# BUILDING OPERATING SYSTEM

STRATEGIES FOR

# ESTABLISHING A BUILDING OPERATING SYSTEM

## FROM DESIGN AND PROCUREMENT TO DEPLOYMENT AND DATA MANAGEMENT


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# INTRODUCTION

Buildings are still largely being designed and developed with disparate systems and often inflexible or proprietary software controls. This silo-oriented approach is one approach but there is another approach that may help as new and retrofitted buildings can realize significantly more potential with new technology integration. Today's smart buildings (i.e., intelligent buildings) are data driven, leveraging sub-system integration and analytics that improve functionality making these facilities an operational and productivity asset.

Effectively achieving smart building objectives starts with reevaluating the way we design, engineer, procure, deploy, and operate buildings. Designing or redeveloping a building as an operating system or platform enables new applications and devices with "plug and play" functionality. The recent pandemic has made this building operating system (BOS) model even more relevant as end users implement applications such as technology-driven social distancing, building equipment condition monitoring, remote working, facility cleaning, and other workplace safety solutions.

In this paper, we explore how to design and deploy a smart building based on an operating system model to help ensure technology flexibility, reduced construction and operational costs, improved return on investment (ROI), and a better and more productive occupant experience. This paper will also examine how smart building technologies like power over Ethernet (PoE)-enabled edge devices, Digital Twins, and Single-Pair Ethernet (SPE) are emerging to deliver additional benefits and the potential for greater asset value.

## SECTION 1. GETTING STARTED:
# THE IMPORTANCE OF A SMART BUILDING DESIGN PROFESSIONAL

Many organizations have difficulty embracing and justifying the value and defining the ROI of a smart building. However, with a few simple building concepts, embarking on a smart building project can be as just as easy as a traditional building project—and ultimately less costly. Having a strategy in place that considers how a building will be used, the needs of its occupants, and its required levels of serviceability, flexibility, and resiliency helps align smart building technologies with stakeholder goals.

While architects, engineering, and construction (AEC) firms, and mechanical, electrical, and plumbing (MEP) design firms are becoming more smart building capable, an essential step to a successful smart building design is partnering with a smart building design professional or subject matter expert (SME) who has expertise in system integration, interoperability, and connected technologies. A master system integrator (MSI), consultant, or other carefully selected smart building design professional can seamlessly work with design teams and act as the owner's representative to ensure that the vision is adhered to across all systems throughout design, construction, and commissioning. A smart building design professional can help ensure that each team is designing their respective building systems with integration and interoperability in mind. For example, both parties can ensure that systems are interoperable and use communication protocols that allow them to share actionable data, converge on a unified physical infrastructure using standardized cable and connectivity, and leverage standards-based technologies like PoE.

Working with the end user and stakeholders, the smart building design professional can develop use cases for managing the disparate building systems. The smart building design professional can leverage established specifications for the technology infrastructure (i.e., wired, wireless, and hybrid networks), building systems, and edge devices. Not every smart building technology needs to be considered immediately but adopting a common platform will facilitate planning and implementation when required. Use cases are an important part of the planning and design process that helps guide design teams toward valuable smart building technologies that serve a purpose, rather than just implementing technology because it is trending. Through use cases, smart building design professionals can also determine the potential ROI of specific technologies.

Common considerations include capital cost savings, operational cost savings, and improvements to occupant experience and productivity. For example, while a smart PoE/low-voltage lighting system is a valuable design asset, it is often engineered out by design team members who are unaware or do not fully understand the benefits of the technology. Additionally, the return on investment is delayed because capital funds may not be available.

The smart building design professional can illustrate how smart PoE lighting costs less to install in a new construction environment, while also providing value through capabilities such as color tuning that can improve employee productivity and increased occupant safety through integration of emergency and public notification systems. For buildings that need to achieve certain environmental goals, the smart building design professional can demonstrate how energy-saving lighting controls like daylight harvesting, occupancy sensing, and timers may be simpler and less expensive to operate with smart lighting versus traditional lighting. Understanding the numerous potential savings of technology investments like smart PoE/low-voltage lighting is critical to the decision-making process.

Once the technology solution(s) has been outlined, the smart building design professional can then seek additional economies of scale. For example, if one system is collecting temperature data and can share that information with other systems, it may not be necessary for other systems to also have temperature sensors. By proactively looking for overlapping data points, smart building design professionals can eliminate redundant technology, while achieving same or better systems operations.

## SECTION 2. DESIGNING THE SMART BUILDING:
# THE NEED FOR A NEW APPROACH

For a smart building design to be successful, traditional cookie-cutter design processes used in the AEC community and centered around siloed, standalone or inflexibe systems need to be altered or their approach modified. Traditionally, systems were not designed to be interoperable and therefore had limited machine-to-machine communication or cross-platform interconnectivity. Connection and demarcation points were used whenever there was a need for integration, since clear and easy to define. At the time, the AEC industry created processes that reflected the reality of the systems they were designing.

Due to the isolated nature of traditional building systems, there was minimal risk in architects assembling separate design firms for each system. The MEP firm could be different from the fire protection firm, and even electrical and plumbing engineers could be from a different firm than mechanical engineers. Telecommunications engineering firms were also often separated from the MEP firm. Even within the area of low voltage technology, it was common to have separate firms for voice and data, audio/video, and security systems. Design of independent building solutions and their respective design teams, with their highly focused tools, perpetuated siloed systems that lack interoperability, efficiencies, and cost optimizations. In many cases, this siloed approach resulted in divisions of scope to their firms with the goal of minimizing fees paid to subconsultants and increasing revenue, but with the drawback of homogenized proposed solutions with limited interoperability and expandability.

