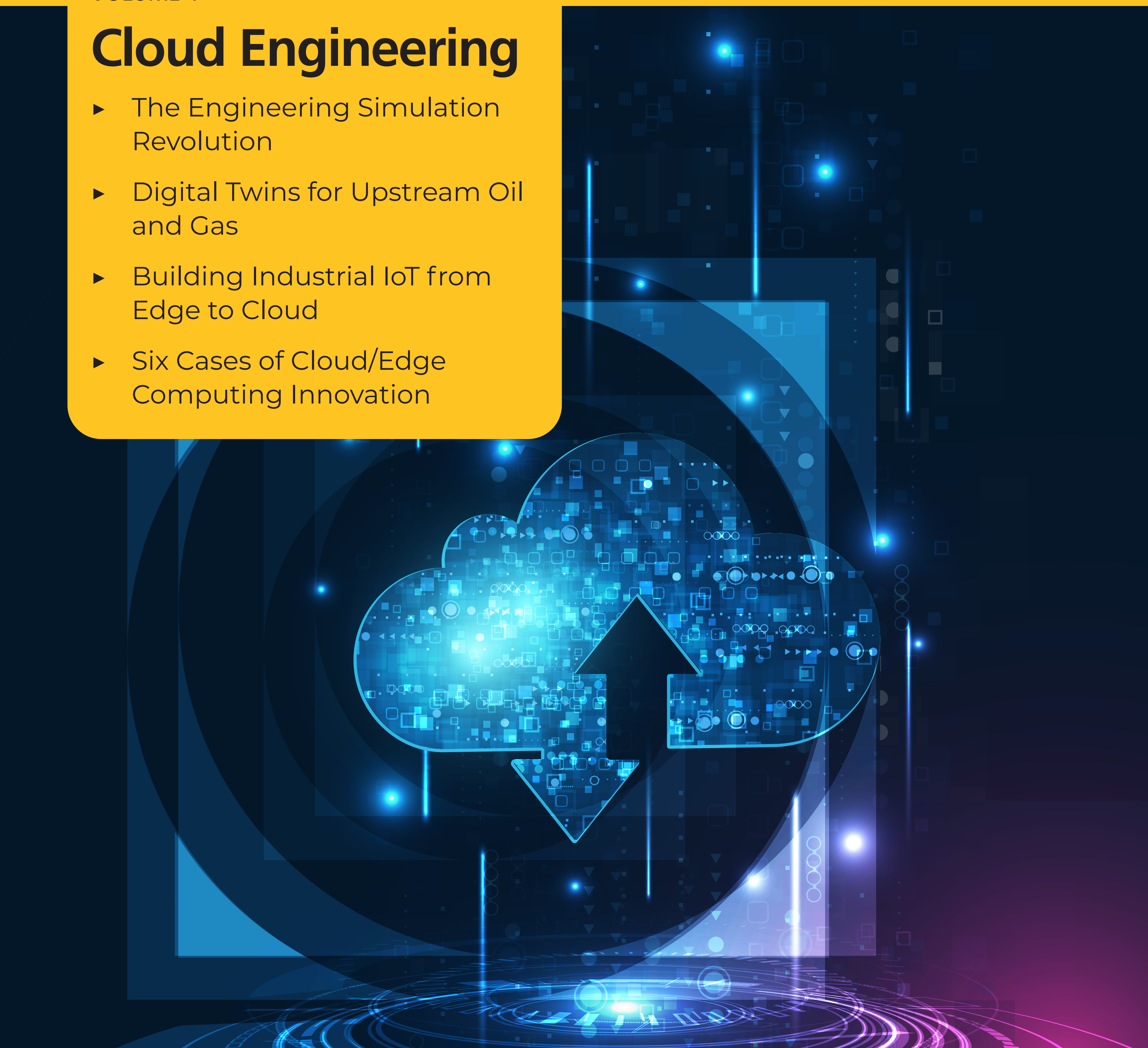
AUTOMATION 2020

VOLUME 4

Cloud Engineering

- The Engineering Simulation Revolution
- Digital Twins for Upstream Oil and Gas
- Building Industrial IoT from Edge to Cloud
- Six Cases of Cloud/Edge Computing Innovation



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Introduction

Cloud Engineering Tools

Engineering software has been slow to embrace the software-as-a-service (SaaS) model, but cloud-based engineering tools are putting sophisticated aspects of the engineering workflow into more hands than ever before. Whether creating complex digital twins or Industrial IoT control systems, cloud-based engineering tools have arrived. The cloud allows companies of all sizes to access the unlimited compute power needed for simulations, as well as enables the real-time collaboration that helps engineers get more done. In this edition of **AUTOMATION 2020**, you'll discover how these tools support digital twins for upstream oil and gas production, learn how to enable a next-generation edge-to-cloud control architecture, and review cloud/edge computing projects that could apply to your facility.

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Essential Digital Twins for Upstream Oil and Gas Production Operations

By Vineet Lasrado, Honeywell

The technology is enabling remote asset and enterprise performance management

Oil and gas producing companies face a number of key challenges today. Oversupply of oil and gas in the short term coupled with the need to reduce greenhouse gas emissions and the loss of valuable industry experience puts a great deal of pressure on the industry's existing staff.

Additionally, we are currently facing an unprecedented environment amidst COVID-19, where oil and gas companies have to keep producing while minimally manning their operations. In this background, we expect more operators to consider remote operations to "de-risk" their business and improve operational efficiency.

Increased field automation, remote operations, reduced costs of sensors, digital twins, machine learning (ML), and improved computational speed are all addressing these challenges. This article provides insights into essential digital twins in upstream oil and gas production operations using industry examples.

Introducing digital twins

If you are reading this article, chances are that you have come across the term "digital twin." Put simply, a digital twin is a virtual representation of a piece of equipment or production process while it is in operation. The digital twin can be composed of one or more underlying technologies.

Process digital twins can pertain to the reservoir/subsurface (e.g., optimization of an inflow control valve to reduce water cut) or the surface (e.g., adjusting the separator pressure or routing the flow of wells from a high-pressure separator to a medium- or low-pressure separator). Ultimately, when the process and assets are connected, they result in an integrated or digital twin of the entire asset or plant.

Digital twins can apply to

- assets/equipment (e.g., compressor, well, electrical submersible pump)
- processes within upstream production operations (e.g., gas lift optimization, electric submersible pump [ESP] optimization, compressor optimization, corrosion monitoring)

The fundamental technology behind a digital twin is various models—first principles models, machine learning models, or dynamic process response models. Often the term used for a combination of first principles and machine learning models is hybrid model.

DIGITAL TWIN TYPE	DESCRIPTION/APPLICATION	DIGITAL TWIN TECHNOLOGY
Equipment digital twin	Running the steady-state simulation model of the equipment connected to real-time data allows continuous improvement/calibration of the model and is used for understanding if there is a deterioration in the performance of the equipment	▸ Steady-state simulation (simulation model of equipment) ▸ Nodal analysis (production engineering)
Process digital twin	Process simulation – CO2 membrane separation, water treatment plant, gas treatment, and gas processing plants	Steady-state simulation
	Simulation of the production or injection network. An integrated digital twin can include the subsurface—surface integrated reservoir and production model	Integrated production model/ integrated asset model
	Operator training simulators commonly used to train operators on the operations of process facilities/topsides in upstream	Dynamic simulation
	Stabilization and optimization of the operation of individual equipment/unit or process and closed-loop process control (e.g., compressor control, gas lift optimization, ESP optimization, inflow control valve optimization)	Advanced process control/model predictive control
	Real-time detection of corrosion along with surveillance data used for understanding internal corrosion risk in oilfield production—onshore and offshore, in wells and pipelines	▸ Top of line corrosion model ▸ General corrosion model

Digital twin first principles and machine learning models

Both first principles and machine learning models have been used in the upstream oil and gas industry. While technology and computing power has certainly transformed the power of machine learning models, first principles models continue to have their advantages. They include:

- Models are often available from the engineering phase of the project—especially in greenfield projects

- Better trust in the models as operating conditions change—because first principles models are built on the laws of physics, fluid flow, thermodynamics, and chemistry, they can determine the expected equipment or process performance when process conditions change with time
- Being able to compare the current operating condition to the design envelope of the equipment/process honoring all constraints related to reservoir management and flow assurance
- Considering opportunities to optimize the operation of the equipment and/or process
- Soft sensors/virtual sensors to estimate operating parameters that are not measured or to compare theoretical parameters and measured parameters from sensors and use this data to detect any faulty sensors
- Analysis of the impact of transient operating conditions (e.g., well startup, subsea well/pipeline cooldown during production shut-ins).

A digital twin solution that combines first principles and machine learning models is expected to have a far greater benefit than each of these solutions on their own. This is where decades of experience in modeling, simulation, and operations becomes very important.

Digital twins for the autonomous oilfield

Much has been written about the promise of digital technology in the upstream industry. Increased amounts of sensors, clever engineering using smartphone capabilities, and machine learning applied to the autonomous car application have given rise to terminology such as "autonomous well," "autonomous oilfield," and various other terms used to describe wells and process equipment whose operating parameters are changed autonomously to optimize production.

The technology to automatically adjust the operating conditions of wells and process equipment (i.e., closed-loop process control) has existed for decades. Honeywell's Advanced Process Control (APC) technology has been used by a major offshore operator in its Ula, North Sea, and Marlin, Gulf of Mexico, offshore assets. Other industry examples of APC implementation in artificial lift is the use of APC technology for adjusting set points of electrical submersible pumps to optimize production while minimizing electrical power consumption. APC goes one-step beyond integrated production modeling in closing the loop, also known as closed-loop process control. Those who understand this subject also know this technology is routinely applied in the downstream oil and gas and process industries.

The obvious question then is what limits the upstream industry from adopting this technology?

Listed below are various challenges that we come across. Some of them are common across industries, while others are unique to upstream oil and gas.

