The ASHRAE Digital Lighthouse & Industry 4.0

BY CHARLES E. GULLEDGE III, P.E., HBDP, FELLOW ASHRAE

I was seven when my father died from cancer. In many ways I was an observer of this experience—watching adults cry and grieve. It was a time when children were more of an afterthought. For me, in the simplest way, it meant my dad was here one day, gone the next. And then my mom and I lived alone in Hamlet, North Carolina.

My mom was a high-school French teacher. *Oui, je parles Francais, un peu.* (Yes, I speak French, a little.) Our summers after my father's death were spent with my grandparents in Valdese, North Carolina.

I called my grandfather Don. He was born and raised in northern Italy, in the high Alps region along the French border. He spoke a beautiful Patois dialect of blended French and Italian. He would often use this language when speaking with me.

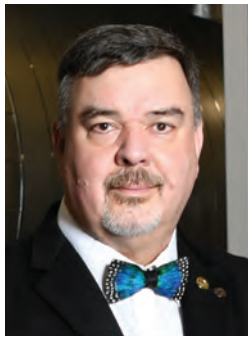
One of his most endearing and often used phrases was "DEE-PON-NIEN-TY, DEE-PON-NIEN-TY!"

Translated, this means "SHUT UP!" In retrospect, I recognize that those were tough love teaching moments: listen, observe and understand before engaging in the moment.

Don immigrated here as a young man with his mother and sister in pursuit of the American dream. Having no grasp of English, he took a leap of faith that led his family to the foothills of western North Carolina. His example has always inspired me to have the courage to embrace change.

I still hold the first dollar he made in the New World.

Charles E. Gulledge III, P.E., HBDP, Fellow ASHRAE, ASHRAE President 2020 – 21



ASHRAE President Charles E. Gulledge III, P.E., HBDP, Fellow ASHRAE, previously served on the ASHRAE Board of Directors as president-elect, treasurer, vice president and director-at-large.

He is the recipient of many ASHRAE awards including the Exceptional Service Award, Distinguished Service Award, Chapter Service Award, Regional Award of Merit, two ASHRAE Technology Awards and the Dan Mills Technology Award.

In addition to his time served on the Board of Directors, Gulledge has served as chair of the Members Council and the President-Elect Advisory Committee, chair of the Finance Committee, chair of the Standards Membership Ad Hoc Committee, chair of the Development Committee for Fundraising and as an ASHRAE Distinguished Lecturer.

Don was the consummate engineer, machinist and farmer. He taught me how things were built and operate. He taught me how to farm the land and put food on the table.

The potatoes we dug were stored in the cool basement of our rock barn: applied cold chain innovation. The beans and cucumbers we picked were canned and stored. The corn we shucked was shaved, packed and frozen.

Working beside my grandparents during those summers provided a bounty of lessons. One of those was the natural progression of work, particularly work on the land.

- Plow: Soil must be prepared and configured.
- Plant: The seed we sow turns into the crop that grows.
- Maintain: What we grow needs continuous attention.
- Harvest: Reap what you sow.

I learned that you can't cheat the natural process. There is no harvest without plowing, planting and maintaining.

FIGURE 1 Industry 4.0 framework and contributing digital technologies.

SOURCE: PWC, 2016

The Bridge to Relevance

Engineering and construction (E&C) is a lot like farming.

- Plow: Preparation requires assembling the correct team.
- Plant: The outcome we desire needs a well-defined path.
- Maintain: Continuous improvement is implemented to drive value.
- Harvest: Built solutions that exceed expectations are delivered.

Yes, the E&C process is no different than nature's own. We can't cheat this natural flow.

Let's pause for a moment to ask why?

Why should we care about plowing, planting and maintaining within our ecosystem? That sounds like hard work.

Here's why!

We can:

- Differentiate ourselves from the competition;
- Identify ourselves as the innovators;
- Improve our profit margins;
- Attract and retain a digital savvy workforce; and
- Deliver value.

Our evolution to digital maturity can deliver this harvest, and more.

The Current State

Every journey has a starting point.

Before we explore the digital path, let's reflect on our current industry state. Let's start by considering how poorly we have managed our crops. Why are we still burdened with marginal yields?

First, our current workflows are ripe with waste!

