ARC WHITE PAPER

By ARC Advisory Group

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Yokogawa's Perspective on the Sustainable Connected Industrial Enterprise

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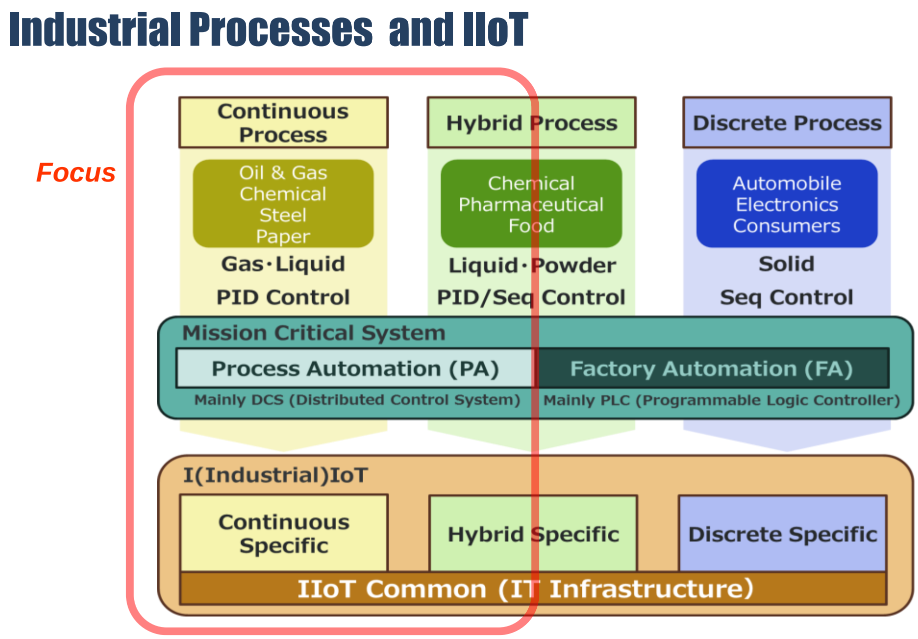
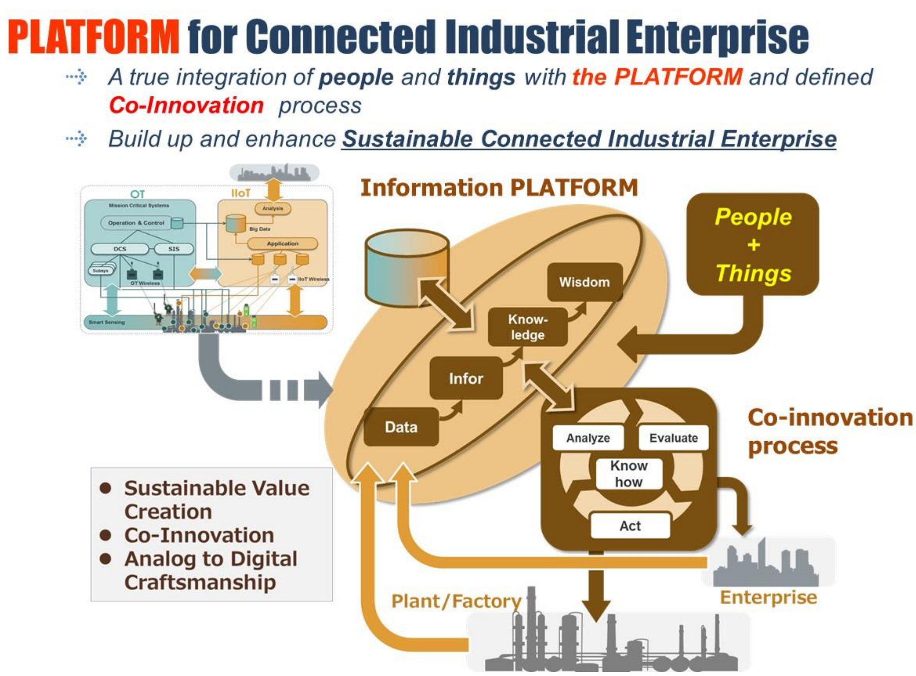


Industrial IoT Focus for Continuous Process Manufacturing Industries (Source: Yokogawa)



IIoT Provides a Platform for the Connected Industrial Enterprise (Source: Yokogawa)

Executive Overview

ARC Advisory Group has been closely following the trend toward more open, standards-based automation systems for more than 25 years. This disruptive trend started when automation suppliers and end users began integrating information technology (IT) into their proprietary industrial automation systems. Today, with the emergence of the Industrial Internet of Things (IIoT), the trend has taken an interesting twist; one with significant potential to help further improve both plant operations and overall business performance.

Last year, ARC produced a report that explained Yokogawa's "VigilantPlant Approach to the Connected Industrial Enterprise." This current white paper builds on that report; providing an overview of how Yokogawa believes its customers can best prepare for and position themselves to benefit from digitization in general and IIoT-enabled technology and solutions in particular.

Now, in addition to incrementally integrating IT *into* their control systems and networks; automation suppliers are looking into how they can enable their mission-critical, real-time industrial automation systems and applications to securely *collaborate with* IIoT-connected smart devices, equipment, systems, and applications.

IIoT connects previously stranded data from smart sensors, equipment, and other industrial assets with predictive analytics and other advanced applications running both in-plant on edge computing devices and remotely "in the cloud." Despite initial concerns, many companies now realize that, when properly implemented, internet-based technologies can provide appropriate security and availability. This further increases collaboration on the plant floor, throughout an industrial enterprise, and across a global value chain.

ARC has observed that an increasing number of manufacturers and other industrial end user organizations have been looking at the technologies to evaluate how IIoT-enabled solutions could be used to help solve specific problems in their own production operations, improve asset management, enhance their service delivery capabilities, and/or fine tune their supply chains. ARC consultants have been working closely with a number of leading technology end user companies across a variety of industrial sectors to do just this.

At the same time, most leading automation suppliers are actively identifying architectures, standards, and business models for deploying IIoT solutions that build on their own strengths in mission-critical, real-time operations. They are also identifying appropriate partners from the IT world and making strategic acquisitions to help them define, develop, and deploy those solutions. Yokogawa is one of those automation suppliers.

"Digital Craftsmanship" is Not an Oxymoron

Analog craftsmanship refers to the traditional knowledge and skills of plant operators, maintenance technicians, and engineers gained through formal and informal training and years of real-world experience. Analog craftsmanship has helped the global process industries attain the relatively high level of performance they currently enjoy. However, analog craftsmanship alone is not enough to take industry to the next level. This is where "digital craftsmanship," comes in. Digital craftsmanship builds on the current skills and knowledge base with new sensor-derived data, predictive analytics, machine learning, and other powerful tools. This supports the move toward autonomous operations, while empowering humans to make information-driven decisions, rather than take critical actions based largely on intuition, instinct, tribal knowledge, and often incomplete, outdated, or even inaccurate information.