1. difficult to sustain APC implementation, as it needs maintenance/ tuning

2. more emphasis on the well/subsurface and less on the process facilities
3. low oil prices/cyclical industry, loss of experienced personnel
4. lack of motor-operated valves/wellhead instrumentation and generally poor instrumentation in many assets
5. constantly changing fluid conditions as the reservoir depletes
6. wells are constantly being added (new wells coming online)
7. monitoring and service of equipment, such as ESPs, is an outsourced service, or ESP is rented equipment
8. changing lift type over the life of the well in unconventional field development
9. concerns about IT security resulting in sabotage attacks that can shut down a field.

Because Honeywell has worked on a number of such projects across multiple industries, our solutions have evolved to address the above challenges. As an example, Honeywell's Control Performance Analytics (CPA) software is used to address the challenge of APC benefits being lost over time because of a lack of maintenance. CPA allows visibility into this loss by quantifying the opportunity lost with time and enabling operators to take proactive action in retuning the APC model.

Connected or composite digital twin

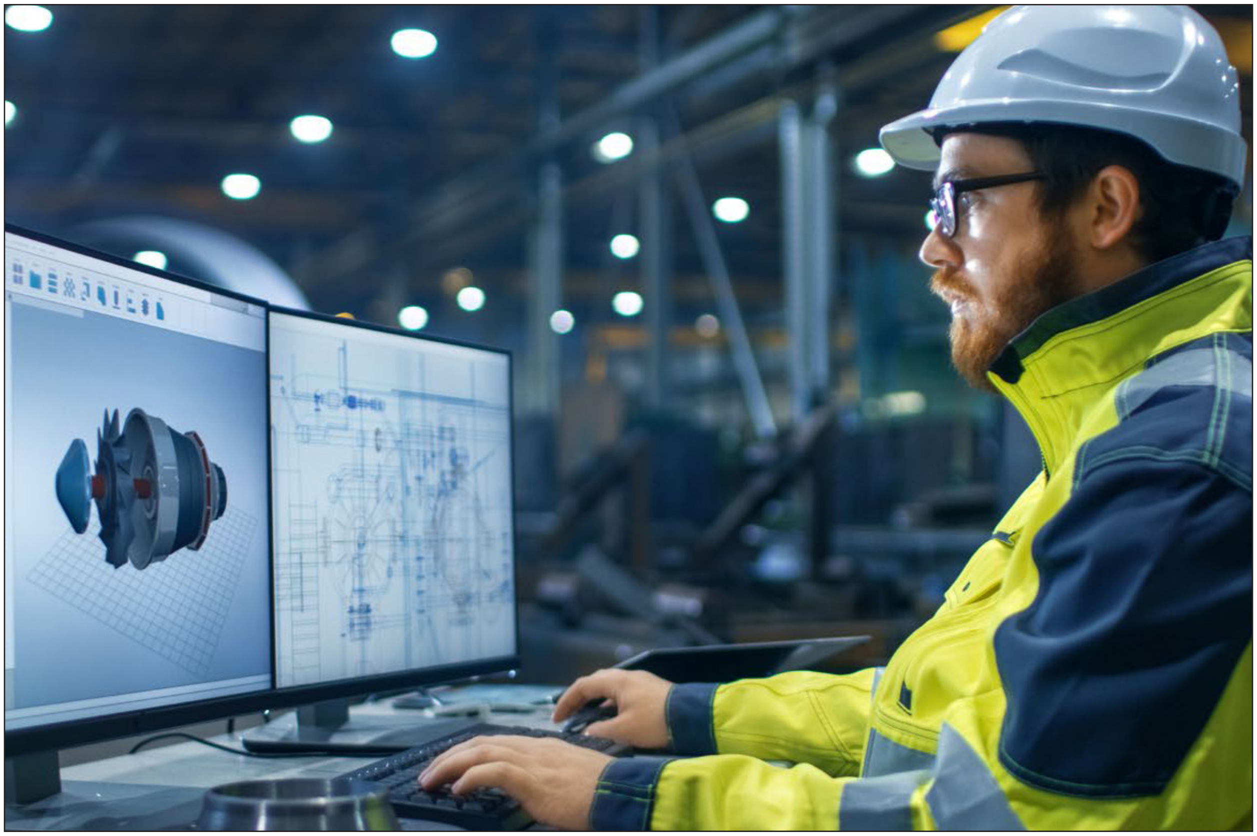
In a world inundated with an increasing number of digital twins and AI/ML vendors, what differentiates the leaders from the rest? Deep domain knowledge, industry experience, and a track record in building digital twins and connected solutions are what distinguish technology leaders. A connected or composite digital twin connects one or more digital twins to represent the performance of equipment or the process.

This is because various simulation models are available that are purpose-built/best-in-class for specific types of equipment or processes. However, in upstream oil and gas, fluids move from the reservoir through downhole completions into the wellbore, and through manifolds into the production separator, and may also go back (injected) into the reservoir. This is one reason for connecting or integrating the digital twins. Wells can have a combination of advanced completions, such as inflow control valves and electrical submersible pumps. Chemical inhibitors may also be injected into the well for flow assurance.

Let's review an industry example for a better understanding of the connected digital twin. In this example, we have ESP producer wells flowing into the gathering network. Using algorithms that look for patterns in data, it is possible to predict a likely ESP failure a few days before the actual event occurs. This is hardly a differentiator from an integrated solution standpoint, since many service providers can provide a predictive analytics point solution. Knowing an ESP is going to fail is important, as operators can prepare for pulling out the ESP before failure and/or plan for a replacement ESP. More important is the ability to keep running the ESP within its operating envelope to extend the equipment's run life. What are the additional things that can be done beyond just raising alarms when important ESP parameters go out of range? Continuous optimization is one such important action where the ESP is operated to remain as close to possible to its ideal condition.

Now let's understand possible linkages between the ESP, chemical injection, and pipeline integrity as a "connected" example. Because ESPs are driven by motors, thermal energy released by the motors raise the temperature of the production fluids. Corrosion inhibition chemicals are often injected to minimize corrosion in the production pipeline network but lose their effectiveness above a certain temperature. The corrosion inhibitor also loses effectiveness in certain flow regimes that require an understanding of the flow conditions within the production network. If a digital twin were to be built to monitor this process, we would need to connect the data from the ESP (i.e., equipment digital twin) and the production system, including fluid flow, fluid temperature, concentrations of chemical inhibitor, and corrosion rate (i.e., process digital twin).

In this example, the ESP motor temperature could have an adverse impact on pipeline integrity. This is where a connected digital twin and domain knowledge help realize integrated operations or integration across disciplines. The process digital twin can also provide useful information about whether chemicals are being over- or under-injected



when combined with surveillance data. This capability has the potential for huge savings from reduced chemical usage while mitigating asset integrity risks.

Industry adoption

Honeywell has been delivering digital twin technology for the oil and gas industry for over 20 years. Adoption of this technology is increasing as oil prices remain low, with reduced demand and increased regulatory pressure related to greenhouse gas emissions.

As a result, we see greater interest in digital twins that can enable operators to improve their performance through asset and enterprise performance management. More specifically, this includes solutions that improve equipment efficiency, reduce downtime, and enable condition-based maintenance and energy efficiency of equipment and processes.

Typical benefits as a result of using Honeywell technology include increasing production by four percent, reducing energy costs, and saving $1 million USD per year in taxes due to CO2 reductions. Additional benefits coming from improved equipment conditions and process and corrosion monitoring can result in an estimated $8–10 million in savings.

Last year, Honeywell signed a 10-year partnership agreement with ADNOC Group for one of the world's largest predictive maintenance projects in the oil and gas industry.

Key ingredients to success

The backbone of digital twins are various modeling technologies, which continue to undergo improvements as the industry has always done. Advances in computing power, big data, and machine learning and sensors, combined with lower technology costs, are driving increased adoption of digital twins.

Domain knowledge and industry experience are the key ingredients to success and maximization of benefits from this technology.

The oil and gas industry will continue to see increased adoption of remote asset and enterprise performance management solutions enabled by digital twin technology. Newer fields with the required instrumentation and control hardware for remote operations will provide opportunities for closed-loop control. As technology advances and engineers become more comfortable with these technologies, we expect to see increased adoption rates in upstream operations.

ABOUT THE AUTHOR

Vineet Lasrado has worked on several digital oilfield projects for upstream oil and gas producing and oilfield service providers for two decades. His experience includes strategy and business case definition, technology selection/definition, process improvement, technical workflows design, solution architecture definition, and implementation.

Lasrado's strengths include a deep domain understanding of upstream production operational challenges, production optimization/artificial lift optimization, and integrated operations. He has consulted with major clients internationally, including in the U.S., U.K., Italy, UAE, Saudi Arabia, Qatar, and Kuwait.

Lasrado is a frequent speaker at Society of Petroleum Engineers (SPE) events and has several technical papers authored in *Digital Fields*. He is a core member of Honeywell's Oil & Gas Technical Solutions Consulting group based in Houston. Prior to joining Honeywell, Lasrado was global industry solutions advisor – production & reservoir management for Halliburton.

Building Industrial IoT from Edge to Cloud

By Josh Eastburn, Opto 22

Next-generation distributed I/O and control open new possibilities for connected infrastructure

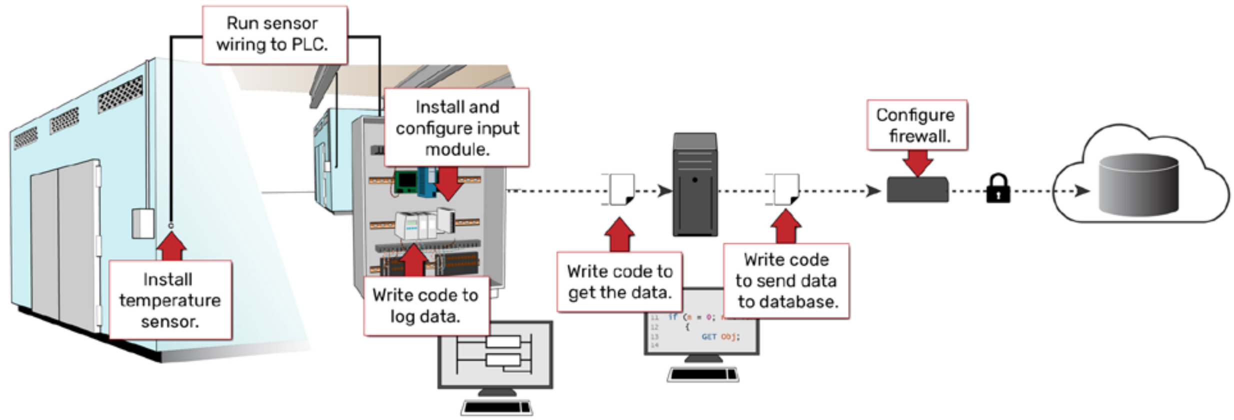
By now, most anyone working in a role involving industrial automation has heard about digital transformation, the Internet of Things (IoT), or the Industrial IoT (IIoT). These initiatives involve ever-smarter devices communicating progressively closer to the "edge," perhaps connected to an Internet "cloud," or even through some kind of intermediate "fog." Even if we consolidate these terms under the umbrella of IIoT, for most folks a simple question remains: what is the goal of the IIoT?