It is estimated that in the U.S. alone, $177 billion is lost annually on nonproductive labor activities. Looking for information; engaging in conflict resolution; dealing with mistakes; and performing rework all impact the bottom line.

$31 billion of this loss is directly associated with poor data and communication. Poor in this context is inaccurate, inaccessible and incompatible.

Second, E&C is a flat ecosystem. Data reflects that we are not very productive. Sadly, our annual productivity growth has only increased 1% over the past two decades.

Stagnation is costly. Does approximately $1.6 trillion of lost annual opportunity catch anyone's attention?

Third, our ecosystem remains one of the least digitized sectors in the world.

To compound this shortcoming, FMI suggests that up to 95% of data that is captured goes unused. We allow knowledge to go dark. Dark knowledge becomes lost knowledge.

Finally, we are shackled to the Analog Age. Over many decades we have perfected the "Dance of the Silos." What does this tethered chain look like?

- Risk and liability keep us from optimizing the whole. We protect our borders from the impact of others.
- We have so many touch points. We manually collect, review and transfer data. We continuously recreate knowledge.
- We rarely consider cost and schedule as inputs to design. Rather, we delete scope when bids are over budget.
- We rely on paper for everything. Paper consumes time.
- We attempt to build something looking across static drawings of variable quality from multiple players.
- Work results get executed by who arrives first.

This is the world we know. We excel at fragmentation and the weeds of waste.

Let's look at our current state from another perspective. What do owners want their harvest to be?

They want us to do the following:

- Resolve issues virtually before they become physical.
- Reduce the level of unknowns, eliminate the need for requests for information.
- Provide better cost/schedule certainty.
- Improve closeout, deliver a complete knowledge base.
- Deliver something that works.

These are not onerous expectations. Somehow our industry has managed to lose track of the harvest.

How do we change course and alter these conditions of satisfaction?

The Future of Work

Improving our harvest begins with altering our view on the execution of work.

For many of us, work is a place to go perform tasks. We go to work, work on a project, finish work for the day and go home.

Since the dawn of the first Industrial Revolution, work has progressed along a maturing transactional path. Our path to fragmentation began many decades ago when the assembly line siloed work. The progression through Industry 2.0 and 3.0 refined work tasks and specialization. Over time, we have systematically built our own silos.

What is the work that really needs to be done? What if work itself was redefined? What if we shifted from tasks to higher value activities?

Prepare yourself. A new vision of human engagement awaits: Work, Workforce and Workplace!

Imagine a world where we break down work silos and become one integrated force.

- Collaboration will engage all stakeholders at inception to find value.
- Digital intelligence will amplify human intelligence. We will be relieved of the exhaustive and repetitive. We will become more analytical and strategic.
- Projects will move from disconnected paper to connected platforms. We will evolve from intent to build to building virtually.
- The Cloud will facilitate contribution from anywhere in the world, at any time, by anybody.
- Digital precision will challenge where physical work occurs. "In the field" will no longer be the only place for work results to play out.

In three steps, we can make this our new reality.

Preparation: Lean Collaboration

Step one of our transformation requires proper preparation via lean collaboration.

The built world ecosystem is a human industry. How people work together along the supply chain is always going to define success. New technologies and business models mandate intelligent and transparent collaboration.

Preparation must always keep value discovery in focus. Beneficial impact is best realized when captured early. Effort that occurs later in development has minimal opportunity to impact value. Changes become expensive.

The success of our ecosystem is contingent on transitioning to this framework.

FIGURE 2 Six principles of lean collaboration.

LEAN CONSTRUCTION INSTITUTE

PHOTO 1 Lean collaboration: The "Big Room."

PHOTOS COURTESY OF ENVIRONMENTAL AIR SYSTEMS, LLC

Lean processes create better customer experiences. Our ecosystem needs to adopt a lesson from manufacturing: That which does not add value is waste.

But how do we uncover value? Six principles of lean illuminate our path (*Figure 2*):

1. Respect for people is the core fundamental. We must evolve to value stakeholders and their knowledge; solve the issues and stop blaming the participants; and honor our commitments.
2. Look beyond the borders to optimize the whole.
3. Define what customer value means. What do they want? How do they want it? And, what are they willing to pay to get it?
4. Map the value stream to identify and remove waste.
5. Create flow.
6. Demonstrate continuous improvement along the path.