The rise of smart buildings now requires the AEC industry to reevaluate what has become second nature in their design processes. Rather than the traditional siloed approach that requires significant effort and expense to interconnect systems, the basic premise of a smart building is convergence.  This allows operational technology (OT) and information technology (IT) systems to be easily integrated and reside on a unified physical infrastructure based on standards-based communication protocols such as TCP/IP Ethernet. Not only are these systems unified at the physical layer, but through accessible communication protocols and data sharing capabilities, they can also be unified at the application level. In a smart building, IT, OT and IoT systems converge; silos and demarcation lines have the potential to disappear.

This new reality requires a completely different design approach. With smart building systems having no clear lines of demarcation and sharing much of the same infrastructure, today's design process must reflect the unified nature of the systems being designed. When the design team consists of a multitude of disparate narrowly focused design professionals, all with their own siloed scope of work, there is less incentive for these teams to integrate. That is where the smart building design professional comes in. The role of the smart building design professional is to bring holistic thought and execution leadership to the entire smart building ecosystem and AEC design process, while enforcing the scope, mitigating conflict, and reducing risk.

A good smart building design and deployment strategy requires different thought processes across many disciplines and specialties. Once the right smart building design team and approach are in place and the design is nearing completion, the project transitions to the procurement process.

## SECTION 3. THE PROCUREMENT PROCESS: NEW STRATEGIES FOR RFPS

Many of the problems surrounding the traditionally siloed systems design approach also apply to the procurement process. Unfortunately, requests for proposals (RFPs) to architects and engineer design professionals often still reflect and foster a siloed approach. It is typical for an RFP to require a breakout of the scope of work and fees for each itemized building system, which encourages the assembly of disparate design teams. In a unified smart building design, procurement professionals developing RFPs need to take a closer look at what is being incentivized and consider the goal of delivering the desired outcomes within a single ecosystem. The following are some key considerations.

- The goal is to create an RFP to solicit holistic design efforts for building systems. Doing so removes siloes and incentivizes collaborative design and integration of the building systems.
- In a unified design process that recognizes a smart building as a unified ecosystem, there are few lines of demarcation. The RFP should therefore no longer demand a breakdown of hours, fees, or meeting counts for each individual system. Unified design meetings will address the entire ecosystem simultaneously, and requiring a breakout no longer incentivizes the right goal. Unification of the procurement process may also provide the opportunity for deeper discounts on products and services.

- A request for information (RFI) is typically a good start to the procurement process as it will help establish baseline pricing and capabilities of responding design vendors. The RFI can be conducted prior to project funding being secured, giving stakeholders the ability to ask questions about available technology and system integration capabilities. Once the RFI process is complete, the information gathered can be used to craft an RFP that better defines the building scope and reflects a unified design process.
- A successful RFP process often includes the use of a scoring matrix derived from the RFP documents. Project awards are based on the cumulative scoring by individuals within a committee of stakeholders or procurement department responsible for evaluating vendors.

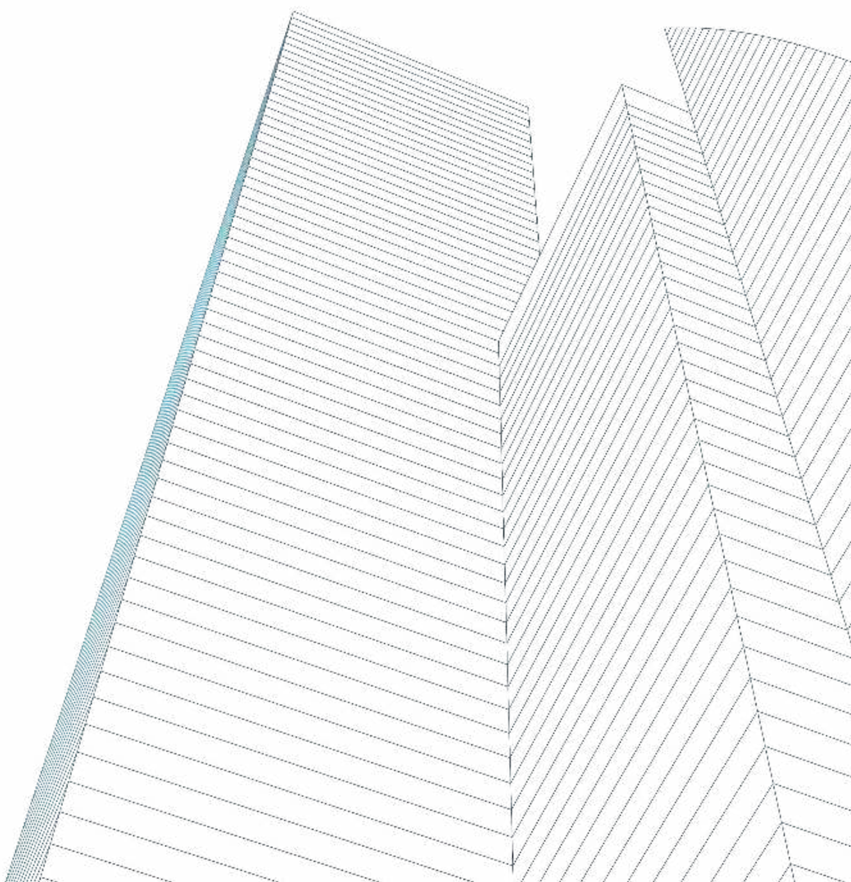
Through an effective design and procurement process—from the schematic design and design development to construction documentation—a smart building project can confidently move into the deployment phase and close-out.

# SECTION 4. DEPLOYING SMART BUILDING TECHNOLOGIES: FROM GREENFIELD TO BROWNFIELD

Many of the problems surrounding the traditionally siloed systems design approach also apply to the procurement process. Unfortunately, requests for proposals (RFPs) to architects and engineer design professionals often still reflect and foster a siloed approach. It is typical for an RFP to require a breakout of the scope of work and fees for each itemized building system, which encourages the assembly of disparate design teams. In a unified smart building design, procurement professionals developing RFPs need to take a closer look at what is being incentivized and consider the goal of delivering the desired outcomes within a single ecosystem. The following are some key considerations.

