Digital Transformation in Process Industries

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Historically, manufacturers have taken a cautious and incremental approach to change in order to minimize risk and deliver mission-critical levels of availability, safety, and security. For decades, technology has made it possible to do what people already do, but more economically and efficiently.

Today, the digital revolution is making it possible to fundamentally rearrange industries, companies, departments, and societies. Operations and manufacturing must improve flexibility and agility while maximizing return on investment (ROI) in order to ensure sustainable profitability. Increasingly, companies look to digital transformation (DX) to accomplish these.

This paper explains how process industries are thinking about digital transformation, how it relates to business models and strategies, and what the macro enablers are. It also describes the convergence of information technology and operational technology and the impact on the industrial automation (IA) technology stack (making IA smarter). Where to digitalize operations and manufacturing (value map) is explained, along with the roles of leadership and organizational change management, and practical steps toward DX.

A successful transformation rests on IT and OT convergence combining a structured approach, willing leadership, and partnering with experts who understand the business process, technology, and organizational needs.

INTRODUCTION

Process industries are under pressure from fluctuating commodity prices, decreased capital expenditures, increased competition, and consolidation. A new generation of tech-savvy yet less-experienced workers are moving into production management, automation, and maintenance roles previously held by industry and plant veterans. At the same time, consumer technologies and customer experiences are raising the expectations of digital adoption. Furthermore, a generational, worldwide energy transition is rewriting the rules for sustainable economic excellence (Figure 1).

In a world characterized by volatility, uncertainty, complexity, and ambiguity, building and enhancing digital capability is the new currency driving organizations' resilience and growth. We define digital transformation (DX) as the novel use of digital technology to accelerate a company's business strategies[(1)]. DX involves the application of digital technologies to empower people, optimize processes, and automate systems of the organization to radically reorient its business performance.

For many organizations, DX is not only a set of new technology programs, but also a strategic imperative linked to company survival.

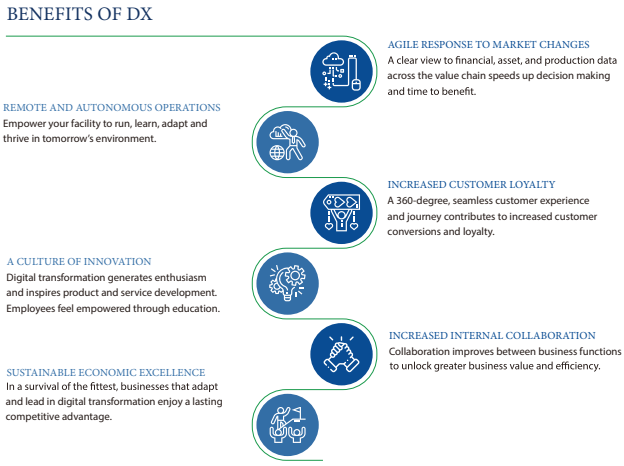

Figure 1 Drivers of digital transformation

DX TOWARD INDUSTRIAL AUTONOMY

Many if not most process manufacturers envision DX as a journey leading to an autonomous future. New technologies such as autonomous robots, additive manufacturing, artificial intelligence, augmented reality, and 5G allow for unprecedented levels of automation, including remote and