Prudent preparation forces us to make critical choices before we plant anything.

By shifting from design-bid-build flow, we can unleash the power of collaboration. Lean integrated project delivery, or Lean IPD, was created for this purpose.

This integrated process changes the timing and order of our engagement. Note specifically: "Who will build what" now precedes "How it will be built."

Execution of Lean IPD requires new perspective. Consider:

- There is one narrative.
- Risk and reward are shared.
- Decisions are value based.

In all phases nothing is done until it should be done. And yes, design is no exception.

I will never forget my first visit to the "Big Room" (*Photo 1*). My comfort zone was attacked. My understanding of order was threatened. I was in a new world just like my grandfather experienced.

Project success wasn't pre-scripted. Humans reached across borders to define what the harvest should be.

"We" became the operative word. How are we going to deliver this as a team?

Flow was no longer associated with fluid transport. How could this be? Flow had a far more important role to play. And just for good measure, flow didn't start at the head waters and move outbound. Not at all. Flow started at the vision of a built solution and backed up to understand the path that needed to be traveled.

A path that revealed:

- How the project would be delivered;
- What the order of events needed to be; and
- Who owned the commitments along the path.

My grandfather's teachings played out right in front of my eyes. My perspective on Lean IPD was immediately and permanently altered.

Maintaining: The Digital Landscape

Proper preparation will reveal all aspects of planting the correct crop. How we maintain that crop defines how bountiful our harvest will be.

Step two requires embracing digital technology. Transformation is not simply associated with adopting new technology. Knowledge needs to be captured and linked.

Let's explore critical aspects of managing this process and what opportunities the digital landscape offers.

Digital technology is creating vast amounts of data. We are literally swimming in it.

We must figure out a way to connect all of this knowledge. The evolution of the common data environment (CDE) is warranted to manage information: a single-source, single-truth lighthouse.

The CDE platform sets the table for all portable knowledge.

Virtual Design and Construction

Virtual design and construction, or VDC, is a process that moves us from static drawings to 7D BIM models. We are making the transition from static geometry to dynamic information. Remember when we shifted from paper to CAD? Well, the shift from CAD to digital models will be just as disruptive.

Intelligent objects contain knowledge. Changing an object anywhere becomes an integrated change everywhere.

Our use of a 7D platform will:

- Verify constructability;
- Reveal time;
- Capture economy;
- Integrate performance modeling; and
- Connect operations and maintenance.

Printed documents will no longer be the primary representation of the project.

The model becomes the database of all project knowledge.

Generative Design

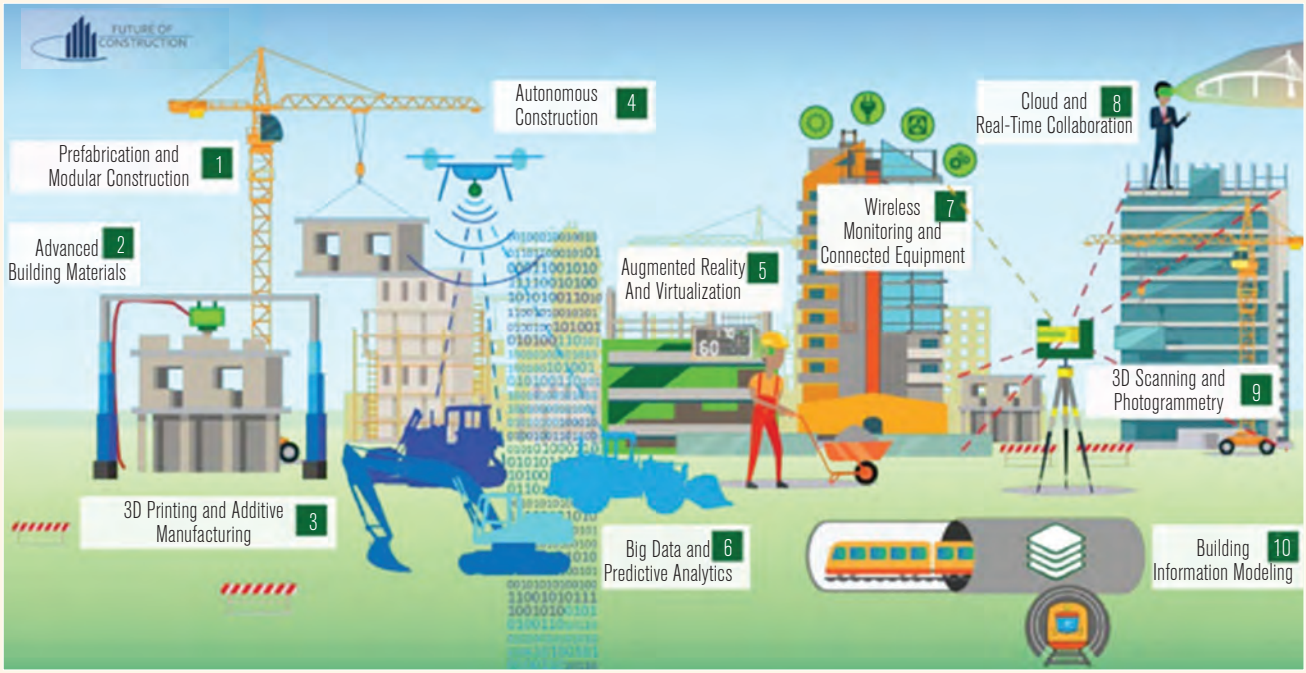
Generative design is a fascinating concept. Picture utilizing an augmented strategy to automate design development.

