*Open Group Guide*

# The Open Process Automation™ Business Guide

## Value Proposition and Business Case for the Open Process Automation™ Standard

Prepared by The Open Group Open Process Automation™ Forum Business Working Group

Open Group Guide

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**Value Proposition and Business Case for the Open Process Automation™ Standard**

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# Preface

### The Open Group

The Open Group is a global consortium that enables the achievement of business objectives through technology standards. Our diverse membership of more than 550 organizations includes customers, systems and solutions suppliers, tools vendors, integrators, academics, and consultants across multiple industries.

The Open Group aims to:

- Capture, understand, and address current and emerging requirements, establish policies, and share best practices
- Facilitate interoperability, develop consensus, and evolve and integrate specifications and open source technologies
- Operate the industry's premier certification service

Further information on The Open Group is available at www.opengroup.org.

The Open Group publishes a wide range of technical documentation, most of which is focused on development of Open Group Standards and Guides, but which also includes white papers, technical studies, certification and testing documentation, and business titles. Full details and a catalog are available at www.opengroup.org/library.

### This Document

This document is the Open Process Automation™ Business Guide, which provides guidance on the Value Proposition and Business Case for the Open Process Automation™ Standard. It was developed and is maintained by The Open Group Open Process Automation™ Forum (OPAF).

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- Julie Smith – DuPont Company
- Van Wilson – Accenture

## Referenced Documents

The following documents are referenced in this Guide.

(Please note that the links below are good at the time of writing but cannot be guaranteed for the future.)

- IEC 61511: Functional Safety – Safety Instrumented Systems for the Process Industry Sector; refer to: IEC 61511-1 Amd.1 Ed. 2.0 en:2017
- ISA84: Electrical/Electronic/Programmable Electronic Systems (E/E/PES) for Use in Process Safety Applications; refer to: www.isa.org/isa84
- ISA88: Batch Control (abbreviated to S88); refer to: www.isa.org/isa88
- ISA95: Enterprise-Control System Integration; refer to: www.isa.org/isa95
- ISO/IEC/IEEE 24765:2010(E): Systems and Software Engineering – Vocabulary; refer to: www.iso.org/standard/50518.html (revised by ISO/IEC/IEEE 24765:2017)
- TOGAF®, an Open Group Standard; refer to: www.opengroup.org/togaf

# 1 Executive Summary

To survive in business, industrial manufacturers like all companies must continually increase productivity and customer satisfaction. The industrial control systems that manufacturers use to automate their processes are critical to the company's productivity and product quality. To increase the business contribution from control systems, manufacturers need:

1. Increases in operational benefits from improved capabilities
2. Improvements in cybersecurity compared to currently available systems
3. Reductions in the system's capital and lifecycle costs

For several reasons, currently installed control systems are predominantly closed and proprietary. This is in contrast to the open, interoperable network of instrumentation devices below them and the Information Technology (IT) systems above them in the typical automation hierarchy. Closed, proprietary systems are expensive to upgrade and maintain, and challenged when trying to insert new technology, especially from third parties. This is the problem that The Open Group Open Process Automation Forum (OPAF) is working to solve.

The Forum will define standards for an open, interoperable, secure process automation architecture. The standards enable development of fit-for-purpose systems consisting of cohesive functional elements acquired from independent suppliers and integrated easily via a modular architecture characterized by open standard interfaces between elements. The first priority is to select standards from existing applicable industry standards. When no applicable standard exists, the Forum will work with standards development organizations to develop one.

The Forum and standards will not define the functional Intellectual Property (IP) of the components. These remain proprietary to their supplier. The objective is to define open standard interfaces, not to require open source.

The scope of the Forum encompasses today's distributed control systems and programmable logic controllers for continuous and hybrid process industries. Safety instrumented systems and discrete manufacturing are out of scope.

The Forum will emulate successful transformations to open, interoperable systems made by relevant adjacent industries. Notable examples include avionics (the FACE™ Reference Architecture) and telecommunications (Network Function Virtualization). Similarly, it will avoid the pitfalls experienced by prior unsuccessful standards initiatives in the manufacturing industry.

The Forum is considering both the business and technical aspects of the Open Process Automation approach. This Business Guide outlines a business ecosystem of end users, system integrators, hardware and software suppliers, and service providers. Roles and responsibilities are defined for procurement, design, development, integration, deployment, operation, and sustainment of Open Process Automation conformant systems. Individual companies can perform one or more roles in the ecosystem. The Business Guide defines how the business models of current stakeholders will be impacted by open interoperability. The Guide answers questions about the value propositions for buyers and sellers, accountability for system performance, schedule for transformation to an Open Process Automation based marketplace, etc. The following table, developed by end-user and supplier members of the Forum, summarizes the benefits from the Open Process Automation Standard.

| **Benefits of the Open Process Automation Standard** | |
|---|---|
| **End Users** | **Suppliers** |
| • Supports reuse of control system applications<br>• Increases value creation<br>• Enables continuous innovation<br>• Solves system integration issues<br>• Is safe and intrinsically secure<br>• Empowers workforce<br>• Reduces Total Cost of Ownership (TCO) | Grows the top line by:<br>• Reaching new markets and customers<br>• Remaining relevant to existing customers<br>• Creating new goods and services for expanded markets<br>Grows the bottom line by:<br>• Increasing margins<br>• Reducing cost<br>• Eliminating non differentiated products |

The Business Guide outlines a spectrum of business scenarios for the current state of industrial control system use and the future state where Open Process Automation conformant systems will be used. The business scenarios are listed below. Note this is not an exclusive list. The Forum intends to span all industry sectors that use distributed control systems and to address scenarios of both control system replacements and new facilities projects.

- Continuous process industry
- Biopharmaceuticals
- Mining and metals
- Specialty chemicals
- Pulp and paper

The essential deliverables of the Forum are a standard of standards and a set of business practices to implement the Open Process Automation approach for industrial control systems. These standards and business practices will be developed by a structured, one-company-one-vote consensus process based on a defined set of key principles and quality attributes. The key principles and quality attributes have been specified and are detailed in Sections 5.1 and 5.2 of this Business Guide.

To operationalize the Open Process Automation standards and business practices, the Forum will set up and steward a standards conformance certification process for hardware and software to ensure that components completely satisfy the requirements of the Open Process Automation Standard. Suppliers will be able to certify that their products conform to the Standard. End users will be able to procure certified components that are backed by warranty.

Furthermore, the Forum will provide a Contract Guide document to assist buyers and sellers with generic contract language for use in Requests for Proposals (RFPs) and the corresponding proposal responses.

In summary, this Business Guide expresses the motivation and vision for a standards-based, open, interoperable, and secure process automation architecture as a business imperative for both users and suppliers of industrial control systems. The Forum will define the standard and business practices required to realize and sustain the desired future state. This Guide establishes the business framework for success of both buyers and sellers.

All industrial control system stakeholder companies – end users, system integrators, hardware and software suppliers, and service providers – are encouraged to join the Open Process Automation Forum. Learn more about the Forum at opengroup.org/open-process-automation.

# 2 Introduction

Industrial manufacturers are under increasing pressure to lower the capital and lifecycle costs of the systems that control their processes and to improve the profitability of their operations. Achieving these objectives is difficult due to the predominantly closed and proprietary nature of the currently installed control systems. Closed systems are expensive to upgrade and maintain. Although the newest automation systems incorporate some aspects, it can be challenging to integrate best-in-class, third-party components into closed, proprietary systems. Additionally, although automation vendors are working towards the adoption of security industry standards and best practices, today's systems generally lack the built-in cybersecurity needed to protect operations, equipment assets, and other capital investments.

