SPECIAL REPORT

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Understand the Promise of Open Process Automation

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Process Automation Opens Up

Ongoing effort aims to improve operational flexibility and asset performance

By Mohan Kalyanaraman, Don Bartusiak, Steve Bitar, Bradley G. Houk and David L. DeBari, ExxonMobil Research and Engineering, and Brandon Williams, CPLANE.ai

No trend in the past thirty years likely will revolutionize chemical processing as much as the imminent implementation of "digital transformation" technologies and practices. This transformation encompasses a proliferation of Industrial Internet of Things (IIoT) sensors and actuators, a flood of time-series data, and exponential growth in computers directly participating in plant operations. However, one central concept — low-cost implementation of change — will drive the real power and productivity benefits of digital transformation, namely, the ability to make rapid, iterative and data-driven innovations to plant operations at a fraction of the cost previously possible. This demands overcoming the restrictions to innovation created by closed proprietary systems.

Numerous factors are driving this need: global markets and competition make laggards in innovation unsustainable; changing environmental laws and sensitivities require new tools for compliance; and reimagined capital budgets consider operational flexibility and profitability not only efficiency and safety.

Digital transformation and asset performance maximization place a call on business systems, cloud and computing architectures, and process automation and control systems that operate manufacturing plants. Major global industrial and chemical companies are collaborating with leading process automation vendors and system integrators to accelerate this revolutionary change in automation through the adoption of The Open Group Open Process Automation Standard (O-PAS).

Low-cost implementation of change demands overcoming the restrictions to innovation created by closed proprietary systems.

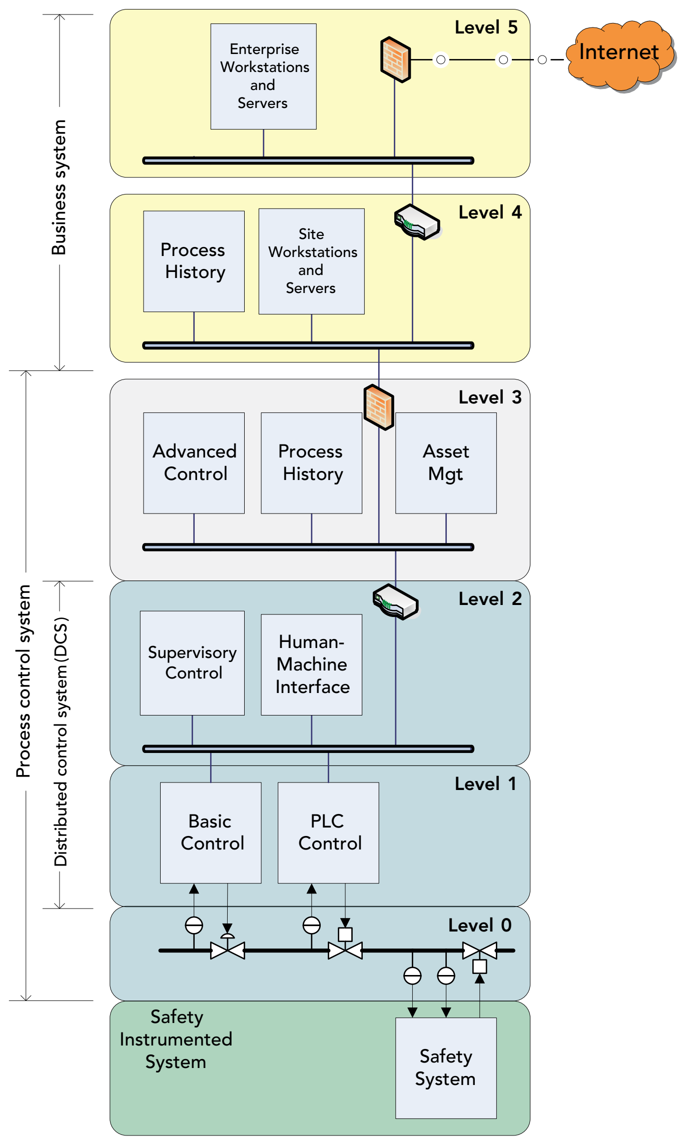
To fully benefit from the immense power of new digital tools such as artificial intelligence, machine learning, cloud computing, data analytics and edge computing, the chemical industry must adopt an open standard like O-PAS to accommodate and implement continuous change. Such a move will enable operating companies to affordably upgrade equipment in-situ, rapidly reconfigure production to respond to sudden market opportunities, and continually apply improved algorithms with deterministic results. Moreover, it will allow working within system constraints such as keeping human/machine interfaces and operational procedures usable by current and new workers, aggressively implementing digital security, and never compromising operational safety. O-PAS, the second version of which has just come out, provides a critical standards framework to address all these factors and many more.

THE CURRENT SITUATION

Since the 1970s, the state-of-the-art for process control and business information systems at process plants has consisted of a multiple-level hierarchy of interconnected computing devices, sometimes called the Purdue Model. This hierarchy (Figure 1) has the process control systems as Levels 1 to 3 and the business systems as Level 4 and 5.

The process control systems, usually described as distributed control systems (DCSs), monitor and control manufacturing processes. A DCS typically consists of operator and engineering stations, controllers, input/output (I/O) modules and application servers. Such control systems generally remain in service for a long time, often for decades, even as the surrounding business network and enterprise systems (Levels 4 and 5 in Figure 1) are upgraded. The closed proprietary nature of Level 1–3 systems provides a significant obstacle to change at those levels.

However, for legacy systems installed in the 1980s and 1990s, obsolescence of components is a real problem. Obtaining hardware and patching the software to keep the systems running are increasingly difficult; loss of institutional memory and programming skills for legacy systems compound the problem. Opting to "rip and replace" the installed system is very expensive and time consuming, affecting both productivity and profitability. Moreover, closed systems don't allow for ease of access to data that complex algorithms use to generate actionable operational insights that can boost productivity and truly drive a digital-enabled organization. The concept of a layered hierarchy of access seems increasingly at odds with the emerging trend of open access to data and trends in digital enablement.



TODAY'S TYPICAL HIERARCHY

Figure 1. Manufacturers generally deploy process control and business system hardware in five levels.

Security was an afterthought in legacy systems; the majority of security measures focused on physical access controls. As networking and computing technology improved, strong business drivers emerged for interconnecting these networks to allow centralized process control and sharing of information across the enterprise. The convergence of once-isolated control systems with information technology (IT) networks has introduced new security risks, exacerbated by lack of encryption and authentication technologies as well as availability of open-source information regarding industrial control system architectures, operations and vulnerabilities.

In addition to the technical issues, legacy systems pose an inherent business problem by strongly favoring incumbent suppliers. The closed proprietary nature of the interfaces enables those vendors to control access and affords them "vendor lock," whereby they gain a recurring revenue stream for provision of exclusive services.

AN ALTERNATIVE MODEL

Given the limitations of the current approach to process control, what should an alternative model encompass? It should contain four major elements that can provide a framework for creating an improved automation system.

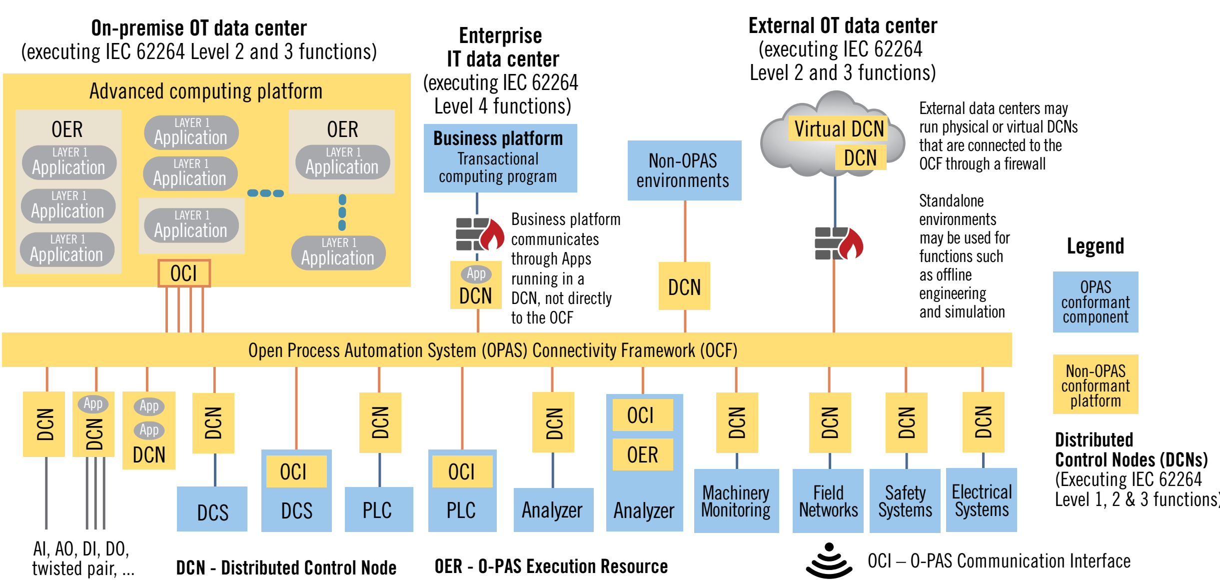
1. A distributed, modular, extensible and scalable platform that lowers the cost, complexity and operational risk associated with expansion or online replacement (to deal with component obsolescence or to open up new opportunities), and that exploits the increased computational power in endpoint (edge) devices to improve application capability and effectiveness. In this new platform, the applications could access data at any of the control nodes as needed, unlike the traditional model.

