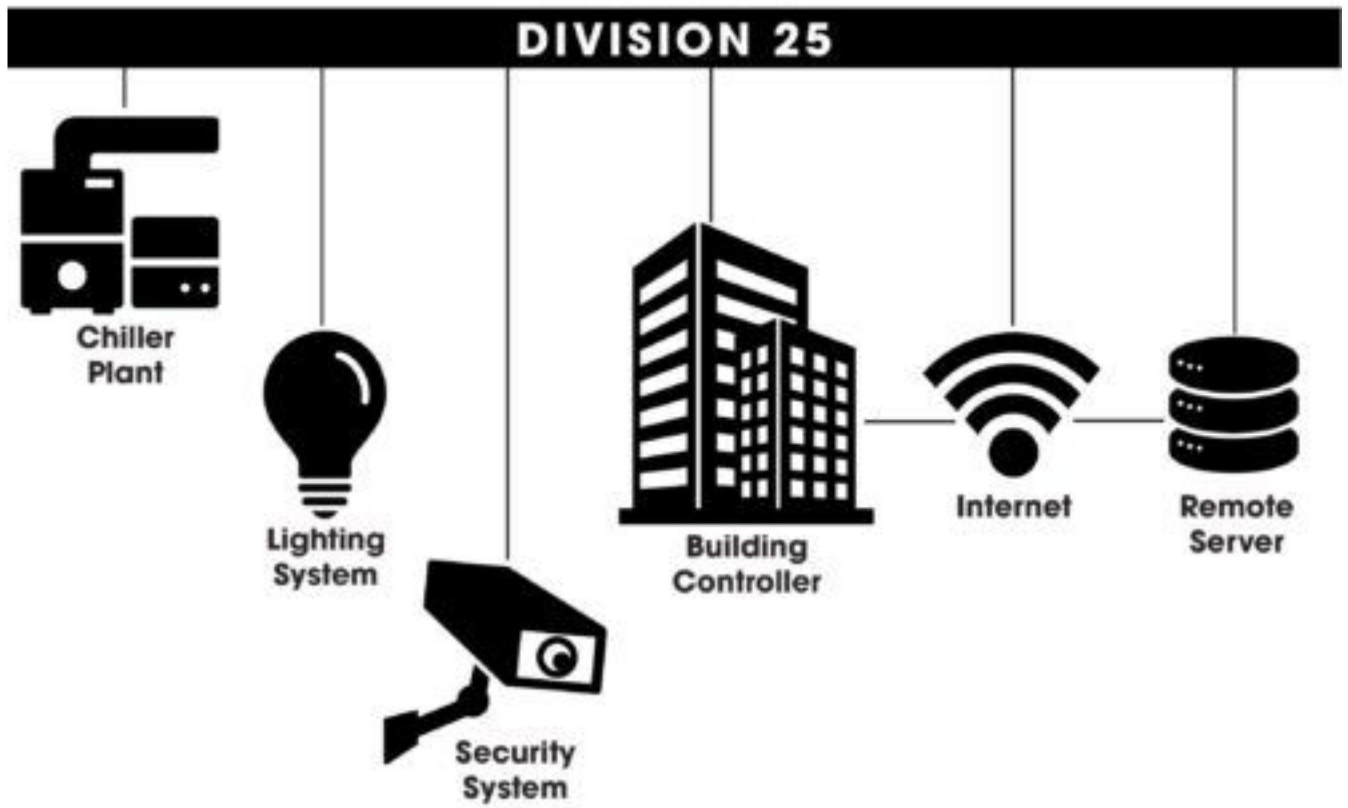


Figure 2: Integrated automation allows for the leveling of layered and siloed building systems into a unified platform. Coordination between construction trades and manufactures occurs in the design phase to allow for a properly executed construction and operational phases for a smart building. Courtesy: Stantec

to over commit to the level of which projects can sustain the implementation of new technologies. smart building design contains a wide range of building systems that it can be applied to.

As such, the use of CSI MasterFormat Division 25 during design process will provide the details and framework for proper coordination and specification of smart building systems and components. In the construction phase, commissioning of these systems is required to confirm operational integrity and to provide the owner and operators with the skills

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

needed to bring a smart building through its life cycle.

In the end, smart buildings do not fail because of technological restrictions, but rather from small incremental issues that culminate in the owner downgrading the systems to operate as a traditional building-level automation system.

Using Division 25 for smart buildings

According to the Memoori report "The Internet of Things in Smart Commercial Buildings 2016 to 2021," the analysis predicts a higher growth rate in the commercial real estate market of 31.5% compound annual growth rate. The report goes on to indicate this sector will grow to represent 34% of overall smart building devices, with more than 3.6 billion devices installed by 2021.

Division 25: Integrated Automation has existed for nearly 20 years and currently includes nearly 90 sections that specify everything from the systems architecture to the wiring needed to create a smart building. It also specifies the commissioning of these systems. The purpose of this division is to connect automation with multiple engineering disciplines/building trades and generate a coordinated, singular product delivery.

Following the framework of Division 25 allows engineers to connect end devices, supervisory systems, network pathways and remote operation of AI/OT solutions together. Coupling proper Division 25 specifications with commissioning can offer a long-lasting, successful smart building solution.