An open, interoperable, secure-by-design process automation architecture mitigates these impediments. Open, interoperable systems foster growth in the supplier market, lowering costs through increased choice and competition. In addition, open systems can enable the integration of products from multiple vendors, allowing the adoption of best-fit and best-in-class components. Ensuring future automation systems adopt and reinforce standards that achieve true heterogeneity while providing intrinsic security, multi-vendor interoperability, future-proof innovation, and an easy pathway for systems migration will help end users reap far more value and profitability from the operations they control.

The Open Group Open Process Automation Forum (OPAF) is selecting standards and specifications for an open, interoperable, secure process automation architecture. The standards enable the development of systems composed of cohesive, loosely-coupled, severable functional elements acquired from independent suppliers and easily integrated via a structured modular architecture, which will be characterized by open standard interfaces between functional elements.[1] The Forum and standards do not define the internal components of the functional elements; they will remain proprietary to their supplier.

The Forum will produce a "standard of standards". That is, the first priority is to select from existing industry standards. Only when no standard is available or acceptable will an effort be made to develop a standard with the appropriate standards development organization.

The Forum is considering both the business and technical aspects of the Open Process Automation approach. It endeavors to engage a broad spectrum of stakeholders and operates by consensus on a one-vote-per-company basis.

From a business perspective, the Forum will explicitly consider how the business models of key stakeholders will be impacted by open interoperability; many of these considerations are documented later in this Business Guide. The key stakeholders are:

- End users
- System integrators
- Hardware suppliers

[1] Adapted from Department of Defense Open Systems Architecture (OSA) Contract Guidebook for Program Managers, Version 1.1, May 2013; refer to: https://acc.dau.mil/osaguidebook.

- Subsystem suppliers
- Software suppliers
- Service providers

Also from a business perspective, the Forum will establish a conformance certification process. A conformance certification program will be operational with the publication of the Standard. This will enable end users to procure systems with confidence, thereby facilitating timely market uptake, revenue to suppliers, and value to end users. The benefits of the Standard to end users and suppliers are listed in Table 1; the conformance certification is intended to ensure that these benefits are realized across the marketplace.

**Table 1: Benefits of the Open Process Automation Standard for End Users and Suppliers**

| **Benefits of the Open Process Automation Standard** | |
|---|---|
| **End Users** | **Suppliers** |
| • Supports reuse of control system applications<br>• Increases value creation<br>• Enables continuous innovation<br>• Solves system integration issues<br>• Is safe and intrinsically secure<br>• Empowers workforce<br>• Reduces Total Cost of Ownership (TCO) | Grows the top line by:<br>• Reaching new markets and customers<br>• Remaining relevant to existing customers<br>• Creating new goods and services for expanded markets<br>Grows the bottom line by:<br>• Increasing margins<br>• Reducing cost<br>• Eliminating non differentiated products |

From a technical perspective, the Forum will select or, when necessary, initiate the development of standards for the data models, interfaces, and real-time behaviors of the software and hardware functional elements of the process automation architecture. The Forum will also specify the technical requirements for standards conformance certification. To perform these tasks, the Forum will employ Enterprise Architecture practices and will proactively liaise with all appropriate standards development organizations.

The Forum will produce a number of deliverables, including:

- Business Guide (this document)
- Requirements White Paper
- Snapshot for the Standard
- Standard
- Conformance Program Documents
- Contract Guide
- Problem Report/Change Requests Process

## 2.1 Open Process Automation Scope

The scope of the Open Process Automation effort is shown in Figure 2. It will encompass the functions of continuous and hybrid control, the viewing and operation of the control systems, advanced control strategies, and the manufacturing operations management activities needed to run a real-time production facility.

Different industries use different combinations of continuous and discrete control, and these will be considered as a part of the Open Process Automation scope (see Figure 1). The initial focus of the Forum will be on continuous and hybrid manufacturing. Discrete manufacturing will be considered at a later time due to the type of equipment used and the requirements of a discrete operation.