## Ensuring Integration

The process of deploying smart building technologies in a new or greenfield project is potentially smoother when a smart building design professional is engaged early in the process and the design and procurement does not take a siloed approach that involves multiple divisions of construction. This helps eliminate the challenge of having various systems that often use different communication protocols, closed application programming interfaces (APIs), inflexible data naming schemas, and disparate infrastructure. With a smart building design professional who understands the owner's vision and has the systems integration expertise to carefully select technology that ensures devices, sensors, and systems can share and act



upon information, more unified interconnectivity is required to achieve integration. The Master Format, published by the Construction Specifications Institute (CSI) and used as the standard for formatting construction specifications, includes Division 25 that defines the hardware and software integration, contractors' roles and responsibilities, and the standards necessary to build an integration platform upfront. Implementing a robust CSI Division 25 specification can save time and money in the deployment phase.

Given that building systems may be using different protocols, Division 25 format includes a subsection on network gateways that work as translators between different protocols and enable data sharing. For example, gateway devices are available that make existing Modbus devices used in boiler control and metering applications appear as BACnet devices and able to communicate on a BACnet/IP network and be managed from a BACnet building management system (BMS). However, the use of gateways should be limited whenever possible as they add hardware to the network and potential failure points. To achieve unique naming schemes, it is best to define an export table or schema translator so data can be recognized by the building's BMS and the analytics platform.

## Determining the Right Media

In addition to ensuring integration, it is important to determine the right media for connecting edge devices. Ensuring a robust converged fiber and copper structured cabling infrastructure for the CSI Division 27 and other divisions pertaining to communications specification is also paramount to supporting communication between systems. It also provides the flexibility to quickly adopt future edge devices and technologies driven by new operational and occupant requirements.

While fiber is being deployed closer to the edge to support greater distance and bandwidth requirements and reduce space and material needs, few edge devices feature fiber connections since category twisted-pair copper cable has traditionally been used for horizontal infrastructure that connects to edge devices. A key benefit to utilizing category cable at the edge is that it supports both data transmission and PoE to power and control edge devices like video cameras and Wi-Fi access points.

Wireless technology also plays a significant role in connecting edge devices. However, it is important to note that all wireless systems are eventually connected via a physical media type, such as copper, coax, hybrid, and fiber cabling infrastructure to transmit data back to the core network. Popular wireless technologies include Wi-Fi, cellular (4G/5G), BLE, LoRa, ZigBee, OnGo/CBRS, and more. This is where OT and IT often overlap.

It is important to make decisions regarding wireless, wired, and hybrid infrastructure early in the design process versus during the construction stage. IoT devices have been a critical driver for adding sensors to the edge that monitor and collect data on air quality, pressure, power, presence of water, and much more. Access to this data is enabling new solutions such as touchless elevators, frictionless welcome centers, smart parking systems, and even smart dumpsters. When selecting solutions and sensors, it is important to look beyond just functionality and consider the built environment, connectivity, appearance, cybersecurity, and sustainability requirements.

## Brownfield Considerations

While greenfield projects are more streamlined for smart building transformation, brownfield or existing buildings can also become smarter, but the digital strategy is more critical, especially if there are multiple buildings on a campus or a portfolio of properties. Depending on the type of organization (e.g., higher ed, life sciences, retail, healthcare, etc.), the digital strategy will define goals in two distinct categories—building performance and occupant experience—both of which can differ significantly from organization to organization regardless of building type. If existing buildings are part of the strategy, the smart building design professional will need to consider what technologies already exist, select technologies that meet the owner's requirement, and select the most economical solutions to transform the building into a smart building. For example, the smart building design professional will need to assess what connectivity is available and if it can be reused, and they will also need to review existing systems to identify protocols and determine how best to integrate all systems for sharing data. This includes:

- Reviewing drawings, specifications, and submittals
- Descoping selected vendors and manufacturers
- Evaluating network performance metrics and understanding the impact of future proposals.
- Identifying any gaps between the integration expectations and the current design
- Making recommendations on technology and solutions needed to meet the owner's expectations.

Consider the addition of a large IoT deployment that uses Wi-Fi. As OT begin to plan the deployment, they need to work with IT to ensure the current Wi-Fi systems can take on the additional load of 100+ sensors and deploy the proper cybersecurity policies to ensure network security. In some cases, the extra load may require an updated Wi-Fi network like high-throughput Wi-Fi 6 or additional Wi-Fi access points and zones.

This is just one of several examples of the importance of OT and IT collaborating to avoid conflicts and failed projects.

## Testing and Commissioning and Warranty

Once the systems have been installed, testing and commissioning take on a whole new meaning in a fully integrated smart building. Prior to integrated smart building systems, testing of the cable and connectivity was straightforward but limited. Today, testing includes assurance of all facets of the network, including both active and passive components, and verifying appropriate bandwidth, power, and distance. This is especially important when smart building systems are being deployed via cabling, new or existing.

Traditionally, a system would be tested and commissioned based on its standalone or narrowly defined solution parameters. In an integrated system, additional time, effort, and consideration must be allocated as solutions must also be tested and commissioned to work with external systems from various manufacturers. This testing may need to consider network protocols, naming schemas, bandwidth, connectivity, and multiple types of power delivery.

Commissioning needs to ensure end-to-end system functionality in the way the owner and end-user will use them. The goal of integrated systems is to ensure that data is readily available for making smart decisions that align with the owner's vision and optimize the operations and occupant experience.