2. Standards-based open interoperable architecture that offers the freedom to choose any procurement strategy, allows owners to preserve custom software for the lifetime of the plant asset, provides incentives for software developers to create and sell directly to asset owners, and enables integrators to connect different hardware and software components without modification.

3. Designed-in security using a standards-based secure architecture that allows asset owners to protect against known risks, detect abnormal situations and evolve with emerging threats.

4. A *less-complex and more-productive user environment* realized via technologies such as plug-and-play field devices, flexible notification capability and an enterprise-wide asset information portal. These would enable workforce empowerment and innovation through use of industry standard tools for creating applications.

Figure 2 shows a reference architecture to illustrate what the future might look like.



ALTERNATIVE MODEL

Figure 2. Unlike current proprietary control systems, an open one based on O-PAS readily integrates multiple vendors and enables easy upgrades.

The Open Process Automation Reference Architecture flattens the design, eliminating the hierarchical nature, and attempts to ensure data are always available to the desired user with the minimum overhead. An important aspect of the new architecture is the concept of a distributed control node (DCN) as the edge device connected to the field wiring. Many functions of today's DCS and programmable logic controller (PLC) systems might migrate to the DCN. The DCN will include I/O signal processing as a minimum, with the potential to have expandable computing capability. Depending on the functional requirements, the DCN could host regulatory controls, more-advanced control applications and, eventually, advanced optimization and analytics applications. The future world includes the capability to run the latest applications directly at the edge, if required for data latency or availability. This allows for future-proofing as new possibilities open up on how plants are operated and monitored.

A real-time bus provides the data backbone to connect the DCN and all components in the system. For brownfield applications, gateway devices would allow integration of legacy devices into the new architecture. A high-availability advanced computing platform supports the system and provides the computing power to host applications that don't need to run at the edge. Examples include abnormal event detection, procedural automation, advanced control and process optimization. In the new architecture, data are readable from the source in the DCN to either a local enterprise-level IT data center or to external data centers with proper security authentication and based on trust as defined in the standards-based security protocols. This allows for true business control of operations and, thus, fosters the success of digital initiatives.

THE ROLE OF OPAF

The Open Group Open Process Automation Forum (OPAF), www.opengroup.org/forum/open-process-automation-forum, has a broad scope, encompassing today's DCSs and PLCs for the continuous and hybrid process industries. Its core work is to define the standards for an open, interoperable, secure process automation architecture. The Forum is using a "standard of standards" approach to minimize re-work and avoid "reinventing the wheel." The Forum will select the best available standard from existing applicable industry standards. When no applicable standard exists, the Forum will work with standards-development organizations to generate a standard. The ultimate goal is to create a thriving marketplace of software and hardware components that use standards-based open interfaces to allow for easy integration, interoperability and more innovation.

Open automation does not require open sourcing. The published standard provides public exposure of software and hardware interfaces and data definitions but a supplier need not reveal the inner workings of its hardware or software component nor does an end-user divulge applications it has developed.

Joint workshops held between end-users and suppliers led to development of a set of quality attributes (QAs) — nonfunctional system characteristics that influence system quality and drive architectural decisions. These QAs serve as touchstones in guiding the work of the Forum. A few key QAs are: interoperability, modularity, interchangeability, conformance, securability and portability. The Forum considers the QAs of safety, resilience and maintainability as fundamental to any O-PAS product, so these aren't called out separately.

A KEY DIFFERENCE

Unlike other standard-development activities, the Forum isn't just a technical effort. In addition to a technology working group (TWG), the forum has created a business working group (BWG) to establish viable business practices and procedures to conduct business in the new open environment. The BWG's role includes reducing impediments to commercial success and providing guidance to the TWG. It has published "The Open Process Automation Business Guide," https://publications.opengroup.org/g182, that defines the ecosystem roles in the new business environment and offers a roadmap for suppliers, end-users, service providers and system integrators about the value proposition and benefits to the participants.

An important part of the task of the Forum's Certification Work Group is to develop a policy for conformance and certification and to maintain a registry of conformant products. For a component to be registered and discoverable, it must conform 100% to the published standard. Outside accreditation laboratories, selected by The Open Group Certification Authority based on the standard, will verify conformance.

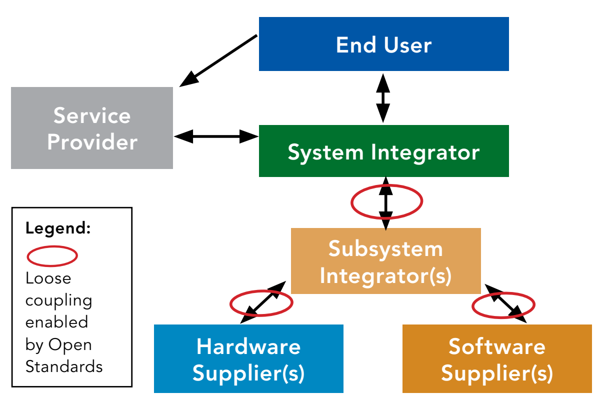
The TWG is charged with developing the standards. Specialist subcommittees handle security, interoperability, technical architecture and portability, among other components. In addition, an Enterprise Architecture Working Group manages the use-cases and translates the business guidance into technical requirements to guide development of standards. The Forum has partnered with a variety of industry associations and standard-development organizations such as the International Society for Automation (ISA), OPC Foundation, NAMUR, CSIA, FieldComm group, PLC Open and others consistent with the "standard of standards" approach.

THE NEW ECOSYSTEM

In the traditional model of automation procurement, the DCS vendor configures its available offering of proprietary hardware and software components to meet end-user specifications. The resulting package reflects the special relationships between the vendor and component suppliers, with integration issues handled by the DCS vendor using proprietary interfaces.

By contrast, in the new ecosystem model, a systems integrator (SI) assembles a system to meet end-user specifications using cost- or performance-advantaged O-PAS-certified hardware and software components. This should ease integration and reduce development cost because there's a loose coupling that enables the different components to work together, facilitated by certified and standards-based interfaces that allow for stitching together the system quickly and efficiently.

Standardization of interfaces lowers the barrier to entry. Therefore, additional specialist hardware or software suppliers can compete, allowing for more innovation. The new ecosystem explodes the monolithic role of the DCS vendor into different constituent roles such as systems (and subsystem) integrator, hardware and software suppliers, and service provider (Figure 3). It's important to note that the new ecosystem model is a role-based model. So, a supplier may serve as a SI or service provider for a given project. It also allows for more players to enter and perform the role of an integrator, increasing competition.



NEW ECOSYSTEM

Figure 3. Exploded view shows interconnections between roles of end-user, systems integrators, hardware, software suppliers, subsystems integrators and service provider.

Accountability for system performance rests with the systems integrator or SI, as spelled out in Section 4.1 of the Business Guide.

BROAD GUIDELINES

The Forum is advancing an entire supplier/buyer ecosystem of traditional DCS vendors, SIs, digital technology providers and process manufacturers toward an open business model. Consequently, the OPAF also establishes business practices for how this open marketplace should operate, unlike traditional technology standards from groups like ASTM International or the Institute of Electrical and Electronics Engineers.

Operating companies implementing systems containing O-PAS-certified components benefit from the capability for continuous process improvement through rapid application of the latest available hardware and software. Once adopted, software applications and system configurations are portable and reusable across systems, reducing total cost of ownership. In addition, end-users gain access to a more-competitive market of offerings and minimize customized development associated with proprietary components. Solution providers also benefit from access to new market opportunities, continued relevance to existing and prospective customers, and reduced development costs due to the entry of smaller specialized suppliers that add value and innovation.

Through the Forum, each incremental definition of the O-PAS technology is matched by business guidelines for use-cases, industry involvement and detailed certification procedures for conformance. Forum members are working to provide the vision, understanding and framework for end-users to make intelligent and strategic decisions about future plant operations and designs. The entire process automation ecosystem is moving forward together.