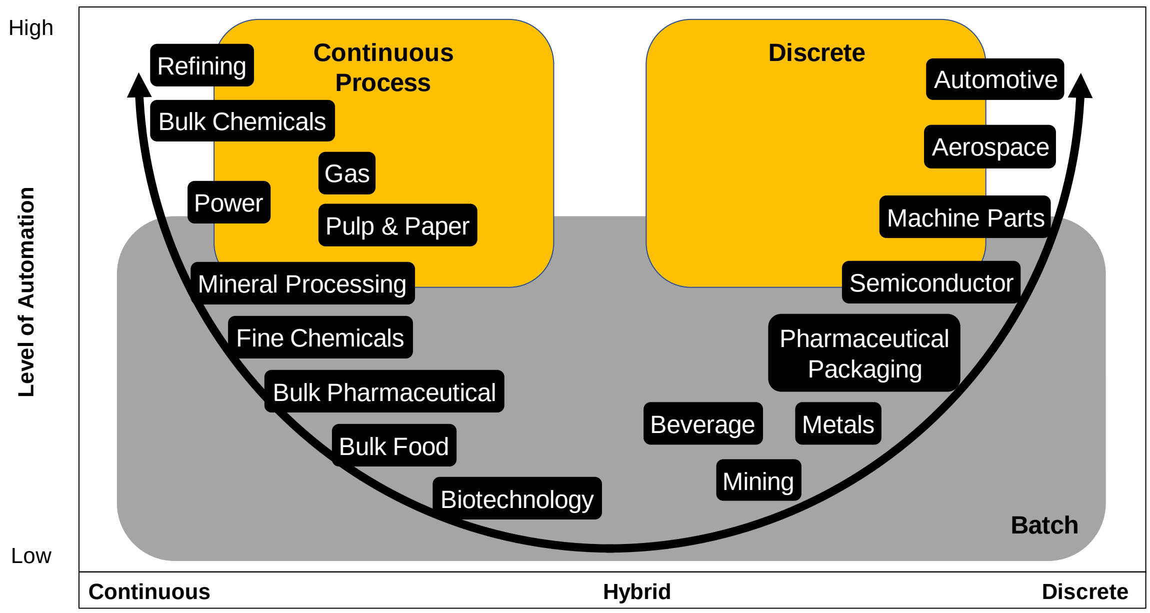


**Figure 1: Industrial Segment Analysis**

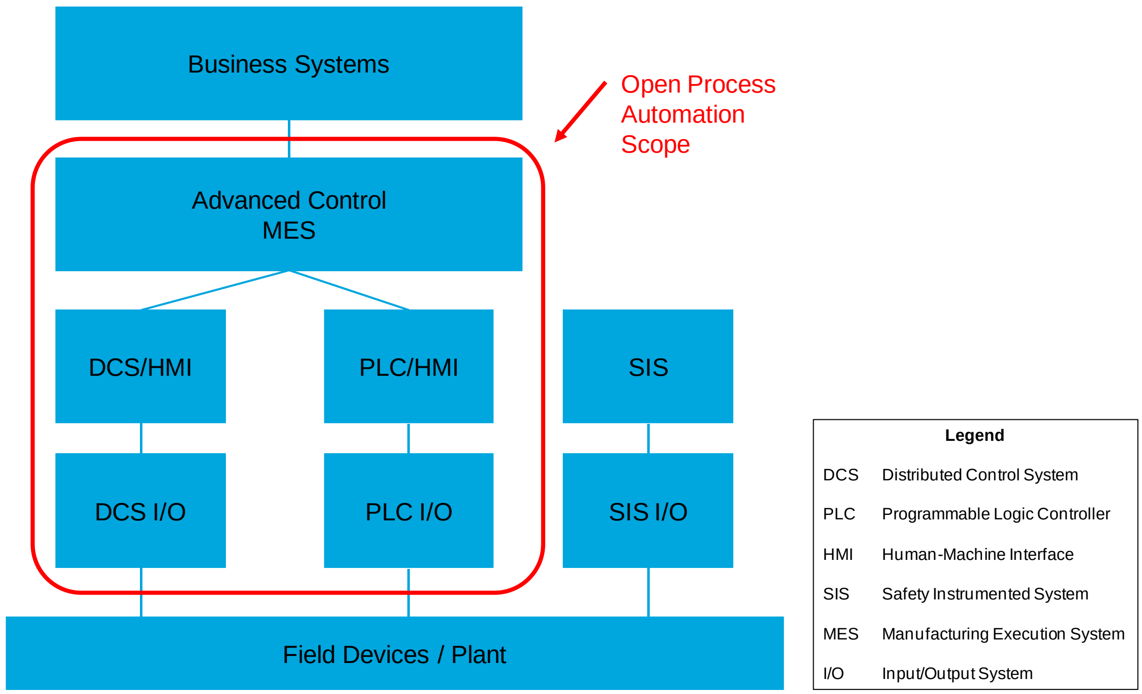


**Figure 2: Open Process Automation Scope**

The Forum will focus on the standards and business practices required to achieve interoperability, modularity, and portability of the software and hardware components comprising the process control layers shown in Figure 2. The business advantage of these attributes is better, more economical reuse of components, more ability to apply innovative technology, and enhanced management of obsolescence. The Forum will leverage the ISA95 Functional Hierarchy to discover functional boundaries where interoperability, modularity, and portability can be specified. Some examples of functional boundaries are:

- The Input/Output (I/O) layer, the control functions, and the Human-Machine Interface (HMI) layer typical of Distributed Control Systems (DCS), and Programmable Logic Controllers (PLC)
- The Advanced Control Layer (Level 3), Manufacturing Execution Systems (MES), and interfaces with the business systems

The Forum will standardize interfaces between both functional software components and hardware components. These components can reside both within and between processing elements of control systems. For software components, this is accomplished by defining a set of Application Programming Interfaces (APIs) and data models. For hardware components, this is accomplished by standardizing form, fit, and functional parameters. These standardized interfaces will enable fit-for-purpose control systems to be implemented and sustained for a wide range of process control applications.

It is the responsibility of the end user to specify requirements for performance, safety, and security. It is the responsibility of the System Integrator (SI) to provide specific fit-for-purpose implementations that meet those end-user requirements for performance, safety, and security. Depending on the end user's preference, it is the responsibility of the service provider or the SI to provide ongoing sustainment services to maintain or improve the performance, safety, and security of the implemented system.

Out of scope for this Forum are business systems and communication protocols between the I/O and field instruments. The Forum also decided that Safety Instrumented Systems (SIS) are out of scope because there must be separate and independent combinations of sensors, logic solvers, and final elements in order to achieve required safety integrity levels per the ISA84 and IEC 61511 standards.

Figure 3 illustrates a reference architecture for an Open Process Automation Standard conformant system. The Forum's intent is to enable a truly distributed control execution environment for best-of-breed manufacturing operations and control solutions that support zero downtime updates, continual performance improvement, and seamless integration of solutions from multiple vendors.

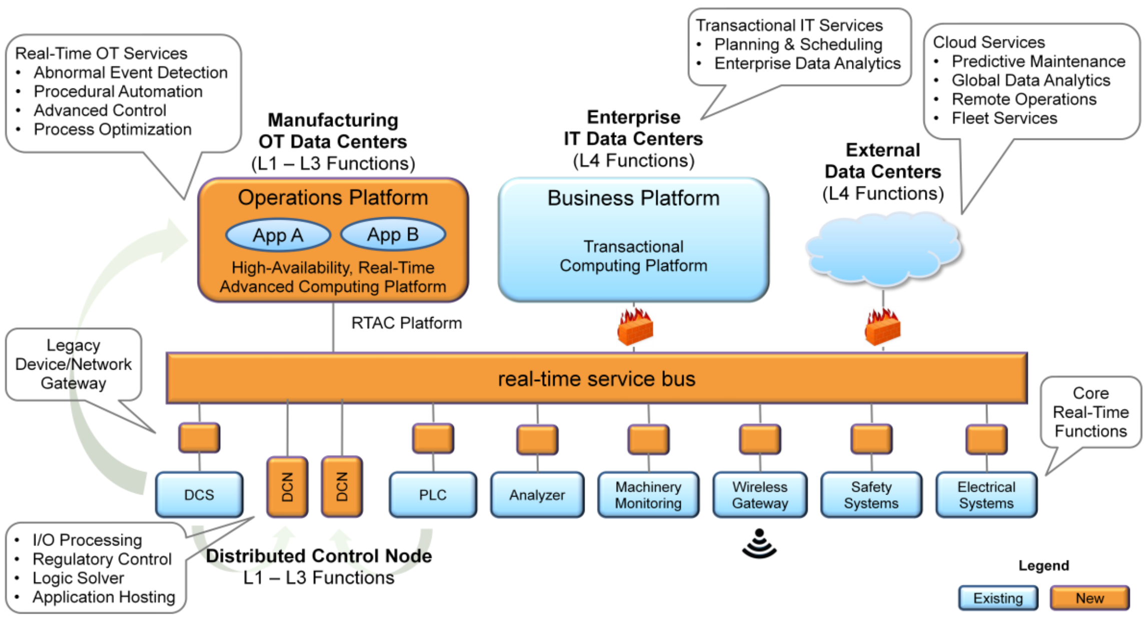


**Figure 3: Open Systems Architecture Vision**

## 2.2 Vision and Mission

### 2.2.1 Vision

The Forum is composed of a broad group of end users, product suppliers, SIs, and academics. The vision of the Forum is to create or adopt a technologically-appropriate, Open Process Automation architecture and specifications along with business guidance for its adoption and use. This will result in a standards-based, open, interoperable, secure process automation architecture – and instances thereof – that has the following characteristics:

- Easily integrates best-in-class components to provide timely access to leading-edge performance
- Employs an adaptive, intrinsic security model
- Enables the procurement and modular integration of certified conformant components into systems that are fit-for-purpose to satisfy end users' needs

- Accelerates the development of applications with an open configuration and information model
- Is commercially available and applicable to multiple industry sectors
- Protects suppliers' Intellectual Property (IP) within conformant components
- Enables portability and preservation of end users' application software
- Significantly reduces the difficulty of future replacements and the lifecycle cost of systems
- Expands suppliers' and SIs' market opportunities for conformant solutions and services
- Promotes innovation and value creation

### 2.2.2 Mission

The mission of the Forum is to realize the vision by:

- Developing, publishing, and evolving a realistic open architecture and specifications that will be supported by industry end users, suppliers, and integrators
- Providing the forum for end users, suppliers, and integrators to work together to develop and consolidate the open standards, best practices, and models necessary to realize this vision
- Operating in a fair, neutral, and open manner
- Enabling and sustaining the open architecture and specifications by a robust conformance certification program
- Ensuring the appropriate technical resources and management commitment are in place for the successful completion of the Forum's work
- Providing a focused business track to produce a framework that ultimately produces products and services that are commercially successful for end users, suppliers, and integrators
- Integrating existing and emerging industry standards and systems whenever possible
- Lowering the barriers for entry to innovation and value creation

## 2.3 Forum Overview

The Forum organization is shown in Figure 4 and is divided into two main tracks:

- Business Track

  Responsible for understanding and identifying the business impact of the Open Process Automation approach on all key stakeholders, including end users, suppliers, and systems integrators. The Business Working Group will study the existing business models of each of the key stakeholders and how these business models will be impacted by open systems.