Ideally, the new worker generation will embrace digital craftsmanship concepts to help ensure the safe and profitable operation of process plants in the future.

Last year, ARC produced a report that discussed Yokogawa's "VigilantPlant Approach to the Connected Industrial Enterprise." This second white paper builds on that report; providing an overview of how Yokogawa believes its customers can best prepare for and position themselves to benefit from IIoT-enabled technology and solutions and digitization in general to emerge as the successful connected industrial enterprises of the future.

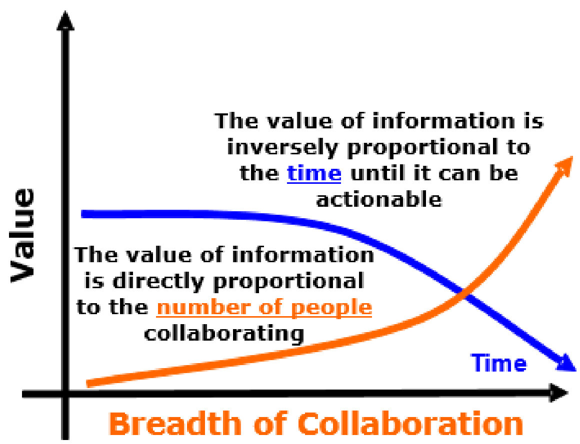
As ARC learned in a recent series of briefings, Yokogawa believes that its unique strength in IIoT extends beyond its well-proven industrial automation technology and solutions to the company's Japanese tradition of Takumi, or artisanal craftsmanship. This places it in an ideal position to help users move beyond conventional "analog craftsmanship" to develop and exploit their own "digital craftsmanship" through IIoT-enabled collaboration, analytics, and decision support.

This Yokogawa white paper presents an overview of what industrial organizations need to know to put themselves in the best possible position to leverage emerging IIoT technology, solutions, and approaches in conjunction with their current operational technology (OT) and information technology infrastructures. According to the company, connected industrial enterprises leverage IIoT to enable them to:

- Autonomously resolve issues and achieve business objectives at both the plant and enterprise levels
- Sustainably integrate ***people*** and ***things*** to enable value creation
- Facilitate infrastructure and define co-innovation processes to successfully transition from conventional analog craftsmanship to digital craftsmanship

What is IIoT and What Value Can it Bring to Industrial Organizations?

Manufacturers and other industrial organizations have pursued horizontal and vertical connectivity within their operations for some time now in their ongoing efforts to improve performance and achieve operational excellence through collaboration. Most existing sensor and actuator points in an industrial automation system are in place to support process/production control, safety, and regulatory compliance. Increasingly, sensor data is also being used to support operations management and maintenance activities. These points are typically connected to a dedicated real-time system or application that may (or may not) share certain data with other plant or enterprise systems.



Value of Collaboration (Source: ARC Advisory Group)

So what does the Industrial Internet of Things (IIoT) bring to the table?

IIoT emphasizes remote access to connected devices, assets, and applications. By connecting previously stranded data from smart sensors, equipment, and other industrial assets with advanced applications and predictive analytics, the IIoT is becoming a strategic enabler to improve manufacturing performance. Despite initial concerns, many companies now realize that, when properly implemented, internet and wireless technologies can provide appropriate security and availability of services across multiple plants and facilities. This helps further meld plant floor and enterprise systems, creating an opportunity to transform manufacturing operations.

One transformational outcome of this union of business and automation technology is to reduce maintenance and operations costs by changing the way plant maintenance is executed on critical assets. Much like the way Uber has disrupted ride services or Air bnb has disrupted room rentals, industrial companies must recognize that IoT and digitization are disrupting the industrial world.

IIoT Reshaping Plant Information Architectures

Through IIoT-enabled technologies, services, and strategies, industrial users can collect, manage, store, and analyze huge volumes of data ("Big Data") from almost anything at extremely high frequency and relatively low cost. This enables efficiencies in work and business processes that were not possible in the past.

Distributed control systems (DCS) and programmable logic controllers (PLC) with process historians have been performing some elements of this for decades. While they also involve sensors and computing, IIoT-enabled solutions can deliver very different outcomes than DCS- and/or PLC-based process automation architectures alone. IIoT solutions also tend to be more flexible than traditional automation architectures, which are often bound tightly to the design of the industrial processes being monitoring and controlled. In general, while automation systems are control driven; IIoT solutions are data driven. However, as we'll see, the two can work together harmoniously to solve problems and improve asset availability and performance.

Historically, process automation systems have been designed for a single purpose; to support process control based on the process design characteristics as spelled out on the process & instrumentation design (P&ID) diagrams.

Historically, process automation systems have been designed for a single purpose; to support process control based on the process design characteristics as spelled out on the process & instrumentation design (P&ID) diagrams. As the technology evolved and business challenges increased, automation suppliers started enhancing their process control systems with more advanced capabilities for real-time information management, basic decision support, and advanced process control. (ARC's Collaborative Process Automation System model, or CPAS, covers these in considerable detail.)

Process sensors and actuators included in a front-end engineering design (FEED) process were almost always expected to be connected to DCS or PLC I/O to support process control, logic control, alarming, and trending, and basic human machine interface (HMI).

Process automation follows the ISA95 model for enterprise-control system integration, which has its origins in the circa-1980 Purdue Model for computer integrated manufacturing. While the ISA95 model focuses on feeding predominantly process-related plant data up to the enterprise; the IIoT model extends horizontally across a plant, an entire enterprise, and out to suppliers, customers, and partners to create a flexible platform for co-innovation and digital transformation.

Industrial IoT vs. Commercial IoT

While IoT has already taken off and gained significant traction in the consumer products and commercial worlds, Industrial IoT is still in its nascent stages.

IIoT vs. M2M

Many people remain confused about the distinctions between IIoT and its forerunner, machine-to-machine (M2M) communications. Remote device access over a variety of network types (3G/4G/wireless, Bluetooth, ZigBee, IP-based networks, etc.) is common for both solutions, but Yokogawa stresses that commonality between the two solution types largely ends there. For example, traditional M2M solutions typically rely on point-to-point communications between sensors and "things" largely to collect data. In contrast, IIoT solutions generally employ the internet for communications and typically include people, data analysis, and services that support some sort of action. In other words, while M2M is important in many applications, IIoT represents a much richer solution set.

"Commercial" IoT, exemplified by today's wave of "smart" connected appliances (refrigerators, air conditioners, etc.), home monitoring systems, smart thermostats, personal fitness devices, smart watches, and so on; have very different requirements and characteristics than IIoT.

Security, robustness, and data integrity issues rarely come up when considering consumer/commercial IoT products, where loss of connectivity, the occasional application interrupt, or a security breech might be annoying, present an inconvenience or, at worst, create a minor embarrassment for the user.