For example, these changes in ecosystem allow for new business models to evolve similar to the changes in the enterprise IT business (e.g., software as a service) and transference of owner-controlled operation to a "tolling" model reflecting the desired level of owner involvement.

TECHNICAL COMPONENTS

The O-PAS Standard includes eight parts:

- Part 1 — Technical Architecture;
- Part 2 — Security Aspects;
- Part 3 — Profiles;
- Part 4 — Connectivity Framework;
- Part 5 — System Management;
- Part 6 — Configuration Portability;
- Part 7 — Physical Platform; and
- Part 8 — Application Portability.

Here, let's take a high-level look at three wide-interest aspects: cybersecurity, communications and system management.

Cybersecurity is an O-PAS imperative and of upmost importance to OPAF members. Managing security (Part 2) in a highly distributed environment such as in O-PAS requires consideration of security in all elements of the technical architecture (https://publications.opengroup.org/s184), including the physical and communications platform, operating system, system management services and applications. The security specification is based on the broadly accepted ISA/IEC 62443 Security for Industrial Automation and Control System standards. An O-PAS environment may consist of thousands of O-PAS-conformant components from multiple vendors. Version 1 focuses on providing O-PAS-conformant components from a product supplier that can be made secure in a system configuration (see: "O-PAS Version 1 Explained," https://bit.ly/2YBPt3V).

The Connectivity Framework (Part 4) defines the information models and transport protocols for communicating data using Open Platform Communications Unified Architecture (OPC UA). Version

1 describes the necessary OPC UA security and services to ensure interoperability for OPC UA clients and servers and the services for client/server actions and for publish/subscribe communication. The "Version 2 Preliminary Standard," https://publications.opengroup.org/p201, which came out in late January, adds standard information models for DCNs, signals, alarms and function block applications.

System Management (Part 5) uses the Distributed Management Task Force Redfish standard. Version 1 focuses on providing system management of compute node hardware (e.g., chassis, board, and cooling information for hardware with and without a baseboard management controller). Version 2 extends system management by operations-technology-specific DCN information including runtime, metrics and sensor interfaces, as well as in-band operating systems information and metrics.

Version 2 of the standard (https://publications.opengroup.org/i201m), which was published in January 2020, addresses portability of configurations. Version 2.1, scheduled for publication in the second half of 2020, extends definitions for information exchange models and standard interfaces that support some event processing, and standards-based application processes. Version 3 will focus on application portability.

CURRENT STATUS

Since its inception in January of 2017, the OPAF has grown to include more than 90 companies from around the world. Each iteration of the standard will undergo testing in real-world scenarios both to guide development of the O-PAS as well as to demonstrate feasibility and viability. Because "seeing is believing," OPAF held its first interoperability workshop in June 2019 based on Version 1 of the standard. The second workshop is planned for the third quarter of this year (but may be delayed depending upon Covid-19 travel restrictions). Companies evaluating design and purchasing decisions should review "O-PAS Certification Policy," https://publications.opengroup.org/x201, which was published in February.

Separately, some member companies have developed an active "test bed" to prove out and refine O-PAS-compliant technologies from multiple vendors.

Key success factors for the activity are a critical mass of input from end users and consensus among members in the ecosystem. The adoption and success of O-PAS standard will significantly impact automation and process control in the continuous and hybrid process industries by expanding innovation while improving security, flexibility and productivity — maximizing asset performance. Don't let your company be left behind. ◻

MOHAN KALYANARAMAN is technology acquisition advisor, strategic planning for ExxonMobil Research and Engineering, Annandale, N.J. **DON BARTUSIAK** is chief engineer, process control for ExxonMobil Research and Engineering, Spring, Texas. **STEVE BITAR** is R&D program manager for ExxonMobil Research and Engineering, Spring, Texas. **BRADLEY G. HOUK** is senior engineering advisor for ExxonMobil Research and Engineering, Spring, Texas. **DAVID L. DEBARI** is instrument engineering associate for ExxonMobil Research and Engineering, Spring, Texas. **BRANDON WILLIAMS** is executive vice president of CPLANE.ai, San Carlos, Calif. Email them at mohan.kalyanaraman@exxonmobil.com, don.bartusiak@exxonmobil.com, steve.bitar@exxonmobil.com, Bradley.g.houk@exxonmobil.com, david.l.debari@exxonmobil.com and brandon@cplaneai.com.

Getting Started with O-PAS

Dave Emerson, Vice President, US Technology Center, Yokogawa

Many end users are closely watching the advancing work of the Open Process Automation Forum (OPAF) as it develops the Open-Process Automation Standard (O-PAS). The potential for O-PAS to standardize the interfaces between automation system components to enable their interoperability and interchangeability in addition to portability of control strategy configurations between systems and versions is very attractive to the industry.

As shown in Table 1, the O-PAS standard is being released in multiple versions.

The multiple versions provide prospective users the opportunity to view the work in process, offer feedback and plan for development of O-PAS-certified products, system design and adoption.

From version 1 to version 2, the standard grew from five to nine parts, including updating and expansion of previously released parts (Table 2). If this trend continues, we can expect to see additional parts and further updates in versions 2.1 and 3.

With the progressive O-PAS version releases, some end users are taking the opportunity to setup laboratory systems, or test beds. End users usually setup the test beds in cooperation with automation suppliers that are active in OPAF, have access to pre-release hardware and software, and act in the capacity of open process automation (OPA) system integrators.

TEST BED OVERVIEW

Test beds can range from small tabletop systems to larger systems with hundreds or thousands of inputs and outputs (I/O) controlling simulated processes. Use of test beds allows end users to plan adoption of O-PAS by their companies, train employees, acquire knowledge, and understand the qualification processes and testing that will be needed prior to deploying O-PAS-certified products in a live process.

Prospective end users and system integrators are urged not to be overwhelmed by the reference architecture figure from the O-PAS standard, which is depicted in Figure 1. They should, rather, set the initial target number of distributed control nodes (DCNs) to be small, perhaps two or three.

O-PAS Version	Release Date	Version Theme
V1	February 2019	Interoperability
V2	January 2020	Configuration
V2.1	Soon	Configuration Portability
V3	TBD	Portability

Table 1: O-PAS releases

O-PAS V2 Parts	Part Title
Part 1	Technical Architecture Overview (Informative)
Part 2	Security
Part 3	Profiles (Informative)
Part 4	O-PAS Connectivity Framework (OCF)
Part 5	System Management
Part 6.1	Information and Exchange Models: Overview and Interfaces
Part 6.2	Information and Exchange Models: Basic Configuration
Part 6.4	Information and Exchange Models: Function Blocks
Part 7	Physical Platform

Table 2: O-PAS V2 consists of nine parts

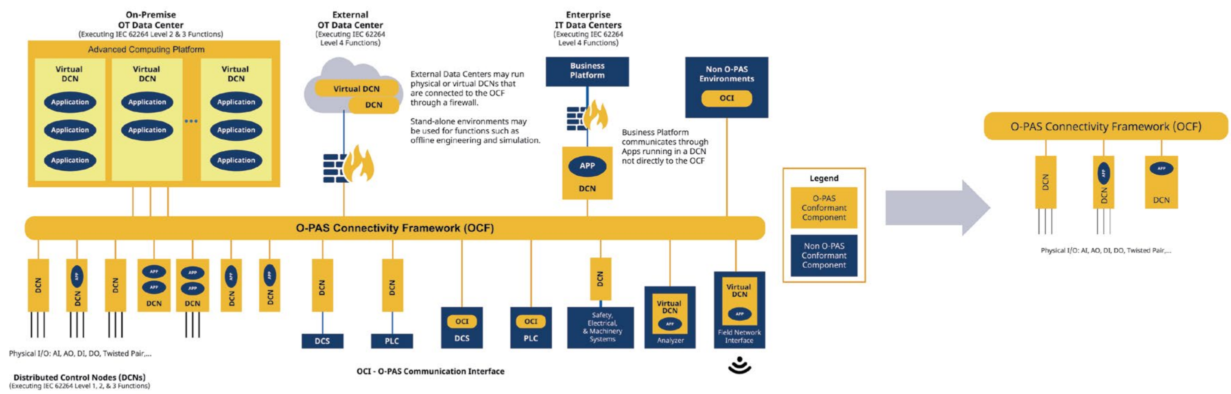


Figure 1: OPAF suggests end users start with a small O-PAS test bed system architecture.

The O-PAS Connectivity Framework (OCF) shown in this figure is an abstraction that represents the logical data exchange between the O-PAS-certified products. Since the reality is that this will be OPC UA and other technologies communicating over Ethernet, the small OPA test bed system in Figure 1 could be drawn as shown in Figure 2.