- Technical Track

  Responsible for identifying and specifying the open standards that will be used to create an open and interoperable control system. The Technical Working Group will survey existing standards to find those that are appropriate for the new Open Process Automation Standard and to create a new standard when one does not currently exist.

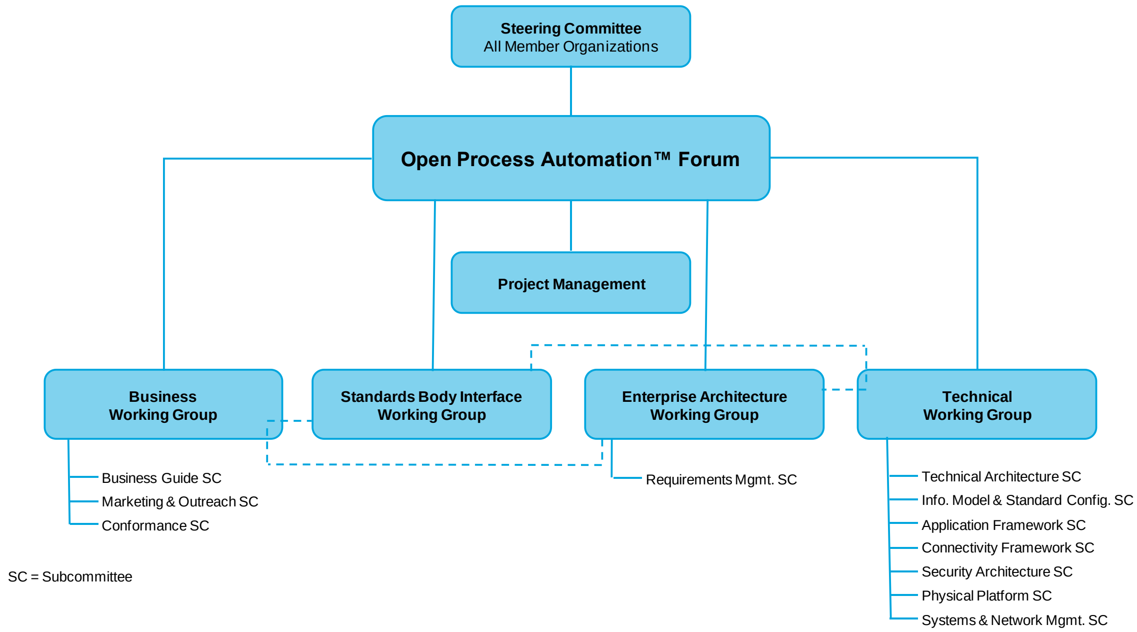


**Figure 4: Open Process Automation Forum Organization**

There will be various subcommittees formed for more specific functions as needed. Current subcommittees are shown in Figure 4.

Further details of the Working Group functions are provided in the following sections.

### 2.3.1 Business Working Group

#### Purpose

The Business Working Group (BWG) seeks to develop, implement, and communicate industry-wide business models that incorporate the Forum vision and mission of developing open standards, reference architectures and implementations, guidance materials, conformance criteria, and a certification mechanism for the process automation industry.

The BWG is organized into three subcommittees:

- The Business Guide Subcommittee will utilize inputs from users, suppliers, and other market participants' business scenarios to guide the selection and implementation of the standards, such that the result is advantageous and attractive to all segments of the industry
- The Marketing and Outreach Subcommittee will publicize the Open Process Automation project within the industry and ultimately work to attract the active participation of the broadest possible base of industry participants including users, integrators, and suppliers

- The Conformance Subcommittee will develop the processes and procedures for the certification of conformance of the developed products to the Open Process Automation Standard

The BWG will promote the adoption and use of the Open Process Automation Standard throughout the industry to ensure it is adopted broadly and rapidly and to the benefit of all industry participants.

#### Strategy

- Utilize experience from The Open Group FACE Consortium where appropriate to develop a clear path towards broad and rapid adoption of the Open Process Automation standards and practices
- Seek alignment among various industry segments on viable business strategies that will address both user requirements while providing attractive business model options to suppliers and integrators
- Develop brochures and other materials for active outreach at key industry conferences as well as continue direct, targeted outreach to industry participants
- Coordinate efforts with the TWG to ensure that standards development and deployment are compatible with viable business models

### 2.3.2 Technical Working Group

#### Purpose

The charter of the Technical Working Group (TWG) is to work to fulfill the Forum vision and mission by identifying open standards where such exist, defining standards that do not yet exist, and providing guidance for using these standards leading to specification of a rigorously-defined, open, interoperable, secure automation architecture.

#### Strategy

The TWG will achieve this charter by serving as the technical body responsible for all Forum technical aspects. The TWG defines the Standard for the Open Process Automation reference architecture, provides guidance supporting the use of the Standard, develops additional support documentation and tools, provides implementation guidance, and defines criteria for certifying conformance to standards produced by the Forum.

### 2.3.3 Enterprise Architecture Working Group

#### Purpose

The purpose of the Enterprise Architecture Working Group (EAWG) is to document a clear picture of the target Open Process Automation architecture for Forum member viewpoints and concerns. The EAWG will guide the development of and manage the lifecycle of architectural artifacts (requirements, views, models, definitions, lists, etc.) that describe the target architecture to meet the requirements from the BWG and to be used to define the new Standard.

**Strategy**

- Record and manage the Open Process Automation requirements and use-cases, tracing them to the Open Process Automation ecosystem and technical specifications
- Use the existing Enterprise Architecture method (e.g., the TOGAF® standard) as a starting set of artifacts (views) and general Enterprise Architecture artifact sequencing (e.g., vision, scope, etc.)
- Provide guidance to other Working Groups in the development of models to maintain a consistent architecture; the models will be created as their need is identified
- Ensure Forum members have learned enough of the TOGAF method/artifacts to develop artifacts, and augment with expertise from The Open Group and other members as needed
- Adopt best practices from the FACE Consortium's Enterprise Architecture experience on practical issues and methods to succeed
- Develop artifacts using commonly available desktop software and/or open software
- Empower BWG and TWG members (making up the EA Artifact Development Team) to submit artifacts to the Conformity and Librarian team for approval
- Establish a Conformity and Librarian team to set model standards, review all submissions, and manage the content repository, with the team approving artifacts as per The Open Group methods
- Regularly prioritize/track developments within the EAWG and publish the information to all Forum members

## 2.4 Misconceptions about the Open Process Automation Approach

**The Open Process Automation approach adds a layer of complexity without adding sufficient value (Are open architectures really necessary?)**

An Open Process Automation approach is designed to be extensible, using industry standard interfaces that ensure changes can be made when the need arises. There will be additional systems engineering work at the start of a project to ensure the key elements in the system conform to an Open Process Automation approach. This investment enables lower TCO over the life of the facility by allowing newer, more cost-effective technology to be incorporated, thus continuing to increase a plant's productivity. The majority of a system's TCO is attributed to its integration and maintenance. Because the facilities being developed will be in operation for decades, the additional Open Process Automation effort will enable modifications for new capabilities or replacements to be installed much more expeditiously and cost effectively.

**Hardware standards will limit innovation, not encourage it**
**(Where's the value in open standards? How do vendors differentiate themselves with open standards? Aren't distributed control systems already a commodity?)**

The envisioned Open Process Automation hardware standards do not define the functionality or capability of modules, just how the modules must interface and work together. For example, USB does not define what USB connected devices do; instead, it provides a standard for how they plug in and interface. Open Process Automation hardware standards will define the physical and electrical interfaces, the environment in which they must operate, security considerations, and any other salient attributes required to effectively operate in the targeted system.