Once the smart building technologies are deployed, documentation (e.g., as-built, test results, warranty information) becomes a crucial asset for maximizing the operations of the building.

# SECTION 5. DOCUMENTING AND MANAGING SMART BUILDING DATA: A CRITICAL PRACTICE

Accurate and complete digital building documentation through the mapping of a physical asset to a digital platform (e.g., as-built drawings, floor plan maps, technologies, etc.) enhances the ability of organizations to efficiently manage the design, construction, integration, deployment, and operation of their building spaces. Many such use cases include more efficient facilities management, improved tenant experience, improved compliance/reduced risk, improved security, and improved finance/asset management.

## Smart Building Documentation as an Asset

Availability to quality digital building data in a timely manner is an especially compelling attribute in the aftermath of the pandemic as the commercial real estate industry repurposes, redesigns, and rebuilds spaces to accommodate return to work/school rules and regulations and practices. Smart buildings must also be prepared to readily accommodate new rules, regulations, standards, and mandates coming from the organization, the industry, and local, national, and federal governments. These resulting projects often require smart building sensor technology that captures imagery, thermal, lighting, CO2, or connectivity data to monitor performance, manage Key Performance Indicators (KPIs), and assure safe occupant experiences within buildings. Project procurement costs and cycle times to provision these systems can be minimized if the building documentation is readily available online to bidders, enabling them to streamline their proposal process without time-consuming and costly onsite survey(s) to capture field data, inventory assets, and building features of interest.

Consider an office building that is upgrading their traditional lighting system to a smart LED lighting solution. Procurement develops an RFP that provides qualified bidders online access to accurate building floor plan maps that depict the locations of walls, doors, and windows and include detailed layers with location and relevant info (e.g., type, count, model, etc.) of all existing lighting fixtures, skylights, light switches, and controls, as well as electric panel diagrams. The online floorplan maps may also include layers that provide cubicle and workstation locations, candlestick power heatmaps, and a 360-degree imagery viewer with measurement tools to allow bidders to remotely walk through the building. This online availability improves bidder understanding of the as-built environment and allows them to prepare their RFP responses at a significantly reduced cost and risk. The lower procurement cost and cycle time reductions positively impact the ROI for these projects. Access to this level of detail helps to improve building occupant experience as well as the bottom line by potentially lowering vacancy rates, increasing rental income, and lowering operating costs.

For existing buildings, digital building documentation is also vital for new owners/tenants to assess the value of the assets and more accurately determine development costs. In this scenario, the documentation should be available prior to the final transaction. The cost and time required to produce documentation post acquisition can quickly skyrocket.

The key takeaway is that digital building documentation is an asset that can generate significant ROI and benefit for building owners, property managers, and tenants. However, adequate time and budgeting must be allocated to procure an accurate digital record of the building status. Additionally, it needs to be effectively managed, maintained, and made available to relevant users across functional teams and vendors to support the entire lifecycle, from acquisition through development, operations, and ultimately disposition (or re-development).

## Managing Digital Building Documentation and Data

For digital building documentation to support multiple use cases and functional work teams, it needs to be made available in multiple formats, structures, and level of details based on user and system requirements. To document continuous changes and improvements made to the built environment, complete building data should also include multiple formats and versions, from design to as-built to as-maintained. When available in multiple formats, digital building documentation can be interpreted by a variety of software-based systems that are used to lease, maintain, operate, and develop the building. The diagram in Figure 1 below references Centralized Maintenance Management Systems (CMMS), but there are many others—from Enterprise Asset Management (EAM) systems to help manage building infrastructure and assets, to Computer Aided Facilities Management (CAFM) and Integrated Workspace Management Systems (IWMS), to people and asset tracking and routing software systems. To be leveraged to their fullest potential and facilitate the management and operations of the built environment, these systems require accurate building documentation in specific digital formats.