Simply put, end users would like the IIoT to create a cohesive system of devices and applications able to share data seamlessly across machines, sites, and the enterprise to help them optimize production and discover new cost-saving opportunities. Sharing process data has long been a goal of industrial automation, but traditional operational technology (OT) architectures are poor at scaling, priced prohibitively, and demand complex configuration and support. So what is changing to achieve this new, more ambitious goal?

Much as consumer hardware and software technologies have shifted to improve ease of use and connectivity, industrial products and methods are following the same trend. By adopting information technology (IT) capabilities, they are making it easier to connect industrial equipment with computer networks, software, and services, both on premises and in the cloud. This article discusses how a more distributed global architecture is enabling connectivity from the field to the cloud for sensors and actuators, and for the input/output (I/O) systems and controllers linked to them.

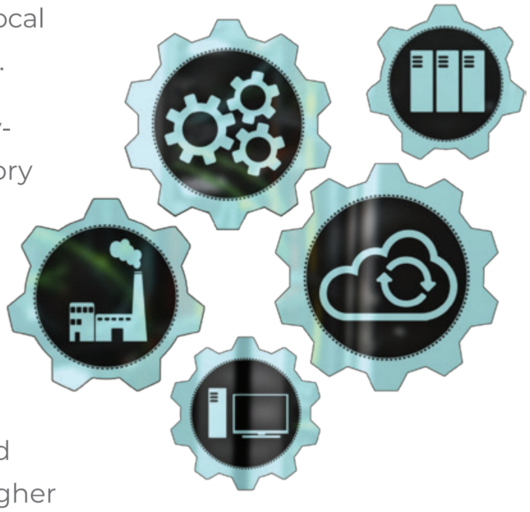
Up and down the architecture

Industrial automation architectures generally address data processing from a hierarchical perspective, as with the classic Purdue model. One good feature of this hierarchy is the clarity it provides with regard to where data can originate, be stored, undergo processing, and be delivered. However, the task of transporting data and processing it in context is often quite difficult, because so many layers of equipment are required to connect devices and applications. For example, the illustration below shows a traditional method of acquiring temperature data from facility equipment and moving it to a backend client, like a database.



Traditional data acquisition methods require configuring and maintaining many layers in a hierarchy of hardware and software.

The lowest level of an automation architecture is made up of the physical devices residing on process and machinery equipment: sensors, valve actuators, motor starters, and so on. These are connected to the I/O points of control system programmable logic controllers (PLCs) and human-machine interfaces (HMIs), both of which are well suited for local control but less useful for advanced calculations and data processing.



However, using industrial communications protocols, these low-level devices can respond to data requests from upstream supervisory control and data acquisition (SCADA) systems where data might be historized or made available to corporate-level analytical software. Sharing data within multivendor systems, however, often requires additional middleware, such as OPC device drivers, to translate the various industrial protocols.

More advanced site manufacturing execution system (MES) and overall enterprise resource planning (ERP) software also reside at higher levels of the architecture, hosted on PCs or servers on site or in the cloud, where the cloud is defined as large-scale, Internet-based shared computing and storage. Information generally flows up to higher levels to be analyzed and used to optimize operations, but the middle layers are required to interpret, translate, filter, and format the raw data produced by low-level devices and protocols.

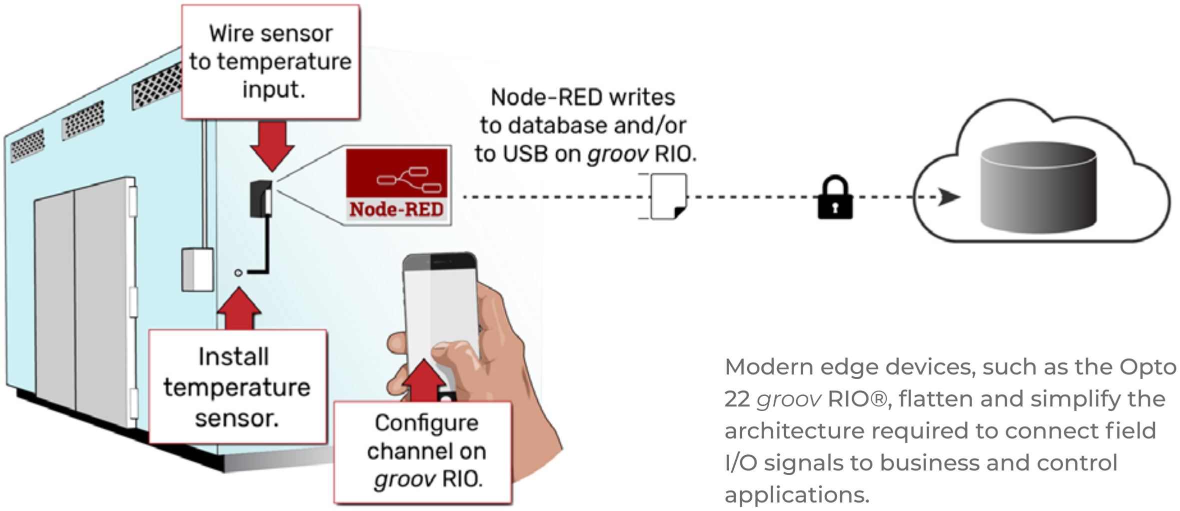
Because these low-level devices typically lack protection against cyber-intrusion, a clear division must also be maintained between high-level systems exposed to external networks and low-level systems. Developments over the past decade are significantly altering this traditional hierarchy, flattening and simplifying it to a great extent.

Spanning edge, fog, and cloud

The hierarchical approach was necessary when computing capability, network bandwidth, and security features were much less available. Each step up the hierarchy from a basic hardwired sensor to cloud computing systems was required to access greater computing and networking resources. It also clearly delineated the security measures networks required around unsecured field equipment.

Today, the relationship has changed because sensors and other edge devices are far more capable, with some of them including processing and communications abilities similar to a PC. Security protections like embedded firewalls are also becoming a standard feature, allowing each device to act as a peer on the network instead of passively listening and responding to high-level systems.

The architecture is evolving to become flatter and more distributed, as in the image below, which illustrates the same data acquisition scenario but replaces several layers with a low-level device capable of sending data directly to its destination.



Modern edge devices, such as the Opto 22 *groov* RIO®, flatten and simplify the architecture required to connect field I/O signals to business and control applications.

The edge, made up of low-level networks, is still a critical source of data, and the cloud is still a valuable resource for heavyweight computing. However, the resources in between, especially at the site level, are becoming a blend of data-generating devices and data-processing infrastructure. This fuzzy middle ground earns the name *fog*, because it is akin to a widespread, pervasive, and middleweight *cloud*.

Many other factors besides advancing technology are driving this shift to a flatter architecture. The most straightforward motivation is to balance computing and networking demands between the edge and higher-level systems. Edge computing offloads central processing, preserves data fidelity, improves local responsiveness and security, and increases data transfer efficiency to the cloud. Ultimately, however, this new edge-to-cloud architecture depends on having new options at the edge for acquiring, securing, storing, and processing field data.

Distributed I/O evolves

Field data can be raw I/O points connected at the edge or derived calculation values. Either way, the problem with traditional architectures is the amount of work it takes to design, physically connect, configure, digitally map, communicate, and then maintain these data points. Adding even one point at a later date may require revisiting all these steps.

To create more scalable, distributed systems, some vendors are making it possible to bypass these layers between the real world and intermediate or top-level analytics systems. With enough computing power, all the necessary software for enabling communications can be embedded directly in an I/O device. Instead of requiring a controller to configure, poll, and communicate I/O data to higher levels, I/O devices can transmit information on their own. This kind of edge data processing is also becoming possible due to a proliferation of IIoT tools, for example:

- MQTT with Sparkplug B – A secure, lightweight, open-source publish-subscribe communications protocol designed for machine-to-machine communications, with a data payload designed for mission-critical industrial applications
- OPC UA – A platform-independent OPC specification, useful for machine-to-machine communication with legacy devices
- Node-RED – A low-code, open-source IoT programming language for managing data transfer across many devices, protocols, web services, and databases.

Today's smart remote I/O, also known as edge I/O, takes advantage of these technologies and combines them with standard IT protocols like transport layer security (TLS) encryption, virtual private networking

(VPN) for secure remote connection, and dynamic host configuration protocol (DHCP) for automatic addressing. Rather than requiring layers of supporting middleware, edge I/O devices are first-class participants in distributed systems.

Another obstacle to scalability for IIoT systems based on classic I/O hardware is the work required to provide power, network connections, and the right I/O module types. To address these issues, vendors are taking advantage of new technologies to make distributed I/O more feasible and flexible.

Power plus networking

One example is power over Ethernet (PoE) capability, which uses an Ethernet network cable to simultaneously supply low-voltage power and network connectivity. When PoE is embedded into an edge I/O device, it can even supply I/O power, simplifying electrical panel design and saving money on additional components and labor.

Flexible I/O

To make it easier for designers to specify the right I/O interface types, some new I/O devices also have more flexible configuration, like mixed and multifunction I/O channels. These provide extensive options to mix and match I/O signal types as needed on one device, reducing front-end engineering work and spares management.