Suppliers innovate within the hardware standards by providing a better solution for the functionality required. The key is that when a different company comes up with a better mousetrap that is also designed to the standard, it can be removed from the first module and replaced with the new module, thus improving overall system performance.

#### The Open Process Automation approach is only for new installations and cannot be applied to existing ones

The Open Process Automation approach includes gateways and interfaces to existing systems, allowing mixed systems. While the native capability of new Open Process Automation system elements would not be available on legacy systems, legacy system information can be shared with appropriately-defined gateways. Legacy systems can thus be incrementally upgraded through the use of gateway modules that allow connectivity between proprietary networks and the Open Process Automation network. This transition between legacy and new systems also lets the user take advantage of more modern applications through a compliant Open Process Automation software infrastructure and transitions legacy applications to the Open Process Automation infrastructure.

#### Open Process Automation systems will cost more because of the need for open interfaces

Cost today is often driven by the size of each vendor's market. As the market moves to open systems, there is usually increased competition, lower end-user costs, and lower production costs due to economies of scale.

#### The experience of the FACE Consortium with one buyer cannot be applied to the Open Process Automation approach that involves many buyers from several industry sectors

This important distinction is acknowledged. Recruiting a critical mass of end-user companies into the Forum is a key objective.

The three distinguishing characteristics of The Open Group work processes are:

1. Establish the business framework
2. Establish a standard of standards
3. Provide early availability of the conformance certification

The processes will result in faster progress than other Standards Development Organizations have made. This pace will incentivize the active participation of both end-user and supplier companies because of faster time-to-value and time-to-revenue.

#### Accountability for the performance of an Open Process Automation system cannot be assured

At present, control SI companies deliver working automation systems to end-user companies with contracts that enforce their accountability for system performance.

Given the Open Process Automation Standard conformance certification processes, control SI companies will be better equipped to engineer, assemble, configure, and commission systems for end-user companies relative to current practices. Similarly, control SI or service provider companies will be better equipped to provide ongoing sustainment to maintain and improve end-user systems relative to current practices.

#### It will be a decade before an Open Process Automation conformant system is available

The Forum will establish the standards that enable multiple suppliers to develop conformant component technologies. This is in contrast to the current market, which is characterized by serial development of whole systems by each supplier. Parallel development of components complemented by conformance certification processes and a robust system integration ecosystem will decrease the time-to-market compared to current practices.

#### Hazardous material industries (e.g., oil and gas) will delay their implementation of Open Process Automation systems until it has been proven in other industries

"Never underestimate the conservatism of the oil and gas industry." While this statement is true, it does not mean the benefits of the Open Process Automation approach are not applicable to other industries that are not as conservative. Successful implementation and operation of industrial automation facilities using the Open Process Automation approach will be a catalyst for acceptance and use in other industries.

# 3 Business Scenarios

The following use-cases and business scenarios illustrate some of the limitations of current state industrial process control technology and highlight the potential of the Open Process Automation approach.

## 3.1 Biopharmaceutical Industrial Control System Integration and Qualification

One of the goals for the biopharmaceutical industry in developing open standards is faster time-to-market for new drugs and medicines. The economics of the biopharmaceutical industry rewards the company that is first to market with a medicine or therapy, thus driving the need for companies to quickly build and qualify a plant to manufacture the product. At the same time, biopharmaceutical companies want to delay deployment of capital until the latest possible stage in clinical trials, during which time a candidate may fail, to better assure a return on deployed capital. These two factors result in a compressed timeline for building and qualifying a production facility. For a facility that employs a high degree of automation, the development and qualification of the automation system is the rate-limiting step in the overall readiness of the facility to manufacture. By simplifying the integration via a standard process control architecture, biopharmaceutical companies hope to shorten the project schedule for building and qualifying a plant for manufacturing medicines and therapies.

Given these factors, biopharmaceutical companies are seeking seamless interoperability between control systems from different vendors to reduce the time for engineering development and qualification. Modern factories are composed of fully automated process skids for unit operations (e.g., fermentation, centrifugation, and chromatography) from Original Equipment Manufacturer (OEM) vendors. The automation equipment is supplied by any number of process control vendors in the industry. For data collection, analysis, and reporting purposes, companies will integrate the various process skids to systems with ISA95 Layer 2 and Layer 3 functionality.

Biopharmaceutical companies are often compelled to use the control system offered by the skid or OEM vendor. Re-engineering the control system to a preferred vendor’s system is expensive and time-consuming. Given the need to get to market as quickly as possible, companies will settle for the skid/OEM vendor’s offering and then develop custom interfaces to a preferred control system that runs the overall facility. A standard, open process control architecture, as proposed by the Forum, would facilitate the connection of disparate automation equipment at the skid level to the higher-level control system. The inclusion of a universal data bus would allow seamless integration between systems provided by different vendors. Once in place, a control system developed under the standard architecture could be upgraded with minimal or zero downtime.

## 3.2 Mining and Metals

One of the goals of the mining and metals industry is to deliver minerals to the market at the lowest possible cost per unit. A major lever of lowering unit costs is maximizing throughput within the installed capacity of the supply chain. Miners typically use fixed plant equipment to transform raw materials from the ore body into a saleable product. Depending upon the commodity and nature of processing required, this can include crushing/milling, performing physical and/or chemical separation, conveying, stacking, reclaiming, sampling, and loading transport (rail, truck, ship).

Often, large, cumbersome, high cost-to-operate industrial equipment is used to execute these processes. As such, process control technology plays an important role in the operation and automation of these processes. Challenges in integrating best-in-class process control technologies from multiple vendors restrict a mining operator's ability to optimize throughput across the entire plant. Mining, like other industries, suffers from high costs to implement, upgrade, integrate, and expand process control technology due to today's lack of Open Process Automation standards.

Another major challenge in the mining industry is the inability to provide model-driven, event-based data from process control systems to business systems, including Manufacturing Operations Management (MOM) systems and MES, as well as big data and analytics platforms. The typical approach of passing time series data through historians to other business systems limits the benefits that can be achieved from these other technologies, which can include further value chain optimization and a greater return on investment through value chain improvement insights and initiatives. Furthermore, with the advent of the Industrial Internet of Things (IIoT), mining companies are seeking to implement workarounds by implementing additional network infrastructure to support IIoT data being fed to these systems.

The mining and metals industry is also moving towards autonomous mobile plant equipment for drilling, digging, dozing, and loading and hauling processes. The mining and metals industry is recognized for advancing autonomous mobile equipment, but the approach has largely been without sufficient technical consideration for modularity and interoperability. As such, many mining companies that have implemented autonomous mobile equipment are now finding the same issues are present with traditional fixed plant process control equipment and their supporting technologies.

Opportunities for the mining and metals industry include:

- Improved production throughput of units per hour (e.g., tons per hour):
  - Reduced plant downtime by utilizing online upgrades and expansions
  - Optimized process control functions, as interoperability enables best-of-breed process control hardware and software components to be utilized, which will enable improved plant optimization, leading to improved throughput and reduced unit costs
  - Optimized MOM/MES levels
  - Improved big data feeds and analytics platforms (e.g., predictive maintenance and better equipment and personnel scheduling will reduce bottlenecks)
- Lower production costs:
  - Lower cost, time, and effort to integrate, configure, and implement process control technology
  - Lower network costs through reduced capital from less duplication of networks for IIoT

— Defer or avoid capital spending on process control technology

- Improved cybersecurity through intrinsic security model across IT/OT

## 3.3 Specialty Chemicals and Semiconductors

The semiconductor industry is charged with deploying new functionality as quickly as possible in the marketplace. It is also extremely risk-averse, given the proliferation of consumer electronics over the past decade. Any threat of a recall is to be avoided at all costs. Product traceability is also more valuable now than ever before.

