

YOKOGAWA IS HELPING CUSTOMERS CREATE SIGNIFICANT VALUE THROUGH DIGITAL TRANSFORMATION

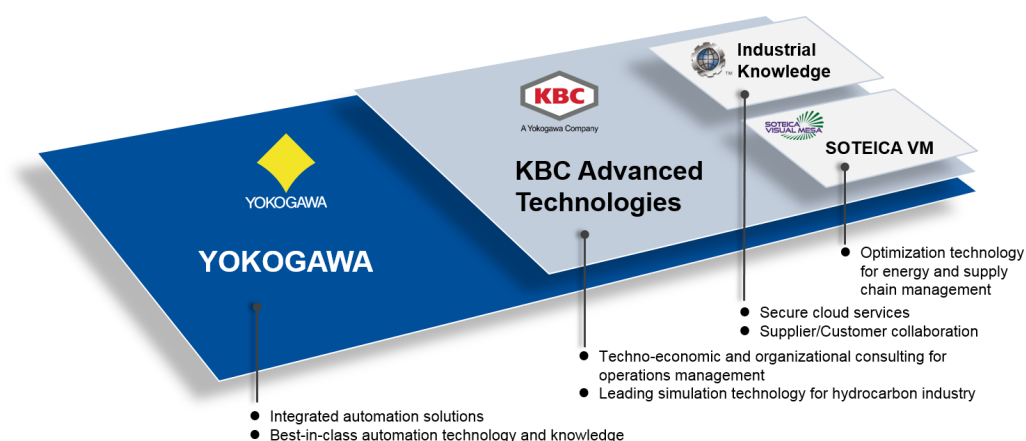
**ARC White Paper
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Yokogawa has a long history of co-innovation in process control and safety. Combined with recent strategic know-how and IP-rich acquisitions, the company can now apply its deep domain expertise to create a differentiated offering in the industrial automation space. From analog or manual data being digitized to the complete digitalization and improvement of work process, with recently-acquired KBC, Yokogawa is helping industrial organizations transform their businesses to help meet both current and future challenges.

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Yokogawa's Alignment of Business Value Drivers, Technology Solutions, and Data (Source: Yokogawa)

Executive Overview

Today's energy companies and chemical manufacturers are becoming increasingly aware of the business opportunity presented by digitalization. What is not so clear, however, is how these industrial organizations can use these new technologies and approaches to transform their businesses to gain

more value from their data, assets, people, and value chains.

Yokogawa has established a solid reputation as a global provider of digital automation technology and associated services. The addition of KBC with its recently added Industrial Evolution, Inc. IT/IIoT solutions and Sotetica Visual Mesa energy management and supply chain optimization capabilities, greatly enhances Yokogawa's capabilities as a provider of successful digitalization outcomes.

For technology suppliers, customer engagements now focus on Industry 4.0, Industrial IoT (IIoT), and associated outcomes. While the DCS and associated hardware and infrastructure remain important for sustainable operations, these are no longer the center of the discussion. The customer conversation, in turn, has shifted from the technology itself to the outcomes and new value that it can deliver. There is new focus on shortened technology planning horizons and increased speed in deployment, value, and agility while solving their complex business and operational challenges.

Energy and chemicals companies are still asking trusted suppliers and advisors for help on how to better leverage technology, but now the focus has shifted to business improvement imperatives. End users need to be better positioned to implement new technologies such as advanced analytics and mobility without compromising cybersecurity. Initially, at least, digital transformation efforts will take better advantage of the existing infrastructure using the massive amount of data already being gathered. Here, the goal will be to squeeze more value from existing sensors, systems, and applications before progressing to the next level.

While many suppliers are talking about developing new business models, energy and chemicals companies are embarking on transformation programs that address age-old problems such as improving margins and safety and managing risk. Most end users could care less about new business models. Instead, owner-operators seek suppliers with deep understanding of the intricacies of how they should run their equipment, plant, and facilities. This provides the fundamental basis for digitally enhancing current processes, reducing manual effort and errors, and – only if needed – creating new work processes. This industry operating domain knowledge and know-how

around business value drivers is critical for driving change on the front line and helping ensure that digitalization efforts deliver the desired outcomes.