However, the use of Division 25 is typically limited to large organizations with multiple buildings (industrial, higher education, health care) where impacts of energy and oper-

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

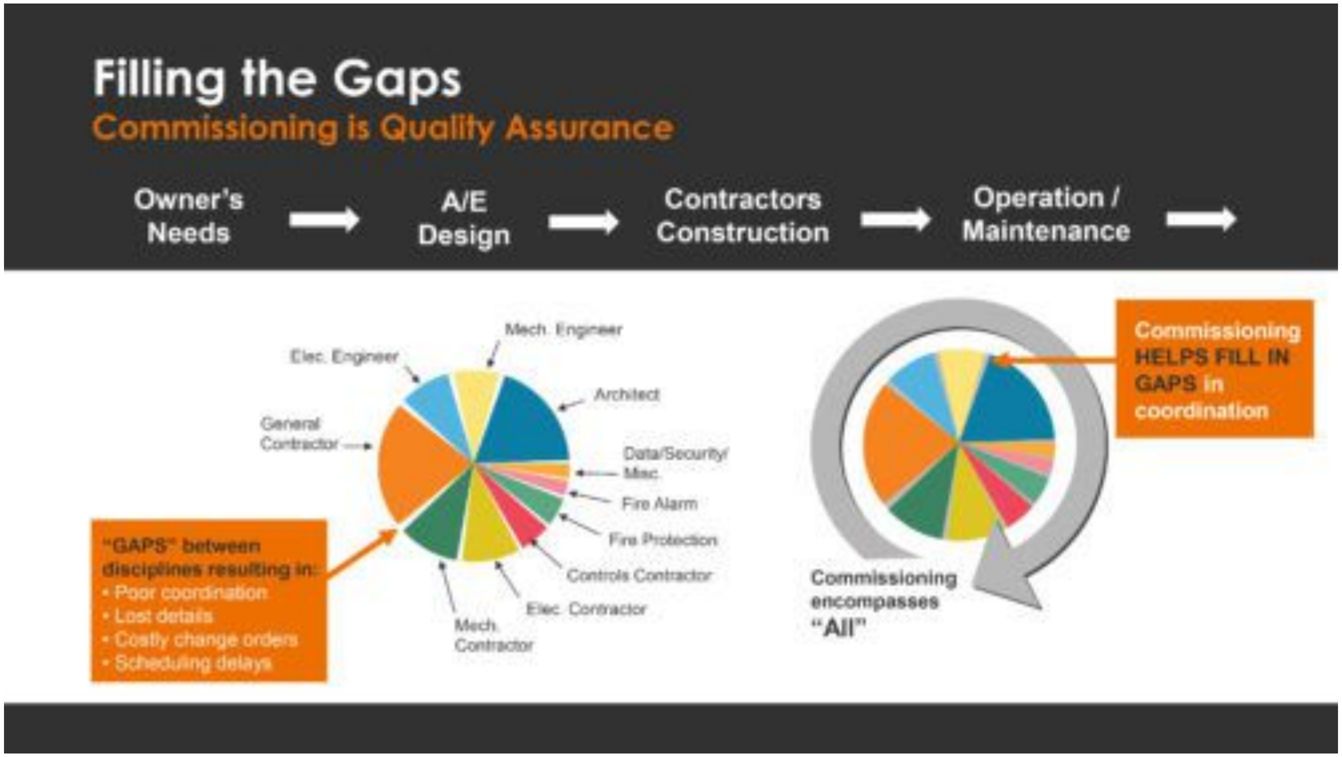


Figure 3: Smart buildings require a higher level of coordination and operational performance to achieve the desired functional benefits of the artificial intelligence/operational technology. Including commissioning in each phase of a smart building design and construction allows for scope gaps to be identified and resolved. Courtesy: Stantec

ations and maintenance costs have a larger overall impact on the organization. It is a missed opportunity for those of smaller building footprints that can leverage local incentives for smart buildings to reduce implementation costs or for commercial real estate building developers where the O&M costs are the tenant's responsibility.

Without the proper validation of needed control points, sequences, sensors and data management methods during early design phases there may be functional issues of remote AI/OI tools baked right into the design. Likewise, when reaching the turnover

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

phase of a project a building commissioning professional or commissioning agent should conduct point-to-point checks to validate that all is operating as intended.

The complexity of multiple systems layered on top of each other in a smart building solution requires a higher level of owner and operator training that is best achieved though the involvement of a commissioning agent. Not only does training need to teach the specific approach to controlling the systems installed, but it also needs to include how to deal with data management and analytics to properly set up an owner's team for success. A commissioning agent will ensure that all of this takes place.

Smart buildings and commissioning

With the design and specification of smart buildings being facilitated by Division 25, there is still the opportunity to degrade the performance of the systems via the unpredictable aspect of human error during construction. Each device, pipe, electrical connection, controller, valve and all other building components are manufactured and installed by skilled individuals. Commissioning has been created as the last defense to ensure that these human errors will be identified, mitigated and resolved early in the life of the building. Errors are typically simple mistakes that can cause a negative compounding effect on occupant comfort and energy costs or early failure of equipment while the building is under operation for the next 40 years.

Some examples of errors include:

- Pump motor wiring: Wiring a pump's motor is backward, it will cause a pump to flow backward through the discharge to the suction side. Small loops may appear to be operating correctly but will not have the correct heat exchange in coils or