As specialty chemical suppliers to this industry, there are unique challenges in facility lifecycle management. Facilities must be flexible enough to rapidly deploy new product formulations, yet assure quality control and traceability at all times. Each new formulation must undergo a rigorous qualification process, involving lot segregation, sampling, and customer testing. This process often lasts from six months to a year before standard, saleable product can be declared. Such lengthy and involved processes reduce the return on capital investment, driving the use of multi-purpose batch plants that make heavy use of OEM skids to reduce costs.

Such challenges also create impediments to process control system upgrades. Skid integration is one issue, as described in the biopharmaceutical use-case. But that is typically a one-time, though significant, cost to get a process up and running. A larger cost is almost always incurred in the requalification process, should any significant process changes be made. The definition of "significant change" is rather nebulous, but typically includes most process and procedural control changes as well as formulation changes. Thus, there is little incentive for continuous improvement, unless significantly better quality or higher capacity can be achieved. Process control system upgrades typically do not cross either of those hurdles, particularly when the application layer needs to be rewritten (which is always true when switching suppliers today).

Adoption of a portable, reusable, standardized application layer as proposed by the Forum would have huge benefits for this industry, enabling specialty chemical suppliers to modernize their systems without the costly requalification process. It would also facilitate sharing of continuous improvements across facilities that use different process automation system suppliers, as the improvement would only need to be demonstrated once.

## 3.4 Pulp and Paper

The pulp and paper industry includes almost every component of other continuous process industries, including some batch processes. It contains:

- Power and recovery boilers
- Steam turbine generators
- Heavy tree processing, including chipping, screening, and material handling equipment
- Chemical recovery and chemical plants
- Cooking vessels
- Water and sewage treatment facilities

- Large cooking and bleaching processes
- Evaporators
- Paper machines, roll handling, and varieties of converting equipment

The pulp and paper industry uses renewable resources in the form of trees and converts them to many products used for commercial, packaging, and consumer markets. Most of the energy is from internally generated bio fuels. There are also valuable by-products produced which are used as feed stock by other industries.

Large, costly equipment – often made from exotic corrosion resistant alloys – is used to run these processes. Process control technology plays an important role in the operation and automation of these plants. A primary challenge of the paper industry is that the product must be uniform in quality with minimum variability as it comes out of the machines, since there is no possibility of correcting, blending, and remixing to the desired specification once it is embedded in the sheet. Therefore, the process must be optimized with feed forward modeling capability across the entire plant. Pulp and paper, like other industries, is challenged by the high costs of implementing, upgrading, integrating, and expanding process control systems due to the lack of open standards for process automation.

Further improvements will be realized in the future by implementing IIoT. This will require expanded network infrastructure to support additional IIoT data being fed to these Open Process Automation systems delivering reliability diagnostics and failure predictions for its large number of heavy rotating machines.

Opportunities for value from the Open Process Automation approach in the pulp and paper industry include:

- Improved production throughput (e.g., tons per day):
  — Reduced plant downtime by utilizing new reliability data and analytics for prediction and prevention of failures
  — Optimized process control functions, as interoperability enables utilization of best-of-breed process control hardware and software components thereby leading to improved throughput, quality, and reduced waste
- Lower production costs:
  — Lower cost, time, and effort to integrate, configure, and implement process control technology
  — Lower network costs through more efficient data transport
  — Minimized future capital spending on process control technology by utilizing systems that can be continuously upgraded
- Improved cybersecurity through intrinsic security model across IT/OT

## 3.5 Online Cutover for Industrial Control System Upgrade

#### Justification

Due to the capital costs involved, justification for an upgrade almost always comes down to rising maintenance and engineering costs due to equipment age near the tail end of the "bathtub" curve. Increased functionality typically has not been a driver.

#### Strategy

An online cutover strategy is advantageous in larger plants for the following reasons:

- Avoids loss of revenue due to downtime
- Easier to "line out" loops when done one at a time

  Large-plant start-ups are often more difficult when a "big bang" approach is used due to all the loops being brought online in the new system at once.

- Another significant benefit for the online cutover is the schedule flexibility it provides given the long time between outages in many facilities (i.e., it decouples project schedule from the turnaround schedule)

An offline cutover strategy may be used in smaller plants or smaller supporting units in a large plant due to:

- The project typically takes a shorter time to complete and the cost savings could offset the loss of revenue due to downtime
- Risk associated with trips during cutover

  For example, if a trip results in an environmental "recordable", the online strategy may not be worth the reputation hit.

#### Online Cutover Process

A phased approach is typically used.

For example, the first phase will install a new HMI layer and "gateway" so the new HMIs can be used with the old DCS. A training system/simulator is used to train the operators on the new HMI layer. Once the training is complete, the operators "cutover" to the new HMI layer, and the old HMI layer is decommissioned. This can be done across multiple units or an entire plant before the next phase. One of the challenges is that two sets of graphics may be needed on the new HMIs. One set references data from the old DCS. The second set will be developed and used with the new controllers in a subsequent phase. A key component of this strategy is eliminating any confusion for the operators during the cutover, over which graphics are "live" and used for control.

The second phase involves setting up the application software for the new controllers along with the HMI graphics to be used with them. One strategy is to mimic the old application logic "as-is" and not take advantage of new features that may be available in the new DCS. However, it is often better to take advantage of the new features that could save (or make) money in the long run and offset the additional setup costs. Once the application logic and HMI graphics have been developed in the new DCS, the next phase can begin.

The third phase involves staging the new controllers in the various equipment areas. Space can be a challenge because both the old and new controllers must run in parallel. The next step is moving wires from the old terminal blocks to the new terminal blocks, one loop at a time. As each loop is migrated, the loop can be tuned, if necessary, in coordination with the operators. Once all the I/O for an old controller is migrated, the old controller can be decommissioned. One of the challenges with lifting wires is ensuring the signal to valves is maintained. Several techniques can be used, such as process bypassing, manual valve control, and mechanical blocking, but using an "electrical loop take over" tool is typically preferred because it has features, such as offset control, the other techniques might not have.

**Where is the cost located?**

- Engineering man hours to develop HMI graphics and test
- Engineering man hours to migrate application software and test
- Staging new equipment and related wiring to prepare for I/O cutover, which may require some creativity due to space constraints
- Process of cutting over one loop at a time is very time-consuming and expensive

**How can a new architecture address these challenges?**

- Standardize the HMI graphics layer so it can be upgraded independently from the underlying controllers and I/O
- Eliminate the need for two sets of graphics (in above scenario)
- Standardize APIs
- Resolve the issue of staging the new DCS controllers along with the old controllers (space issues) during the cutover
- Standardize I/O subsystems so controllers can be upgraded independently from the I/O
- A new architecture should reduce the risk of online cutovers

  This can be accomplished, for example, by making verification tools available that help ensure the system is free of configuration or other types of errors.

## 3.6 Offline Cutover for Industrial Control System Upgrade (Continuous Process)

Some end users prefer to migrate control systems for continuous process plants during shutdowns, particularly when I/O cards are involved. Migrations are typically carried out during turnarounds, which typically occur at varying frequencies between one and seven years, depending upon the nature of the process. To keep productivity high, the overall turnaround time needs to be as short as possible, and the DCS is required to operate (e.g., cleaning procedures, monitoring temperatures, connecting new devices, etc.) during most of the turnaround. As a consequence, there are critical requirements for the DCS migration, especially when loops need to be opened. Whenever possible, the new system is pre-installed in the switch room so that only wiring needs to be changed. To prevent errors in the startup phase, functionalities should be tested in advance, and a loop check conducted to ensure wires are properly connected. This loop check typically determines the migration time and, hence, is carried out in shift systems. On the other hand, the loop check activities may be in conflict with other turnaround activities, making thorough planning necessary. For some legacy systems, certain foundational changes require the entire DCS to be powered down and brought back up one node at a time. The only way to safely do this is to have the system de-inventoried in advance of the outage.