Yokogawa has established a solid reputation as a trusted, global supplier of digital automation technologies and associated services to help assure plant operability. The addition of KBC; Industrial Evolution, Inc.; and Soteica Visual Mesa greatly enhance Yokogawa's capabilities as a provider of digitalization outcomes that help customers achieve their business objectives.

KBC's "techno-economic" and organizational consultants complement Yokogawa's portfolio with deep industry operating domain knowledge of upstream, refining, and petrochemical processes. This been codified into KBC's process simulation and optimization technologies. Recently added IT/IIoT solutions from Industrial Evolution, Inc. and energy management and supply chain optimization capabilities from Soteica Visual Mesa fill additional portfolio gaps and address some of the key issues discussed in the next chapter.

The fusion of Yokogawa's heritage focus on optimal operability through base-layer control, devices, and sensors with KBC's advanced technology applications and industry know-how provides the basis for ensuring successful and sustainable outcomes and value.

Yokogawa's investment and co-innovation strategy brings together mission-critical control and safety with fog and cloud computing and analytics applications and infrastructure to deliver "Synaptic Business Automation™," which the company defines as a more holistic and ambitious successor to process automation. The two key elements are:

- Yokogawa's OpreX™ portfolio of offerings designed to assure optimal plant operability. This portfolio includes OpreX Transformation, OpreX Control, OpreX Measurement, OpreX Execution, and OpreX Lifecycle.
- Yokogawa's KBC portfolio focused on optimal plant operability and performance across the extended value chain. KBC consultants have helped customers define and prioritize their business issues and define a digital transformation journey in the context of their strategic objectives, regardless of where they are in their digitalization journey.

Value Drivers and Enablers

Industrial organizations around the world are entering a period in which new digital technologies can augment people and processes to an unprecedented degree. New commoditized computing resources in the Cloud and at the network edge and artificial intelligence (AI) are changing how people work. Approaches such as the Industrial Internet of Things (IIoT) and Industry 4.0 have helped pave the way for digital transformation across a broad swath of industrial sectors.

Digital transformation spans industrial products, operations, value chains, and aftermarket services. It augments people and knowledge through expanded use of sensors, data, and analytics. ARC Advisory Group believes that most industrial process companies globally will soon undergo a digital transformation. Many are already actively piloting advanced approaches.

However, many companies today tend to focus their efforts on technology, without considering the full organizational impact. ARC research shows that only a small percentage (5 to 8 percent) of industrial organizations consider themselves ready for a digital transformation program. Many others are not prepared to scale up the pilot programs currently in progress.

ARC research also indicates that barriers to organizational accountability, culture, and change management impede transformation. Digital transformation requires a shift in how technology is deployed and utilized.

Key Technologies Impacting Industrial Manufacturing

Digital technologies and approaches – from advanced data analytics and digital twins to procedural automation and autonomous operations – are transforming the energy, chemicals, and other process industries. This is helping companies improve margins, productivity, and safety.

However, organizational barriers have slowed progression. These include the process industry's traditionally conservative approach toward adopting new technology; poor data quality due to poor data management systems and assets that have changed ownership; and cultural gaps between operations, engineers, and IT professionals.

Within the broader umbrella of digital transformation, several emerging technologies will have major impact on the process industries, each in a unique way.

Many of the newer technologies require changing the way technology leaders think about people, technology architecture, and process. Current plant-centric approaches may not support new technologies and approaches. Historically, plant-level operational technology (OT) systems have been procured and supported by plant engineering or operations staffs. But new information technology (IT)-based systems require internal IT staff or cloud service providers to manage and host the platform infrastructure, with engineering and/operations helping define the operational and supply chain outcomes.