Due to security and other concerns, measurements from IIoT-connected sensors are not currently (and, in fact, may never be) used for real-time, mission-critical process control. But, increasingly, they are being used to feed IIoT-connected asset management, predictive maintenance, and environmental monitoring applications; off-line asset or process optimization applications; operations decision support; and so on.

As a result, a loss of connectivity, application error, or security intrusion are primary concerns for IIoT devices and applications since these could result in suboptimal asset availability, asset performance, safety performance, or environmental performance. In other words, like mission-critical process control, IIoT has a direct impact – positively or negatively – on an industrial organization's business performance and sustainability.

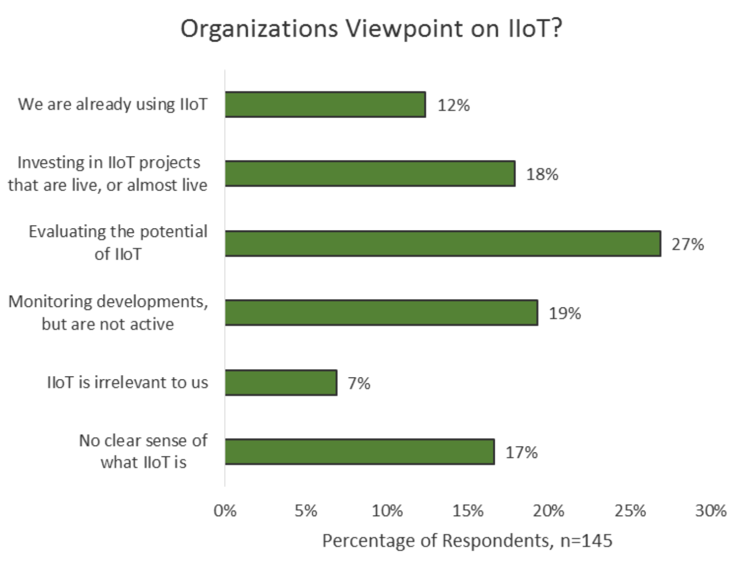
IIoT for Process Manufacturing vs. IIoT for Discrete Manufacturing

As most readers of this white paper already know, while all industrial processes share some similarities; continuous processes, hybrid/batch processes, and discrete manufacturing processes all have distinct characteristics, requirements, and challenges.

ARC research indicates that, to date, IIoT has achieved greater traction in the discrete manufacturing industries than in the process industries. This is possibly due to the much larger volume and variety of smart sensors available for discrete manufacturing than for process manufacturing.

But due to the typically asset-intensive and global nature of the process industries, the momentum toward IIoT is growing and will further accelerate as suppliers fine-tune their IIoT strategies, establish reference models, develop focused solutions, and convince end users that the potential benefits far outweigh any perceived drawbacks.

Benchmarking IIoT Readiness



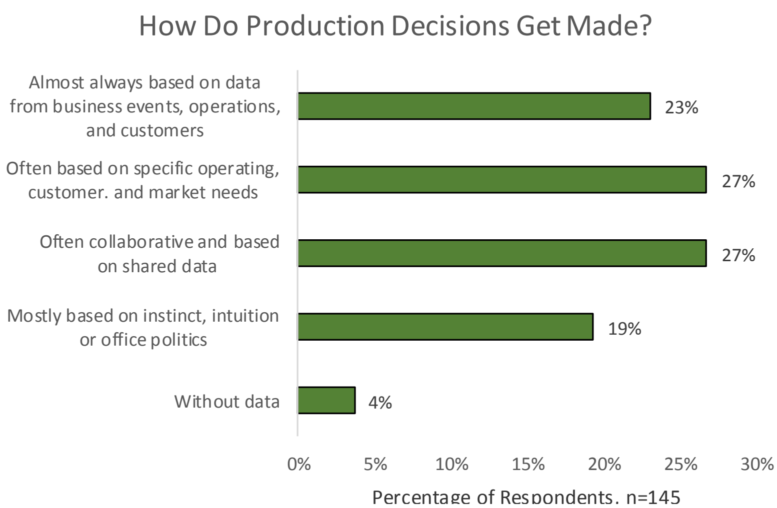
Many Companies Today Remain Confused about IIoT (Source: ARC Survey)

While IIoT has gained wide exposure in the media, actual take up remains limited. Many industrial organization even remain confused about what it is and how it can benefit them, if at all.

Based on the results of a recent ARC Advisory Group web survey performed in conjunction with PLANT SERVICES magazine, one in six survey respondents (17 percent) did not understand what IIoT is, or more importantly, how it can help them. On a more positive note, the survey data shows that many organizations are quite advanced in their thinking. Almost one-third (30 percent) of survey respondents are already actively using IIoT, or investing in projects that will soon be live. (However, this could be optimistic, since it's likely that many of the companies that participated in the survey already have IIoT on their respective "radar.")

What is interesting is that the maturity of IIoT adoption shown by the survey maps closely to the classic technology adoption curve. The 12 percent of survey respondents who have already deployed IIoT solutions are quite broad in their application and vision for IIoT. However, there currently appears to be slightly keener focus on products (either new, or existing) than there is on tweaking existing services or introducing new services.

How Production Decisions Get Made Today

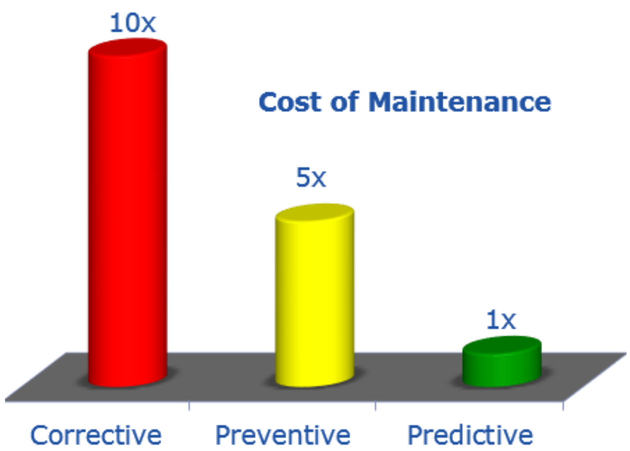


Most Companies Today Rely at Least Partly on Data to Drive Production (Source: ARC Survey)

Based on that same ARC web survey, we learned that only 23 percent of the companies participating in the survey currently base operational decisions on data. This gives rise to some key questions. First and foremost, how will such companies compete effectively in the all-encompassing digital age of industry? The good news is that most companies that took part in the survey rely at least partly on data to drive production. In fact, half of all survey respondents are in a reasonable position to move forward with their industrial IIoT strategies. These companies are already incorporating feedback from customers and their supply chains to drive production decisions. For these companies, IIoT will serve to extend and enhance their decision making.