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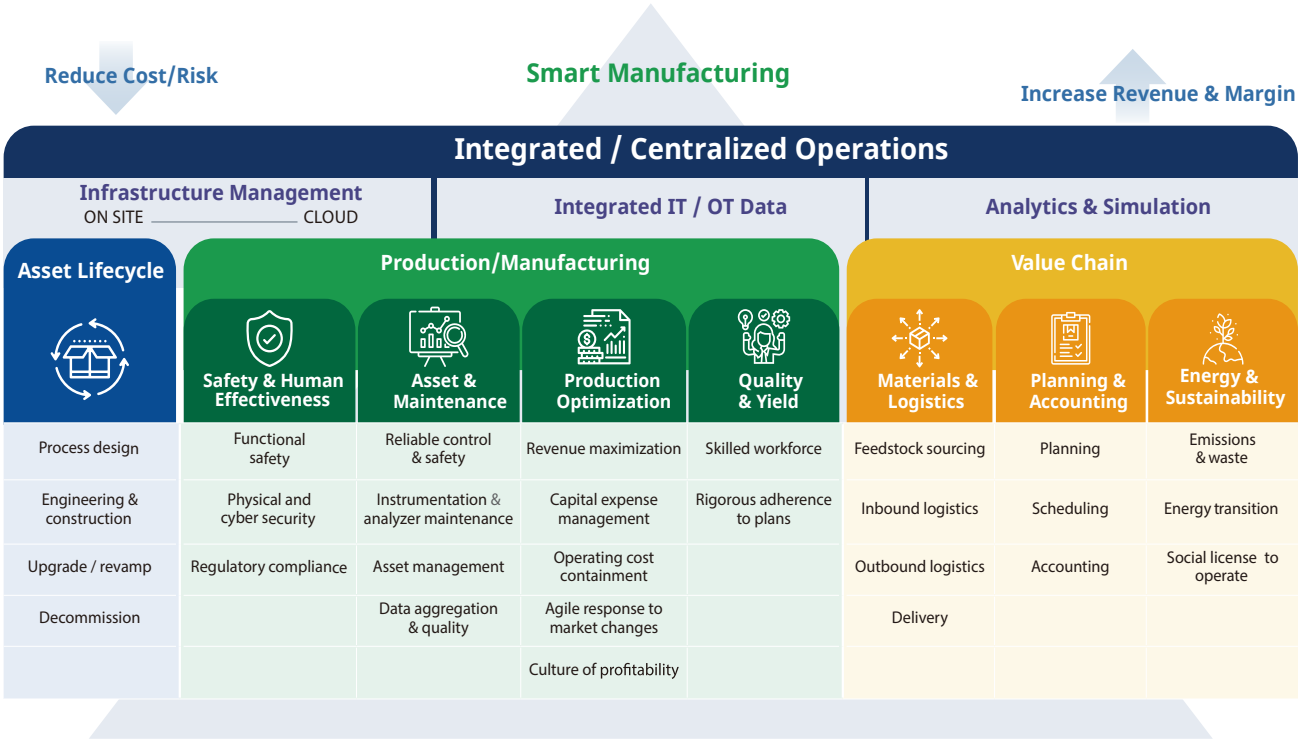

Figure 2 Smart manufacturing value map

unmanned operations. Putting humans out of harm's way, a facility might entirely automate its operations, maintenance, and incident management.

An autonomous future will require sensing and digital infrastructure that spans the entire operation and integrates data, smart devices at the edge, and bulletproof hardware and software that deliver the required level of flexibility, adaptability, and resilience. Furthermore, autonomous operations will enable process manufacturers to pivot from "product push" to "demand pull." Beyond technology, this change will likely include the need for organizational change management, new competencies, and bold leadership.

DIGITALIZE EVERYWHERE IN OPERATIONS

A process manufacturer's perspective of the business is often one of a portfolio of assets that exist in the context of supply chains and the surrounding business environment. To maximize revenue and profit margins while minimizing cost and risk, the totality of assets together with the supply chain should continuously respond, in unison, to market signals and disturbances as quickly as possible.

An ideal set of operational processes and best practices would manage the company's assets through its lifecycle, production, and manufacturing processes, in view of the value/supply chain and sustainable operating processes (Figure 2). The DX of operations seeks to uncover these operational best practices, automate them, and support decision making through technology.

Asset/Facility Lifecycle

The most capital- and human resource-intensive aspect of operations is production/manufacturing, including the construction of plants and other facilities. Whether brownfield or greenfield, an asset undergoes years or decades of planning, design, engineering, operation, and maintenance.

Throughout the asset lifecycle, there are significant opportunities for the convergence of information technology (IT) and operational technology (OT) and productivity improvements, ranging from engineering design, simulation, education, and maintenance to incident response, obsolescence management, and data management. Ontologies, or data structures, can be used to convert 3D P&ID data and steady state simulations into a semantic model for the creation of dynamic simulations, control and safety system configurations and logic, and, ultimately, the asset knowledge graph.

Value Chain

Management, automation, and value chain (asset and supply chain) optimization are central to all process industries. From raw material supply to product delivery and consumption, process manufacturers must respond quickly and efficiently to market changes and shifts in demand.

Digitalizing and integrating data and applications across the value chain enables optimization. Because data and applications are spread across organizational silos, an integrated supply chain approach typically requires an enterprise initiative to stimulate collaboration and information sharing. Today, value chain optimization is highly manual

and dependent on skilled subject matter experts using simple linear models that may be poorly maintained. As enterprise-wide integration becomes a reality, companies can achieve automated value chain optimization with data-driven automated models and work processes, enabled by the cloud and machine learning to deliver significant business agility and outcomes.