Technology	Application	Value Proposition
Cybersecurity, Connectivity, Industrial IoT	Remote services, Cyber processes	Lower cost services, connectivity
Public Cloud, Cloud Services	Software-as-a-Service (SaaS)	Business agility, business process standardization
Cognitive Intelligence	Semantic search, knowledge graph	Unbinding human experience, operational knowledge
Blockchain	Deals, contracts, logistics, and invoicing	Sales, margin improvement
Robotics and Drones	Safety inspections, spare parts	Maintenance improvement, spare parts, uptime
Process Engineering Simulation	Process optimization	Margin improvement, safety, process improvement
Mobility, 4G, 5G	Ubiquitous access to information	Productivity and safety
Artificial Intelligence (AI)	All work and business processes	Big Data, new insights, discover the unknown

Digital Transformation Technologies, Applications, and Value Propositions

Clearly, the digital transformation of industry has the potential to contribute significantly to global economic growth. The World Economic Forum estimates that Industry 4.0 alone could contribute more than \$20 trillion to global gross domestic product (GDP) by 2020.

However, this will require a well-focused effort that includes preparing the workforce, implementing the appropriate IT infrastructure, and adjusting business processes. ARC research indicates that many management systems

currently in place create barriers to digital progress. Often, hierarchical management structure, weak employee change management leadership, and organizational silos create artificial barriers to information, impeding decision making, and - ultimately - hampering business performance.

Many in industry believe that organizational and human elements are the biggest challenge when implementing a digital strategy. However, while some of the barriers may indeed relate to company culture, ARC research finds gaps in how digital programs address change and in the change leadership skills of the company's digital advocates. These gaps will impact progress, but this depends on where companies are on their digital journey and experience in areas of digitization and digitalization.

From Digitization to Digitalization

ARC is aware of the confusion many in industry have about the distinction (if any) between the terms “digitization” and “digitalization.”

Digitization focuses on technology and infrastructure and typically impacts a relatively small number of stakeholders within a company. Digitalization, on the other hand, involves making use of digital data and technologies to improve a business or work process.

One way to look at it is that “digitization” involves creating digital versions of previously analog data such as by creating digital work orders to replace paper-based work orders. Replacing analog technology with digital technology, such as the transition from analog field instrumentation and control systems to digital instrumentation and control systems, would be another

example. Digitization focuses on technology and infrastructure and typically impacts a relatively small number of stakeholders within a company.

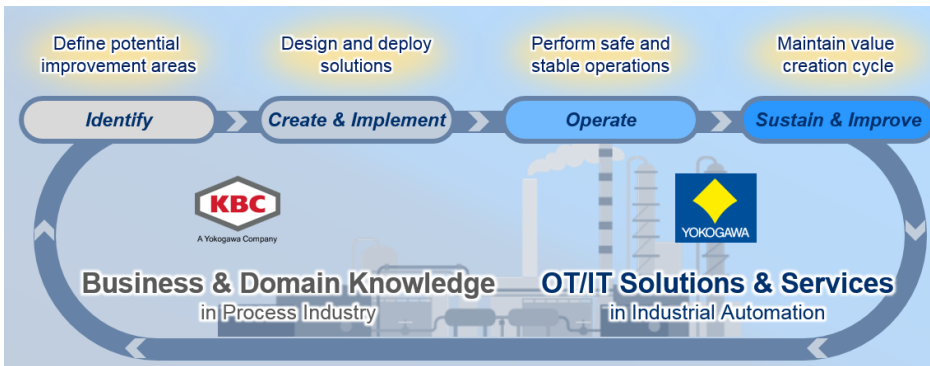
Digitalization, in turn, involves *making use of* digital data and technologies to improve a business or work process. For example, utilizing data from a digital work order to improve maintenance work processes and execution, or using digital twins to improve asset information and/or engineering processes. In other words, digitalization utilizes digital technologies and data to improve the way people work, collaborate, and get things done within a plant or across a company.

What Makes Yokogawa Different?

Most technology suppliers in the industrial automation space today have programs to support their customers' digitalization and digital transformation efforts to one degree or another. Based on recent co-innovation initiatives, key acquisitions, and the company's overall strategic direction, Yokogawa appears to be particularly well-positioned in this respect.