Algorithms can test hundreds of variables in thousands of iterations. Humans still define the boundaries and goals, but software handles comparison.

I still remember the countless hours that performance modeling used to require. Drawings had to be measured by hand to capture geometry. Elements had to be found on details or in specs. Systems had to be manually configured in singular fashion. One change required a complete redo of the entire simulation.

Those days are behind us now.

Digital Landscape Showcase



Digital technologies can improve productivity. Shaping the Future of Construction: An Action Plan to Accelerate BIM Adoption, The World Economic Forum, February 2018.

Computational Fluid Dynamics

Airflow patterns are vital. Simple throw patterns and arrows on 2D drawings do not reveal truth.

What doors would open to us if we had insight into how air should act?

Computational fluid dynamics (CFD) allows us to:

- Visualize thermal impact;
- Understand the path of air;
- Compare ventilation strategies;
- Simulate thermal comfort; and
- Demonstrate ventilation effectiveness.

Digital Twin

By connecting sensors to a digital platform, we can create a virtual mirror of our physical asset. This digital twin allows us to embark on a continuous journey. We:

- Collect real-time performance data;
- Provide an evolving profile of past and current behavior;
- Employ analytics to mine the data lake searching for trends and patterns;
- Identify actionable intelligence; and
- Repeat the cycle.

Now, consider what the power of this insight yields.

- For commissioning, we have a connected tool for tuning performance.
- For operations, we transition from reactive to predictive response.
- For R&D, we have real-world information that supports validation of analytical models and performative simulations.

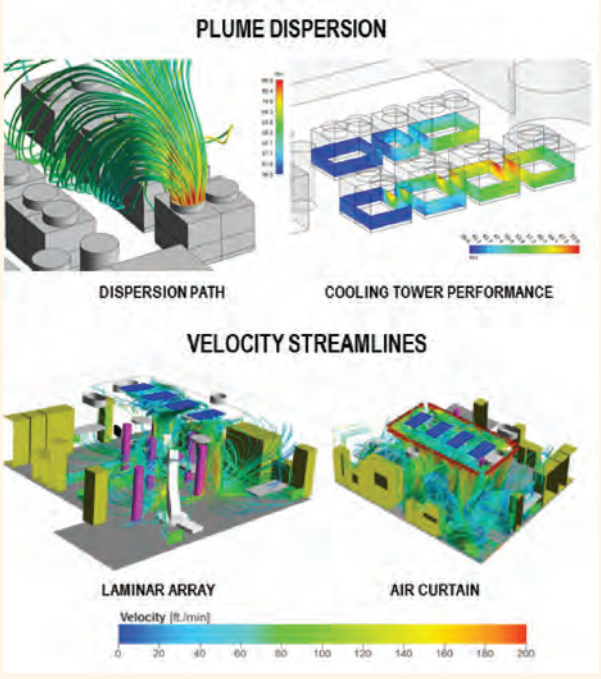
Last year, Presidential Member Boyce enlightened us on the importance of a digital twin to support effective building operations. I'm excited to announce that our new ASHRAE headquarters is going to have one.