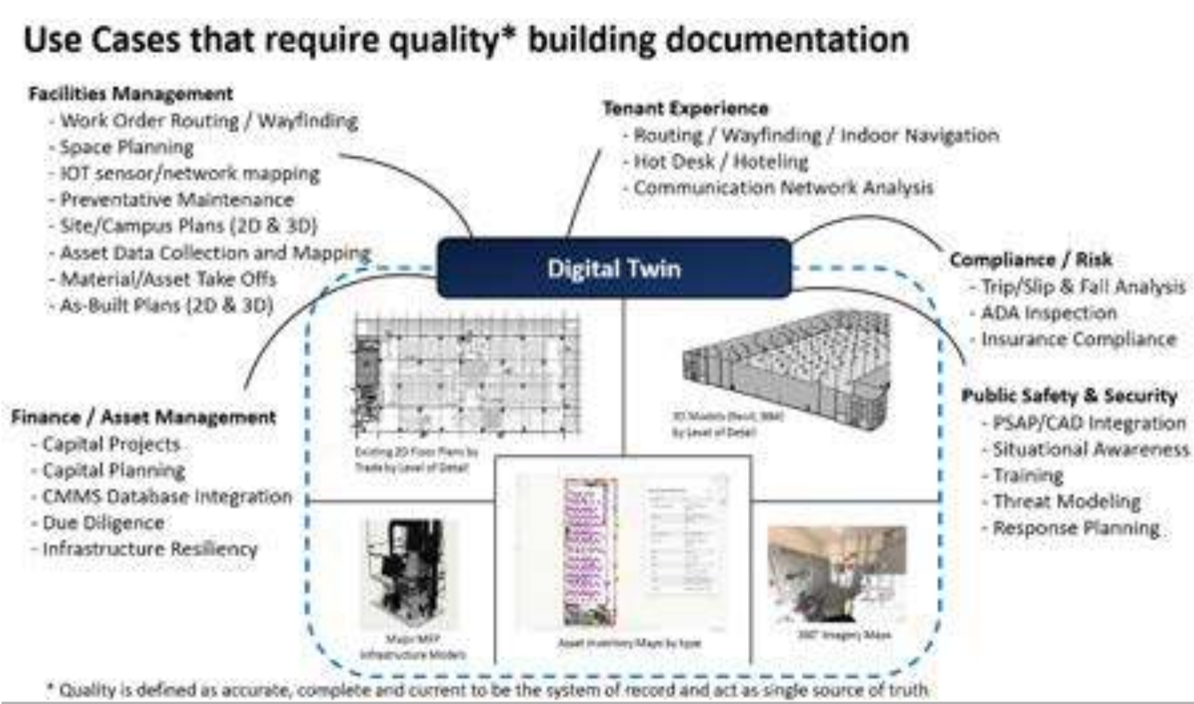



**Figure 1:** Use cases that require quality building documentation. Courtesy of Mozark PTE Ltd.

While not a requirement, the use of a digital twin inherently solves the single biggest problem of outdated, obsolete building data trapped in standalone silos. The digital twin model is a real-time virtual representation of a building that is intended to share data across silos that exist in functional organizations, including vendors. Different business units such as facilities, property, construction, and project management have traditionally captured and stored data in their own repositories. The digital twin can potentially remedy this problem by acting as a proxy to collect data from sensors and other sources across all systems and business units rather than each silo constraining its own data. The digital twin model understands the relationship between all the siloed data sources to readily map the connections and data from the physical building to the digital building representation where analytics can be used to optimize the experiences for occupants and minimize downtime and maintenance costs for assets.

It's important to note that developing accurate 3D models of the built environment has traditionally required specialty Light Detection and Ranging (LiDAR) laser scanners that are complex and require highly trained staff to produce the desired outputs. However, emerging technologies like photogrammetry that use 3D coordinate measuring techniques and 360-degree photographs of the indoor environments to create 3D models and geographic information system (GIS) maps for building documentation can be utilized without the skills and technology required by LiDAR. This technology can also work with emerging Machine Learning (ML) software to generate geospatially accurate building documentation from the processed imagery. In fact, solutions are available that enable an individual to walk through a building within the 360-degree imagery maps and simply click to add an asset or feature of interest into a 2D or 3D floor plan.

Emerging technologies that enable the creation of digital models that are more accessible than LiDAR means that building owners, vendors, and other stakeholders can now more easily gain access to quality building data that allows them to capture and assess building changes, upgrades, and retrofits. New assets and systems can be added to the existing geodatabase and reflected in all new building models to manage the building infrastructure, equipment, and user experiences.

## Storing and Analyzing Data

Per Figure 2 below, the building data repository or digital twin includes relevant building model and data that can be stored and curated to be made available to users via access controls that define usage rights (e.g., administrator, edit, view, etc.) and accessibility to specific documentation based on user credentials.

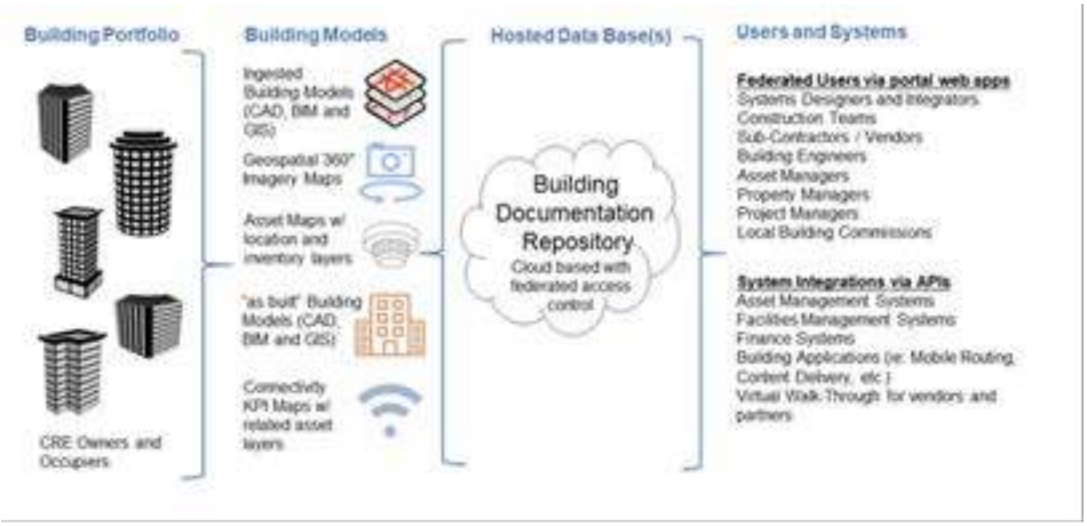



**Figure 2:** Centralized repository to foster sharing and eliminate siloed building data. Courtesy of Mozark PTE Ltd.

While on-premises data centers historically provided the computing power for storage and analytics, the past decade has seen a shift to cloud computing where data repositories can be managed by IT and hosted in the cloud as part of a software as a service (SaaS) or platform as a service (PaaS) offering. There are many providers of cloud-based solutions that enable enterprises to manage the building documentation, including Autodesk, Microsoft, IBM, Esri, and hundreds of others. Many of these platforms have APIs defined to integrate into other business systems such as EAM, BMS, CMMS, CAFM, IWMS, and other finance and facilities systems.

The MSI may need to give consideration for additional telecommunications space due to the need for lower latency in processing time-sensitive data and delivering real-time immersive and responsive user experiences, edge computing is now gaining ground.  While the cloud provides access to massive compute and storage power, it was not created with the agility to handle the volume, velocity, and real-time analysis of the data generated by IoT devices. According to recent reports from Gartner, “Around 10% of enterprise-generated data is created and processed outside a traditional centralized data center or cloud. By 2025 this figure will reach 75%”. Computing workloads are therefore becoming decentralized and moving to the edge as shown in Figure 3.