Synaptic Business Automation

Unveiled back in 2005, VigilantPlant laid down a path toward operational excellence in the then-current context of Yokogawa's offerings and capabilities. However, the company's capabilities and the challenges its customers face have both evolved considerably in the interim. In response, the



Synaptic Business Automation Value Creation Cycle
(Source: Yokogawa)

company launched Synaptic Business Automation as a core underlying concept. Yokogawa conceived Synaptic Business Automation as a way to help its clients realize operational excellence by

connecting everything in an organization and integrating business and domain knowledge with digital automation technologies.

With Synaptic Business Automation, Yokogawa is looking beyond process automation to create sustainable value for industrial customers and help them realize profitable and sustainable growth. This holistic approach has three aspects:

- **Resilient Operation** – improving clients' operational resilience against heightened business risks from increasing cybersecurity threats, regulatory compliance mandates, and more strenuous plant and personnel safety requirements.
- **Optimized Production** – reframing the (lengthy) operational phase of the plant as something much more than an afterthought to the capital

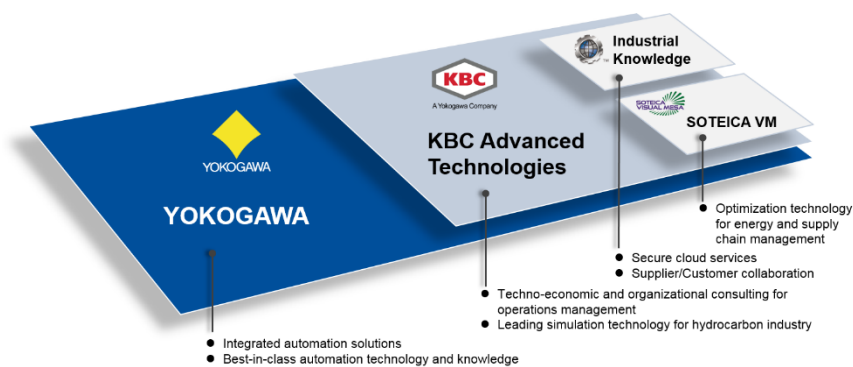
construction phase and, accordingly, managing operational expenditures through initiatives such as IIoT connections to critical plant assets.

- **Business Innovation** – leveraging relevant technologies and domain expertise to co-create new business models with customers and partners and introduce environmentally friendly manufacturing practices that are essential for a sustainable society.

While any business requires strong customer relationships to succeed, with Synaptic Business Automation, Yokogawa looks to further deepen these relationships through extensive co-innovation activities.

Recent Acquisitions Extend Digitalization Capabilities

With the acquisition of KBC in 2016, Yokogawa made a significant leap forward in the oil & gas and petrochemical industries.



Recent Acquisitions Increase Yokogawa's Digitalization Capabilities
(Source: Yokogawa)

KBC's techno-economic and organizational consultants have deep industry operating domain knowledge of upstream, refining, and petrochemical processes. This has been codified into its process simulation and optimization technologies. Yokogawa can now use this domain knowledge to rigorously define the business

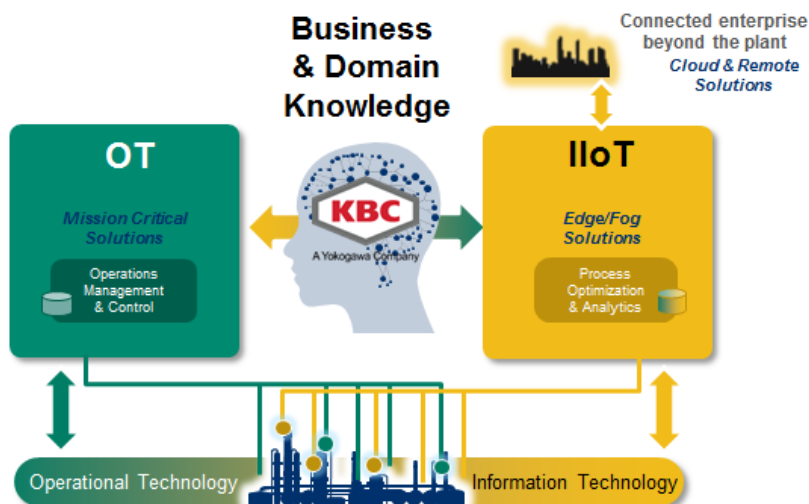
case/case for change and develop a roadmap of activities and solutions to help clients achieve sustainable operational excellence through digital transformation.