The combination of these features within edge I/O devices makes it possible for implementers to easily add I/O points anywhere, starting with a few points and scaling up as much as necessary at any time. Wiring needs are minimized, so long as networking infrastructure is accessible. For more comprehensive integration, control, and calculation, any number of edge controllers can also be integrated.

groov RIO edge I/O module

Edge controllers bring it all together

As with traditional I/O hardware, traditional industrial controllers are limited in scope and require intermediary systems in order to connect process data to the rest of the organization. Like edge I/O, modern edge programmable industrial controllers (EPICs) leverage new technologies to assimilate more automation functions than previous generations could.

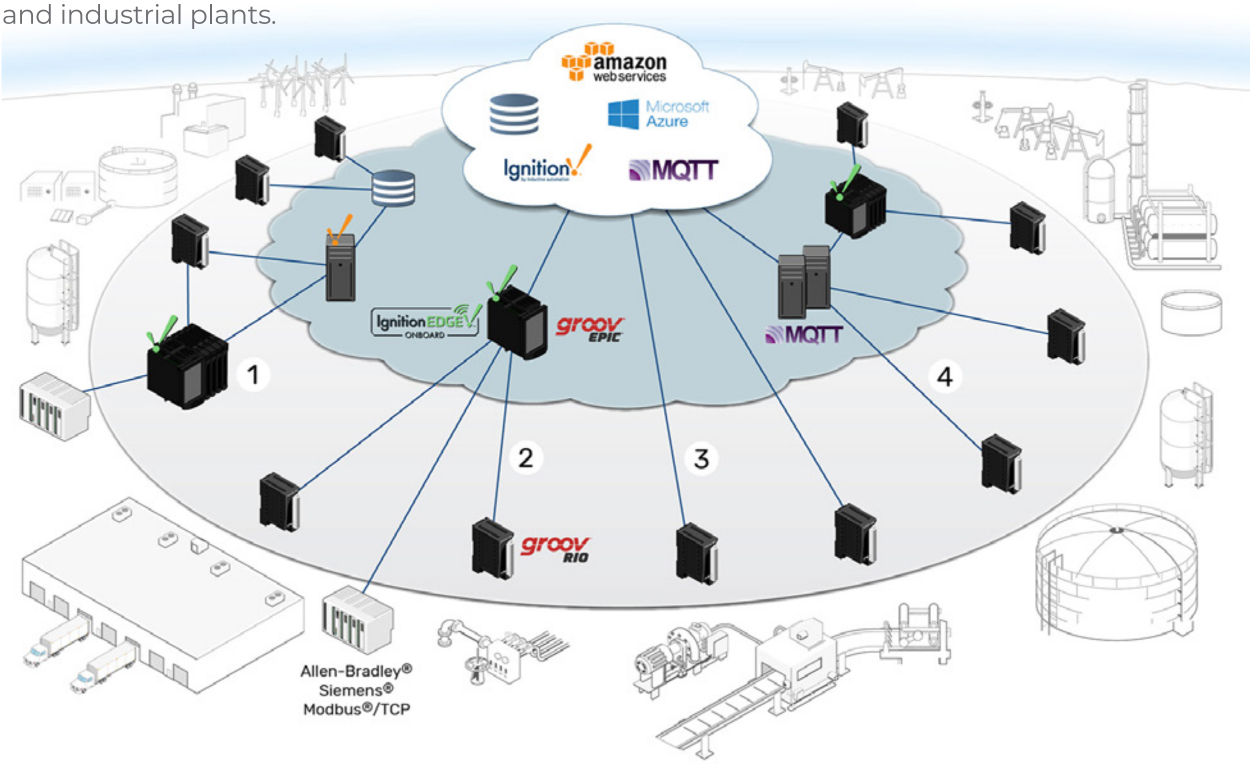
With industrially hardened components, secure networking options, multilanguage programming, and multicore processing, edge controllers can perform traditional real-time I/O control while also hosting communications, visualization, and even database servers. In the case of IIoT applications, edge controllers can use this flexibility to communicate with an array of data producers, transform their data in meaningful ways, and deliver it securely to data consumers.

groov EPIC edge programmable industrial controller

Edge controllers like Opto 22's *groov* EPIC® combine sensing and control of traditional I/O, intelligent device fieldbus protocols, and modern edge I/O. They can also host OPC UA servers like Ignition Edge® from Inductive Automation® to communicate with a variety of networked devices, making them uniquely efficient at bridging disparate automation networks. Then, with support for IT-compatible MQTT and REST interfaces and a variety of networking options, EPICs can securely connect OT networks to IT systems while reducing the layers of middleware required to do so. The combination of edge I/O and edge control leads to a new distributed data architecture.

New architecture options

So what new architectural possibilities are available to industrial automation designers using modern edge I/O and edge controllers? With edge devices making local data available to computing resources at the edge and at higher organizational levels, the logical hierarchy can be flattened even as the geographical distribution is expanded (see the image below). Here you can see some examples of new information architectures that are becoming possible for use in places like remote equipment installations, commercial facilities, campuses, laboratories, and industrial plants.



Edge controllers and edge I/O enable new information architectures in which devices can share data locally and across the organization, through edge, fog, and cloud:
1. Shared infrastructure with edge data processing
2. Legacy device integration with edge controller as IoT gateway
3. Direct-to-cloud I/O network
4. Many-to-many MQTT infrastructure

Shared infrastructure with edge data processing

Where field signals are distributed over large geographic areas or multiple sites, edge devices can facilitate data transmission to networked applications and databases, improving the efficiency and security of local infrastructure or replacing high-maintenance middleware such as Windows PCs. For example, area 1 in the image above shows edge I/O (*groov* RIO) placed at multiple remote sites with an edge controller (*groov* EPIC) at another site integrating data from existing PLCs. Two of the edge I/O modules are sourcing, processing, and communicating field data directly into a central corporate database, using Node-RED. The EPIC and other edge I/O exchange data for local control while also transmitting data to a central SCADA over MQTT. Data processing is distributed throughout the edge network, allowing central systems to ingest data more efficiently.

The combination of smart hardware and software closes the gap between OT and IT systems, creating a unified data network that is scalable and centrally managed.

Legacy devices can use edge controller as IoT gateway

Edge I/O can form a basic data processing fabric for existing equipment I/O in brownfield sites and work in combination with more powerful edge controllers and gateways using OPC UA to integrate data from legacy RTUs, PLCs, and PACs. This approach improves security and connectivity without interfering with existing control systems.

The example in area 2 of the image demonstrates this pattern. An edge controller acts as a secure gateway for legacy devices, allowing them to interact with cloud-hosted IoT platforms, SCADA, or MQTT clients while protecting them against unauthorized access from external networks. At the same time, edge I/O is used to integrate facility equipment (pumps, blowers, temperature sensors) and new equipment skids into the same network. The *groov* EPIC may control the *groov* RIO modules, aggregate and buffer their data in an embedded database, or simply transmit data to external systems.

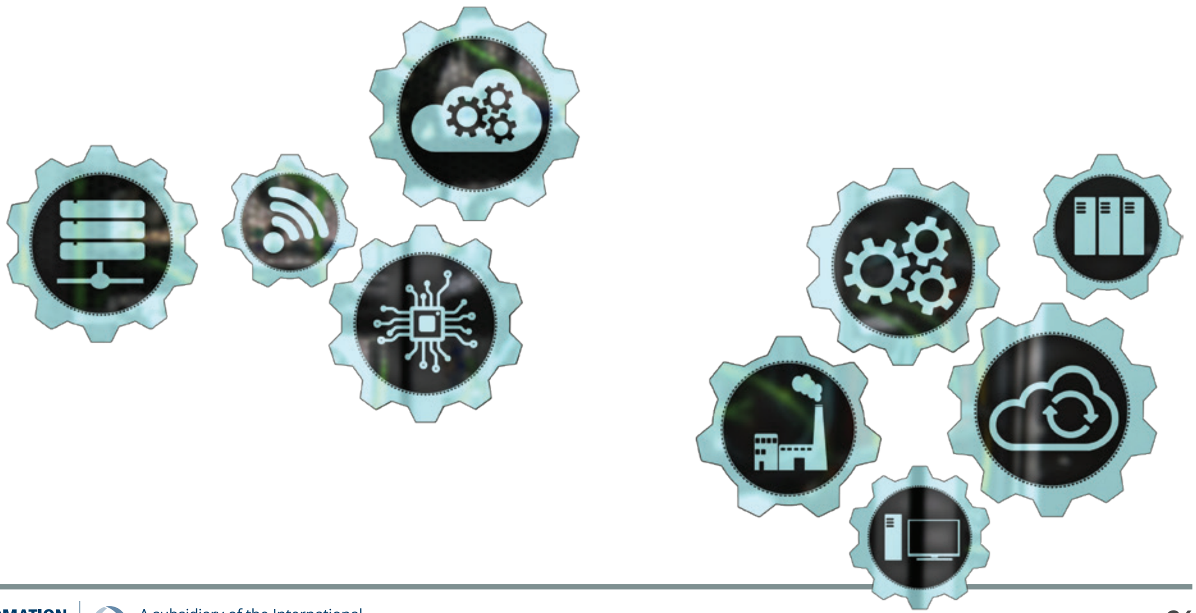
Direct-to-cloud I/O network

Engineers can also design simple, flat, data processing networks using only edge I/O devices (without controllers or gateways), expanding as needed to monitor additional field signals. A distributed I/O system like this can process and report data directly to cloud-based supervisory systems, predictive maintenance databases, or MQTT brokers.

In our example, area 3 of the image shows two *groov* RIO modules reporting data from the factory directly to the cloud, via Node-RED or MQTT. There is no need for intermediary control hardware, because each module provides configurable firewall and data encryption settings as well as a data processing engine to combine, filter, and format data. Since each edge I/O module is independent, the network can grow incrementally, reducing capital project expenditures required to integrate new equipment.