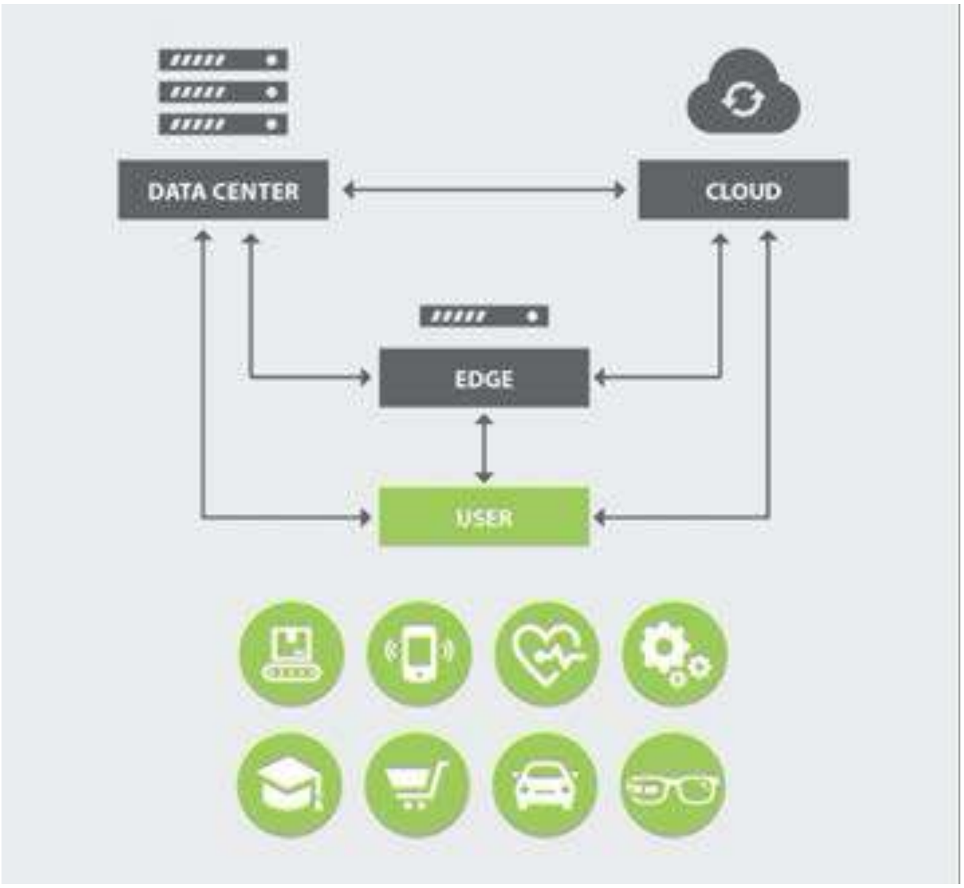



**Figure 3:** Computing at the Edge. Courtesy of Leading Edge Design Group.

The availability of accurate building data that can be securely accessed by permitted users and ingested into business and facilities management software systems will streamline all aspects of building ownership, operations, and management. The building documentation can also become part of the deliverables provided by the smart building design professional or master systems integrator rather than being the sole responsibility of the AEC industry. This allows these individuals to deliver technology upgrades and retrofit information to the data model that captures the technology, assets, and infrastructure within the digital twin of the smart building.

# SECTION 6. THE FUTURE OF SMART BUILDINGS: A LOOK AT EMERGING TECHNOLOGIES

Traditionally, progress within data transmission has been measured by speed. However, when one looks to the future of building technologies and convergence, new devices like sensors, HVAC controls, and lighting controls are not bandwidth intensive. They simply require a reliable data connection at a minimal data rate.

Smart building devices also require power connections. In brownfield deployments wireless device connectivity can make deployments quick and less invasive but trying to run building systems over a battery-powered wireless connection can create long term reliability issues as the batteries start to lose power over time. A wired connection can effectively last for the lifetime of the building and is therefore the preferred method of deployment in new construction projects.

As we look forward to new underlying smart building technologies, the following advances are occurring in both data and power and can be used to enable the next generation smart buildings.

## Single-Pair Ethernet

Single-Pair Ethernet (SPE) is a new enabling technology that allows for low-speed data transmission over longer distances, along with power delivery. While typical category twisted-pair cables use four pairs of conductors, SPE uses only a single pair. SPE connectors and cables have been standardized by both the IEC and TIA industry standards bodies for commercial buildings, with examples shown in Figure 4.

**Figure 4:** Single Pair Ethernet IEC 63171-1 type 1 and ANSI/TIA-568.5 SP1 Connector and Cable. Courtesy of Panduit.

The IEEE has completed work on two SPE versions—10BASE-T1L and 10BASE-T1S—as shown in Figure 5. 10BASE-T1L is a long distance, point-to-point connection, similar to traditional Ethernet. 10BASE-T1S is a shorter distance, multidrop technology (one point to many points). Both technologies are aimed at enhancing an existing building's IT and OT infrastructure through the consolidation of previously siloed communications systems by using the same basic twisted-pair cabling technology to connect and power low-speed smart building devices at greater distances.