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

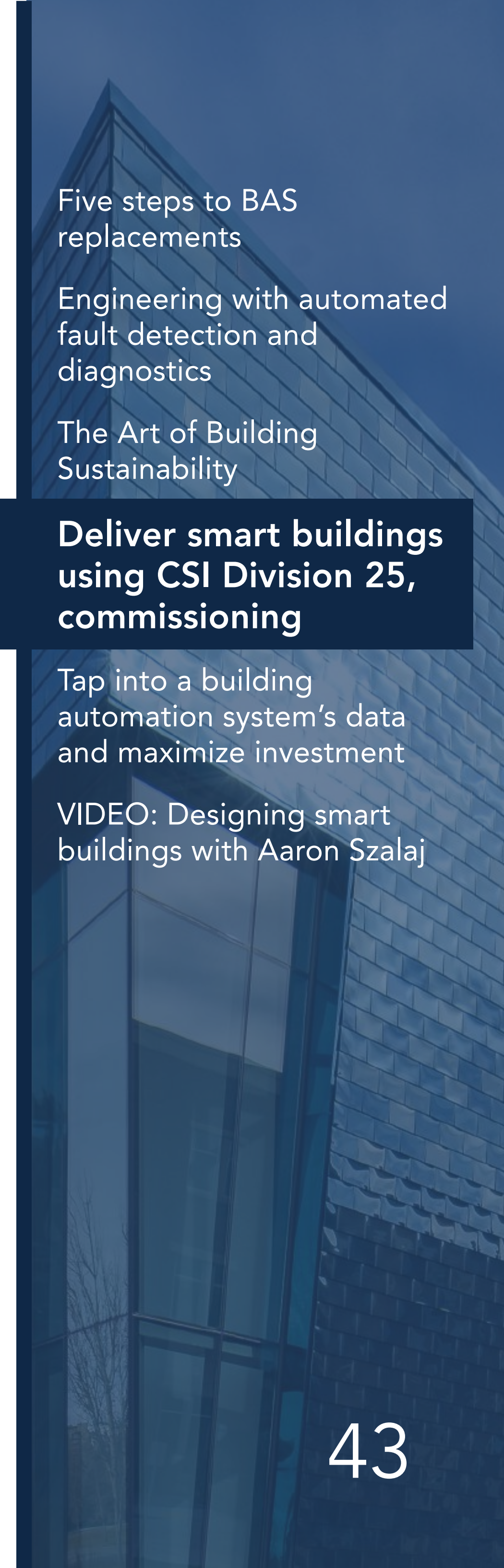
through boilers/chillers. In larger systems with multiple floors, it may appear that the flow is not reaching the coils located on upper floors during balancing.

- Chiller compressor arrangement: Without proper factory startup a multiple compressor circuit chiller may be incorrectly set up to have the on/off compressor as the lead compressor rather than having a digital scroll or variable speed compressor as the lead. This will cause short cycling to happen, which will degrade the operation of the chiller's performance, increase energy costs and will cause early failure of the compressor.

Commissioning provides the quality-focused process for enhancing the delivery of a project and casts the best and most reliable safety net for the simple or complex problems generated by human error. Commissioning is the last defense and best assurance to offer an owner that these human errors will be identified, mitigated and resolved early in the life of the building and specifically directed at reaching this goal during the construction phase.

Limiting a project by not including the commissioning process from concept to operation allows for a wide variety of potential errors and omissions and leaves the facility vulnerable to early failures, repeated tuning and higher operating costs.

Commissioning of buildings has evolved significantly over the past 40 years with the initial driver coming from ASHRAE in 1984 with the formation of the commissioning guidelines committee. It wasn't until 1989 that ASHRAE first released Guideline 1: Commissioning of HVAC Systems. ASHRAE then created a more complete commissioning document titled Guideline 0 in 2005. ASHRAE Standard 202: Commissioning



Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

Process for Buildings and Systems was updated in 2018 and facilitated its maturity into a code-level document.

U.S. cities, municipalities and states have begun adopting the 2018 International Building Code, which includes the International Energy Conservation Code containing commissioning scope under section C408 – Maintenance Information and Systems Commissioning. The IECC contains limited scope of systems to be commissioned (HVAC, lighting controls and service water heating) and, as such, it should be augmented with additional scope to allow for a sufficient level of validation for smart building purposes.

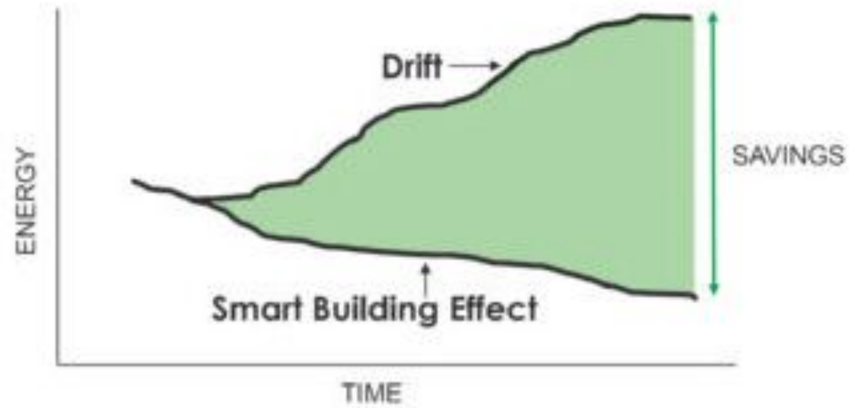


Figure 4: Smart buildings allow for the ongoing and increased energy conservation to occur via artificial intelligence/operational technology. Traditional buildings will experience an energy usage increase drift due to unseen deficiencies in calibrations or improper operational conditions. Courtesy: Stantec

Smart building control systems can and do vary in complexity depending on the desired function/type and the objectives determined by the building owner and design team. Installing a new BAS with smart building technologies or updating an existing system can be a major capital investment and, like most business decisions, must yield an acceptable return on investment.