The decision cycle for investment planning, production planning, supply chain scheduling, production accounting, and process control can be accelerated through digitalization and IT/OT integration, resulting in greater certainty and impact. The holy grail of value chain optimization lies in the closed loop optimization of planning, scheduling, operations, and autonomy.

Production and Manufacturing

A DX journey toward further growth and improvement often encompasses the adoption of smart manufacturing in the areas of production and manufacturing.

While DX is often viewed as a program with prioritized digital initiatives oriented toward business processes rather than point solutions, smart manufacturing involves applying digital-enabling technologies to production and manufacturing to facilitate self-learning, self-adapting, autonomous operations.

The key element of smart manufacturing is deriving real-time data, such as raw material availability and work-in-progress inventory, from the manufacturing process for decision making and problem solving. This entails obtaining process and asset data from individual manufacturing stages by using devices and solutions such as (smart) sensors, control and automation, and automation networks.

DX in the area of production and manufacturing leads to work process improvements and facilitates the adoption of new technologies to continuously enhance levels of automation.

(a) Human reliability

Human reliability affects health, safety, security, and environment (HSSE), efficiency, and availability. In the airline industry, 90% to 95% of all accidents are caused by human factors. Studies show that process industries have similar characteristics, with the leading cause of unplanned downtime and accidents attributable to human error.

New digital technologies such as operator training simulations and advanced decision support are improving human reliability. Augmented and virtual reality are used to train and assist workers in following procedures and making better decisions.

(b) Domain knowledge

As IT and OT converge, much of the domain knowledge will follow. The Internet of Things (IoT) technologies and IT/OT convergence are also enabling the significantly improved management of domain knowledge. By digitalizing domain knowledge in a variety of formats, enterprises will reduce the risk of large expertise losses when individuals retire. For example, it can allow a process pressure expert to expeditiously get up to speed on wireless networking and data transfer technologies.

(c) Health, safety, security, and environment

Together, safety and human reliability serve as a cornerstone of operations in the energy and chemical industries. Rigs, plants, ships, pipelines, terminals, and assets are constantly changing to meet new and evolving regulatory requirements, production targets, and operational objectives. Safely managing these changes is a daunting task that requires risk assessment, approvals, change management, and documentation. Many layers of protection are needed to ensure HSSE. Generally, these include design integrity, asset integrity, and operational integrity.

Because DX can potentially introduce new security risks, program implementation teams must employ edge, data diode, and cybersecurity practices to ensure enterprise connectivity with equivalent security and resilience. Safety and security controls need to work together to mitigate risk and minimize the business impact of any incidents.

A NEW IT/OT ARCHITECTURE

Traditionally, process manufacturing operations are built and engineered to involve a wide variety of mission-critical equipment, control systems, and human machine interfaces that operate as an independent technology stack, and applications are isolated from enterprise systems to ensure safety and security.

A key pillar of digitalization and DX lies in the ability to infuse IT into the company's operations and OT, and the integration of business and production environments (Figure 3).

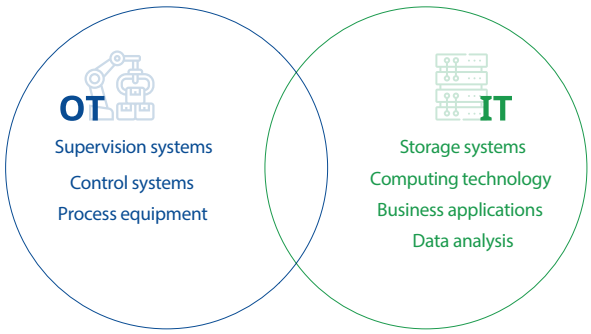

Figure 3 IT/OT convergence

In the absence of IT enablers, on-premise OT systems can generate dark data not used to derive higher level business insights for decision making, such as production efficiency vs demand and return on capital employed. Furthermore, independent OT systems will result in more manual processes and maintenance for common activities such as user management, reporting and dashboard creation. By introducing a cloud-based platform that consolidates OT and IT data securely through an edge, process industries can