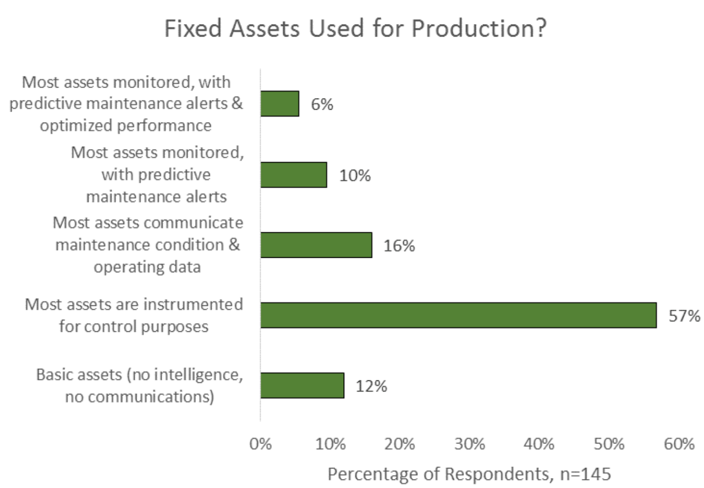
The Case for IIoT-Enabled Asset Monitoring

In addition to many other potential business benefits, IIoT-enabled asset monitoring and predictive analytics provide an excellent opportunity for all industrial organizations to minimize (and possibly eliminate) unplanned downtime and reduce maintenance costs for their fixed production assets. ARC research indicates that corrective maintenance can cost ten times as much as predictive maintenance (see chart). This represents an excellent example of the difference between "analog craftsmanship," and "digital craftsmanship."



Corrective Maintenance can Cost Ten Times as Much as Predictive Maintenance

According to the recent web survey that ARC performed in conjunction with PLANT SERVICES magazine, while the majority (57 percent) of survey respondents indicated that they instrument most of their fixed production assets for control purposes, only 6 percent currently monitor their production assets with predictive maintenance alerts and optimized performance. (And, once again, this may be optimistic, due to the bias of the companies that participated in the survey.) This clearly represents a significant missed opportunity, one where IIoT can help.



While Instrumented, Most Fixed Assets are Not Widely Monitored with Predictive Alerts

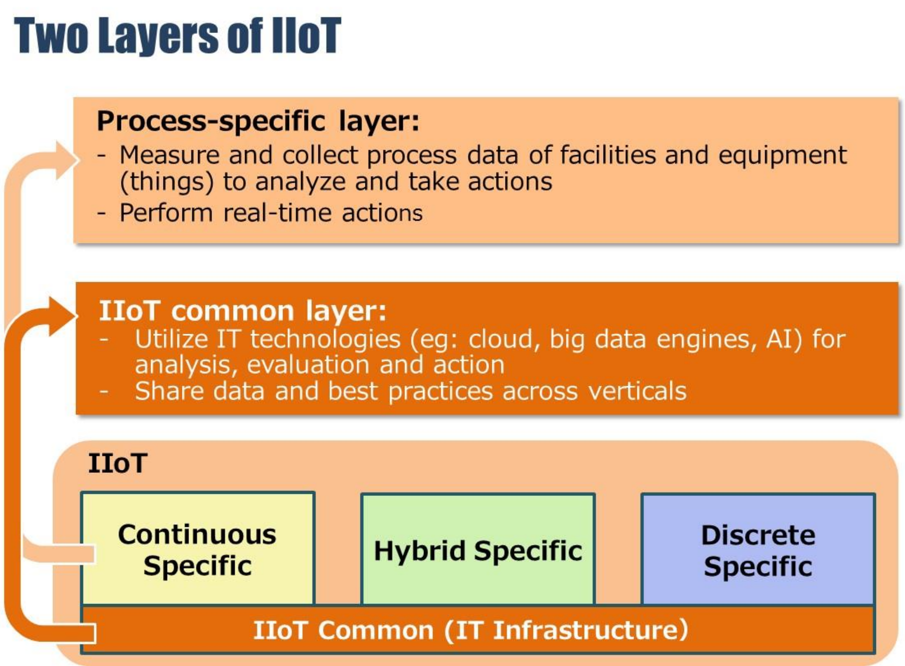
Data collected by sensors on fixed assets – combined with predictive analytics – can provide a powerful way to get an early warning of impending failure. With advanced notice of an upcoming failure, the parts in question can be replaced at the next scheduled maintenance. Replacing parts before they fail can eliminate unplanned downtime and cut costly repair bills.

As the survey indicated, approximately 6 percent of companies already pursue this approach for their fixed assets and an additional 16 percent use conditioning monitoring.

However, IIoT-enabled predictive maintenance represents a significant step beyond simple conditioning monitoring, combining data from multiple sensors with advanced analytics techniques.

Roles of Process Automation and IIoT in a Connected Industrial Enterprise

Yokogawa's evolving reference model for Industrial IoT identifies two layers – an IIoT process-specific layer and an IIoT common layer. This white paper focuses largely on the process-specific layer, particularly as it applies for continuous process plants.



Common IIoT Infrastructure Can be Shared Across all Plant Domains (Source: Yokogawa)

IIoT Process-Specific Layer

Within the two-layer IIoT architecture, the process-specific layer measures and collects asset- and process-related data for monitoring, analysis, and decision support. The operational technology supplier has primary responsibility for this layer as well as for interfacing with the IIoT common layer.

IIoT Common Layer

As its name implies, the common layer provides the overall IIoT infrastructure to support all industrial applications, whether related to process, hybrid, or discrete processes, or all three.

The IIoT common layer includes the primarily IT-based cloud infrastructure, Big Data engines, analytics engines, and other advanced applications that utilize normalized or shared data from the process-specific layer. The common layer enables sharing of data, applications, and best practices across all IIoT process-specific domains as well as with the enterprise domain. An application or best practice developed, for example, for a hybrid process can be applied to a continuous process; and an advanced analytical application from the enterprise domain can be introduced for the process domain. This makes it cost-effective for companies to plan, implement, and continuously update the IIoT common layer with leading-edge information technology and practices.