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

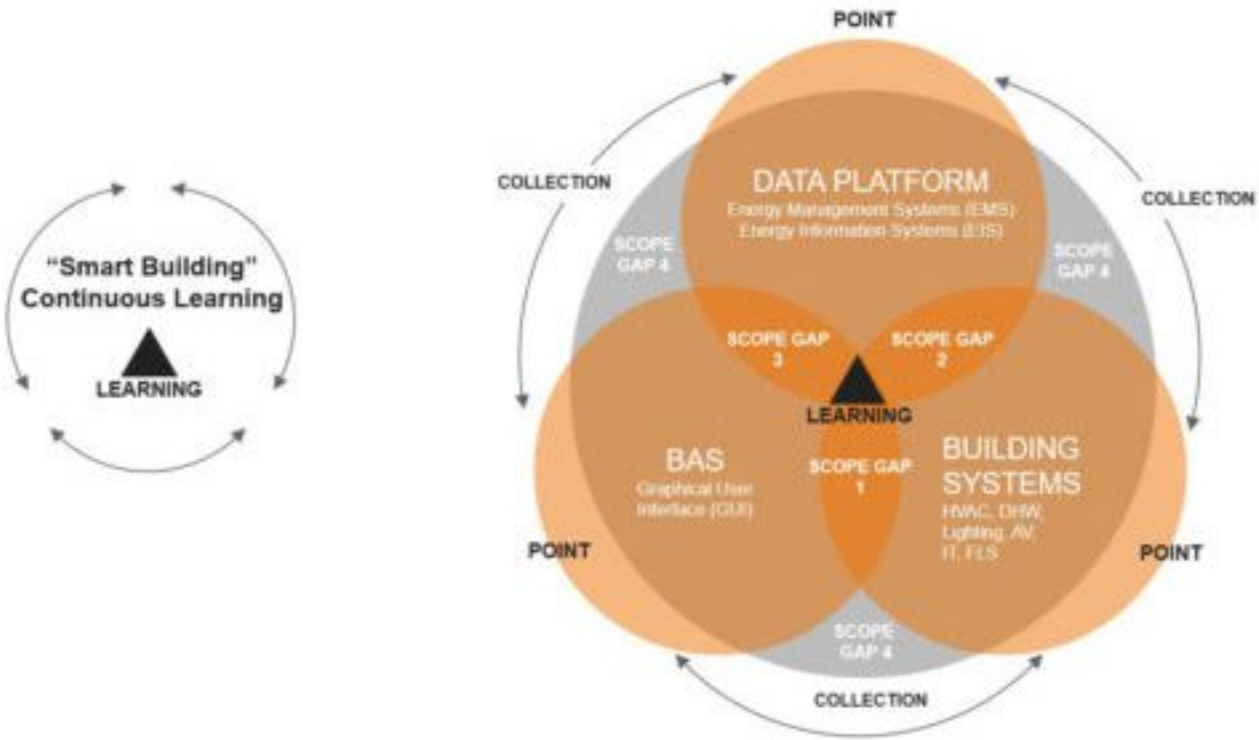


Figure 5: Smart buildings allow for continuous learning of the building's true operation, which can only be assumed during the design of a project. This process of testing, verifying and improving the operation of a building will allow for a greater level of energy conservation. Courtesy: Stantec

A smart building can provide many benefits such as lower energy costs, lower operating and maintenance costs, better indoor air quality, improved occupant comfort, increased productivity, increased security and data collection. There will be less reliance on human interaction to operate a smart building as remote monitoring abilities continue to take over routine activities.

Commissioning a BAS will help to deliver consistent quality in performance, reliability and programmability of smart buildings. With each new technology, there are risks to

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

implementing them and smart buildings are not immune to a variety of issues.

Creating a data connection between a building and a remote server allows for potential infiltration by cyberattacks. A study of 40,000 smart buildings in 2019 by Kaspersky found that 37.8% of computers used to operate the buildings had been compromised by variants of spyware, worms, phishing or ransomware attacks. In addition, design phase mistakes made by owners or design teams by integrating in too many smart building AI/OI applications will result in data not being used, degradation of the system performance and in some cases sidestepping the application and moving back to a more traditional BAS approach.

This will cause unneeded expenditure of first costs of designing and constructing smart building systems that will not be used. While the technology exists to integrate nearly every building system into the IoT, a targeted approach to limit first costs and create real savings for the owner is the responsibility of the design team.

Why do we need smart buildings?

Smart building providers have created a set of enterprise applications that have been advanced over the past decade to seek out more energy savings and operational efficiencies. The applications typically consist of analytics, visualization, data collection and management and AI/OI to predict and reduce energy consumption.

Recently, the construction industry has been driven by consumer trends that place more focus on climate change and the desire to reduce the carbon footprint. With the typical construction budgets and schedule constraints in the design of a building, it is required that the practitioners be trained in the application of smart building design