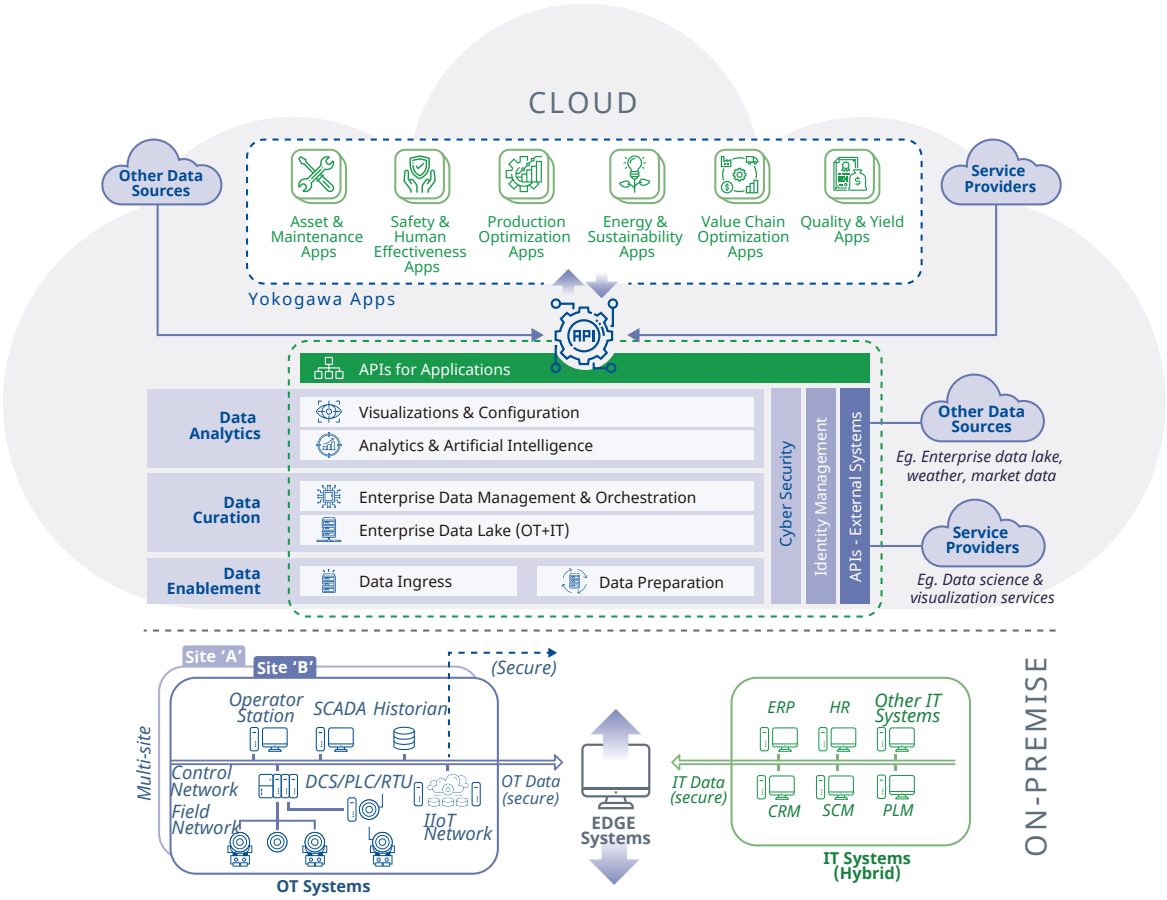

Figure 4 Yokogawa DX platform

leverage IT enablers including cloud computing (storage, computational scale, and connectivity), integration with other cloud applications and solutions, advanced analysis including artificial intelligence, and user-centric agile design.

To realize smart manufacturing, customers aim to improve the accessibility and actionability of plant data and further automate manual processes by developing and implementing new applications and engineered solutions with enterprise integration by design. Customers' smart manufacturing partner should support them with peer benchmarking, maturity assessments, use cases and road map prioritization. Achieving connectivity beyond plants and enterprises at the Industrial Internet of Things (IIoT) and cloud levels enables the seamless integration of business, production, and supply chain data.

An expanded architecture beyond OT systems and networks is needed to integrate OT with IT systems and develop future applications. Central to this architecture is a cloud platform that Yokogawa refers to as a DX platform (Figure 4), which can also be used to connect with the IIoT devices and other cloud-based systems.

Edge systems are considered to be an important starting point for the convergence of OT and IT. An ideal digital solution would be realized by combining edge and cloud data hosted by on-premise or cloud-based engineering and solutions applications.