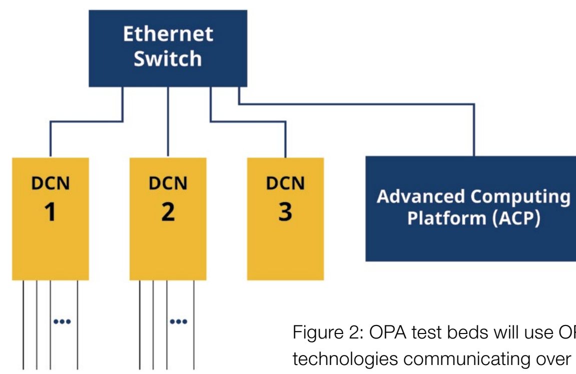


Figure 2: OPA test beds will use OPC UA and other technologies communicating over Ethernet.

The OCF data exchange is realized by OPC UA communications between the DCNs and the Advanced Computing Platform (ACP). OPC UA software in the DCNs and ACP comprise the OCF function.

The ACP shown in Figure 2 might sound like a big and expensive high availability server or set of servers. While that could be the case, it can also be a small server, laptop, IT appliance, or one of several, small industrial servers. In a test bed environment, it is advantageous to run multiple, virtual machines in the ACP. This allows different software functions to be tested independently. Test engineers need not be concerned about the "advanced" aspect of the ACP. It can be as big or as small as required.

The Ethernet switch can be commercially available IT equipment, perhaps something already in the inventory, which could be repurposed. Of course, the faster the network, the better.

The DCNs and I/O form the core of the system from a process control viewpoint. A DCN is the software environment. The hardware is referred to as the "DCP," or Distributed Control Platform. This can be confusing because architecture diagrams typically show DCNs. To alleviate that, a simple thought process follows (please refer to Figure 3):

"DCN" = DCN software

"DCP" = DCN hardware

While this is not a rigorous definition of either term per O-PAS, it does reduce confusion and can help people differentiate between the two. An important reason why this distinction is made in O-PAS is that the DCN software is decoupled from DCN hardware and can execute in different DCPs. This is one way to achieve interchangeability. If a DCP fails, it can be replaced by another supplier's O-PAS-certified DCP. The same DCN software can be downloaded and placed into operation. Another reason for the DCN to be decoupled from the DCP is to allow the DCN to run in a virtual machine, which, in turn, may run in an ACP.

Deciding which DCPs and DCNs to use in a test bed will take some thought. One reason is that the requirements for DCPs and DCNs are not yet complete as of O-PAS V2. V2 indicates that OPAF plans to publish more detailed requirements in this area in further O-PAS versions. One benefit to end users gaining experience with early DCNs and DCPs is to provide feedback to OPAF to help drive their standardization.

Logical choices for test bed DCPs (DCN Hardware) before OPAF standardizes them are industrial computers or IIoT edge devices—which are usually industrial computers. Many industrial computers are on the market and, driven by Industrie 4.0, targeting factory automation applications. In today's market, an industrial computer used as a DCP will come preloaded with an operating system and drivers specific to the hardware. Some industrial computers make drivers and system functions available to third party programs, while others do not. To meet the direction of OPAF, a key requirement for DCPs is that programs not provided by the DCP supplier need to access many of the hardware drivers and services. I/O may be available as part of a

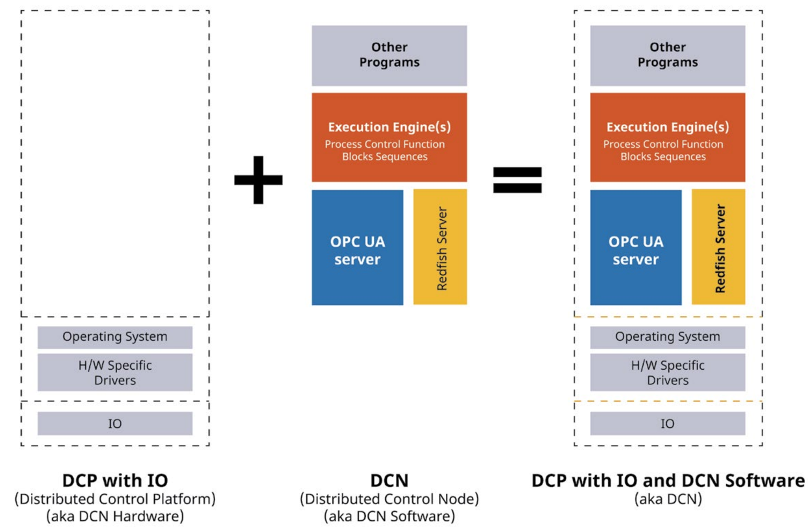


Figure 3: DCN software runs in a DCP. The DCP is the hardware platform

DCP or it could be separate. For a test bed, either hardware configuration will work.

DCN software consists of various programs provided either by the DCP supplier or others. O-PAS places no restrictions regarding which programs can run in a DCN; however, it does specify certain interfaces that can be supported in a DCN. Without going into deep technical detail on the interfaces, following is a list of typical software programs that would be expected in a DCN:

OPC UA Server – OPAF has focused on OPC UA as the primary communications technology for process control data. Every DCN will need an OPC UA server using client/server and/or publish/subscribe interfaces. If the DCP has connected I/O, the OPC UA server will make the I/O available to all O-PAS clients or subscribers in an O-PAS system. If the DCN contains a function block program or other control programs, those will need to communicate using the OPC UA information model specified in O-PAS. This O-PAS information model is the heart of the O-PAS specification. It standardizes the way process control data and I/O signals are transferred between software applications from different suppliers and allows a heterogeneous collection of hardware and software products to become an integrated system. For example, the OPC UA information model standardizes how various function block programs can exchange data, how HMIs access monitoring and control values, and how historians are configured to find the data to collect.

Redfish Server – Redfish is the name of a DMTF (formerly known as the Distributed Management

Task Force, https://www.dmtf.org/) standard for the management of servers, storage, networking and converged infrastructure. OPAF is using the Redfish standard as though an O-PAS system were a data center. That allows each hardware and software component to report its state-of-health and asset information for management on a system-wide basis. Since Redfish is using a RESTful interface, not OPC UA, it is, in a sense, out-of-band relative to the process control data and can provide a separate route for state-of-health information.

Execution Engines – O-PAS uses this as a general term for a class of programs that execute control functions. Typical control functions may be function blocks, sequential logic, IEC 61131-3 logic, IEC 61499 logic, ISA-88 batch control or other, not yet imagined control functions.

Other Programs – This is mentioned to reinforce the fact that O-PAS does not impose a limit on the programs that are allowed run in a DCN. Some examples of other programs are artificial intelligence functions, HMI servers, historian collection, and buffering agents.

Please note that end users should not expect to develop DCN software but should focus instead on process control strategies, at which they excel. Suppliers and system integrators should provide the DCN software.

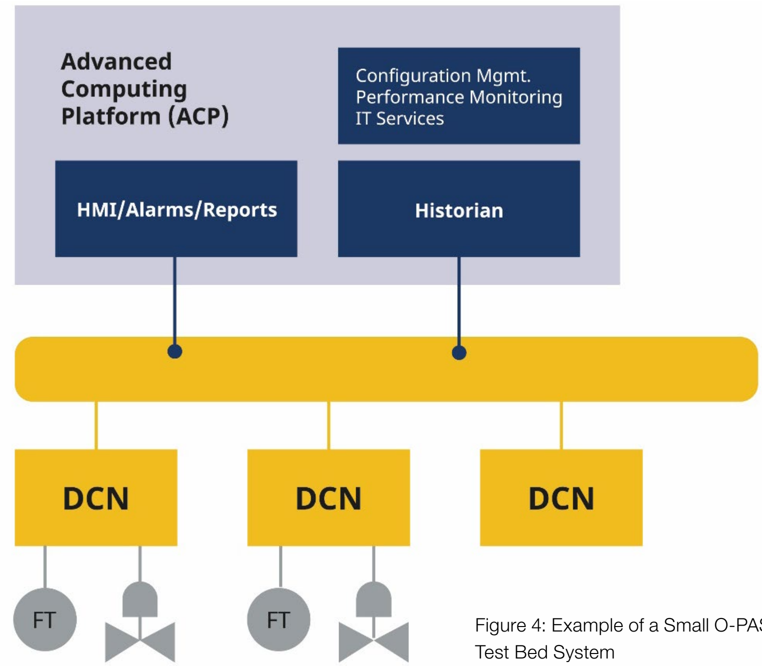


Figure 4: Example of a Small O-PAS Test Bed System

This explanation of DCNs and DCPs is a simplified reference to the O-PAS standard. Participation in the OPAF meetings will provide more rigorous explanations. However, for purposes of planning to set up a small O-PAS test bed, this is a good starting guide. An OPA system integrator will be able to provide an O/O with DCPs and DCN software running in them to make it easier to build the test bed.