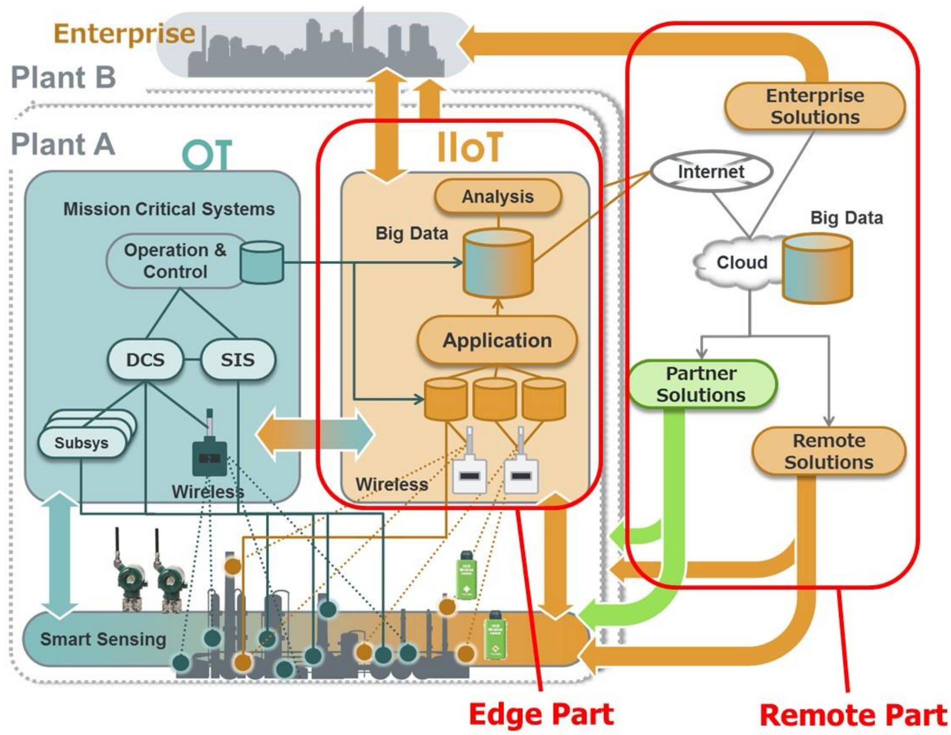
In most cases, IT suppliers are responsible for providing the necessary elements for the common layer, although the OT supplier will frequently assume responsibility for the overall IIoT solution, as Yokogawa intends to do.

IIoT Includes Both In-Plant (Edge) and Remote (Cloud) Solutions

While conventional IoT solutions typically focus on remote, cloud-enabled applications, Yokogawa believes that Industrial IoT solutions will typically focus on the in-plant, edge-part IIoT applications. These easily deployable IIoT applications will support and enhance the functions of the mission-critical OT-based operations and control systems (DCS, SIS, etc.). Rather than employing the traditional hierarchical ISA95-based information flows of the past, with IIoT-based solutions, appropriate data and information can flow freely as needed between in-plant sensors, process automation networks, and edge IIoT components; and remote IIoT components and enterprise systems in a collaborative but secure, functionally de-coupled manner.

Edge-Part IIoT Solutions

Examples of these in-plant, edge-part solution components include smart sensors, cameras, Big Data historians, basic analytics applications, and some optimization applications. Edge-part IIoT solutions collaborate with fixed assets and mission-critical systems in the plant and upward to the enterprise. Typically, these edge-part IIoT applications are implemented at the individual plant level.



IIoT Includes both Plant-Specific Edge Solutions and Non-Plant-Specific Remote Solutions (Source: Yokogawa)

Remote-Part IIoT Solutions

Remote-part IIoT solutions, in contrast, include more powerful enterprise-level solutions for advanced analytics and deeper analysis that typically run in the cloud and are linked to the in-plant edge-part solutions. These remote IIoT solutions can typically be deployed in a standard manner across multiple plants within an enterprise or even extend to other value chain partners. Enterprise-wide IIoT solutions can also be used to benchmark individual plants in areas such as operational performance and asset performance.

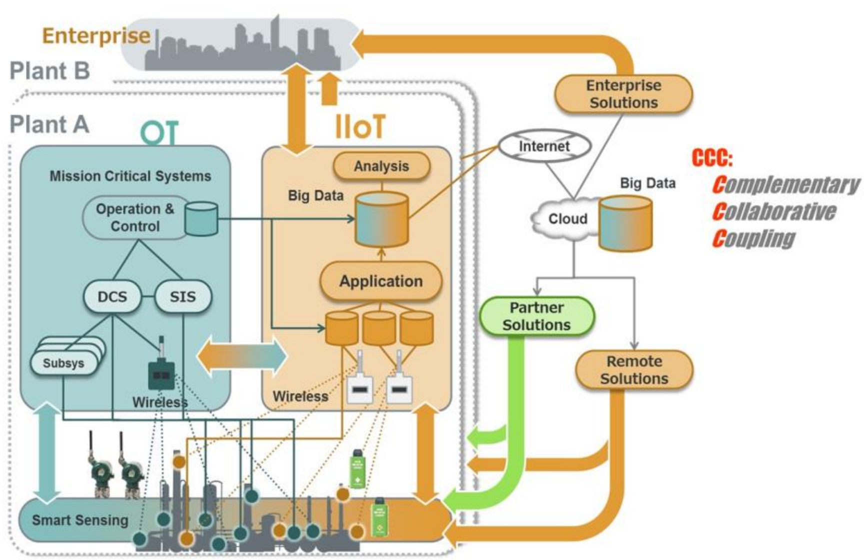
New Business Models Needed

Yokogawa believes that time-critical functions and analysis should typically be performed within the plant, while less time-critical analysis could be performed remotely in the cloud.

Since IIoT technology has leaped beyond the current business models, end users and suppliers will need to develop a model for who "owns" the data and how plant data can be collected, managed, and stored to support IIoT-enabled improvements. Clearly, it would make sense for managed service providers to manage at least some of these data.

Process Automation and IIoT Collaboration

Within Yokogawa's vision of the connected industrial enterprise, process automation and IIoT work together in a manner that the company refers to as complementary collaborative coupling, or "CCC." This enables users in mission-critical industrial plants to leverage IIoT-derived benefits, without compromising the safety, security, or availability of their plants.

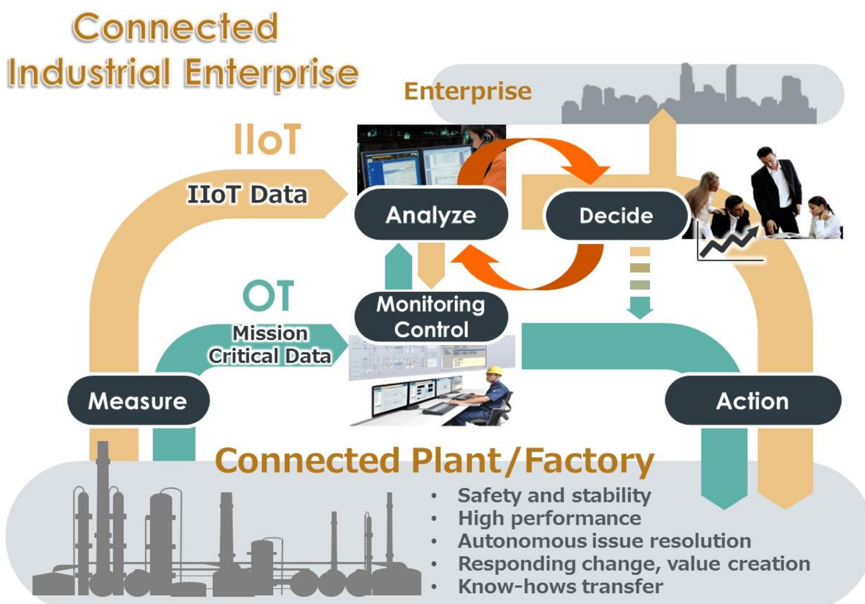


Complementary Collaborative Coupling between IIoT and Process Automation (Source: Yokogawa)

The objective here is to establish multiple feedback loops for both real-time process control and data-driven decision support. Now, in addition to the well-established PID (proportional/integral/derivative) feedback loops that employ mission-critical real-time process data for real-time process control; emerging IIoT capabilities enable creation of "PID-style" feedback loops based on IIoT sensors, analytics, and visualization for advanced analysis, decision-support, and off-line optimization.