#### Shortcomings of Current Technologies

- Time-consuming and expensive loop checks
- Extensive logic tests of re-engineered functionalities
- Cost for re-drawing graphics
- Vertical integration or other interfaces may require the migration effort to start from scratch
- Potential personnel exposure issues associated with the need for de-inventory of the process if loss of DCS view occurs

#### Potential Improvements

- Standardized plugs to speed up cutover time
- Interoperability of systems might allow staged migration of plant sections without loss of control-room efficiency (i.e., a different Distributed Control Node (DCN) in the same control system)
- Reusable CPU configuration based on a set of standards with vendor-independent exchangeability to reduce testing time in advance of migration
- A kind of “plug-and-play” for field devices
- Reusable graphics format
- Standard interfaces to other applications, or based on an “app store” platform
- More modern, open systems will allow all changes to be made without loss of view, thus eliminating the workplace exposure issues

## 3.7 Offline Cutover for Industrial Control System Upgrade (Batch Process)

DCS migrations in batch chemical plants are unique compared to continuous plants. While the typical batch plant has more opportunity to provide a cutover window, online migrations are extremely difficult due to the required interactions between the different process vessels and equipment. This leads to a scenario for which the entire plant or logical sections are migrated in a single phase. In addition to the typical requirements for loop checks and interlock verifications, sequence/logic verifications are critical. This is especially important when migrating to a CPU that runs different programming languages (different vendor or new direction within a vendor's product line) or implementing the ISA S88 Batch Control approach.

The existing systems provide basic, at best self-documenting capabilities. Subtle changes and "tweaks" used to ensure product quality at optimum production rates are rarely captured adequately in the control system documentation, Standard Operating Procedures (SOPs), control narratives, etc. This situation puts an extreme burden on the project team to identify and communicate the "current situation" to the migration team. Failure to do so often leads to plants running at reduced capacity while expensive efforts are required to make the necessary corrections after the plant is running.

For batch plants, decision-makers may choose to delay migrations or limit their scope due to the time and effort required for loop checks, interlock and error handling testing, and sequence testing, as well as the internal resources needed to support migrations. The migration might be limited to a single vendor's equipment or stipulate no changes to I/O. However, the desire to avoid impacting short-term business might sacrifice long-term benefits or interfere with the plant's strategic direction.

#### Shortcomings of Current Technologies

- Time-consuming and expensive loop checks
- Cost for redrawing graphics
- Cost to convert control loops to new system (analog signals, control loops, on/off valves, interlocks, etc.)
- Legacy systems with non-standardized batch execution logic, leading to extensive documentation efforts
- Modern systems supporting S88 Batch Control may still lack direct translation from vendor to vendor
- Extensive logic tests of re-engineered functionalities
- The possible need to start from scratch for S88 implementation or to support vertical integration

#### Potential Improvements

- Standardized plugs speed up cutover time
- Interoperability of subsystems may allow staged migration of plant sections without loss of control-room efficiency (i.e., a different DCN in the same control system)
- Reusable CPU configuration, based on a set of standards with vendor-independent exchangeability, reduces testing time in advance of migration

  Export to standardized template for import based on standardized template.

- Export/import of Sequential Function Charts (SFCs), S88 Batch Control operations, and phases

  An example would be export of SFCs to Excel® for documentation as well as preparation to import into a new system.

- Reusable graphics format or enhanced migration of existing graphics (most have an export to text feature)
- Standard interfaces to other applications, like layering of an S88 Batch Control package with standardized hooks into a basic control system
- Standardized S88 Batch Control support for vertical integration

# 4 Roles in the Open Process Automation Business Ecosystem

## 4.1 Process Control Automation Business Ecosystem

The roles shown in Figure 5 of the Open Process Automation business ecosystem are end users and suppliers who are responsible for the successful procurement, design, development, integration, deployment, operation, and sustainment of Open Process Automation systems. The ecosystem is abstracted on a role basis. Role abstraction is the business concept of creating and defining points of loose-coupling among the Forum suppliers and end users. Loose-coupling is the concept of utilizing open, published, and certified contractual and technical standards, practices, and procedures that facilitate the abstraction of the individual businesses that contribute to the creation of the automation system.

These suppliers provide the systems, subsystems, hardware/software components, and services for the Open Process Automation conformant automation systems. The business role abstraction under the Open Process Automation approach enables the ability of a supplier to be joint or severable with respect to the subsystem, software, hardware, and service provider roles. Traditionally, the role to provide an automation system has been performed by a single business supplier. Under Open Process Automation business practices, the roles of the suppliers can be performed by multiple businesses. The Open Process Automation business approach allows for the traditional approach (i.e., one supplier) of providing the systems, subsystems, and components conforming to the Open Process Automation Standard. The concept of role-based abstraction allows for multiple, distinct suppliers to provide systems, subsystems, and components on a competitive, best value basis to the respective procuring stakeholder up to and including the end user. The business abstraction provides a method to rapidly replace suppliers for cost, functionality, performance, and obsolescence issues and provides the ability to rapidly assimilate new capability into existing Open Process Automation conformant systems.

Because they are dynamic, it must be noted that these roles can evolve over time. For example, when end users incorporate a hardware or software component into the system using in-house resources, they assume the additional role of the SI. The system performance assurance and ensuing liability will transfer from the original SI to the end user in this scenario.