Creating a small test bed system using these O-PAS components may result in a system as shown in figure 4. This system has three DCNs, two with I/O, one without but performing 'compute' functions, only.

The ACP contains the HMI with alarms and reporting functions, a historian, IT services, and programs for configuring the system and monitoring performance. The ACP could be a PC with sufficient memory and CPU power to run multiple virtual machines.

Figure 5 depicts a tabletop system not much different from the figure above, but with no ACP shown. In this example, small industrial computers and an iPad are used for the HMI. This demonstrates that a test bed system does not need to be very large.

Part 2 of the O-PAS standard addresses security. In a nutshell, O-PAS requires every certified product to provide robust security capabilities. When a system is assembled from the certified products, the system owner, probably the end user, must specify the level of security that is needed at the system level. The project's system integrator is then responsible for configuring the O-PAS

Figure 5: A small O-PAS test bed system

components and, if necessary, adding functions to the system to deliver the specified cyber security.

CERTIFICATION

A big question is when O-PAS-certified products will be commercially available. A prerequisite is that the OPAF certification process must be fully established. Since the forum is working on the certification process right now, prospective users should watch for the publication of certification documents, the establishment of test labs, and announcements for the first certified products. OPAF may use the term "O-PAS Certified Product" to identify products that have met their stringent certification tests.

Since end users and system integrators will require high degrees of interoperability and interchangeability as well as software portability, product certification is critical to the wide adoption of O-PAS. A high-quality certification process can reduce risk and minimize project time.

Until O-PAS Certified Products are available, end users can require that software products be certified by the OPC Foundation to ensure they meet interoperability requirements for OPC UA.

CONCLUSION

More and more, end users are asking automation companies how they can plan on adopting O-PAS. A change as significant as adoption of an open process automation standard at the corporate level occurs only when people can envision the benefits it can deliver to their organization. This typically starts with a small group who must sell the vision internally, on-board more people, and build momentum.

Gaining hands-on experience enables the project team to reduce risks when the O-PAS configuration is placed into a process operation. Joining OPAF is critical. It allows the company's feedback and input to OPAF to influence the direction of the standard.

OPAF would like to hear end user inquiries and how they would like to use O-PAS systems. Operating a small test bed system will generate questions and enable users to better envision how they can introduce equipment into their plants.

Last, but not least, O-PAS standard, V2, has been released. Download it at https://publications.opengroup.org/p201 ◻

All figures courtesy of Yokogawa

DAVE EMERSON is Vice President of Yokogawa's U.S. Technology Center in Dallas, Texas. The U.S. Technology Center is tasked with working on frontier technology for industrial automation, helping its formulation within the industry and accelerating its adoption within Yokogawa. Dave is experienced in applying and developing automation and Manufacturing Operations Management (MOM) systems used in the hydrocarbon, chemical, pharmaceutical and food & beverage industries. He is an ISA Fellow and a member of Control Magazine's Process Automation Hall of Fame.

Dave has over 30 years' experience participating on U.S. and international consensus standards committees such as ISA-88, ISA-95, IEC TC65 and ISO TC184. He also represents Yokogawa in several industry groups including leadership roles with MESA, MIMOSA and the OPC Foundation. Dave is Yokogawa's primary representative with The Open Group's Open Process Automation Forum (OPAF) and currently serves as Co-Chair of the OPAF's Enterprise Architecture Working Group.

Designing O-PAS Systems

Dave Emerson, Vice President, US Technology Center, Yokogawa

The O-PAS standard will enable construction of reliable, safe, and secure process automation systems that are scalable from very small to very large. Such systems can be used in new construction or added to existing installations. They will not require system shutdowns to perform updates and extensions. O-PAS will not set a standard that specifies how a system is designed or built but, instead, has defined a set of interfaces that will allow individual products to be used as system components.

The design, construction, configuration, delivery and startup of O-PAS systems will be the responsibility of a system integrator. System integrators will need to work with end users to make architectural decisions in order to provide a fit-for-purpose automation system.

A first step in designing an O-PAS system is to gain confidence in the technology by establishing a test bed. An end user could setup the test bed, work with a system integrator to develop a custom test bed, such as shown in Figure 1, or arrange access to the system integrator's test bed for qualification of components and system testing. No matter which option is selected, the end user will be able to use this experience to make architectural decisions that are foundational to the system's design.

Whether planning on adopting O-PAS or preparing to include O-PAS on a project, it is helpful to consider some of the questions that will drive system architecture for specific projects and an overall company standard:

Is this a system expansion or new system?

- How many IO points will be in a DCP?
- What type of automation will modular process systems use?
- Which interfaces to non-O-PAS systems or field digital networks are required?
- Which process control functionality will the system use?
- Where should control functions be deployed?
- What level of security is required?
- How does the end user balance CAPEX vs. TCO?

Taking a brief look at these questions provides insights to new options O-PAS makes available to end users compared to existing DCS and PLC based systems. This is one area in which a systems integrator experienced with O-PAS systems can help guide end users.

SYSTEM EXPANSION OR NEW SYSTEM?

O-PAS systems will need to meet each facility's unique requirements and work within the facility's constraints. A basic question with great influence on the O-PAS

Figure 1: An O-PAS test bed at a Yokogawa facility

architecture regards which of the following scenarios is applicable:

1. A new facility without an existing automation system;
2. An existing facility in which the O-PAS system will replace the current control system;
3. An existing facility in which the O-PAS system is to be added to an existing system.

A new facility provides the greatest freedom for O-PAS system designs and the opportunity to implement a new system that is fit-for-purpose and forward-looking.

The second situation is a system migration. An automation system that is replacing an existing system, which has reached end of life or whose maintenance costs have grown to an unsustainable level, offers an opportunity to implement a completely new system—but often within the constraints of the existing facility. Constraints could include minimizing the cost to connect the new system to existing twisted pair IO, floor space issues, porting control code from an old software environment to a modern one, and meeting the expectations of users who would like the new system to be just like the system they have worked with for 30 years. These constraints will drive decisions in a manner that differs from a new facility scenario. Change management, maximizing process up-time, and minimizing automation system migration costs are key drivers.

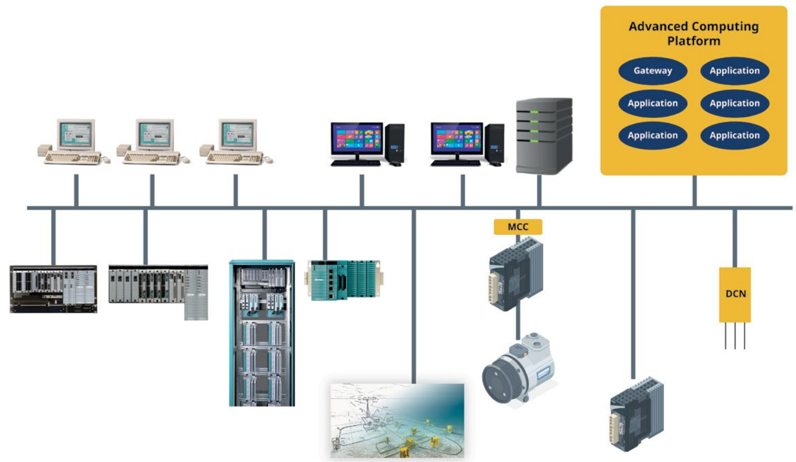


Figure 2: O-PAS DCN and ACP with a gateway connected to a DCS

The third option, adding O-PAS components to an existing system, imposes the most constraints, but will likely be the most common path in our industry. It allows for a gradual transition to the O-PAS ecosystem with likely the least disturbance to operations. Looking at this third option will highlight many of the questions that are also related to the other two options.

The smallest incremental step in adopting O-PAS is adding a DCN to an existing automation system. A DCN can be interfaced to the same Ethernet and physical layer as an Ethernet-based DCS network but the DCN and DCS will not natively communicate. A gateway is needed. An O-PAS gateway is a software application that communicates via the OPC UA-based O-PAS Communications Framework (OCF) and converts, or translates, messages to and from the DCS communications protocol. The gateway software may reside in a DCP (DCN Hardware) or in an ACP (Advanced Computing Platform). Figure 2 depicts the O-PAS gateway to a DCS deployed as an application in the ACP. ACPs are often thought of as large, data center type servers; however they can be as large or small as desired. They can run on small industrial servers and large, rack-mounted servers.

The gateway software effectively makes the data in the O-PAS system available to the DCS and, conversely, makes the DCS data available to the O-PAS system. Access to data from the combined system is available to operator stations on both the DCS and O-PAS system and to Manufacturing Operations Management (MOM) applications in the DCS and O-PAS system.