Five steps to BAS replacements

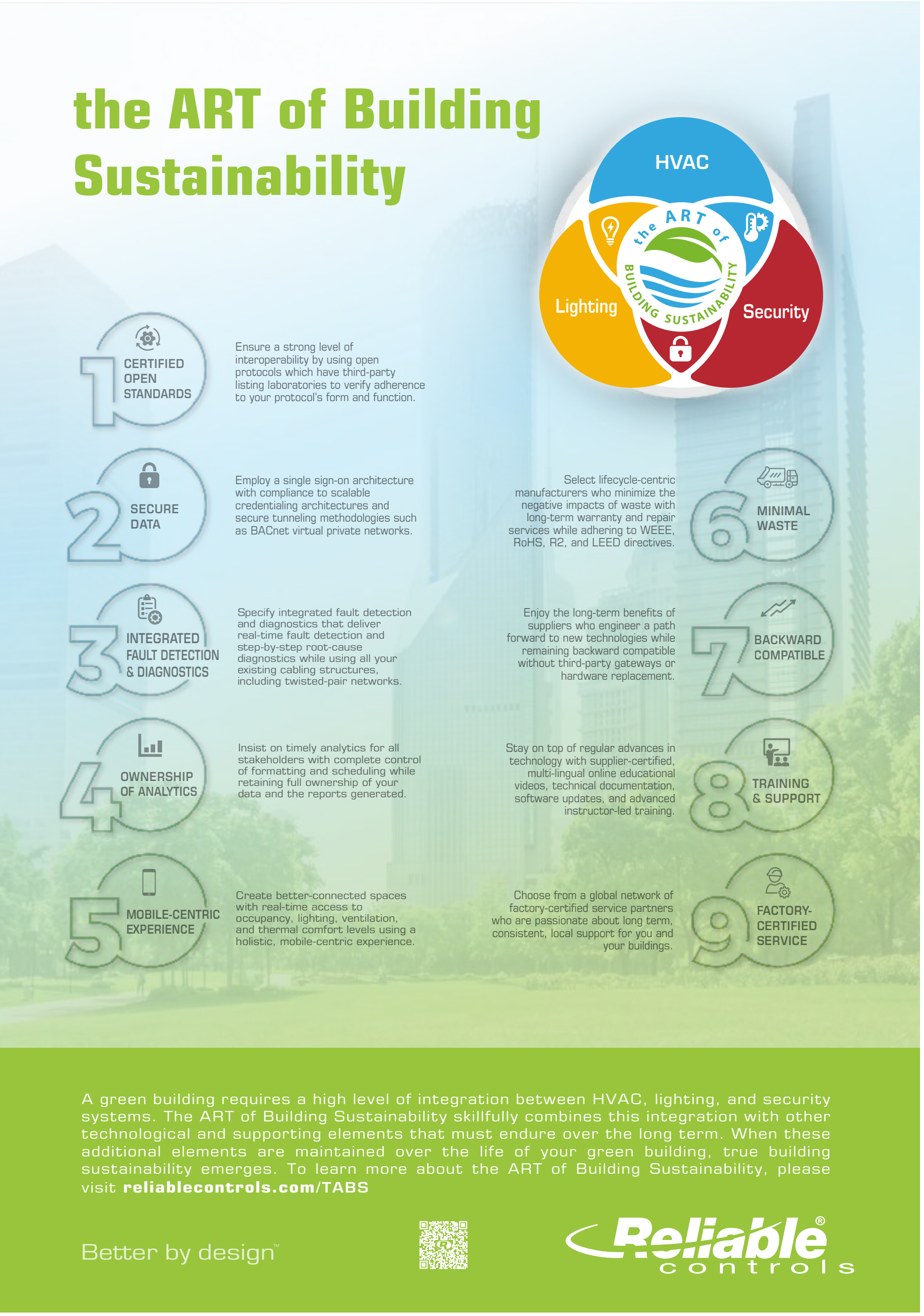
Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj



and understand the benefits and limitations. This effort requires the industry to be proactive and not rely on standard design and construction practices.

Another limitation to the delivery of a smart building rest within the education of owners and operators. When a project is complete, they are the responsible party to be caretakers of a building for the next 40+ years. While they are willing to invest in new technologies, there is an inherent risk taken by them to make the leap forward and as such hesitation is expected. It is incumbent upon the design team to not reach smart building solutions that the owner cannot handle.

Similar to direct digital control integration into building systems, the approach to smart buildings needs to be a gradual process of

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

providing more integration of the enterprise solutions into more building system systems as the industry grows into the next phase of automation. The industry has been provided with a framework via Division 25 and now it is up to engineers to meet the expectations set forth for smart buildings. But then why do smart buildings fail more often than work optimally?

The smart IoT technologies that are implemented in BAS, energy management systems and energy information systems, gather a large amount of data from energy using and nonenergy using devices and systems. This effort takes a significant amount of capital to design, construct and operate. When things fail early in the process of operating a building, the tendency is to fall back to standard operating procedures and pull the intelligence out of the building.

That can be avoided with proper commissioning and, most importantly, owner dedication to training and understanding of what to do when things go wrong without backsliding to the traditional BAS. Building systems are interactive in practice and a variety of system types will impact the operation of others.

For example, building envelope insulation and window properties will impact the heating and cooling operation of terminal units and the operation of central plant equipment. The lighting system will impact how the heating and cooling systems will operate. The occupants may impact the operation of the systems with the way they use the spaces within the building. What is created in a smart building is a living system that must react and optimize performance based upon the actual construction operation of the building, which may be significantly different from what was conceptualized during the early phases of design.