Many-to-many MQTT infrastructure

Edge devices with embedded MQTT clients can publish field data directly to a shared MQTT broker/server or redundant MQTT server group located anywhere the network reaches: on premises, in the cloud, or as part of regional fog computing resources. The broker can then manage subscribers to that data—any number of interested network clients across the organization, including control systems, web services, and other edge devices.



Area 4 of the image shows this architecture. Both *groov* RIO and *groov* EPIC have embedded MQTT clients, allowing any of the other architectures to be combined into an efficient data-sharing network. Two of the edge I/O modules in this example are publishing to a regional server group. The other two are communicating with an edge controller at another site, which is using the edge modules as distributed I/O and publishing their data into the MQTT network. Once data is published to the broker, devices and services that need that data can subscribe to it from wherever they are on the network.

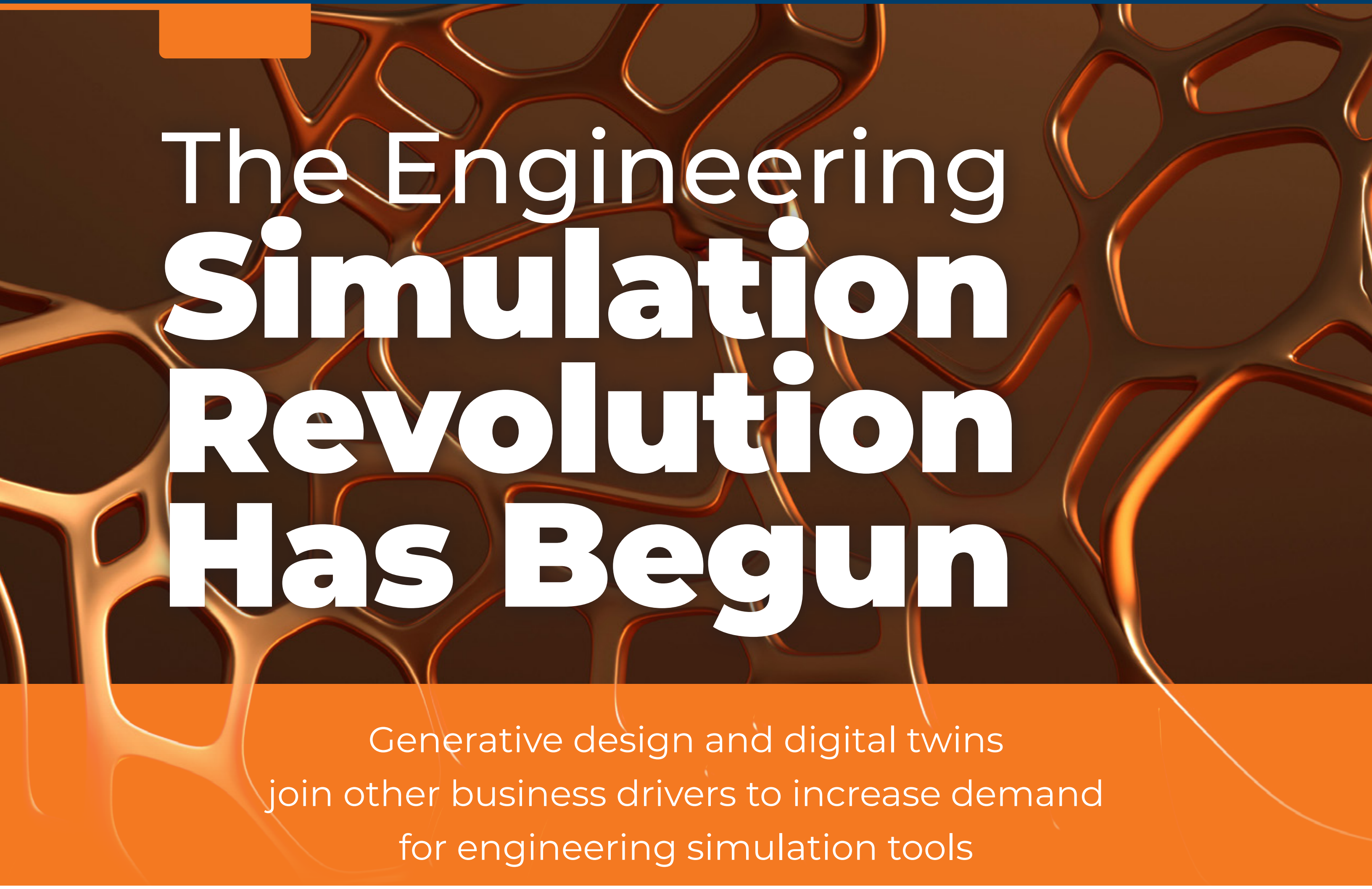
Seamless connectivity is possible

Seamless connectivity is now a reality, thanks to technologies that make ubiquitous data exchange possible. New hardware and software products enable interconnectivity among physical locations in the field, at the local control room, in the front office, across geographic regions, and up to global data centers.

Distributed edge I/O, edge controllers, and associated networking technologies support data transfer through the edge, fog, and cloud portions of an industrial architecture. Using this approach, you can erase the former boundaries between IT and OT domains and get the data you need to optimize operations.

ABOUT THE AUTHOR

Josh Eastburn is director of technical marketing at Opto 22. After 12 years as an automation engineer working in the semiconductor, petrochemical, food and beverage, and life sciences industries, Eastburn works with the engineers at Opto 22 to understand the needs of tomorrow's customers. He is a contributing writer at blog.opto22.com.



The Engineering Simulation Revolution Has Begun

Generative design and digital twins join other business drivers to increase demand for engineering simulation tools

By Joe Walsh, intrinSIM, and Petra Gartzen, Cambashi

Engineering simulation has grown into significant importance in the engineering design process over the past four decades with technology drivers enabling its broader and improved application. This growth in importance has been accompanied by a growth in awareness of the benefits and key business drivers, which then also brings a new set of opportunities and challenges related to increased demand.

The engineering simulation market is struggling to meet this surge in demand, and a simulation revolution is needed to overcome the shortage of expertise, which prevents broader application. Since 2015, Cambashi has been providing insights into the 2D and 3D computer-aided engineering (CAE) market with its CAE Observatory. The 2020 release of the CAE Observatory illustrates that the simulation revolution has begun, with increasing annual market growth rates forecast compared to previous years—excluding 2020 of course. The emergence of generative design and digital twins is combining with the other business drivers to increase the demand for engineering simulation.

Evolution through technology drivers

From the mid-1970s until recently, the role of simulation has been determined by the state of the technology. The advancement of technology enabled more applications and the more efficient application of engineering simulation while delivering higher value. The application and role of engineering simulation within organizations have typically followed a series of technology drivers—failure analysis / design validation / design decision support / design drivers / systems engineering / generative design.

The nature of the technology advancements and the technology drivers associated with engineering simulation made it clear that long-term evolutionary growth was sustainable.

Revolution through business drivers

The worldwide downturn in 2009 had a broad impact on business in general and caused a complete rethink of what it takes to build and maintain competitiveness. The changing role of engineering simulation since 2009 is really about business drivers for improved competitiveness:

- increase innovation
- increase performance
- improve quality/risk management
- reduce time
- reduce cost

Organizations around the world began to realize that a better understanding of product and process behavior and the associated risk was crucial for having a positive impact on these business drivers. The additional realization that engineering simulation is the only viable method to achieve this improved understanding and is, therefore, a major key to all five business drivers is quickly following. However, engineering simulation software is still typically used only by expert analysts leveraging more and more sophisticated tools, and there is a need to significantly expand the usage to a broader audience to affect the business drivers. The business drivers are going to force a “simulation revolution” to overcome the expertise-based limitation, and engineering simulation will be forced to find a way to support its newly found role as a key enabler to increased competitiveness.

The simulation revolution is real

The concept of an inevitable simulation revolution was first introduced by the ASSESS Initiative, which was formed in 2016 to facilitate a revolution of enablement that will vastly increase the availability and utility of engineering simulation, leading to significantly increased usage and business benefits across the full spectrum of industries, applications, and users.

Cambashi’s latest CAE Market Observatory data shows that the CAE market has been growing in double digit figures and will continue on that path—except for 2020—illustrating that the efforts of the ASSESS Initiative and other organizations are beginning to overcome the expertise-based limitations for engineering simulation.

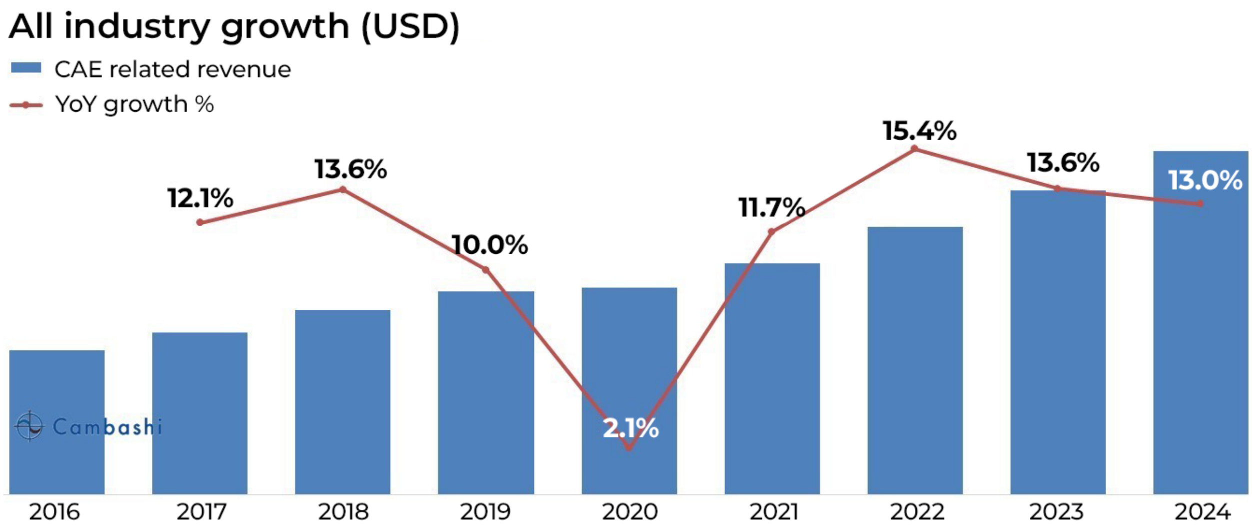


Figure 1. Two-dimensional and 3D CAE market growth

Source: Cambashi, July 2020

While 2020 will present lower growth rates, and Cambashi expects negative growth from the automotive industry, for example, growth overall is still expected to be positive. Going forward, the trends that were driving the adoption of simulation have not gone away. The need to develop new, greener versions of any kind of product will accelerate, especially in industries generating vapor trails. And COVID-19 is also opening up new opportunities for simulation in any industry where people spend significant amounts of time in close proximity. The need to provide a safe working environment to get industries back to some kind of normal situation could also result in new linkages between CAE and building information modeling (BIM) vendors and CAE and Industrial Internet of Things (IIoT)/Connected Application technology providers.