The physical architecture that determines where the gateway is deployed and how many servers are used is flexible. Figure 3 depicts how the ACP and DCS server could be run in virtual environments in the host computer. The decoupling of software from hardware and global access to data that O-PAS standardizes provide this type of flexibility.

The addition of a DCN and gateway software comprise a natural first step to adding O-PAS components to an existing system. Subsequently, the system could be expanded with components such as additional DCNs, operator HMIs, MOM software, and gateways to various systems, computers and field digital networks, as desired.

A time-phased migration strategy could include the replacement of DCS components with O-PAS components anytime a repair is required or in a modular fashion such as the following:

- By process units or equipment modules;
- By operator area of control;
- By DCS racks.
- The migration to O-PAS is gradual and it is up to the end user to decide the point where the hybrid DCS/O-PAS system becomes purely an O-PAS system.

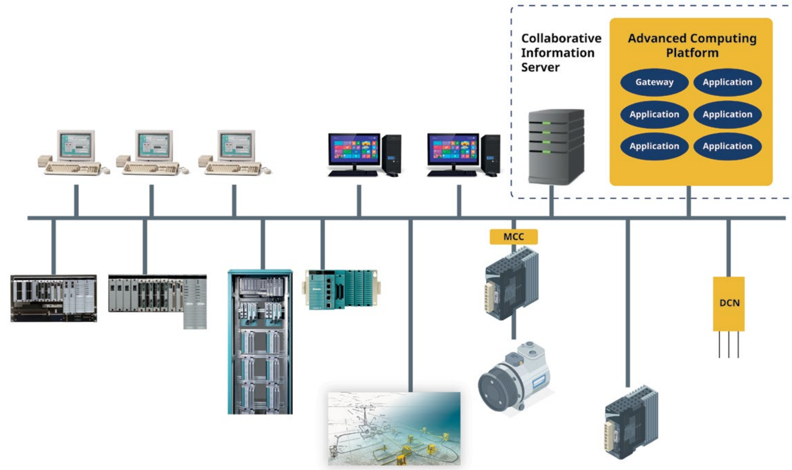


Figure 3: O-PAS ACP and DCS virtualization host deployed on one server

HOW MANY IO POINTS WILL BE IN A DCN?

Over four decades, DCS systems have supported increasing numbers of hardwired, twisted-pair IO. Many have reached a point in which a single controller supports hundreds or even thousands of hardwired IO points. By decoupling controller software and hardware, O-PAS is making many new options available for architecting systems.

Some of the options end users are considering follow:

- A small number of IO per DCN, perhaps as few as eight points or up to approximately 100
- Hundreds of IO per DCN, perhaps 500-1000, such as many DCS controllers currently support
- Thousands of IO per DCN

The number of IO points per DCN is referred to as the IO density. High-density configurations could include thousands of points per DCN. The IO density directly impacts system architecture, for example, more DCNs will require additional network endpoints and switches. Otherwise, the end user could extend coverage of a single controller over a wider area. Manufacturers and system integrators offer on-line calculators or software tools to assess tradeoffs in terms of wiring costs and customized vs. standard IO configurations, smart junction boxes and marshalling components.

Other implications arise with respect to system availability. With low density IO configurations such as 16 points per DCN, the failure of one DCN or one network endpoint jeopardizes perhaps a single process unit or equipment module. Loss of a DCN with 500 IO points could shut down the entire process.

To improve system availability, DCN redundancy is optional in the O-PAS architecture. While 1:1 DCN redundancy will likely be a common configuration, the software/hardware decoupling in O-PAS also provides for 1:N redundancy by allowing multiple compute DCNs to directly access IO in an IO only DCN.

WHAT TYPE OF AUTOMATION WILL MODULAR PROCESS SYSTEMS USE?

Modular process equipment is becoming increasingly popular in process plant expansions and upgrades as well as in new facilities. The modular equipment is typically purchased on the merits of its process technology, not its automation technology. Perhaps most common today is for modular process equipment to integrate PLCs programmed by the modular process equipment supplier.

Interfacing PLC-controlled, modular process equipment with O-PAS systems can be accomplished using digital communications between the PLC and a DCN. As with most DCSs, the project engineering that is necessary could result in significant costs and schedule risks.

NAMUR is overseeing the development of the Modular Type Package (MTP) to aid in automating the integration of modular process equipment into a DCS. OPAF and NAMUR leadership have spoken publicly about O-PAS supporting MTP in a future version. Modular process equipment containing automation designed for MTP can reduce costs and risks of integrating sub-systems into O-PAS systems.

Ultimately, controlling modular process equipment with an O-PAS Certified DCN and MTP application could drive costs and risks even lower for end users.

WHICH INTERFACES TO NON-O-PAS SYSTEMS OR FIELD DIGITAL NETWORKS ARE REQUIRED?

Gateways will do more than interface to existing DCS systems. Gateways can provide interfaces between any non-O-PAS digital protocol and the O-PAS OCF. For clarity, OPAF defines two general types of gateways, "south side" and "north side."

South side gateways interface to field digital networks such as Modbus, Foundation Fieldbus or PROFINET. This is very similar in concept to how a DCS interfaces to these field digital networks today. North side gateways interface to business or operational systems.

Both types of gateways make O-PAS data available to other networks and bring data from the other networks into O-PAS systems where it is treated the same as native O-PAS data per O-PAS's OPC UA information model.

WHICH PROCESS CONTROL FUNCTIONALITY WILL THE SYSTEM USE?

Process control is the primary function of a process automation system. OPAF is working on standardization of interfaces to permit interoperability and portability of IEC 61131-3 and IEC 61499 control strategies.

Control applications that are not standardized in O-PAS can also be used in O-PAS systems. Examples include proprietary function blocks from DCSs, ISA-88 batch control and modular procedural automation, which the ISA106 committee is working on.

End users will be able to select the appropriate process control functionality according to their organization's preferences and technical advantages.

WHERE SHOULD CONTROL FUNCTIONS BE DEPLOYED?

In a typical DCS system design, it is assumed that control functions will be executed in the controller to which IO is directly connected. However, hardware/software decoupling in O-PAS systems provides designers considerable flexibility. Control functions and IO could be in different DCNs.

A deployment example is depicted in Figure 4. The "Compute & IO" diagram shows a DCN with compute capability and control functionality. It also shows four IO Only DCNs in the same field enclosure. In this example, the IO signals can be read by any application in the system, for example, a historian, and the control functions in the Compute & IO DCN can

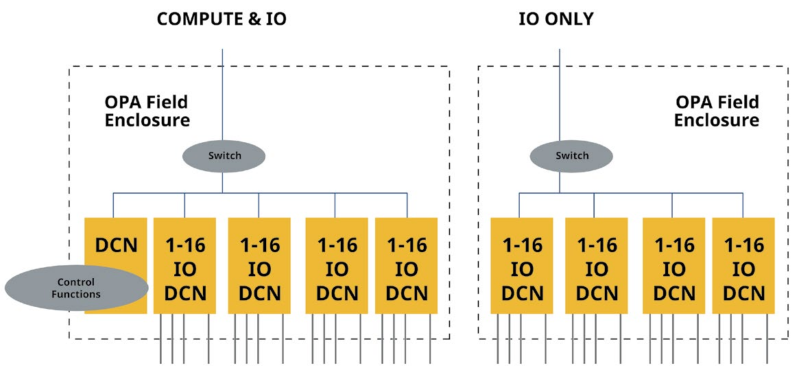


Figure 4: Control function deployment options

access both the inputs and outputs in the IO Only DCNs.

In contrast, the "IO Only" field enclosure on the right does not include control functions. In this case, the control function could have been deployed in an ACP or a Compute Only DCN located in an equipment building and serving multiple field enclosures.

A third deployment option is to deploy the control functions in the DCNs connected to the IO which would make them compute & IO DCNs.

The ability to deploy control functions and other applications to their appropriate locations without constraints by tightly bound software and hardware is a key provision in O-PAS.

WHAT LEVEL OF SECURITY IS REQUIRED?

OPAF has adopted the ISA/IEC 62443 security standard that is widely used throughout the process industries and increasingly spreading to other OT domains.

O-PAS requires all certified products to support Security Level 2 as defined in ISA/IEC 62443. This means that all certified products serving as system components will offer a consistent level of security in their interfaces. This will allow system integrators to more easily meet end user system level security requirements.

The end user system level security requirements are not constrained by O-PAS. End users typically use a risk assessment to determine the security level required for a system. This will be the same for O-PAS systems.