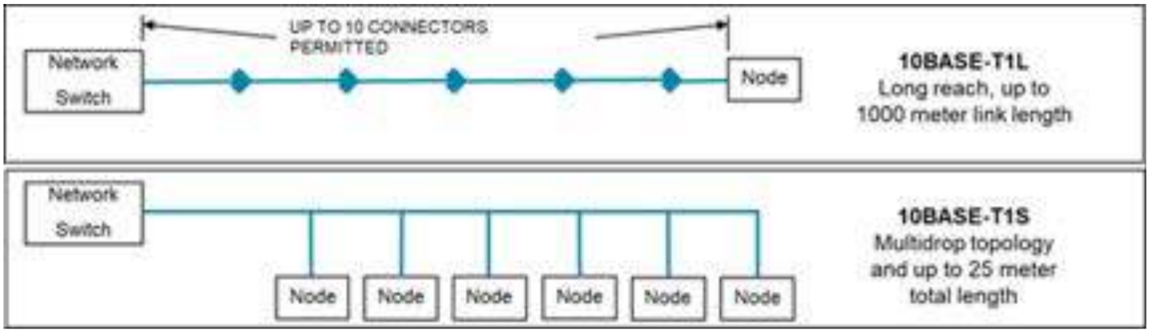



**Figure 5:** Single Pair Ethernet 10BASE-T1L and 10BASE-T1S Comparison. Courtesy of Panduit.

As shown in the comparison of traditional Ethernet using four-pair cabling versus 10BASE-T1L SPE in Table 1, SPE offers the following advantages over traditional Ethernet.

- Longer reach (up to 1000 m versus 100 m), though at a lower data rate
- Able to provide power at the longer reach, though at a lower wattage
- Smaller form factor better suited for sensors

| Parameter | 4-pair | Single Pair (10BASE-T1L) |
|---|---|---|
| Data Rate | Up to 10 Gb/s (10GBASE-T) | 10 Mb/s at 1000 m |
| Power Levels | Up to 71 W (PoE++) | 7 W to 52 W, depending on cable length |
| Reach | Up to 100 m | Up to 1000 m |
| Connector Type | RJ45 | Modified LC |
| RU Density | 48 ports in 1 RU | 96 ports in 1 RU |

**Table 1:** Comparison of traditional 4-pair Ethernet and Single Pair Ethernet (10BASE-T1L). Courtesy of Panduit.

## Powering Alternatives

There are alternatives that support powering devices to smart buildings in a different manner than traditional separate AC power circuits and these include ubiquitous PoE and new and upcoming Class 4 Power, Single-pair Power over Ethernet (SPoE), Power over Data Line (PoDL), and Hybrid Powered Fiber. Each of these alternative methods is outlined below.

### › Power over Ethernet (PoE)

PoE is the now common technology used to provide data and power simultaneously over category four-pair twisted-pair cable to a variety of devices, such as IP phones, security cameras, point of sales devices, and wireless access points. PoE offers a much simpler and lower cost installation of devices compared to having to run separate data and power cables. As shown in Figure 6, PoE variant delivers power from Power Sourcing Equipment (PSE) such as a PoE-enabled Ethernet switch to a Powered Device (PD) over all eight conductors of a category four-pair cable.

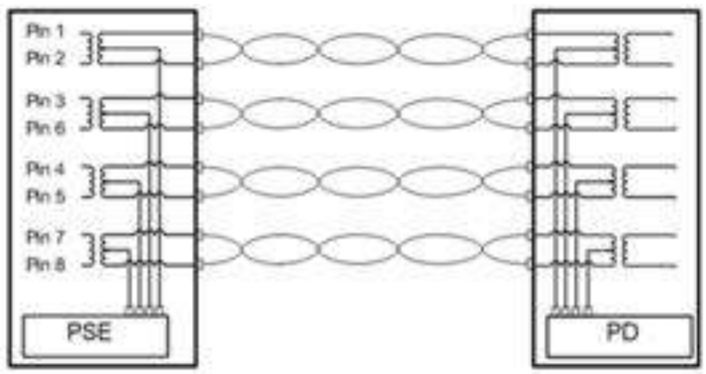



**Figure 6:** Power over Ethernet Diagram. Courtesy of Panduit.

Table 2 shows the current standards based PoE versions available. The latest PoE++ 802.3bt standard includes Type 4 that can guarantee a minimum delivery of 71W of power at the device along with data speeds up to 10GBASE-T (i.e., 10 Gigabits per second), which makes PoE a highly effective means to run power and data to any device.

| Common Name | Standards | Maximum Current | Number of Energized Pairs | Power at Source | Power at Device | Max Data Rate |
|---|---|---|---|---|---|---|
| PoE | IEEE 802.3af (Type 1) | 350mA | 2 | 15.4 W | 13 W | 1000BASE-T |
| PoE+ | IEEE 802.3at (Type 2) | 600mA | 2 | 30 W | 25.5 W | 1000BASE-T |
| PoE++ (4PPoE) | IEEE 802.3bt (Type 3)<br>IEEE 802.3bt (Type 4) | 600mA<br>960mA | 4 | 60 W<br>99 W | 51 W<br>71 W | 10GBASE-T |

**Table 2:** Power over Ethernet Standards Comparison. Courtesy of Panduit.

There are a variety of options for powering remote devices, and in some cases, power decisions are driven by policy. Wireless IoT devices powered by batteries can last from five to ten years depending on the device and how often they report data. But battery-powered devices will eventually need new batteries and some companies may not permit them, for other reasons, and prefer other methods of power delivery (e.g., PoE). For example, there are many institutions such as financial and government entities that do not allow wireless sensors due to increased cybersecurity risk.

- ### Class 4 Power

  Class 4 power is a new and upcoming technology that utilizes new levels of intelligent control to distribute higher levels of power over longer distances. It is sometimes referred to as Fault Managed Power as the system is designed to monitor the distribution of power and react quickly when a fault is detected. This is an entirely new method of running power to a device. Unlike PoE, Class 4 power may operate at voltages up to 450V and is not transmitted simultaneously with Ethernet data over the same conductors.  At the time of writing, the Class 4 nomenclature is expected to be a new class of circuits within the United States National Electric Code (NEC) in addition to the already existing Class 1, 2, and 3 circuits as remote-control, signaling, and power-limited circuits.