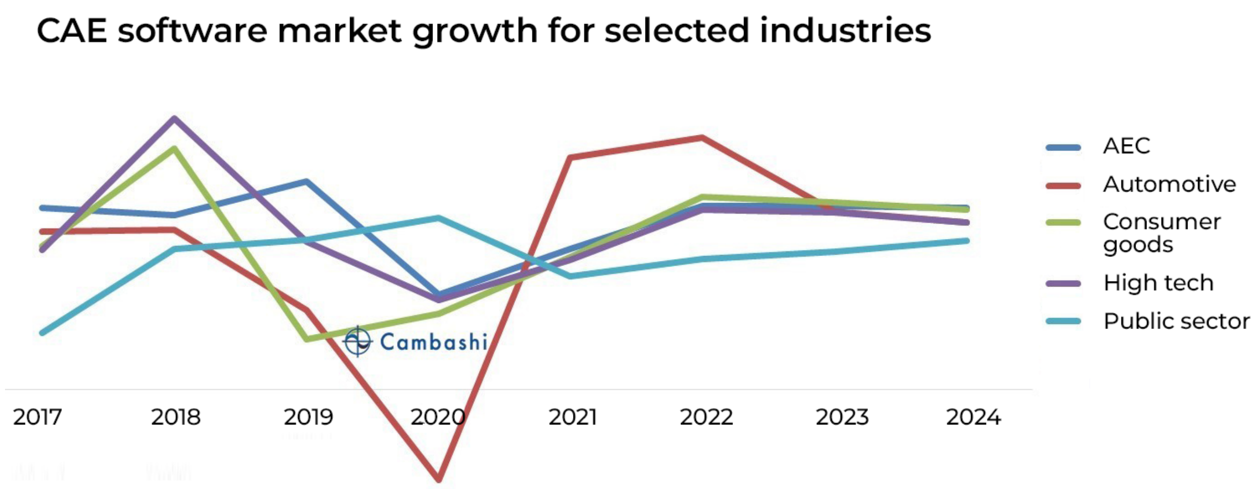


Figure 2. Two-dimensional and 3D CAE market growth, selected industries
Source: Cambashi, July 2020

The emergence of generative design

Generative design has the potential to initiate a significant paradigm shift in the design processes used today with designs that are computer-generated based on a clear specification of rules, requirements, and constraints. This overturns the current practice of design, where designs must first be created so they can be evaluated against their performance requirements. Generative design could be a key enabler of the democratization of engineering simulation by

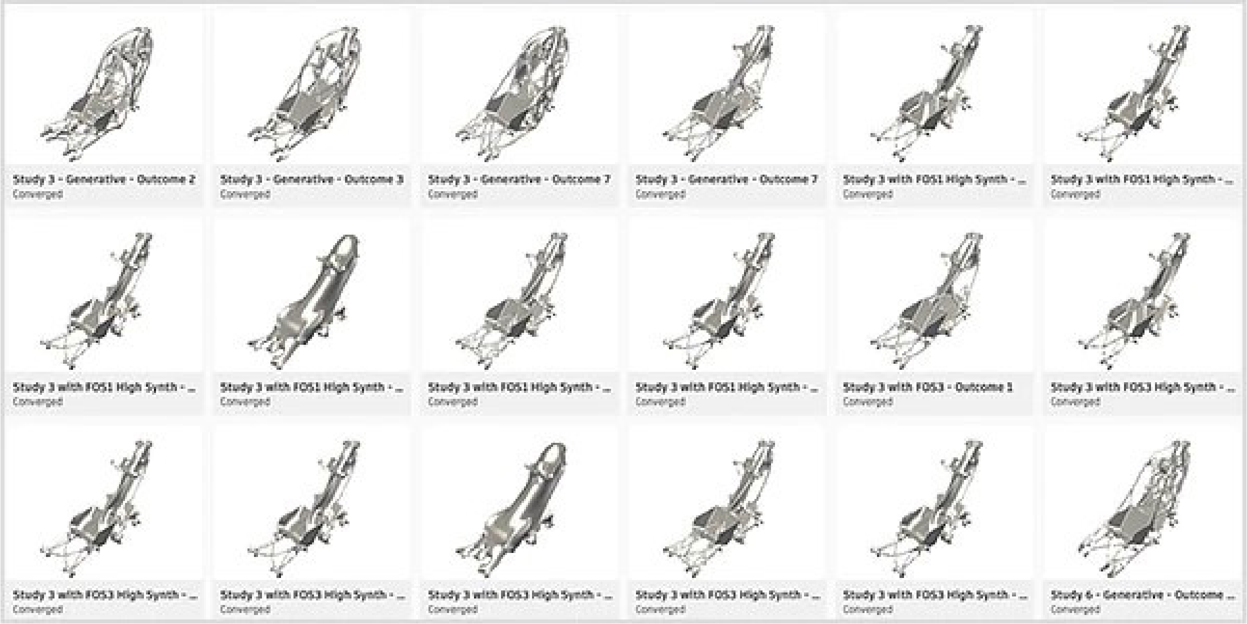


Figure 3. Generated design options *Source: Autodesk*

enabling the user to define a design scenario and a generative design tool to explore the design space for feasible design options.

Driving generative design upfront to the “early stages” of the development process will change the nature of the work that is done, which will cascade to change the work done later in the process. Generative design tools are continuing to expand their support of different manufacturing processes. Some generative design tools support “design for manufacturability” and manufacturing cost estimation.

The emergence of engineering simulation digital twins

Digital twins and specifically engineering simulation digital twins are essential to digital transformation across the domains of product development, manufacturing, and in-service operations. To address the objectives of digital transformation, most major project life-cycle management and engineering simulation vendors are actively pursuing some form of digital twin strategy that includes a physics-based engineering simulation digital twin to capture knowledge and develop an understanding of the current and predicted state and performance of its physical twin.

Exploitation of engineering simulation digital twins is a potentially positive disruptive approach for certain types of physical assets where a) servicing is hard or extremely expensive, b) ongoing maintenance is critical, c) physical assets have a long life, or d) physical asset operations are considered mission critical and/or safety critical. The use of engineering simulation digital twins is also expected to open up the potential for multiple new business models for products-as-a-service, such as aircraft engine contracts that provide "power by the hour" to the airlines, including 24×7×365 maintenance.

The simulation revolution has already begun!

The changing role of engineering simulation is really about business drivers for improved competitiveness. Engineering simulation provides a better understanding of product and process behavior, variability, and risk to support the drivers for increased competitiveness. The revolution supporting simulation's changing role has already begun and is gaining traction. Substantial, sustained growth of the engineering simulation market is likely for the foreseeable future.

ABOUT THE AUTHORS

Joe Walsh founded intrinSIM in late 2009 to enable rapid next-generation application development for engineering software, and he also co-founded the ASSESS Initiative in mid-2016 to significantly increase the usage and benefit of engineering simulation. Walsh has more than 40 years of experience, expertise, relationships, and collaborations in the CAE, CAD, interoperability, and component software industries. Before founding intrinSIM, he was the vice president of business development for Simmetrix, where he was responsible for sales, marketing, and business relationships. Before joining Simmetrix, he was vice president of worldwide sales for IronCAD LLC, vice president of North American sales for DS/Spatial and Spatial Corp., partner and founder of New Renaissance, president/CEO and co-founder of FEGS Inc. (the North American subsidiary of FEGS, Ltd. of Cambridge U.K.),

ABOUT THE AUTHORS

president/CEO of PAFEC Inc. (the North American subsidiary of PAFEC Ltd. of Nottingham U.K.), and director of engineering applications for Clevenger Corporation. Walsh has almost 10 years of experience in engineering analysis positions specializing in CAD/CAE integration, CAE automation, and design optimization. He holds an architectural engineering degree from Milwaukee School of Engineering.

Petra Gartzen is a senior consultant at the market analyst and consulting firm Cambashi (www.cambashi.com). She has been providing market intelligence, insights, and advice to business leaders in technical software companies for most of her working life. Prior to joining Cambashi, she held senior market intelligence positions at Adobe, Sun Microsystems, and Gartner.