Also in 2016, Yokogawa fully acquired Soteica Visual Mesa (SVM) to build out its energy management/optimization and supply chain management capabilities including planning, scheduling and production accounting. These added capabilities should help Yokogawa become a key player in the value chain optimization space for the hydrocarbon processing industries.

Industrial Evolution, Inc., a third acquisition in 2016, further builds out Yokogawa's capabilities. Founded in 2000, Industrial Evolution (now doing

business as Industrial Knowledge) is a pioneer of cloud-based services for real-time data sharing beyond customers' corporate boundaries.

These acquisitions added deep IT and IIoT capabilities to Yokogawa's portfolio, which the company believes will enable it to deliver what it refers to as "Operational Excellence as-a-Service," via the Cloud.



These new acquired capabilities, combined with Yokogawa's well-proven industrial control, safety, and cybersecurity solutions, enable the company to think differently about digital transformation. Together with sensors, optimization software, and its control and safety infrastructure, Yokogawa is digitizing the domain

knowledge of its acquisitions, converging OT and IT to deliver effective digitalization solutions.

A Focus on Co-innovation

Yokogawa prioritizes its commitment to co-innovation to help co-create value with its customers. This was the underlying theme of Yokogawa's mid-term business plans TF2017 and TF2020. This ethos and collaborative approach is fully appropriate in a world of digitalization in which it's vital to be able to innovate at pace and at scale to improve business performance.

Yokogawa has put significant investment into new facilities that allow it to look beyond technologies for innovation ideas; go out into the field, observe users, and co-innovate ideas and solutions with users to create new value.

The (US)\$80 million Co-Innovation Centre that Yokogawa opened in Singapore in 2016 provides evidence of this commitment. KBC's recently announced Energy and Sustainability Co-Pilot hub in Singapore is another example. This hub will build and adapt energy management and optimization systems, conduct research and development to create the next generation of energy analytics applications, and deliver KBC's cloud-based solutions.

OpreX Brand Covers Entire Industrial Automation Platform

Yokogawa's investment and co-innovation strategy brings together mission-critical control and safety with fog and cloud computing and analytics applications and infrastructure to deliver Synaptic Business Automation.

In June 2018, Yokogawa announced its new OpreX™ branding of its portfolio of offerings. According to the company, the OpreX brand stands for excellence in the technology and solutions that Yokogawa cultivates through the co-creation of value with its customers. The five OpreX brands

are:



- OpreX Transformation
- OpreX Control
- OpreX Measurement
- OpreX Execution
- OpreX Lifecycle

Together, the OpreX brand encompasses Yokogawa's entire industrial automation (IA) portfolio from measurement devices all the way up to transformative management solutions. As discussed further on, ARC believes that OpreX Transformation is particularly relevant in the context of this white paper.

Secure-by-Design Cybersecurity

Yokogawa has invested significantly to build a strong cybersecurity program to support its OpreX solutions. This program incorporates ISASecure, EDSA certification, and secure-by-design approaches. Yokogawa engineers receive professional training and certification through global industrial security professional (GICSP) certification (which effectively bridges IT and OT) and/or ISA/IEC62443 cybersecurity fundamentals specialist certification, the global cybersecurity standard for automation.

Today, the company has more than 600 cybersecurity-trained resources including approximately 100 cybersecurity-certified professionals working actively in the cybersecurity programs. These include remote performance monitoring and managed services from a Security Operations Center (SOC) and security consulting services.