Plant-centered technologies that generate data include distributed control systems, safety instrumented systems, tank gauging systems, programmable logic controllers, and other automation components. These components receive inputs from instruments, analyzers, and other field devices. Software logic is applied to these inputs to drive outputs to valves, motors, and other equipment.

This new DX platform will create a higher degree of interoperability at the plant floor level and provide new data to a company's broader IT systems. Therefore, an enterprise architecture approach is needed in the plant environment, in collaboration with manufacturing and operations subject matter experts.

CULTURE, LEADERSHIP, AND CHANGE MANAGEMENT

Because DX is disruptive to conventional work practices, there can be considerable resistance to change. Some resistance comes from departments that do not want to share information and collaborate, and other resistance comes from workers who do not understand how DX will affect their jobs.

DX requires introducing a people and culture strategy that supports change while also enabling the company's overarching business strategy (Figure 5). It asks for informed

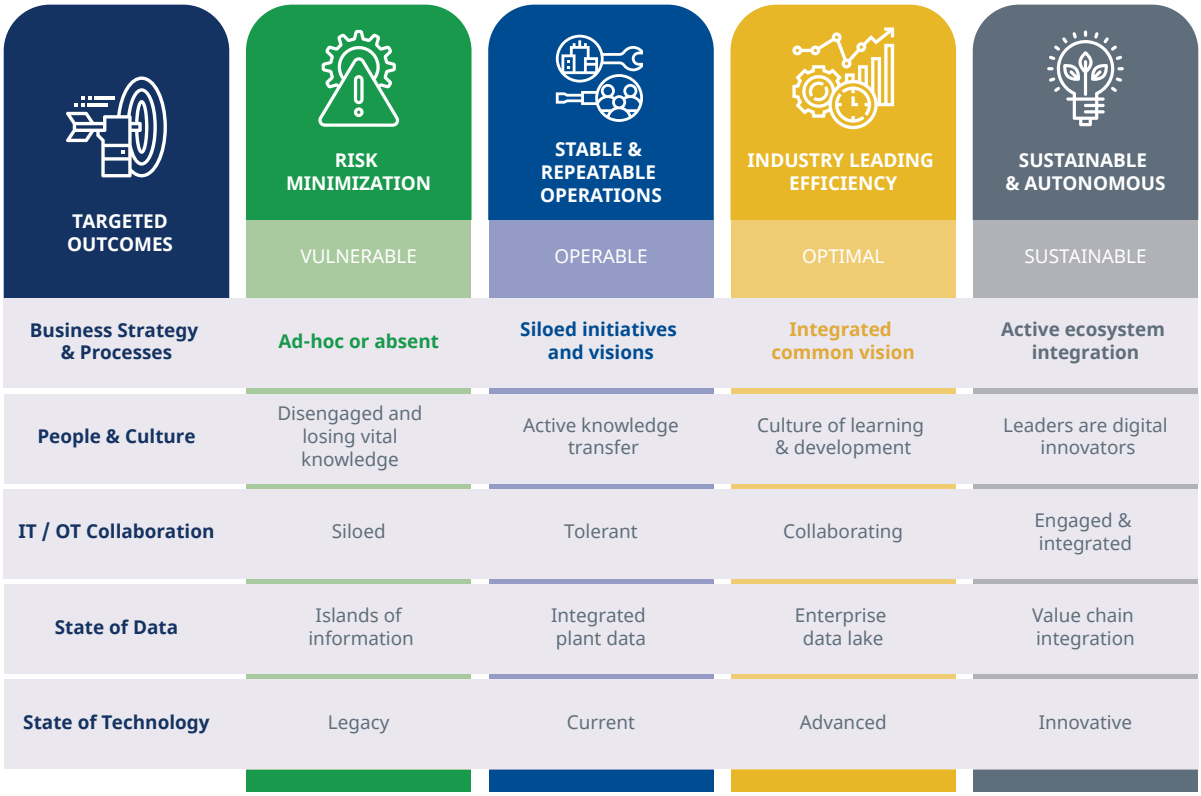

Figure 5 DX maturity model for process industries

leaders who acknowledge the existence of a "digital divide" between plant personnel who deeply understand OT and their counterparts who deeply understand IT. An effective approach to DX recognizes both skill sets and a need for collaboration.