Drones

Drones provide invaluable support logistics:

- Aerial mapping can capture all site and infrastructure content.
- Construction monitoring is available at any eleva-

Computational Fluid Dynamics

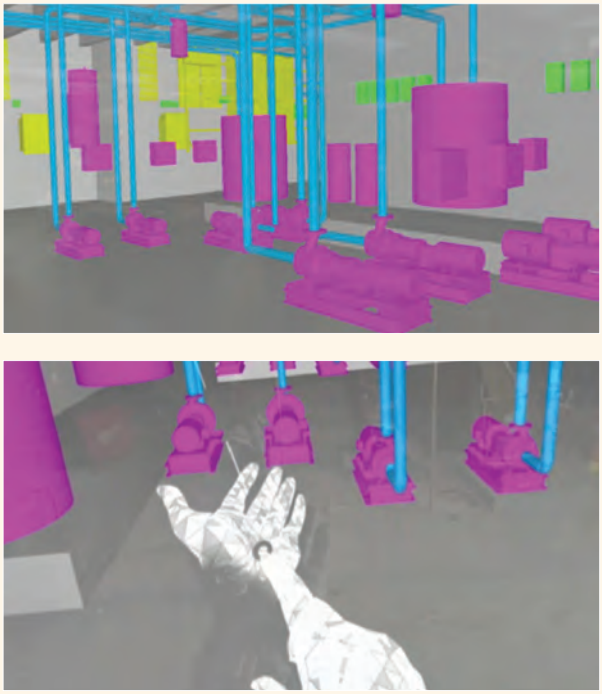


CFD ANIMATIONS COURTESY OF ANSIGHT AND PRICE INDUSTRIES

Computational fluid dynamics allows us to visualize thermal impact; understand the path of air; compare ventilation strategies; simulate thermal comfort; and demonstrate ventilation effectiveness.

Augmented Reality

AR animations of new ASHRAE Headquarters



AR ANIMATIONS COURTESY OF: TRIMBLE

Augmented reality can take model data and project a precision reference in the physical world.

tion. We are no longer tethered to ladders, lifts and safety harnesses to view.

- Thermal mapping can be performed around an entire building envelope. This technology was used to evaluate the as-built integrity of our new headquarters. Thermography provided the insight needed to modify the existing envelope for high performance.

I chuckle at times when talking with Presidential Member Phoenix. As he recounts, his A&E firm was skeptical about the value of drones. I recall the expression "gimmick" being used. They now own multiple drones. They are removing waste and securing new work. They have differentiated themselves.

Light Detection and Ranging

Scanning via light detection and ranging (LIDAR) delivers precise point cloud maps of surfaces and complex geometries. We can scan densely packed settings to capture true as-built conditions.

We no longer need to search for paper and attempt to recreate what was built. Manual measurement is eliminated.

Scanned point clouds can be integrated to our digital models. Technology captures the truth.

Augmented Reality

Augmented reality (AR) can take model data and project a precision reference in the physical world.

Imagine using a simple cell phone and a positioning device to:

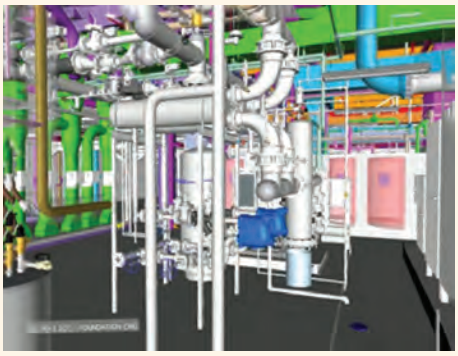
- Locate exactly where penetrations and attachments occur;
- Project a virtual installation onto the target zone; and
- Reveal where hidden infrastructure is located.

Wearables allow us to project complete MEP layouts. Virtual insight allows us to see where work results should be performed. Installed work can be verified with the 7D platform.

Maintaining: Design for Manufacture and Assembly

Our third and final step moves our journey off-site.