Figure 5 shows how different parts of the ISA/IEC 62443 standard are relevant to various O-PAS ecosystem roles. Only O-PAS product suppliers

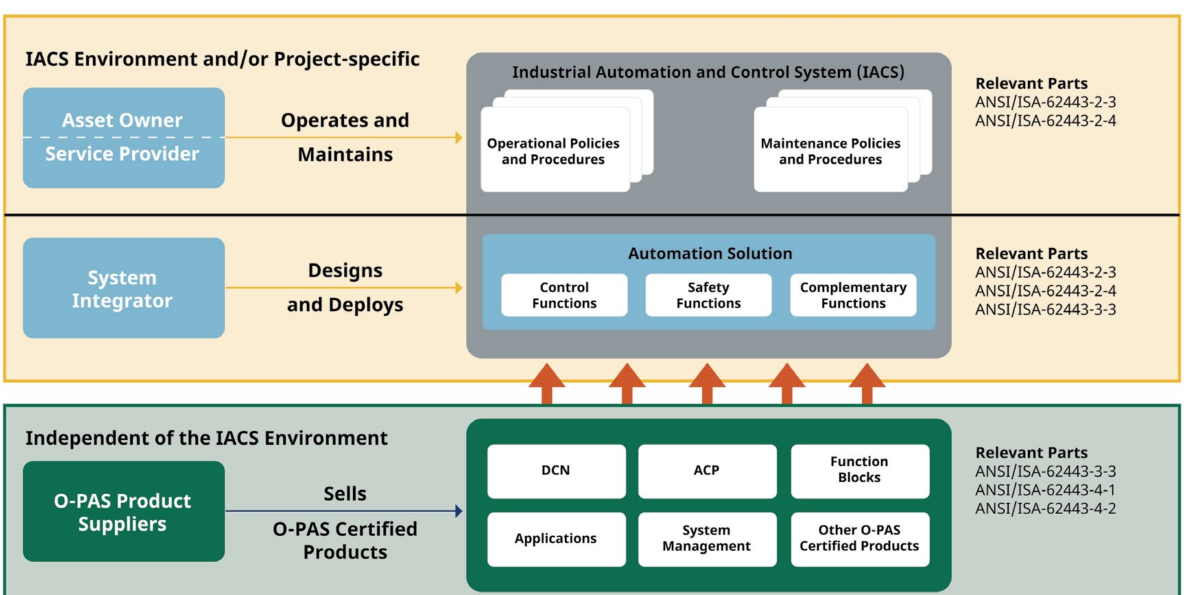


Figure 5: ISA/IEC 62443 parts are relevant to different ecosystem roles

with products certified by OPAF are required to follow the standard; however, it is recommended that system integrators, service providers and end users also follow the relevant parts of the standard.

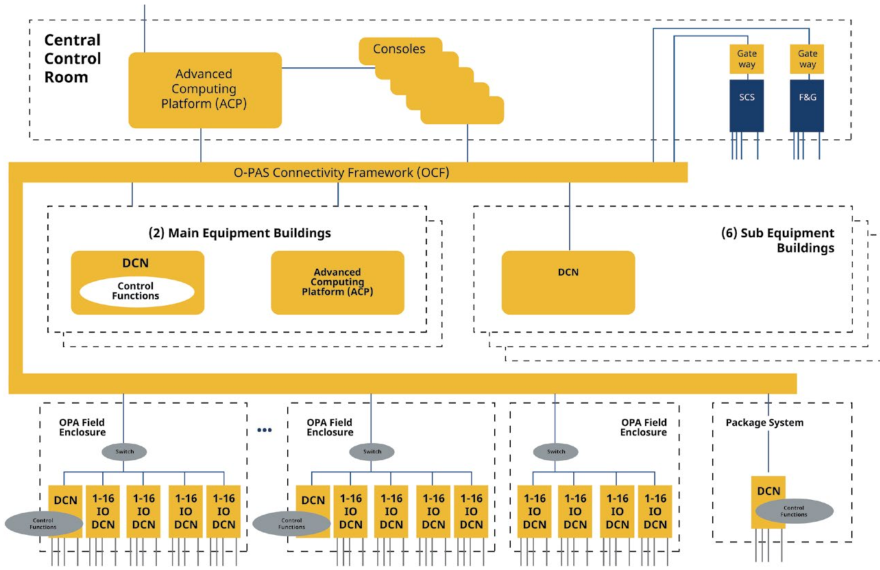


Figure 6: Possible O-PAS system architecture

HOW DOES THE END USER BALANCE CAPEX VS. TCO?

One of OPAF's goals in creating O-PAS is to reduce the total cost of ownership (TCO) of automation systems. A significant component of TCO is the cost of a version upgrade or new release. Not only could the costs of hardware or software purchases and engineering labor be significant, those could be dwarfed by lost production during commissioning. On the other hand, avoiding the latter by performing a hot cutover could incur much higher labor costs during the project.

O-PAS will enable more modular systems that allow components to be added or removed without disturbing the system or the process. Figure 6 shows an alternative to the traditional O-PAS Technical Architecture. Some differences, which provide 'food for thought' are how the OCF extends to the field, the fact that DCNs may be compute only or include compute & IO, deployment options for control functions in field enclosures or in equipment buildings, operator and engineering consoles driven by the ACP or directly accessing the OCF, and interfaces to SCS and F&G systems. No single architecture will fit all applications. The important consideration for this figure is to encourage people to start thinking creatively how O-PAS systems can be architected to best benefit their companies. ◻

All figures courtesy of Yokogawa

DAVE EMERSON is Vice President of Yokogawa's U.S. Technology Center in Dallas, Texas. The U.S. Technology Center is tasked with working on frontier technology for industrial automation, helping its formulation within the industry and accelerating its adoption within Yokogawa. Dave is experienced in applying and developing automation and Manufacturing Operations Management (MOM) systems used in the hydrocarbon, chemical, pharmaceutical and food & beverage industries. He is an ISA Fellow and a member of Control Magazine's Process Automation Hall of Fame.

Dave has over 30 years' experience participating on U.S. and international consensus standards committees such as ISA-88, ISA-95, IEC TC65 and ISO TC184. He also represents Yokogawa in several industry groups including leadership roles with MESA, MIMOSA and the OPC Foundation. Dave is Yokogawa's primary representative with The Open Group's Open Process Automation Forum (OPAF) and currently serves as Co-Chair of the OPAF's Enterprise Architecture Working Group.

Plant Pioneers Use Of Automation Concept

Integration of chiller package marks first industrial implementation of Module Type Package

By Polyana Santos, Evonik Technology & Infrastructure; Andreas Stutz, Siemens; Tim Henrichs, Yokogawa Deutschland; and Martin Rogg, ENGIE Refrigeration

Many challenges faced by the chemical industry, such as achieving increased flexibility and faster time-to-market, necessitate enhancing the interoperability and standardization of automation systems. Modular automation offers a viable solution to these challenges.

The Module Type Package (MTP) provides a standard, manufacturer-independent description of aspects of the automation of a process plant unit to ensure efficient integration into a process orchestration layer (POL). This concept is considered an enabler for modular production. The MTP standard described in Ref. 1 is one of a series of standardization documents either about to be published, in draft or being planned as next steps. The MTP concept solves one of the key challenges — enhancing automated integration of process plant units — for achieving an economically viable approach for modular production.

Package units of non-modular plants have similar complexity in terms of integration. Therefore, this method not only is useful for modular production but also for fast and correct integration of package units into conventional automation systems, which speeds up the engineering work and reduces costs.

The first practical application of MTP standards in an industrial environment has just taken place at Evonik's world-scale amino-acid plant in Singapore. It involved the integration of a chiller package.

THE CONCEPT

MTP enables an automated integration of process plant units, the so-called process equipment assemblies. The whole concept is based on four building blocks: functional abstraction, decentralized intelligence, standardized interfaces and semantical enrichment. The first three elements are related to the automation implementation of the

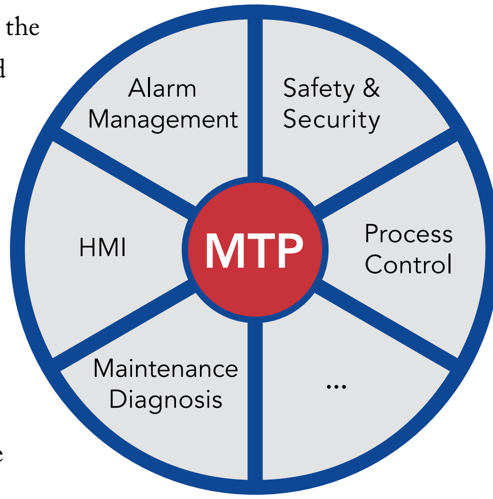
Source: ENGIE Refrigeration GmbH

unit while the fourth represents the MTP content. The standardized interfaces (according to Ref. 1) will be semantically enriched by the MTP content.