The Digitally Transformed Plant

Yokogawa believes that all industrial plants should operate safely, reliably, responsively, profitably, and in an environmentally responsible manner. This requires those plants to adhere rigorously to operating plans, yet respond nimbly to market changes and plant disturbances with a motivated and informed workforce. This is one way to describe plants that exhibit operational excellence. Increasingly, digital transformation is becoming a prerequisite for operational excellence.

Yokogawa understands that, when applied correctly, digitalization allows plants to manage their day-to-day performance safely and reliably, respond to swings in market dynamics, operate in an optimized manner, reduce the gap between potential and realized margin, and outmaneuver competitors. It also enables a process operation to engage with key partners, customers, and suppliers to augment the plant's own capabilities and resources.

Digital transformation makes it possible for industrial plants to:

- Capture value through unexploited efficiency or productivity gains
- Discover and generate new revenue
- Execute and sustain that value in the face of continuous change and disruption
- Solve problems that were not previously solvable
- Improve competitiveness

A transformed plant will make the most of its capabilities (physical assets, supply chain, human resources) to operate optimally in the face of changing economics, feedstock/fuel availability, and operational constraints.

Yokogawa's approach to co-innovation and value co-creation with clients along with the capabilities of its recent acquisitions can help put this future world within reach.

In Yokogawa's view, the tools for digitalization should always be holistic and scalable in nature. They should consider the impact of a change in one area on end-to-end plant economics; be smart enough to identify problems and recommend solutions (rather than just presenting information without context); be easy to use; and automate as much as possible. The company also believes that the reach of these digitalization tools should extend beyond the corporate boundary via the Cloud.

Furthermore, Yokogawa believes that in a digitally transformed plant the human should be an implementer and supervisor of strategy, rather than a worker who is directly involved in basic manual tasks or number-crunching activities. Operating costs should be minimized and production optimized. Assets should be more flexible and fully utilized; the plant should be safe, and the environment respected.

Yokogawa Digital Transformation Solutions

As mentioned earlier in this white paper, industrial organizations around the world are entering a period in which new digital technologies can augment people and processes to an unprecedented degree. Many end user organizations have already started to pilot these new approaches, solutions, and technologies in their plants. Yokogawa has identified relevant use cases and/or customer case study examples and provided estimates of the associated business benefits.

OpreX Transformation

OpreX Transformation is designed to help drive operational excellence across an enterprise's business activities, from production to the supply chain and business management. It brings together KBC's management consulting capabilities and deep operating domain knowledge with Yokogawa's production automation and other solutions. The goal is to enhance corporate value by optimizing customers' operations and supply chains.

Profit-Driven Operation (PDO)

A major challenge for process manufacturers is to achieve and sustain profitability when faced with volatile market conditions, often-conflicting priorities (e.g., safety, reliability, and efficiency), and the loss of experienced personnel. Yokogawa designed its OpreX™ Profit-driven Operation (PDO) solution to match KPIs to customers' business objectives and help them meet these challenges. Components of the PDO Solution include:

- Synaptic Performance Indicators (SPIs)
 - Top-to-bottom SPI tree
 - Algorithms to “score” performance and help balance competing SPIs
- Visualization
 - Overview dashboard screens by role and objective
- Analytics

- Digital twin
- Data analytics and AI (including machine learning)
- Expertise
 - Embedded expertise in SPI selection
 - Expertise to set and tune targets and ranges
 - Interpretation/recommendations to address deviations
- Workflow
 - Provide managerial oversight of operator performance
 - Escalate non-compliances

For PDO, Yokogawa leverages domain knowledge with real-time production data from the plant automation and execution systems to create the role-specific “Synaptic Performance Indicators” or SPIs. The company has identified many performance indicators for operation, technical, management and leadership in process facilities across the energy and chemicals industry. These cover critical elements of each function including production, profitability, energy conservation, asset reliability, and safety.

A balanced scorecard approach is then used to minimize conflicting priorities that would otherwise generate inefficiencies and reduce profitability. The performance indicators help management drill down on issues related to the working levels. Improvements at the working levels also ultimately contribute to the management performance indicators.