IIoT will introduce opportunities to create new data/analysis-driven feedback loops that collaborate with the conventional feedback loops to enable the connected industrial enterprise to drive positive actions to:

- Enhance plant safety and stability
- Increase performance
- Support autonomous issue resolution
- Respond to changes
- Transfer knowledge, and
- Create value through continuous improvement



OT-Based Process Automation and IIoT-Based Solutions Enable Multiple Feedback Loops for to Support Continuous Improvement (Source: Yokogawa)

"CCC" for Pump and Valve Monitoring

While there are innumerable opportunities in which mission-critical operational technology systems can collaborate with non-mission-critical IIoT-enabled sensors and applications; pump and valve monitoring/optimization provides a particularly good application example.

Piping & instrumentation diagrams (P&IDs) used to map out the process equipment, piping, and instrumentation in process plants typically include both pumps and valves, along with associated measurement instrumentation and controllers. While critical for stable process operation, pumps and valves are both subject to performance issues that often only increase based on ambient conditions (temperature, dust, vibration, etc.), process characteristics (fluid corrosiveness, abrasiveness, temperature, entrained air, etc.), age (time in service), use (number of cycles), or any combination of these.

Control valves in particular tend to be one of the most important, yet often overlooked, assets in the process industries. Control valves are critical for good process control. Without reliable control valve operation, the process would quickly become unmanageable for the process operator. Nevertheless, the majority of control valves currently in service continue to be plagued with stiction-related issues and subject to frequent, often costly and unnecessary maintenance.

Many pumps, in turn, are subject to vibration and cavitation issues that can impair performance, availability, and could ultimately cause the pump to self-destruct.

Most Control Valve Maintenance is Expensive and Reactive

Research has shown that the majority of maintenance performed on industrial assets is unnecessary and certainly costly. Unnecessary reactive and costly break-fix maintenance or preventive maintenance usually constitute over 80 percent of the actual work performed by maintenance and operating technicians. Studies also show that it is common practice to remove and overhaul many control valves during a turnaround or shutdown. In many cases, no improvement is made to the valve and, in some, cases new faults are introduced.

IIoT-Enabled Predictive Analytics for Pumps and Valves

Leading automation suppliers such as Yokogawa are developing asset performance and asset management solutions for control valves, pumps, and other critical assets to complement their DCS platforms. When used effectively, these systems can provide an accurate prediction of asset health, minimize downtime and equipment damage, help maintain product quality and consistency, and avoid performing unnecessary maintenance.

> When used effectively, these systems can provide an accurate prediction of asset health, minimize, downtime and equipment damage, help maintain product quality and consistency, and avoid performing unnecessary maintenance.

Through complementary collaborative coupling and data exchange between the process automation system, process historian, plant asset management system, intelligent valve positioners, and IIoT-connected smart sensors (vibration, temperature, etc.)

and predictive analytics; operators and maintenance technicians can receive predictive alerts on their respective systems informing them of performance issues on their pumps or valves or the need for maintenance or repair to prevent further performance degradation or costly failure. These alerts are generated by the predictive analytics and failure prediction models that can now accurately identify performance degradation or impending failures by leveraging the combined dataset. Sensor-derived analytics can also help plant personnel identify the root cause of problems to speed resolution.

IIoT-enabled sensors and analytics could be used to create new feedback loops to further improve both asset performance and availability in a conventionally instrumented P&ID process flow loop.

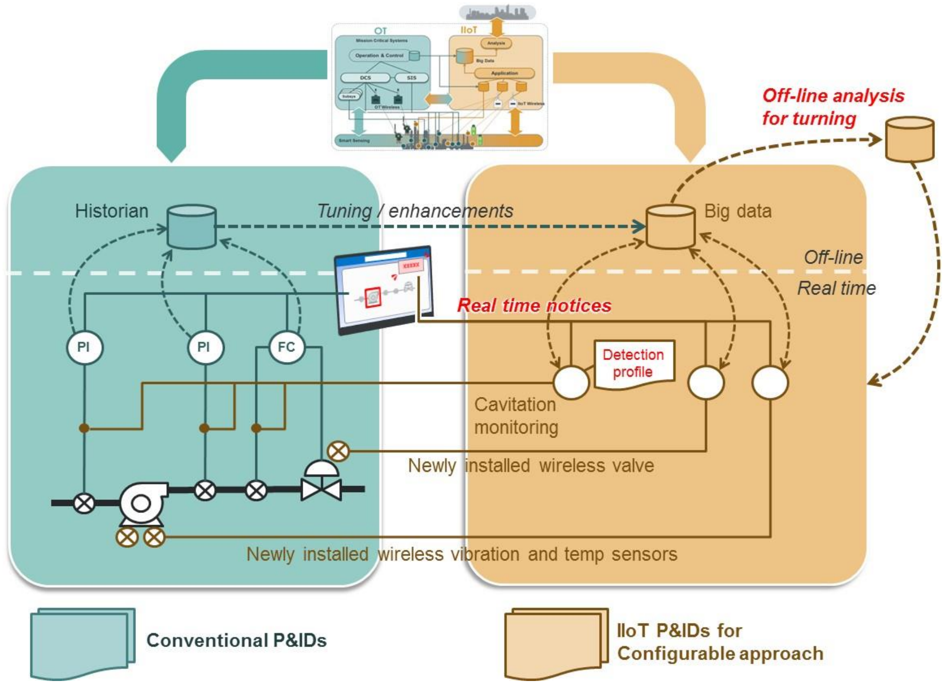
Here's an example in which IIoT-enabled sensors and analytics could be used to create new feedback loops to further improve both asset performance and availability in a conventionally instrumented P&ID process flow loop.

On the "conventional" side, we have pressure and flow transmitters, a pump, a control valve equipped with an intelligent positioner, and a DCS-based flow controller. Time-stamped process variables are collected and stored in a process historian.

On the edge-part IIoT side, we have added a non-intrusive wireless connection to the intelligent valve positioner to monitor valve position and stiction, installed wireless vibration monitoring sensors on the pump, and incorporated Big Data and predictive analytics applications.