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

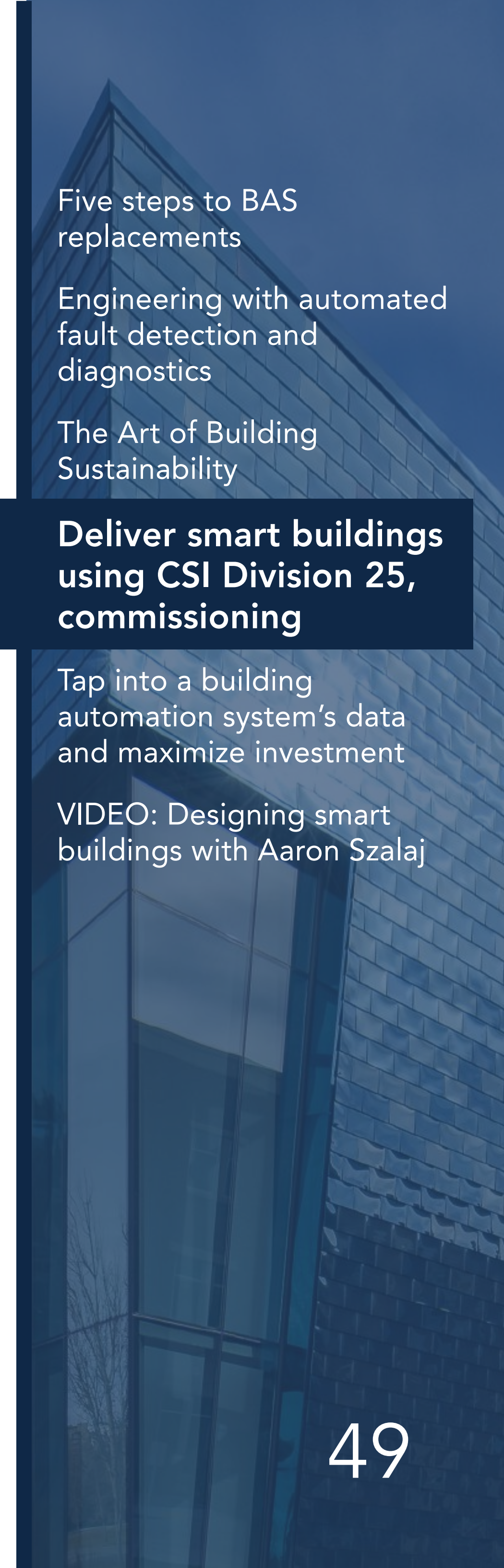
VIDEO: Designing smart buildings with Aaron Szalaj

The primary reason behind early failure is the scope gaps between the BAS, building systems and data platforms. Scope gaps can be as simple as failure to coordinate communication protocols or as complex as cascading sequencing problems causing equipment to work against each other. The layers of system typologies that interconnect within each other begin to expose scope gaps during the process of operating the building or even during construction.

Beyond physical equipment scope gaps, the data being collected in an improper way can cause a failure in the AI/OI applications to analyze and correct a simple problem within the systems. This does not always mean the methodology or engineering was flawed. In most cases, it means that the critical paths were not tested or commissioned to make sure the data was collected in a clear and relevant way that allow the algorithms and protocols to perform as the design intended.

The macro view of this issue shows how all of this is intended to work together as with a simple switch or sensor that is tied into a pump or air unit that controls it functions. A temperatures or pressures sensor is typically an analog device, which requires a link to a digital component and produces a digitized signal. This is also referred to as a direct digital control.

Once the potential thousands of points begin to get installed, many failure points issues can occur. All these points must be put through a vigorous process of testing and verification that is referred to as a point-to-point check. If commissioned properly, this will be the main connection to a unified and integrated system. After the point-to-point is concluded, the final issue is tying this all back to the system that collects all this information and serves as an overlay to the systems. This is where the majority of the "learning" scope gaps occur.



Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

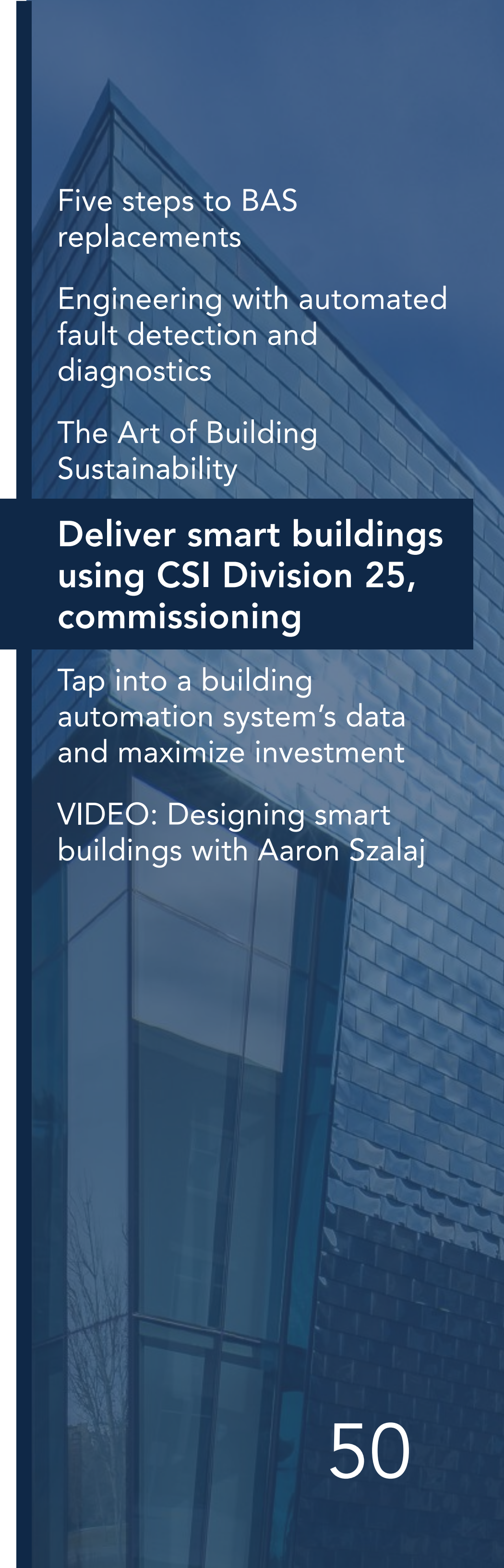
Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

It is important to understand the focus with these smart systems and determine what to look at it in part and on the whole. The parts need to work together to achieve the goal of a smart building. Once in operation, without a committed ownership team and a wiliness to conduct the learning phase, systemic problems may start to arise and overshadow potential capabilities that the system should be able to perform as promised or intended.