The data from the automation platform provides the basis for the operations-related performance indicators. The system uses real-time data to measure control and process performance, alarm management performance, product quality and yields, energy consumption, and other key business metrics.

The operations dashboard displays individual performance indicators along with a composite score. It can also display each performance indicator with its ideal range. If outside the ideal range, expert advice is displayed so operators can take appropriate corrective action. The operations dashboard helps operators analyze and balance their priorities and identify areas for improvement. This enables plants to make the transition from event-driven operations to profit-driven operations.

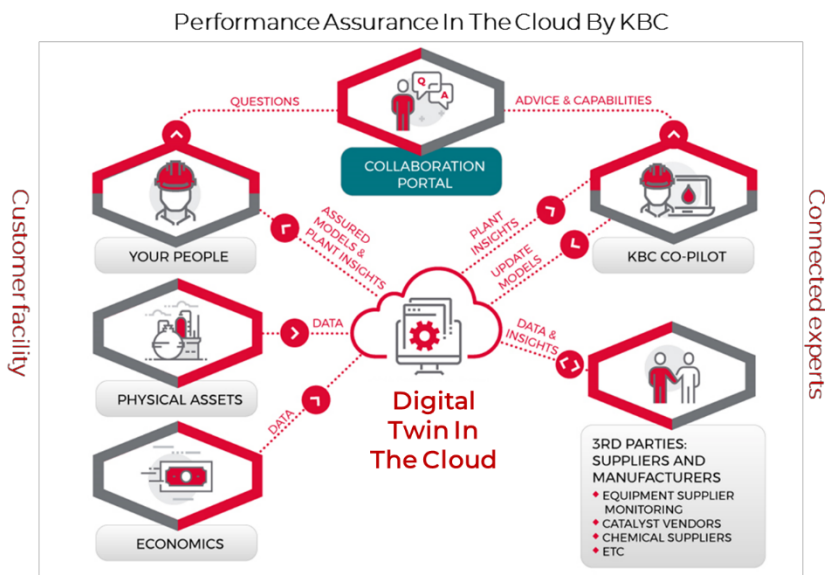
KBC Co-Pilot Program

The KBC Co-Pilot Program™, part of Yokogawa’s PDO family, incorporates a virtual representation, or digital twin, of a physical asset as an indispensable source of information for decision support. The digital twin provides an

accurate, up-to-date representation of the asset. It can be used for simulation purposes to obtain information about non-measured variables, predict impending alarm states based on current conditions, predict future states, optimize operations, and train operators.

The KBC Co-Pilot Program can serve as an extra subject matter expert and extra set of eyes for many industrial processes.

A private cloud-based service, the program utilizes a combination of plant historian data, process models, linear program (LP) models in the form of a real-time digital twin of the plant, and the services of remotely located KBC experts. The current KBC Co-Pilot activities involve KBC's first principles-based simulation and optimization technologies (Petro-SIM® and Visual MESA™) and include an intuitive dashboard. In an oil refinery, Petro-SIM model simulations in the cloud can provide real-time unit reconciliation and optimization or validation of the LP planning model. KBC engineers steward performance analysis insight, recommendations, and reporting. Co-Pilot can compare actual-to-predicted results and adjust the LP model for a complete refinery.



Petro-SIM model updates and calibration are performed in the cloud, each mirroring the actual plant and synchronizing with the on-premise model (if available). Co-Pilot can establish performance indicators in near-real-time and monitor variables, including many variables that are not directly measurable but can be inferred. Equipment and other data can also be monitored through the

performance indicators dashboard. Performance indicators provide relevant actionable information with progressively more information and detail the deeper you go into the dashboard.

Through simulations and expert advice, the Co-Pilot Program can help users optimize processes, improve yields, improve plant reliability, and optimize operating costs. According to KBC, customers can expect potential savings of \$3 million to \$10 million per year for a single hydroprocessing unit.