In this IIoT application, the IIoT "P&ID" loop accesses the differential pressure and other flow measurements to detect and alert plant personnel to pump cavitation, which can negatively affect performance and lead to premature pump failure.

The IIoT-based analytics utilize a combination of real-time process data from the DCS, historical process data from the plant historian, and both performance and asset data to identify or predict asset performance and/or asset management issues. In this manner, plant personnel can receive timely notification on their workstations, PCs, or mobile devices, enabling them to avoid unnecessary maintenance and schedule and perform needed actions before the issues can impact plant performance, efficiency, or availability. This type of IIoT-enabled information loop can also help plant operators and process engineers tune or optimize the process itself, if needed.

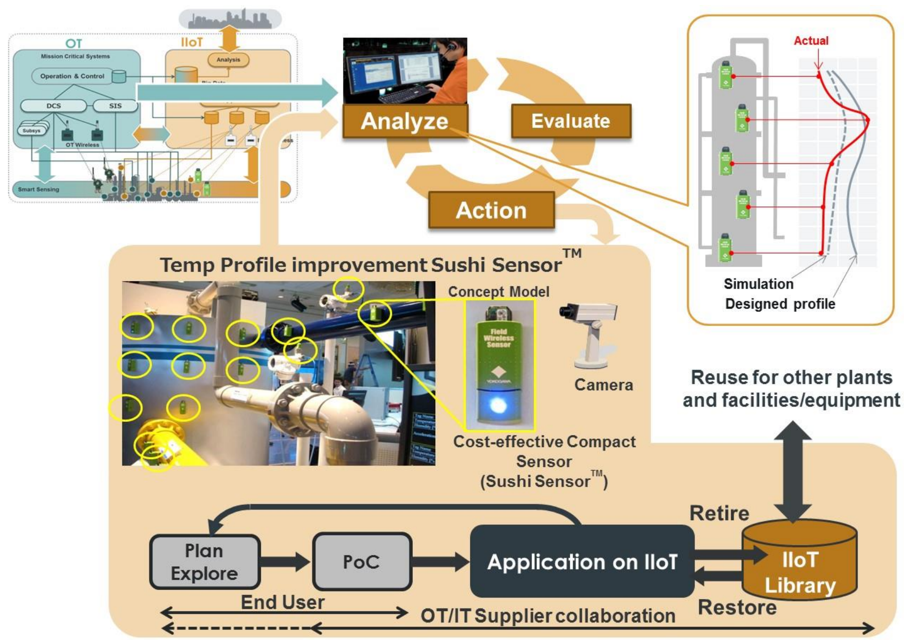


IIoT-Enabled Predictive Asset Monitoring and Optimization (Source: Yokogawa)

Significantly, these IIoT information loops ("IIoT PIDs") can be configured in a similar manner as conventional P&ID loops. Yokogawa believes that this will make them familiar to plant personnel and thus encourage creative utilization. Also significantly, IIoT applications such as these can be implemented, modified, replicated, and retired as needed without interrupting or interfering with normal process operations.

"Metabolism" for Asset Optimization

The inherently flexible and quick-to-deploy nature of many IIoT-enabled solutions mean that these solutions can be easily deployed as needed, fine-tuned, re-deployed, and then just as easily taken out of service over the lifecycle of an asset. Yokogawa refers to this as "metabolism." This type of ad hoc solution can typically be funded out of operating budgets, making them quicker to deploy; rather than capital budgets, which typically require extensive, time-consuming justification, pre-planning, and often-complex commercial arrangements.



IIoT-Enabled Solution for Temperature Profiling (Source: Yokogawa)

Let's say, for example, that the performance of a distillation column (or other complex asset) installed in a refinery or other process plant starts to deviate from its designed (or desired) state for reasons unknown. In this particular case, by exercising their digital craftsmanship, engineers launch a trial to see if they can effectively examine the unit's temperature profile. This trial could involve temporarily installing a wireless camera and several compact wireless temperature sensors that can also transmit their location (Yokogawa calls these "Sushi Sensors") at points throughout the column to see if this enables users to plot the temperature profile on a photographic image of the unit.

If the initial trial is successful, a more comprehensive proof of concept could be developed by installing additional wireless temperature sensors, access points, and cameras; and incorporating real-time and historical data (such as process variables) and more sophisticated analytics applications. Assuming that this temperature profile provides the plant engineers and/or distillation column OEM with the data and information needed to resolve this particular performance issue, the solution could remain in place, be replicated in other units, and/or quickly taken out of service.

This obvious exercise in digital craftsman would require close collaboration between the plant engineers and operators, control system supplier, equipment OEM, IT supplier, and analytics application supplier. The key point here is that, unlike the typical capital project which would require extensive pre-planning, would be expected to take a long time to deploy, and remain in service for many years; this type of IIoT-enabled diagnostic application could be implemented ad-hoc and "metabolize" (evolve) along with the application requirements, and be easily replicated or quickly taken out of service as needed.

Asset Monitoring and Optimization as a Service

While IIoT-enabled asset monitoring and optimization can be performed internally within an organization at the local plant or enterprise levels, increasingly we're going to see IIoT-enabled functions performed remotely "as a service" by the automation suppliers' resident experts, the OEMs' experts, and/or third-party service providers. These experts typically have deeper understanding of the systems or equipment (pumps, valves, compressors, heat exchangers, reactors, distillation columns, etc.) than is available within the end user organizations.

> As the knowledge base and expertise in industrial plants continues to erode due to corporate downsizing and retirements, remote, supplier-provided services will become increasingly important for connected industrial enterprises.

By combining this knowledge with advanced predictive analytics tools, the automation supplier and/or equipment OEM can provide end users with appropriate alerts and guidance, enabling them to avoid or mitigate the impact of issues or optimize their equipment and/or processes.

As the knowledge base and expertise in industrial plants continues to erode due to corporate downsizing and retirements, these types of remote, supplier-provided services will become increasingly important for connected industrial enterprises. Yokogawa and other leading automation and equipment suppliers have already begun to develop and implement these important asset monitoring and optimization services for customers across a variety of industries – upstream, downstream, and midstream. This often involves close cooperation between the automation supplier, equipment OEMs, third-party partners, and the end users.

Sustaining IIoT-Enabled Innovation

Innovation is at the heart of any discussion on IoT, industrial or otherwise.

In the consumer space, IoT technology is leading to a wide variety of innovative electronic products and solutions. These range from home monitoring systems that can enhance energy efficiency, safety, security, and peace of mind; to wiz bang consumer gadgets with a somewhat less-clear value proposition, but never the less are very appealing. Apple, Google, Microsoft and other industry leaders have already established standards and platforms for these types of devices that appear to be here to stay.

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In the industrial space, however, partnerships are still being explored and formed, standards are still evolving, and for the most part, IIoT platforms have yet to emerge. The largely capital expenditure (capex)-based business models in the industrial space are also ill-suited to IIoT-enabled innovations that will largely come from operational expense (opex) budgets. This changes the way end users engage with their technology suppliers, and vice versa.