Virtual Design and Construction



PHOTOS AND ANIMATION COURTESY OF ENVIRONMENTAL AIR SYSTEMS, LLC

Virtual design and construction moves us from static drawings to 7D BIM models. Printed documents will no longer be the primary representation of the project.

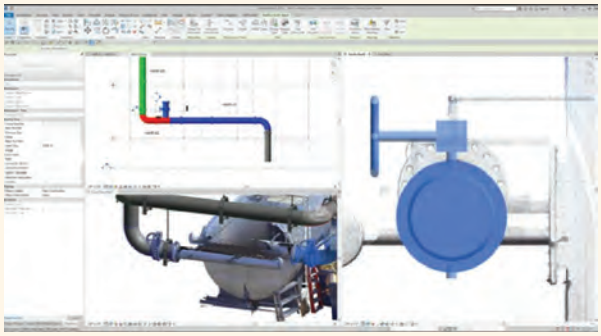
Drones

Drone thermography photos of new ASHRAE Headquarters

DRONE THERMOGRAPHY COURTESY OF CMTA COMMISSIONING

Drones provide invaluable support logistics, such as thermal monitoring.

Light Detection and Ranging



LIDAR ANIMATION COURTESY OF TRIMBLE

Scanning via light detection and ranging delivers precise point cloud maps of surfaces and complex geometries. We can scan densely packed settings to capture true as-built conditions.

Design for manufacture and assembly (DfMA) strategies challenge where work is physically performed.

Benefits

What are the benefits of decoupling work?

- Parallel work leads to shorter schedules and reduced overhead.
- Vertically integrated supply chains drive costs down.
- Automation reduces human and material waste.
- Precision enhances quality control and reduces rework.

Applied correctly, this equates to enhanced economy, time and quality.

Logistics. DfMA, or modular, requires us to think differently about system design.

- Transport logistics will influence layout.
- Repeatability and standardization enable production efficiency.
- On-site logistics determine interface.

We are only limited by what can be shipped or moved!

Assemblies. Modular is a scalable expression that can be executed at many levels. In its simplest form, we can prefabricate basic assemblies for on-site or off-site use. Components can be procured, cut, assembled and staged to support just-in-time flow.

Equipment. Let's increase scale to the equipment level. Unitized skids can be built, tested, commissioned and validated, offering complete MEP setup.

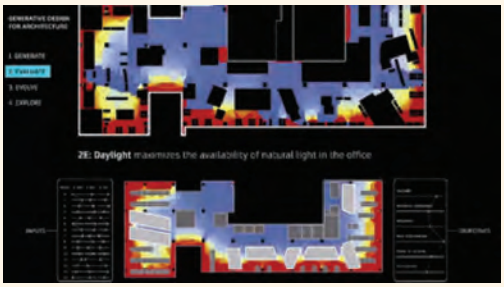
I can personally attest to the value offered for owners. Wiring integrity can be verified. Sequences of operation can be simulated. Functional attributes can be checked off. Addressing problems in the field is all but eliminated.

Owners get to see firsthand that their systems do what they are supposed to do. There is nothing more rewarding than demonstrating success alongside an owner.

Rooms. Imagine the ability to provide complete, MEP solutions off-site. Super-skids, rooms and floors can all be "Imagineered."

Picture a world where central plants are delivered to the jobsite.

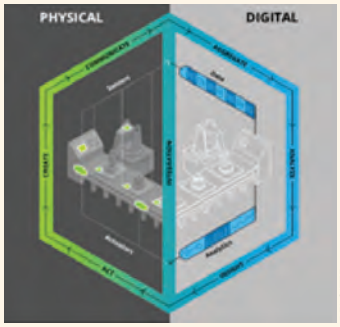
Generative Design



GENERATIVE DESIGN ANIMATION COURTESY OF AUTODESK

Generative design helps automate design development. Algorithms can test hundreds of variables in thousands of iterations. Humans still define the boundaries and goals, but software handles comparison.