Digital Twin-enabled Asset Performance Management (APM)

Intelligent asset performance management strategies have evolved to incorporate complex math/physics/chemistry/probabilistics and advanced deep learning techniques to answer previously challenging questions. Examples include: How critical is the asset for meeting business objectives? What's the consequence of an asset failing and the effect on related assets? What are the ways an asset can fail? How do you mitigate the failure risk? How can you ultimately automate and evergreen this process?

KBC and Baker Hughes, a GE Company (BHGE), are working together to find ways to ensure that asset management isn't being optimized without also considering process, yield, or energy (or vice versa). This approach avoids siloed, sub-optimal decision-making on the plant and individual unit levels or between different groups, such as planning, scheduling, operations, and maintenance.

BHGE is fusing KBC's first-principle models with data to create more accurate, continuously updated models. This allows for continuous interrogation of process data against the process model. The goal is to enable simultaneous optimization of operations, maintenance, and planning in near-real-time, providing the potential for multimillion-dollar benefits for customers.

Sushi Sensor-enabled Condition-based Maintenance

Without continuous monitoring, it can be challenging to plan operations effectively or detect signs of abnormal behavior to be able to optimize maintenance through condition-based maintenance. This often requires new and innovative sensors, such as Yokogawa's compact, wireless "Sushi Sensors."

Yokogawa developed the company's first compact, wireless "Sushi Sensor," to monitor the health of plant equipment as part of a condition-based maintenance program for rotating machinery.

With today's advanced sensor and analytics technologies, plants can now get a better picture of their equipment to improve operating performance and enable more effective condition-based maintenance. Since assets such as rotating equipment (e.g., pumps, motors, compressors) are often particularly problematic, Yokogawa developed its first

Sushi Sensor to monitor the health of plant equipment as part of a condition-based maintenance program for rotating machinery.

This easy-to-deploy sensor measures important physical quantities for plant health monitoring such as vibration and surface temperature. Cloud or on-premises servers can be used to connect to and combine data from the Sushi Sensors with other sensor and non-sensor data to analyze equipment condition, detect signs of abnormality, and recommend appropriate maintenance actions.

Process Data Analytics (PDA)

Yokogawa's Process Data Analytics solution uses the Mahalanobis Taguchi (MT) method to solve challenging product quality and traceability issues. This pattern-recognition technology compares collected data and helps de-

Yokogawa's PDA software is designed to monitor and detect the causes of process deviations. With early visibility into quality issues companies are better able to manage production proactively to achieve on-spec product.

tect deviations from normal conditions. Any deviation will trigger a warning that product quality may have deteriorated.

Many manufacturers source materials from multiple sources. Any fluctuations in the quality of raw material or other factors such as aging equipment will affect the final product quality. Yokogawa's

Process Data Analytics software is designed to monitor and detect the causes of process deviations. With early visibility into quality issues companies are better able to manage production proactively to achieve on-spec product.

Conclusion

Yokogawa announced its acquisition of KBC in 2016. Clearly, we're starting to see how this – along with the other strategic acquisitions discussed in this report – helps differentiate it from other major automation suppliers. KBC domain expertise in the energy and chemicals verticals; combined with Yokogawa's well-proven automation, safety, and connectivity infrastructure are helping the company transform its customers' businesses. This is consistent with the company's Synaptic Business Automation concept and OpreX portfolio of solutions.

KBC provides an advanced combination of analytics technologies and management and engineering consulting for upstream and downstream oil & gas and refinery-integrated petrochemicals. KBC's software portfolio of process unit reactor models, high-fidelity thermodynamics, and plantwide simulation software complements Yokogawa's existing suite of solutions.

Within Yokogawa, KBC is already extending its successful operational excellence business model into adjacent industries, especially where there is strong market growth or where Yokogawa is particularly strong. A significant proportion of KBC's order book consists of chemicals, utilities, and renewable energy companies.

Furthermore, KBC's consultants have deep domain expertise and extensive C-level customer relationships, which is expected to increase Yokogawa's mindshare among these key decision makers and help it further its goals of being a trusted partner for customers.

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