Due to the long time frames and large expenditures involved, capex-based projects tend to have a lot of inertia, making them difficult to adapt to changing market requirements and changing feedstocks and other raw materials. Here, the focus is often on obtaining the necessary financial and other resources, defining the requirements (P&IDs, I/O data, equipment specifications, etc.), completing the project on time and on budget, and in general, minimizing overall risk.

Lower-cost opex-based IIoT projects as employed by the connected industrial enterprises of the future will be inherently flexible and adaptable over time, providing a platform for continuous innovation and improvement. Here, rather than creating new industrial assets, the focus will be on maximizing the uptime and improving the performance of existing assets. The lower cost and shorter time frames of IIoT projects typically minimizes exposure to risk, further encouraging experimentation and innovation.

But this gives rise numerous challenges and yet-unanswered questions. Challenges include developing a reference model for how industrial organizations can best share IIoT-derived data with partners, customers, and service providers and adjusting and balancing staffing and skills to be able to successfully implement and leverage IIoT-enabled solutions. And let's not overlook the value of the data itself as intellectual property. Who owns these data? How can it be best used? How can it be monetized?

Can control engineers in the end users' plants take the lead in developing IIoT-based solutions, or will this remain the domain of the corporate IT groups, and/or automation suppliers and IT or middleware suppliers?

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With their closed, proprietary heritage, can mission-critical real-time process automation systems really be made to collaborate with inherently open and interoperable, non-real-time, non-mission-critical IIoT technology components? And if so, how can this be best accomplished?

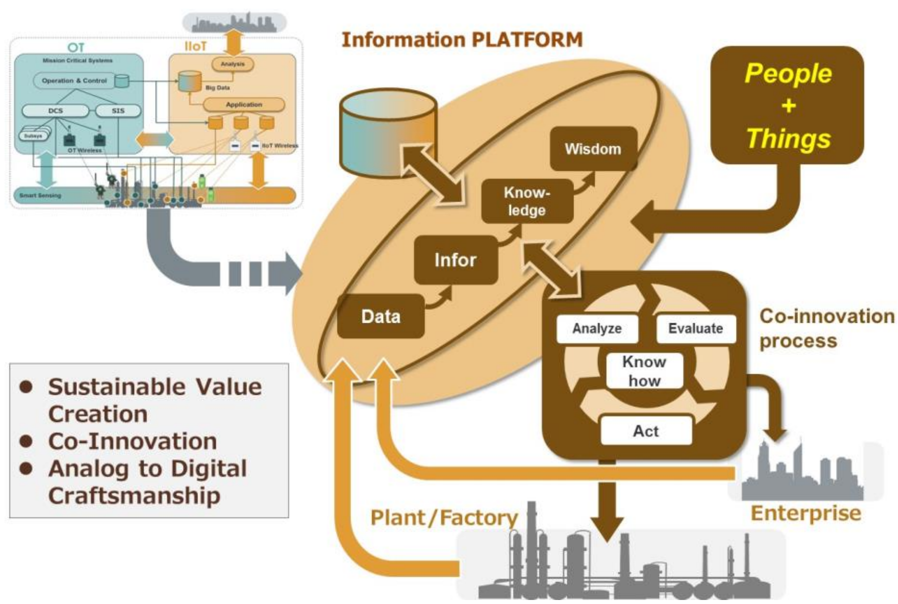
Yokogawa believes that the best approach is for industrial organizations to go slowly. Begin by identifying current pain points and evaluating how IIoT solutions might best be employed to help ease that pain. One of the problems today is that the technology has outpaced the business model. While plenty of IIoT technology and solutions are now available, the business models are still evolving. (Even leading technology suppliers such as Intel are looking five years out.)

To maximize their potential gains from IIoT, industrial organizations will need to develop the technical infrastructure to collect data from throughout the extended enterprise. That is, data from their own internal operations, from the products and services they offer, and from data sourced from beyond the walls of the company itself. Once collected, these data must be managed and processed, and analytic tools used to gain insight into potential challenges and opportunities. But more than anything else, industrial enterprises may need to shake up their decidedly "analog" decision-making cultures. The Industrial Internet of Things will not just generate lots of data, it will generate fine-grained, time-critical data. To take full advantage of these data, companies must ensure that decisions take place at the right level within the organization. For some, that may require developing both decision-making skills and management culture to succeed in an IIoT world.

IIoT is more than just a simple extension of the mission-critical operational technology-based system. OT is control driven; IIoT is data driven. The data-driven approach is a new concept for the OT world. However, as discussed in this white paper, both can work together in a complementary manner. Questions remain as to how to best utilize data to improve plant and business performance.

OT tends to be very closed loop, based on established setpoints and real-time process measurements; controllers drive predetermined actions based on fixed logic or algorithms to maintain those setpoints.

IIoT in contrast, tends to be more open ended. Sensor-based data, combined with historical data, are used to predict future outcomes; providing humans across an industrial enterprise with the information they need to make better decisions.



IIoT Provides a Platform for the Connected Industrial Enterprise (Source: Yokogawa)

Co-Innovating Tomorrow

As a company that tends to take the long view (and admirably so), Yokogawa has developed and published its next Long-Term Business Framework. This Framework includes the vision statement: *Through Process Co-Innovation, Yokogawa creates new value with our clients for a brighter future.*

Based on this vision statement, Yokogawa also established its new corporate brand slogan, "Co-innovating tomorrow." Clearly, Yokogawa aims to create new value through co-innovation with its customers, business partners, community members, and so on.

ARC believes that "Co-innovating tomorrow," demonstrates the company's forward-looking vision, which embraces IIoT, digital craftsmanship, and digital transformation in general to support the connected industrial enterprises of the future.

ARC will continue to monitor the company's progress in these areas along with end user take-up and encourage industrial organizations to further explore the potential value of incorporating these concepts within their global operations.

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Acronym Reference: For a complete list of industry acronyms, please refer to www.arcweb.com/research/pages/industry-terms-and-abbreviations.aspx

AI	Artificial Intelligence
B2B	Business-to-Business
BPM	Business Process Management
CAPEX	Capital Expenditures
CCC	Complementary Collaborative Coupling
CPAS	Collaborative Process Automation System
DCS	Distributed Control System
EAM	Enterprise Asset Management
ERP	Enterprise Resource Planning
FA	Factory Automation
FEED	Front End Engineering Design
HMI	Human Machine Interface
IoT	Internet of Things
IIoT	Industrial Internet of Things
IT	Information Technology
M2M	Machine to Machine
OEM	Original Equipment Manufacturer
OPEX	Operational Expenditures
OpX	Operational Excellence
P&ID	Process & Instrumentation Diagram
PID	Proportional Integral Derivative
PAS	Process Automation System
PLC	Programmable Logic Controller
PA	Process Automation

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