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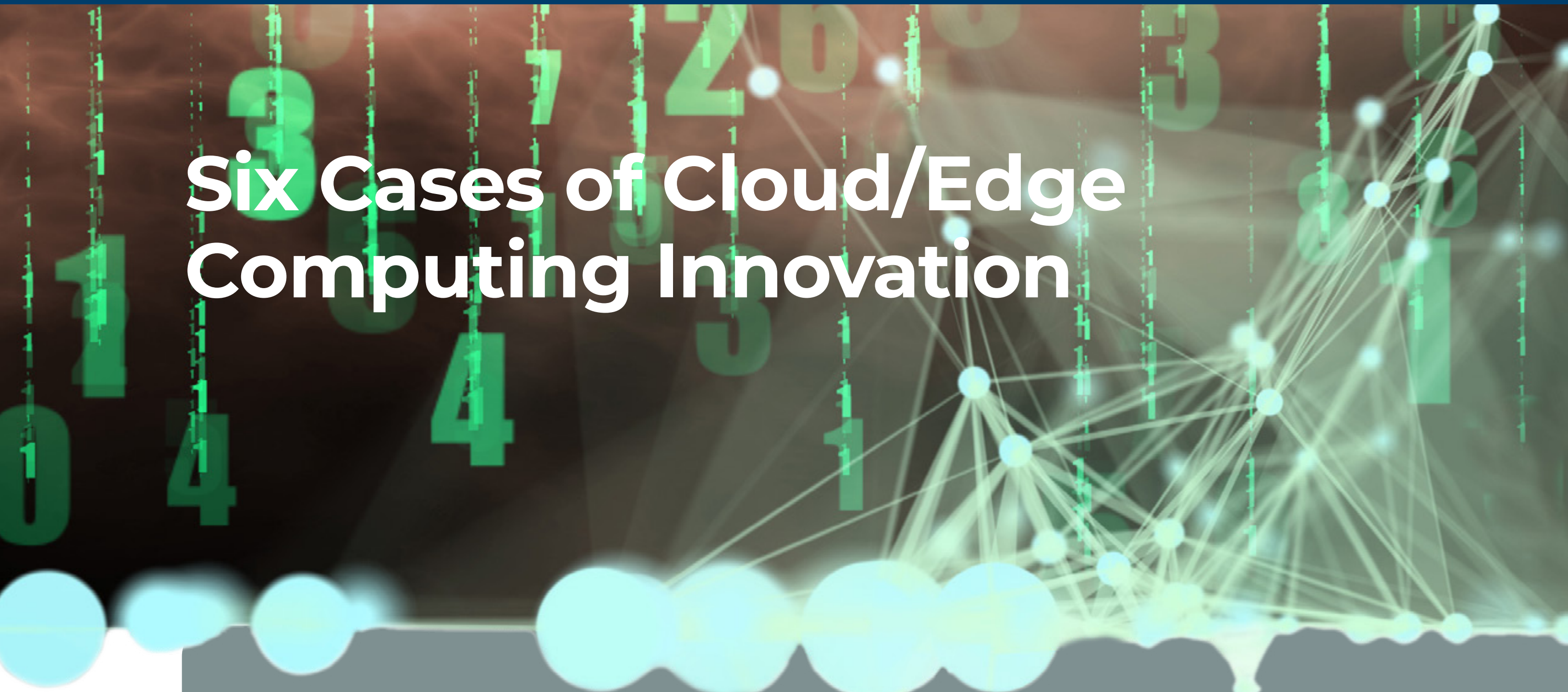


Six Cases of Cloud/Edge Computing Innovation

Projects come from the Discovery Gallery, part of Inductive Automation's 2019 ICC conference

By Bill Lydon, Automation.com

Steve Hechtman was a frustrated system integrator looking for solutions when he decided to start Inductive Automation to focus on "reducing the friction that has stifled the creation of solutions in the industry." Now the CEO and president, Hechtman said the organization has a goal of "making integration easy, fun, and affordable" and to keep serving the "dreamers and doers."

Ignition Edge is the Ignition software designed specifically to embed into field and original equipment manufacturer (OEM) devices at the edge of the network. It has been adopted by a number of suppliers, who presented at the 2019 Inductive Automation Ignition Community Conference (ICC) (see box). The Discovery Gallery at the ICC conference is always an inspiring highlight, sharing many examples of companies' real-world efforts to combine edge and cloud computing to benefit engineering, operations, and more.

1. Fast SCADA for multiple sites

ARB Midstream acquired a new pipeline asset that includes 36 remote terminal units (RTUs) and central gathering locations. As part of the agreement, ARB was required to completely take over pipeline supervisory control and data acquisition (SCADA) in four months. Challenged with this aggressive schedule, ARB contracted Industrial Networking Solutions (INS) to deliver a SCADA solution with cloud-based reporting, management, visibility, control, and a communications network with failover capabilities and store-and-forward technologies.

Company: *Industrial Networking Solutions for ARB Midstream*

Project scope:

- Tags: 10,000
- Screens: 12 overview screens plus one per site (total of 115)
- Clients: 97 Ignition Edge Nodes plus 15–20 view clients
- Alarms: 3,500
- Devices used: approximately 145 (Rockwell, Koyo, and ROC)
- Architectures used: hub and spoke, hub includes AWS, EAM, and Cirrus Link MQTT
- Databases used: three plus redundancy
- Historical data logged: 3,000 historized tags

More details: https://icc.inductiveautomation.com/discover-gallery-detail/2019/industrial-networking-solutions

2. Building management for Italian data center campus

Aruba S.p.A. is a leading company in Italy for data centers, web hosting, email, certified email (Posta elettronica certificata or PEC), and domain registration services. Aruba is also active in key European markets. This project gave Aruba an advanced real-time monitoring and control system for its ANSI/TIA 942 Rating 4 compliant Global Cloud Data Center, the largest data center campus in Italy, measuring 200,000 sqm.

Company: *MTECH Engineering for Aruba*

Project scope:

- Tags: approximately 124,000
- Screens: 190
- Clients: approximately 30 daily active clients, four dedicated terminals
- Alarms: approximately 50,000
- Devices used: More than 250 devices, such as ABB AC500 PLCs, Socomec UPS, Pramac gensets, ABB Network Analyzers, and MV Relais, Honeywell Firefighting Systems
- Architectures used: Standard Ignition Architecture
- Databases used: MySQL database
- Historical data logged: 15 billion rows, 40,000 historical tags, two years data retention, week partitioning

More details: https://icc.inductiveautomation.com/discover-gallery-detail/2019/mtech-engineering

3. Edge, MQTT help convert toxic gas to sulfur

Streamline Innovations operates natural gas treating units in South and West Texas that convert hydrogen sulfide (H2S) into fertilizer-grade sulfur. Hydrogen sulfide is an extremely toxic, explosive chemical found in most natural gas. Streamline is using Ignition to facilitate the automation of three semi-autonomous, midsized units; one large-scale gas treatment facility; and several fully autonomous skids, all with full remote bidirectional control and historian data collection. Ignition will be used at several new locations as well.

H2S is found in about 50 percent of natural gas wells worldwide. Streamline Innovations has developed a unique chemical technology that converts H2S to elemental sulfur, which in turn can be used for agricultural applications. This chemical technology has been tried commercially before, but it has not been profitable due to operational difficulties.

Streamline has circumvented these issues and has made the Valkyrie process an attractive solution to H2S removal. Its success is due to updated chemistry, modern surfactant additives, and a robust but complex control and automation system that includes the Ignition software platform.

Streamline operates at three different scales: (1) unmanned "small" units that treat 200 – 2,000 pounds of sulfur per day and are roughly the size of a large truck; (2) manned "large" units that treat 20,000 pounds or more per day and are the size of a football field; and (3) completely autonomous "micro" units that are single pieces of equipment in remote locations that perform ancillary tasks.

Company: *Streamline Innovations*

Project scope:

- Tags: 400
- Screens: 20 (large systems) and 25 (mobile systems)
- Clients: 3
- Alarms: 1,200
- Devices used: one AB PLC + one Moxa + one ProSoft per project
- Architectures used: hub and spoke
- Databases used: six (four edge, two cloud) and two DB each in PostgresSQL
- Historical data logged: 1,800 per project, recorded each second (for most values)

More information: https://icc.inductiveautomation.com/discover-gallery-detail/2019/streamline-innovations

4. Artificial intelligence drives mining innovation

Andritz used Ignition software to create a platform for training an artificial intelligence (AI) controller to run an industrial plant. The company built a software application in Ignition that integrates process simulation software and machine learning components. Andritz built a prototype as an internal development project using its own funds. The company then entered and won the 2019 GoldCorp #DistruptMining competition, a contest that focuses on digital transformation of the mining industry to optimize profitability and competitiveness. The prize is a $1 million (Canadian) project to execute a pilot at one of GoldCorp's sites.

Company: *Andritz for GoldCorp*

Project scope:

- Tags: 5,700
- Screens: 26
- Clients: 2 (Vancouver, Canada and Freiburg, Germany)
- Alarms: 0
- Devices used: 0
- Architectures used: Standard, deployed on MS Azure cloud VMs
- Databases used: one Microsoft Azure SQL Server
- Historical data logged: 225 tags

More information: https://icc.inductiveautomation.com/discover-gallery-detail/2019/andritz-automation

5. Wonderware migration for massive oil and gas operation

This project involved the migration and updating of one of the largest SCADA systems in Ecuador developed in Wonderware. Its main challenges were to bring the customer's operations from the late 1990s into the most modern technology for control and monitoring, and to deliver information from five field sites in the jungle into Agip's corporate level, located in its headquarters in Quito, Ecuador.

Company: *Automation Solutions Ecuador for Agip Oil Ecuador B.V.*

Project scope:

- Tags: 40,000
- Screens: 300
- Clients: 25 (and increasing)
- Alarms: 10,000
- Devices used: 90 Ignition devices among PLCs, VFDs, and monitoring equipment + OPC DA Connections
- Architectures used: two pairs of redundant gateways with three standard satellite gateways
- Databases used: MySQL 3 servers
- Historical data logged: 4,000

More information: https://icc.inductiveautomation.com/discover-gallery-detail/2019/automation-solutions-ecuador

6. Replacing five SCADA systems with one

The utility department for Fort Smith, Ark., provides water and sewer service to a population of approximately 150,000 within the city limits and in the greater Fort Smith area. The new system synchronizes data across all city utility sites, including four treatment plants, all water distribution pump stations and tanks, and all sewer collection pump stations.

Company: *Brown Engineers for City of Fort Smith (Ark.) Utility Department*

Project scope:

- Tags: 20,000+ UDT instances; 25,000+ OPC tags; 200,000+ memory/expression tags
- Screens: 200+ windows
- Clients: 33

- Alarms: 2,500
- Devices used: 70 (Allen Bradley, Schneider)
- Architectures used: Ignition Gateway Area Network connects four treatment plants, all water distribution pump stations and tanks, and all sewer collection pump stations
- Databases used: 10 Microsoft SQL Server databases
- Historical data logged: more than 2.5 million historical records per day

More information: https://icc.inductiveautomation.com/discover-gallery-detail/2019/brown-engineers

This article originally appeared on Automation.com in November 2019 under the title, "The Industrial Automation Transformation Change Agent – Inside Inductive Automation's ICC 2019 Conference."