The MTP itself is structured into a core description, the manifest and several optional extending aspects for subsystems of the POL such as the human/machine interface (HMI), procedural control for process plant orchestration (process control), communication and more (see Figure 1) [1]. Each of these aspects has its own model set and can be developed and extended independently.

The communication aspect contains all the data about existing standardized interfaces and how they are provided via a specific communication technology. The chiller integration project used a simplified information model of an access via OPC UA described in Ref. 1a.

The HMI aspect provides a supplier-independent description for



Module Type Package

Figure 1. This concept enables automated integration of process equipment assemblies.

operational graphics to guarantee control and monitoring capability as well as unif orm look and feel for different automation systems [1b]. To furnish a consistent cross-module look and feel, the visualization system of the POL must adapt the connected standardized interface types with its proprietary graphic objects.

The semantically enriched data within the various descriptive aspects of the MTP enable the use of the data in algorithms to pre-configure and generate runtime data within the POL. The goal is to ensure an easy and automated integration of such units. This and many other requirements are summarized under the topic of modular production. It offers a viable way to speed up time-to-market for new products by decreasing engineering and adaptation time compared to conventional production.

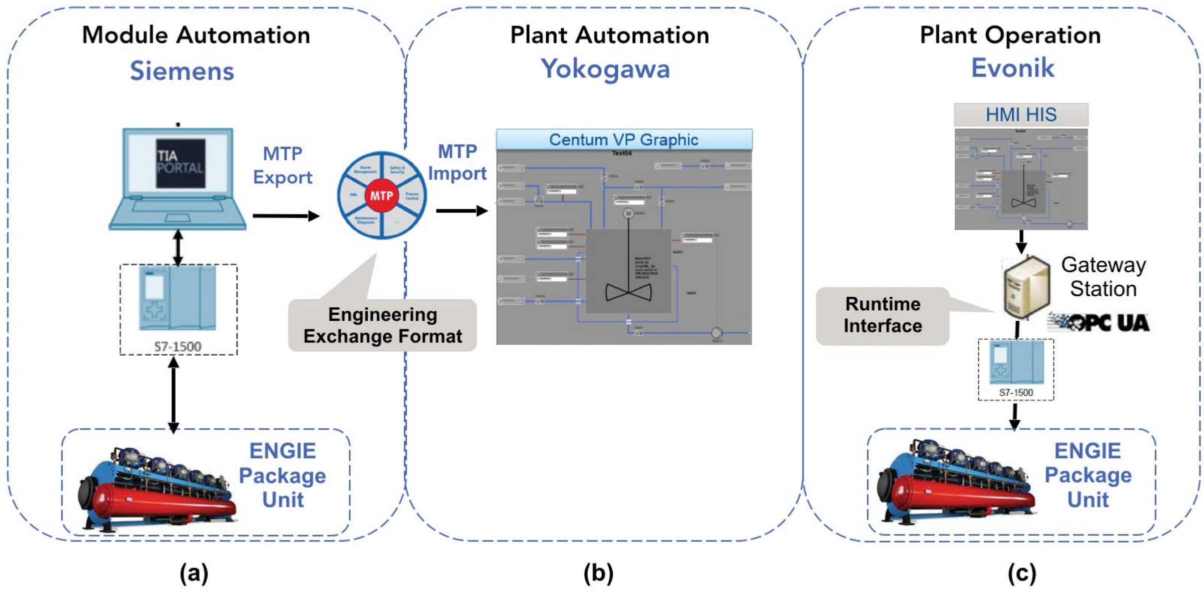
PROJECT DETAILS, CHALLENGES AND RESULTS

Evonik, ENGIE, Siemens and Yokogawa worked together on this project to integrate a chiller package unit into a conventional production facility by means of the MTP standard (Figure 2). The MTP integration covered HMI aspects and communication aspects via OPC UA. The built-in controls of the chiller run in a monitoring-only mode, due to warranty issues between the package unit

ENGIE	Siemens	Yokogawa	Evonik
Module Supplier Package Unit	Module Automation Engineering	Plant Automation Engineering	Plant Integrator End User
Cooling Machines 	PLC S7-1500 	DCS Centum VP	Evonik Site

Collaborative Effort

Figure 2. Four firms worked together to integrate a chiller package with an existing DCS via MTP.



INTEGRATION STEPS

Figure 3. The project involved modifying the chiller and plant automation programs as well as runtime integration of the package unit into the process orchestration layer.

supplier, ENGIE, and the unit end user, Evonik.

The project involved the two automation systems: a Siemens S7-1500, the programmable logic controller (PLC) on the chiller package unit, and a Yokogawa Centum VP, the distributed control system (DCS) at the Singapore site. Figure 3 shows the steps in the integration. It took advantage of two prototype MTP tools — a modeler one and an import tool.

The development process faced some challenges as this was the initial project of its kind. The first one was to determine a common basis of the MTP standard. It is important to note that MTP is a new concept and most parts of the standard are still in development. Transferring knowhow from the working groups required several workshops and face-to-face meetings between the module supplier ENGIE and its automation vendor Siemens.

The system integration via MTP taught valuable lessons. The HMI aspect model provides semantically enriched information to enable a one-to-one transfer of HMI information across automation systems. However, some challenges arose during the integration test when using the MTP and importing it into the target system. These fell into a number of categories:

- Handling of different dimensions of VisualObjects (the lessons learned were used in enhance the model in Ref. 1b);
- eClass classification classes for static display elements;
- Limitations of available systems (Ref. 1c defines certain restrictions and notes some limitations); and
- OPC UA namespace model capabilities (insights have been forwarded to the taskforces developing Ref. 1d).

We will not get into the specifics of these here because the details are more meaningful to automation specialists and control engineers than process engineers. We have published another article that goes into the specifics [2].

After tests in the lab had been completed, the package-unit PLCs and DCS were updated with MTP functionalities at the Evonik site.

The OPC UA connection was configured between the Yokogawa UGS (universal gateway station) and the package unit network with the S7-1500 PLCs. Start-up took place in June 2019. The data transfer via OPC UA was established without error immediately after physically connecting the systems.

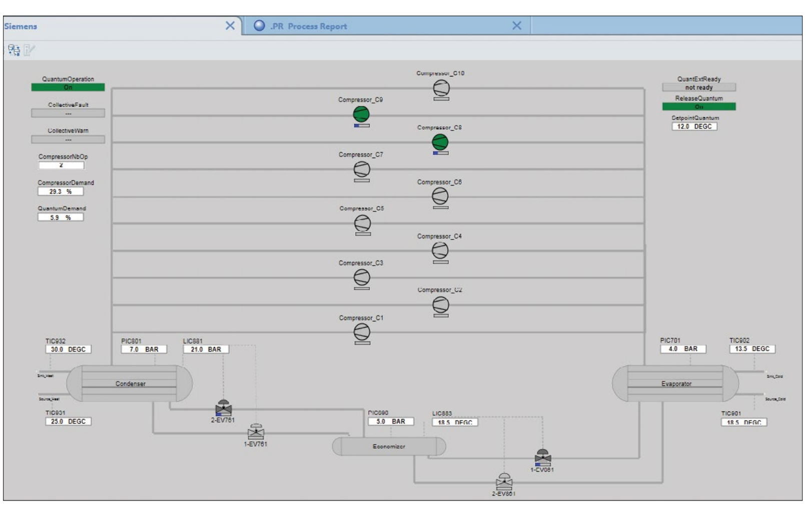
Operators were impressed by the quality of the HMI graphics, which maintained the same look and feel as those in the main process plant (Figure 4). Additionally, the graphics can be used and even modified like any other DCS graphic.

A SUCCESS STORY

The successful commissioning and start-up of this pioneer project at Evonik's Singapore production site demonstrates the practical advantages of the MTP standard. Further projects of this type already are in the pipeline, aimed at improving and enhancing the MTP capabilities.

The MTP concept likely will become established as a standard for the chemical and pharmaceutical industries. It can be used for modular plants as well as for package units. Integration via MTP description reduces manual effort, avoids mistakes and saves time and money. ◻

POLYANA DA SILVA SANTOS is project engineer, process control for Evonik Technology & Infrastructure GmbH, Marl, Germany. **ANDREAS STUTZ** is a research engineer for Siemens AG, Karlsruhe, Germany. **TIM HENRICHS** is marketing manager, Germany, Austria and Switzewrland for Yokogawa Deutschland GmbH, Ratingen, Germany. **MARTIN ROGG** is project manager, controls for ENGIE Refrigeration GmbH, Lindau, Germany. Email them at Polyana.da-silva-santos@evonik.com, Andreas.stutz@siemens.com, Tim.Henrichs@de.yokogawa.com and martin.rogg@engie.com.



COMPRESSOR UNIT HMI

Figure 4. Graphics provide the same look and feel as those in the main process plant.

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