DX provides a framework for aligning the leadership team, who can speak with one voice through this lens to reinforce the company's strategy and promote a new way of working. To mitigate anxiety and fear of change, digital leaders have a responsibility to create an environment in which employee development and experimentation are encouraged.

WHERE SHOULD WE START?

Although strategies should be developed within an external context, the practical execution of DX begins internally, where a company can fully own its actions and outcomes. (Figure 6)

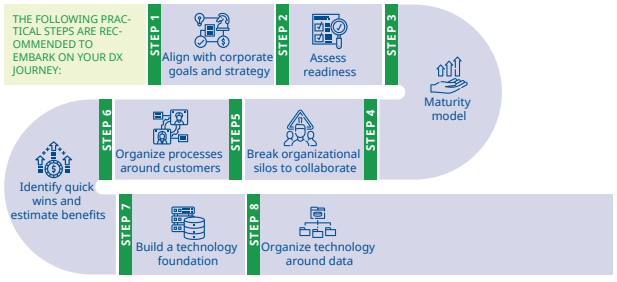

Figure 6 Practical steps in the DX journey

(a) Alignment with corporate goals and strategy

A company's business objectives and strategy will frame its DX approach. Some digitalization efforts can lead to long cycles of technical discussions as well as limited perceived impact. Without a business case and ROI linked to C-level initiatives, digital investments in production and manufacturing are difficult to sustain by cost centers principally charged with delivering maximum productivity at the lowest cost. An important first step is to establish a business case that is recognized and endorsed as part of a C-level DX initiative.

(b) Assessment of readiness

DX readiness should be considered as an integrated set of business strategies, people, processes, and technology. An unbiased evaluation of as-is capabilities or maturity can help to baseline and develop support for the upcoming change.

(c) Breaking silos to realize collaboration

Every organization naturally develops organizational silos because camaraderie and communications naturally form around day-to-day team structures, roles, and projects. Although restructuring can address some of these issues, it can also be a lengthy and complex process. If not executed with adequate preparation, restructuring can create unintended consequences and new silos.

A more practical approach is to identify the key trusted

staff who others turn to when they have questions. As influential people at key points across the organization are revealed, they can be invited to participate in a DX task force, becoming a new cross-functional team organized around transformational objectives, reinforcing messages, and delivering change on the ground.

(d) Organize processes from the outside in
DX involves the evaluation and improvement of work processes through technology. These business processes should be oriented customers' or users' experience.

(e) Identify quick wins
Having a clear view of customer-oriented business processes provides a clear connection to the value created for customers and, therefore, the company's business.
Ideate and prioritize use cases by estimated return on investment or value to the business against the level of effort.

(f) Build an architectural and data foundation
Leading companies ensure a stable technology foundation before moving to cross-functional integration and acceleration.
Case studies show that in the early phases of digitalization, up to 80% of digitalization efforts may be spent on janitorial and data-housekeeping activities. While tedious, a clean and stable data foundation is essential to support effective analysis, decision making, and automation through applications.

(g) Organize technology around data
The quest for digital nirvana is enabled by technology and built upon a systematic approach to the aggregation and normalization of data. In process industries, this means auditing a company's connectivity and access to all process and asset data with the aim of integrating all OT data in a single data lake and ensuring data fidelity and quality.
Defining all current and desired data ingress sources will reveal some automated, manual, and non-existent areas where technology can be applied.
A data-centered approach to technology ensures a reliable foundation from which analytics, application logic, and interoperability can be applied.

CONCLUSION

As DX continues to disrupt, transform, and re-shape global business, the imperative to change is clear and present in process industries. To make this change, a company will need to shift its focus from reactive operations to proactive, predictive, and profit-optimizing operations.

Companies cannot make the DX journey alone. They need to leapfrog innovation by partnering with experts fluent in both OT and IT.

These partners must understand the company's existing operations, technology, and data. As complexity differs for each company, the imperative is to co-create solutions that fit their needs, requirements, and budgets. Many solution providers have piecemeal offerings that include consulting and IT/OT technologies. Increasingly, the optimal DX approach requires a partner who will support the company throughout this journey, is open and oriented to all possibilities, and takes responsibility for all aspects of the process from planning to performance-based results.

REFERENCES

(1) Yokogawa Electric Corporation, Digital Transformation in Process Industries eBook, https://www.yokogawa.com/solutions/solutions/digital-transformation/#Resources (accessed 2021-03-01)