ABOUT THE AUTHOR

Bill Lydon, contributing editor, brings more than 10 years of writing and editing expertise and more than 25 years of experience designing and applying technology in the automation and controls industry to Automation.com.

Inductive Automation Ignition Community Conference

The 2019 Inductive Automation Ignition Community Conference was another high energy, creative, and stimulating leadership event. With the company illustrating the power of the next level of software technology and using this with a new business model, Inductive Automation illuminated its progression in being more responsive to industry and customer requirements.

While many talk about leveraging the latest technologies and changing their business models to boost customer satisfaction, Inductive Automation's event served as a great example of the company going beyond talking points to action. CEO, president, and founder Steve Hechtman shared a vision of the company as "the new SCADA," built on four pillars:

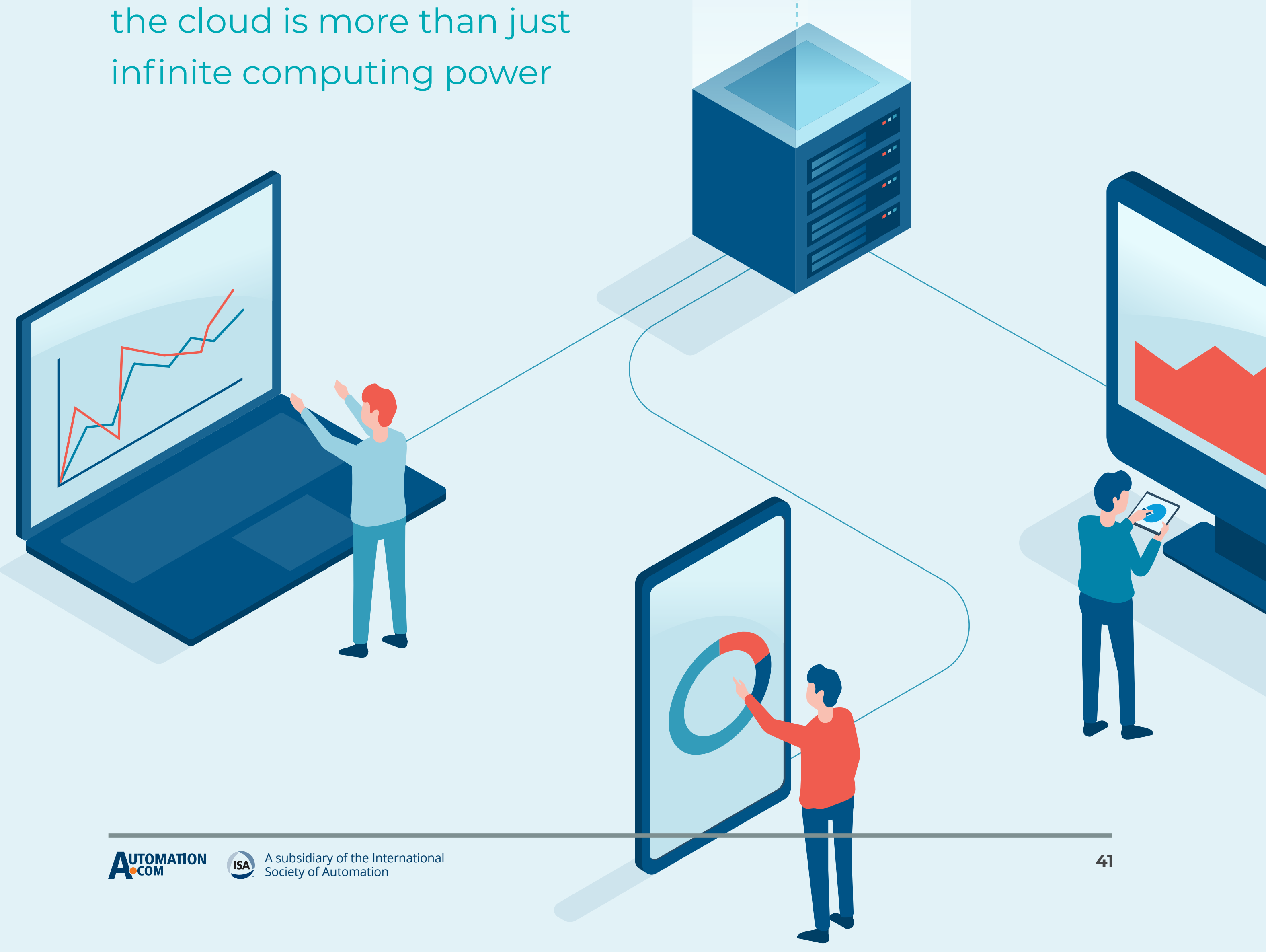
- New Technology Model – A whole new paradigm for practically any operating system, leveraging open source, and conforming to Internet of Things (IoT), industrial standards, and open interfaces.
- New Licensing Model – "It's the zero-hassle licensing model. An unlimited licensing model, sold by the server, with a single affordable price no matter how many clients or tags are used."
- New Business Model – "Our New Business Model balances development (new innovation), quality assurance, marketing, sales, support, accounting, training, and about 20 other functions into a well-functioning pipeline all focused solely on delivering the new user experience."
- New Ethical Model – "We love what we do, we love this community, and we really do want to make the world a better place!"

More on Steve Hechtman's founder's message is online.

Cloud Computing: Collaboration Facilitator

By Dave Opsahl, Actify

When it comes to simulation, the cloud is more than just infinite computing power



If the history of simulation has an arc, it's one that bends toward democratization.

It used to be that simulation was a massively complex undertaking. Within an organization, you might have one particularly brainy PhD sitting in front of a complicated piece of software that was running on a high-performance computing system that cost tens of thousands—and possibly even hundreds of thousands—of dollars.

Given these conditions, you would want to think twice before running a simulation, perhaps only doing it at the very end of the design process, as a final validation.

But then a funny thing happened: simulation software packages started becoming more accessible—not just from an economic perspective, but also from a "know-how" perspective. Suddenly, "ordinary" people like designers could start using simulation at any point in the design process to improve and iterate, rather than leaving simulation as the sole province of the analysis engineer or the scientific computing engineer.

The cloud presents an opportunity to democratize simulation still further, by serving up unlimited compute power that companies of all sizes can tap into. Heavyweights in sectors like aerospace and automotive were historically the only ones that could afford to invest in hardware that was powerful enough to support heavy-duty simulation tasks like nonlinear structural mechanics or fluid flow. Today, the cloud opens that door to all companies.

More than compute power

It is important to recognize that when it comes to simulation, the cloud is more than just a supply of infinite computing power (although that is a big part of its value)—it is also a collaboration facilitator. For example, a simulation expert within an organization can collaborate in real time on simulation settings and setups with a design engineer within the same organization who is less familiar with simulation; alternately, a consulting engineer can easily collaborate with an external client. Regardless of the participants, simulation becomes a much more collaborative endeavor with the help of the cloud.

Before these activities can occur, the web application providing the simulation service needs to be highly capable on several fronts. For starters, it needs to be able to readily handle 3D CAD files in a variety of formats. After all, simulation is not a starting point: people will have already come up with a design they want to simulate, and any online platform needs to be able to work smoothly with those initial CAD files.

Additionally, simulation platforms need powerful 3D web visualization capabilities. Computational fluid dynamics (CFD), finite element analysis (FEA), and thermal simulations are areas where mediocre rendering performance is not an option, making third-party technology components a popular choice for simulation platforms seeking vibrant, uncompromising 3D graphics.

This new, accessible cloud-based simulation is gaining traction in several areas, including small-to-medium sized companies and the architecture, engineering, and construction (AEC) vertical.

Part of the reason for the popularity of cloud-based simulation in the AEC space is simply because the building industry has been kept very busy over the past decade by an ongoing building boom, coupled with ever-stringent building requirements—which, naturally, requires AEC firms to draw upon more sophisticated simulation capabilities.

For example, AEC firms increasingly need to perform city-level flow simulation to check the urban wind comfort of a large building, or they might have to carry out a thermal comfort analysis of certain occupant spaces inside the building. This advanced analysis can even extend to specific building problems, such as analyzing the flow of exhaust fumes to improve contaminant control inside parking garages.

As more of these energy efficiency and regulatory requirements are folded into building codes around the globe, there is a growing need for designers and engineers to quickly iterate on building designs so that they can meet these requirements—and simulation helps them do it quickly and effectively.

A compelling option

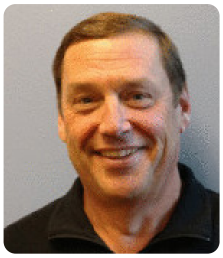
Nearly every software vertical has embraced software-as-a-service (SaaS) as an option for customers. Engineering software is one of the last verticals where it has not yet fully happened—and there is a reason why that has historically been the case. Engineering software is complex; it is graphics heavy; and the customers who are using it are very particular, as they have an existing workflow in place centered around valuable intellectual property.

However, the benefits of the cloud—the unlimited compute power, the ability to collaborate with others—are too compelling to ignore for long. Does this mean the engineering world is going to go 100 percent SaaS overnight? Of course not. Some verticals might be ready to make that move today; others might take years, while still others might never move to a public cloud application because of specific regulations.

While the vision of an entire engineering software stack is slowly being realized by companies like AutoDesk and OnShape, most of the engineering workflow is already available in the cloud—and that includes simulation. The democratization of even the most sophisticated aspects of the engineering workflow puts simulation into more hands than ever before, and the benefits will accrue not just to the companies that embrace it, but to everyone who interacts with the designed world—which is to say, everyone.

This article originally appeared in Automation.com in April 2019.

ABOUT THE AUTHOR



Dave Opsahl, CEO of Actify, is a former VP of corporate development at Tech Soft 3D. He is the founder and first executive director of the 3DPDF Consortium, a former CEO, and a confessed PLM industry geek going back farther than he would care to admit. This article was originally published in April 2019 as a Tech Soft 3D blog post titled, “Simulation in the Cloud Isn’t Just about Simulation.”