The industry has reached a stage in which smart buildings can be an obtainable goal. With proper planning from the early stages of design, using Division 25 and including commissioning of these systems, a successful smart building delivery is possible. Smart buildings are obtainable with a collaborative team of design professionals, trade workers, commissioning agents and owners/operators who are committed to the overall goal.

Timothy Howe, Marcus Myers and Jeri Pickett
Timothy Howe, PE, CEM, Stantec, Rochester, New York; *is a project manager and mechanical engineer with Stantec. He has spent the last 15 years designing and commissioning project for higher education, industrial and science and technology facilities.* ***Marcus Myers, CxA, CEM, LEED AP, Assoc. AIA, LFA, Stantec, Chandler, Arizona;*** *is a project manager and director of commissioning and energy services, U.S. West with Stantec. He has spent the last 20 years commissioning projects for higher education, industrial, biopharma and science and technology facilities.* ***Jeri Pickett, PE, Stantec, Rochester, New York;*** *is a project manager, electrical engineer and principal with Stantec. He has spent the last 30 years designing and commissioning projects for higher education, industrial and science and technology-based facilities.*



Five steps to BAS replacements
Engineering with automated fault detection and diagnostics
The Art of Building Sustainability
Deliver smart buildings using CSI Division 25, commissioning
Tap into a building automation system's data and maximize investment
VIDEO: Designing smart buildings with Aaron Szalaj

Tap into a building automation system's data and maximize investment

It's possible to marry the old building automation system with newer pieces of mechanical equipment, gaining functionality and efficiency without having to replace the entire automation system

A key component to successful building operation lies in the performance and sustainability of the systems that heat and cool facilities, as well as filter and clean the air that keeps occupants healthy and comfortable. It's no surprise this equipment becomes less efficient and wears out over time.

Building systems are generally overdesigned and very robust. They can handle failures and problems, and while that's great, it may mean the building has an invisible issue.

Many component failures don't show any symptoms as other system components work extra hard to overcome the issue. No one catches the utility bill increases because they're handled by accounts payable. Occupants remain comfortable and don't recognize anything has failed; meanwhile, the systems are working double time to overcome the deficit. This undetected problem places excessive wear and tear on the building systems while creating a ton of wasted energy.

When a building is new or newly commissioned, it performs well. System performance erodes over time due to normal wear and tear. The facility may be recommissioned or receive routine preventive maintenance and it performs well again. The performance eventu-

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

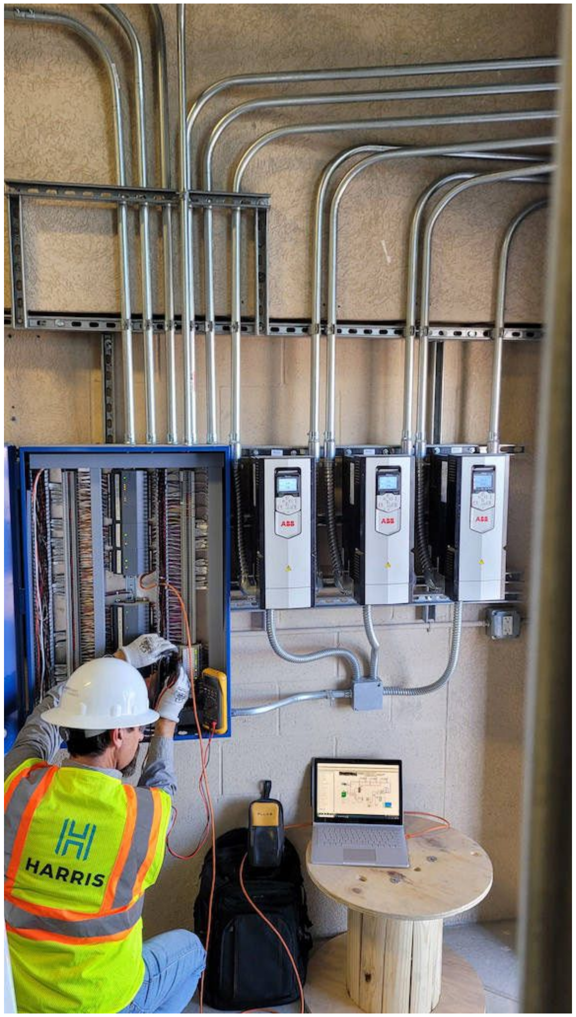
Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

ally erodes again and the vicious cycle continues resulting in a gradual decline in performance.

Now add in the probability the building automation system controlling the heating, ventilation and air conditioning equipment is original to the commercial building and hasn't been kept up to date — and, there's not a lot of system communication happening.

Today's available connectivity just didn't exist when most commercial buildings were constructed. Antiquated systems typically used proprietary technology platforms available only through a stand-alone terminal with obscure terminology and simple graphics that had to be decoded by anyone who could — which means, not much data from the facility was used to improve building performance.



Methods for managing buildings have changed and become better, but how do owners optimize their existing investment while taking advantage of new technology? Courtesy: Harris

Using the building automation system wisely

Fortunately, methods for managing buildings have changed and become better. The question is: How do consulting engineers help owners optimize their existing investment while taking advantage of new technology?

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

Take this example. The owner of a 25-year-old building with a 15-year-old BAS. The owner could get a few more years out of the BAS, but some of the mechanical equipment, such as the boiler or chiller, is deteriorating and need to be replaced soon. The newer equipment produces rich performance data and can communicate with new building automation standards, but cannot communicate with the old BAS, leaving the owner with a decision to either spend the extra money to upgrade the BAS and equipment or piecemeal the systems together and forfeit the benefits of an integrated system.