  As shown in Figure 7, one variant of Class 4 power distribution takes standard AC or DC power and transforms it into a pulsed current waveform that is delivered over common multi-conductor power cables such as an 18 AWG two-conductor cable. Each pulse has a short duration of time (e.g., 2ms).

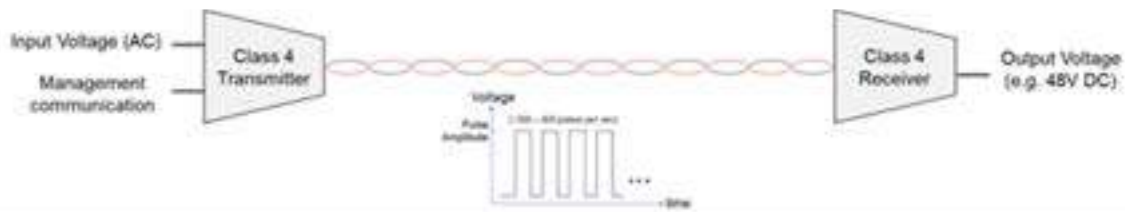



**Figure 7:** Class 4 Power (Fault Managed Power) Diagram. Courtesy of Panduit.

In a Class 4 power system, issues such as electrical shorts, over current, and human contact, are quickly detected by a fault detection system and power transmission stops within milliseconds, which is much faster than a traditional AC circuit breaker. Class 4 power offers the following advantages over other powering methods:

- **Safety** — The ability to stop transmission immediately after detecting a fault makes Class 4 power inherently safer over traditional AC or DC power.
- **Lower Cost** — Class 4 power may enable the use of smaller copper wire gauges, which in certain jurisdictions, would not require electricians or conduit for installation.
- **Greater Power and Distance** — Class 4 power may provide approximately twenty-five times the power of Type 4 PoE at 20 times the distance.

Currently, systems that would be categorized as Class 4 are being used for power-specific applications such as the Distributed Antenna Systems (DAS), where power needs are well understood. As it becomes more common, Class 4 systems will be used for many other building systems and likely increase the use of hybrid fiber optic cables.

## Single-Pair Power over Ethernet (SPoE) and Power over Data Lines (PoDL)

SPoE is specifically defined to work with the 10BASE-T1L 10Mb/s SPE protocol. The IEEE 802.3 working group originally standardized powering over a single pair of conductors at 100Mb/s and 1000Mb/s in the standard IEEE 802.3bu, known as Power over Data Lines (PoDL). IEEE 802.3cg extended the specification to support lower 10Mb/s speeds for sensors in OT environments. In practice there are two variants of single-pair powering—SPoE and PoDL. SPoE describes implementation utilized in commercial OT networks, while PoDL is typically implemented in engineered industrial environments such as in-car networks.

## Hybrid and Powered Fiber Cables

Hybrid and powered fiber cables allow end-users to take advantage of DC power and fiber in one cable to safely deliver low-voltage power and data over longer distances to remote locations where standard AC power is unavailable or too costly to install. Examples include the deployment of security cameras atop parking lot light poles or wireless access points in a warehouse. These cables typically consist of fiber strands for data and copper conductors that range in number and gauge (e.g., typically 12 to 20 AWG) depending on the number of connected devices and their power requirements. Larger conductors can carry more power over greater distances. Note that the power provided via these cables is typically considered non-PoE Class 2 power per the NEC. Hybrid and powered fiber cables can also distribute Class 3 power to active equipment, lighting grids, commercial sound systems, and life safety and security systems that require more power than Class 2 can deliver. It is anticipated that similar cable designs will be utilized extensively in Class 4 power distribution systems.

As previously mentioned, one consideration is the lack of fiber connections on most smart building devices. Some devices may also not include separate terminals for connecting to the power conductors. In this scenario, using a hybrid and powered fiber cable to support data and power may require the use of active equipment that can perform media conversion (e.g., PoE media converter, optical network terminal, etc.). The active equipment converts optical data signals to electrical and DC power to PoE for delivery to connected devices over short category twisted-pair cabling (i.e., patch cord). When using these types of cables, pre-planning is critical to ensure enough power to support a device based on its current draw and distance from the power source. In addition to supporting greater distances and bandwidth, another advantage of systems utilizing hybrid and powered fiber cables is the ability to centralize maintenance via power sourcing equipment.

# CONCLUSION

The concept of a building hosting several disparate building systems with independent and often incompatible software controls is a relic of the past. Current technologies are already enabling the convergence required for the next generation of smart buildings. While some "behind the wall" smart building technologies may not be overtly exciting, they are paving the way for even more convergence among building systems. This will enable a building operating system (BOS) model where the buildings become a plug-and-play platforms for current and future smart building devices that can revolutionize operations and occupant experiences.

However, as clearly demonstrated in this paper, effective smart building design, procurement, deployment, and data documentation and management requires new approaches and poses unique aspects. Having a qualified design team that includes a Smart Building Design Professional who can work outside of the antiquated siloed design approach and effectively collaborate with an integrated design team is critical for success. Using a well-thought-out procurement process that aligns the RFPs/RFIs with the project deliverables, deployment strategies that consider converged infrastructure, power delivery, wireless connectivity, and end-user use cases will increase potential efficiencies. Effective documentation and data management that includes a digital twin or other means to effectively document, share, manage, and analyze building design and data goes a long way in ensuring a successful smart building project that meets owner objectives and delivers optimized ROI, operational savings, and occupant experience. At the same time, having a Smart Building Design Professional with an understanding and willingness to embrace emerging and future technologies for connecting and powering smart building devices will ensure that smart buildings continue to evolve and deliver maximum value.

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