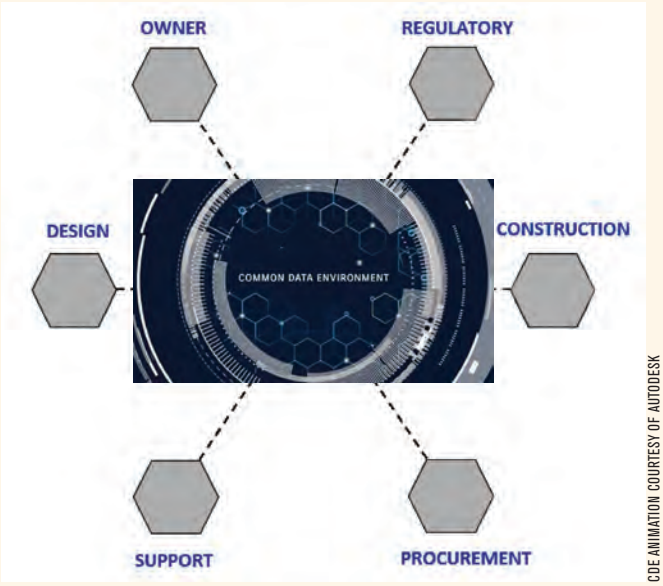
Digital Twins



DELOITTE

Digital twins allow us to create a virtual mirror of a physical asset, such as a data center. One application is providing an evolving profile of a system's past and current behavior. .

Common Data Environment



CDE ANIMATION COURTESY OF AUTODESK

The evolution of the common data environment (CDE) is warranted to manage information: a single-source, single-truth lighthouse. The CDE platform sets the table for all portable knowledge.

Buildings. The true definition of "at-scale" can be understood when we realize complete buildings can be modular.

Pause and reflect on this a minute. We can now:

- Design a virtually precise building;
- Build it off-site;
- Prepare the site to receive the modular solution;
- Ship the modules to the project site, staged for "just-in-time" flow; then
- Assemble the modules in sequence to form a complete structure.

PHOTO 2 DfMA: Modular equipment.

PHOTO COURTESY OF ENVIRONMENTAL AIR SYSTEMS, LLC

The recent tragedy of the COVID-19 outbreak has revealed to the world a view of what is possible.

In China, a 2,500-bed hospital facility was:

- Built off-site;
- Assembled like building blocks on-site; and
- Made operational in weeks.

How do we even begin to quantify the value delivered, comparing two weeks on-site versus two years on-site?

Let your takeaway on the DfMA narrative flow something like this. Work results no longer need to adhere to start-to-finish thought. We have decoupled the sequential supply chain.

The New Age

Welcome to the future ASHRAE!

A new age awaits. Collaboration, value, digital and off-site are changing our ecosystem.

Collaboration breaks us from fragmentation.

We have an opportunity to challenge what work is; how it should be approached; and where it can be performed.

We can engage our workforce in activities that seek and create value.

Data becomes a critical resource. Everything that unfolds in the future revolves around data.

I know some of you have already started to travel this path. Many of you have not. Innovators and novices, here's a critical point to remember. Our harvest is realized when we implement technology to improve our productivity. Humans are the key! It is up to us to determine how we benefit from a connected digital world.

The year 2020 will be remembered in infamy as the year of the global pandemic. We are witnesses to indescribable tragedy. As for our industry, supply chains have been broken; projects have ground to a halt; colocation events have ceased; and for the first time in Society history, our Annual Conference is virtual.

If we can look past the tragic, opportunity can be found. The very tools and procedures needed to improve our harvest are being thrust upon us. We are engaging in digital collaboration to survive.

Reactive measures, however, do not resolve the question: What can I do to deliver a bountiful harvest? Here is what you can do, or better yet, should do.

Implement a corporate digital core. Work, workforce and workplace must be connected.

Commit to a digital culture that expands appetite for risk; encourages experimentation; invests in digital talent; and expands collaboration skills.

Adopt lean as a core philosophy.

And finally, connect with ASHRAE members and resources to expand your understanding of what is possible.

Industry 4.0 and the Age of Connection are here. Our world and industry are changing dramatically by force and maturation.

Let's look at ASHRAE. We have grown up with E&C. The challenges we see in industry can be seen in our own society:

- Silo effect;
- Slow to change; and
- Behind the digital curve.

As Your Society President, here is our challenge. We must:

- Transform our Society to be a digital beacon for our ecosystem;
- Find our internal value and eliminate waste; and
- Prepare us to be innovators in a digital world.

Join me in preparing, planting, maintaining and delivering our bountiful harvest. ■

https://bit.ly/2Z2fFn7
Rate this Column