With today's technology, it's possible to marry the old BAS with newer pieces of mechanical equipment, gaining functionality and efficiency without having to replace the entire automation system.

By leveraging existing data being generated by the equipment and BAS, owners can preserve their assets, improve performance, reduce energy costs and increase occupancy comfort. Skilled BAS specialists and facility analytics engineers can also discover what equipment information is available, but not currently communicating within the building. That data can be monetized to improve overall business and facility performance once it is accessed, configured and analyzed.

It's about innovation and thinking beyond the restraints of the past. And, with the right facility analytics platform, a simple retrofit, such as adding motion sensors to a lighting system, can become pieces of information to be leveraged to improve other building systems.

Building automation system data and analytics

There are millions of data points generated in a typical building. Unlocking the data and knowing what to do with it is key. With facility analytics, data can be collected from

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

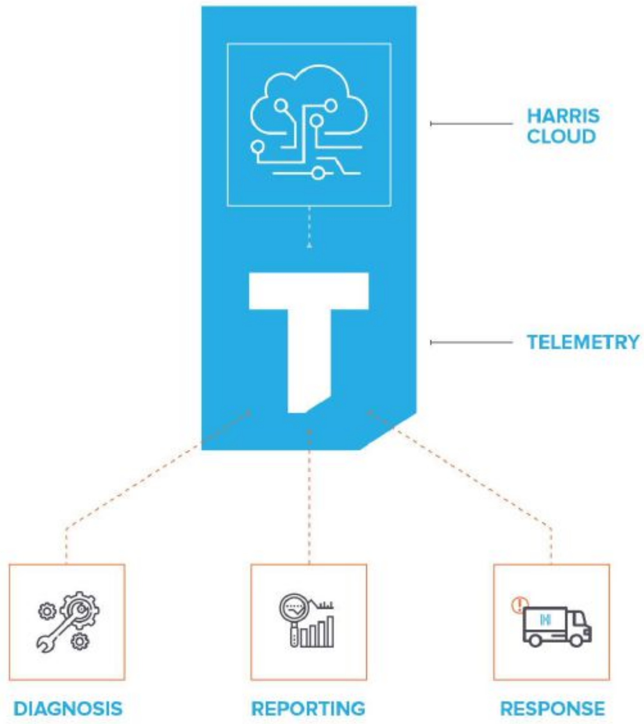
The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

sensors on a building's existing equipment systems to better diagnose malfunctions and find energy savings opportunities. Leveraging this information improves service and outcomes for the building, which means reduced energy costs and more sustainable systems for owners.



Telemetry uses facility analytics to help diagnose building maintenance needs, identify issues early and find energy savings opportunities. Courtesy: Harris

So, what has changed in facility management? Traditionally, system maintenance has fallen into three general models.

- A "run to failure strategy" where a new system is put in and when it breaks, service is called. Technicians may also clean or change a filter, but it's 100% reactive.
- Then there's the preventive plan. This model is a little more proactive as maintenance follows manufacturer guidelines (i.e., change filters every quarter, clean coils in the spring, etc.).
- Higher yet is the predictive model where maintenance becomes even more preemptive. Measures are used, such as vibration analysis or infrared thermography, to assess the reliability of a building's systems.

Five steps to BAS replacements
Engineering with automated fault detection and diagnostics
The Art of Building Sustainability
Deliver smart buildings using CSI Division 25, commissioning
Tap into a building automation system's data and maximize investment
VIDEO: Designing smart buildings with Aaron Szalaj

The problem is building owners are proactively chasing a reactive problem. While it's proactive to identify an issue, the reality is, you're picking up something that has already happened. Users can fix the vibration, but they don't know when it occurred or how much damage it caused. While fixing the problem is better than nothing, but it doesn't provide a complete picture.

That's the real role of data — finding deviations in real time. With facility analytics, data scientists can see what's happening in the building 24/7 year-round and apply a set of rules to see trends and determine how well things are performing — with no additional manpower. If certain patterns are known to lead to the eventual failure of a component that trend can be identified early and action can be taken to prevent a more costly fix down the road.

Bob Swanger

Bob Swanger, *executive vice president, Service + Building Automation, Harris, is a successful executive and business leader with more than 30 years of industry experience.*

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

VIDEO: Designing smart buildings with Aaron Szalaj

In this conversation with Aaron Szalaj from Stanley Consultants, hear how designers can help their clients select the most appropriate smart building technologies

Smart buildings and smart control systems are being requested by building owners, but how does a consulting engineer select and design smart systems for the client? What types of buildings or campuses are appropriate for smart, integrated systems? In this conversation, Aaron Szalaj talks about how smart buildings can help with reliability and sustainability, as well as managing emergency response using these smart building controls.

Aaron Szalaj, PE, *is a principal control systems engineer with Stanley Consultants, Denver. He has more than 20 years of professional engineering experience. His project experience includes renewable energies, water and wastewater, energy systems and federal installations. Szalaj has extensive experience with control systems and electrical engineering.*

Five steps to BAS replacements

Engineering with automated fault detection and diagnostics

The Art of Building Sustainability

Deliver smart buildings using CSI Division 25, commissioning

Tap into a building automation system's data and maximize investment

VIDEO: Designing smart buildings with Aaron Szalaj

Content Archive

2021 Fall Edition

2021 Summer Edition

2021 Spring Edition

2021 Winter Edition

Smart Buildings

Thank you for visiting the Smart Buildings eBook!

If you have any questions or feedback about the contents in this eBook, please contact CFE Media at *customerservice@cfemedia.com*

We would love to hear from you!