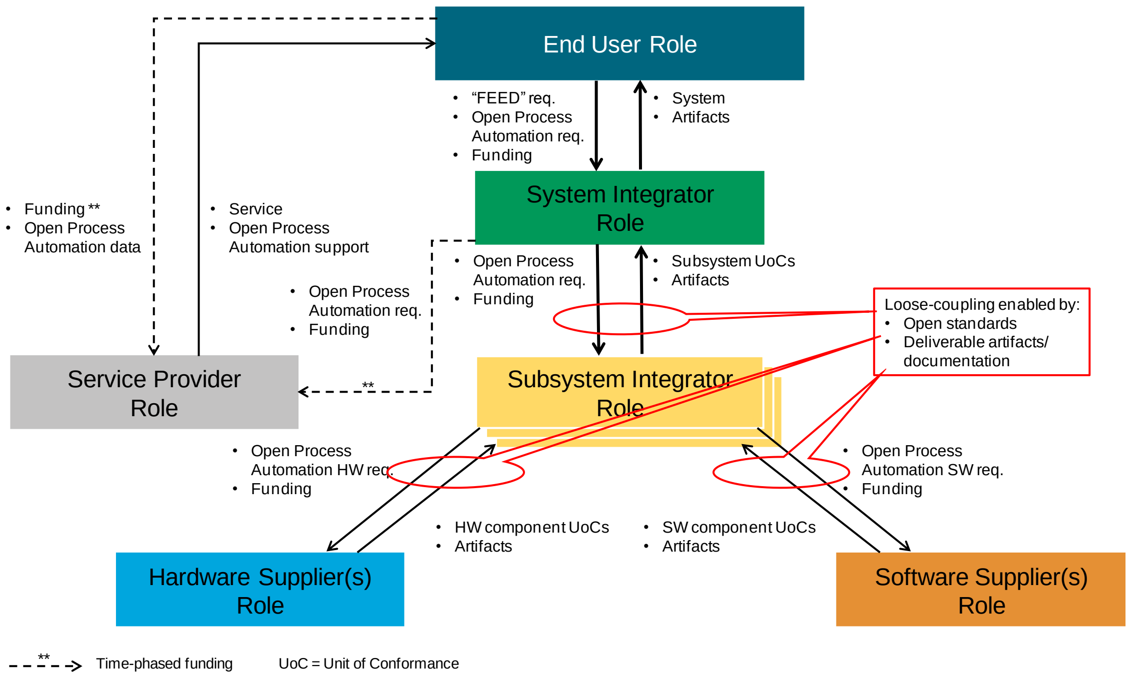


**Figure 5: Open Process Automation Business Ecosystem Roles**

To facilitate the procurement of Open Process Automation conformant systems, subsystems, and components, Open Process Automation business practices mandate the Open Process Automation Standard as part of the requirements flow between the roles. These Open Process Automation requirements are in addition to the functional requirements. The supplier of systems, subsystems, and components under the Open Process Automation Standard must provide specific Open Process Automation defined artifacts that prove hardware and software conformance to the Standard in addition to functional conformance to the requirements.

### 4.1.1 End User Role

#### Current State

Today, process control automation system hardware and software from different vendors is not interoperable. Upgrading hardware can render layered software inoperable, requiring rewrites, and thereby making upgrades more time-consuming and expensive. For new projects, standardizing on a DCS vendor can introduce several other subsystem dependencies that must be addressed from an integration perspective. Identifying the requirements for these dependencies and completing the implementation can be quite expensive. This is especially true for new manufacturing locations. In a typical plant, there are more than ten subsystems (e.g., PLC) from package vendors and module suppliers that must be integrated into the main DCS. In addition, algorithms for custom automation, control, and optimization strategies cannot be ported easily from one vendor system to another.

Due to a lack of standards and non-interoperable components, maintenance expertise in one vendor system is not transferable to another vendor system, which drives up maintenance costs. Furthermore, current integrated and inflexible system designs often mandate the shutdown of an entire plant during maintenance or critical hardware upgrade unless redundancy is built-in. The downtime related to a DCS upgrade can be expensive to the business. In addition, the inability to manage at a single valve level often requires moving wiring, which multiplies the overall costs.

HMI design and the operator user experience are different from one system to the other, depending on the DCS vendor. Even communication from the HMI to the controllers in a system is proprietary. Therefore, training requirements for the operations staff in HMI and plant emergency handling vary, depending on the specific DCS and HMI being used.

Software compatibility is another area of concern. Third-party application software can only be operated on servers at ISA95 Level 3. This restricts data access to users at a specific control system security layer. Even remote operations setup requirements are different for each vendor. Overall, the Capital Expenditure (CAPEX) required to set up and operate process automation solutions limits the number of projects (or installations) that can operate profitably. The time required to upgrade the DCS, as well as the extended costs, are limiting factors in justifying capital approval for migration.

An Engineering, Procurement, and Construction (EPC) contractor can take on the role of the end user during the initial procurement and commission of the system. This is a transitory phase after which the system owner assumes the end-user role after the plant is in operation.

### Future State

The Open Process Automation initiative can make capability in one vendor system transferable to another vendor system. With this portability, end users can improve their resource utilization. As controllers become simplified and are responsible for one or just a few loops, it will be possible to avoid shutting down an entire plant for maintenance. Instead, only a part of a process will be shut down. This approach would support more frequent, or even continual, update and maintenance. Algorithms and application configurations can be transferred to new hardware and software after upgrades without the need for major application and interface rewrites. System availability will be higher due to the simplified process and the use of virtual computer equipment. Overall, the Open Process Automation approach can reduce the maintenance and operations cost for end users.

With the standards supported under the Open Process Automation approach, it is possible to simulate entire processes without restrictions due to proprietary interfaces. This flexibility, combined with the ability to run supervisory software applications at ISA95 Level 1 (e.g., a Model Predictive Control (MPC) system), improved data access, and a distributed approach, can lead to more creative solutions from suppliers that are implemented at ISA95 Level 1. Open Process Automation modular manufacturing units and the ability to choose the best-in-class hardware and software can become economically viable, enabling hardware and software to scale-out as the business grows.

In addition, the Open Process Automation approach can greatly simplify remote monitoring and operation by standardizing hardware and software interfaces, and building intrinsic security into all layers of the control system.

### Value Proposition in Future State

With the Open Process Automation approach, the execution model can be much more flexible for end users. For example, an end user can engage an EPC contractor and work with an Open Process Automation SI to select and integrate hardware. The end user can then work with service providers to configure the application software and HMI to design and implement custom strategies for control, automation, and optimization as well as receive operations training from the service providers. As a result, the SI and service provider roles could be uncoupled. This would help both end users and vendors by expanding their options for services in the marketplace while creating a larger market for the integrator and service provider services.

End users can benefit from access to a large variety of technologies and solutions in the marketplace that can be procured and used without having to change their distributed control systems. In addition, end users can also innovate and provide standards-based software to the marketplace.

#### SWOT Analysis for the Future State

The Open Process Automation approach can lower barriers to entry and enable innovation to thrive in the hardware, software, and services marketplace, expanding the overall market for process control and automation solutions. This transition will increase the options in the marketplace for the end user while standardizing operations and maintenance processes. The expected increase in competition should lower TCO.

Transitioning to the Open Process Automation ecosystem could distract end-user resources from their regular operational responsibilities. Additionally, executing Open Process Automation strategies, while continuing to maintain end-to-end performance of Open Process Automation systems, might be another challenge for end-user organizations.

Widespread industry recognition, support, and adoption of the Open Process Automation Standard will require commitment from end users and participating suppliers. Without that commitment, the Standard may stagnate. Also, early adopters may incur new costs related to the Open Process Automation learning curve and in resolving issues. Consequently, they may opt not to participate in the Open Process Automation ecosystem. There is potential for a legal dispute, such as determining who is at fault when an Open Process Automation part causes failures and multiple vendors are involved.

### 4.1.2 System Integrator Role

#### Current State

The closest we have to an Open Process Automation integrator today is existing project systems integrators, who integrate equipment from multiple vendors using hardware and custom software elements, as well as assist in the development of control system code, system configuration files, and system database information. Today, SIs have a main business relationship with a primary hardware supplier, either as a group within the hardware supplier company or as a separate entity that is certified by the hardware supplier. Fewer SIs have expertise with all competing control system hardware (DCS, PLC) suppliers, which limits the availability of appropriately trained and experienced SIs when the hardware is selected separately.

#### Future State

In the future with the Open Process Automation approach, an SI will be qualified to operate on Open Process Automation certified equipment, incorporating all elements of an Open Process Automation system into a deliverable system to the end user or EPC.

The Open Process Automation approach brings a major change to the integrator role and market conditions, such as:

- The effort required to perform hardware and software integration of equipment from multiple vendors will decrease due to the availability of suitable standard interfaces
- The number of vendors involved in an Open Process Automation integration effort might increase due to the availability of suitable standard interfaces, which can result in approximately the same level of effort and time currently consumed in integration
- There will be significantly more competition, because the hardware and software interfaces will be open and standardized

  The ability to develop systems without vendor extensions will be more competitive, whereas existing non-open systems that require vendor extensions will not be as attractive to end-users.

Note: If during the service lifetime of a system, changes involve new hardware, new software, or new subsystems that require integration into the system, then this is performed as part of the integrator role and not as part of the service role.

#### Value Proposition

As the Open Process Automation approach gains acceptance, integrators will no longer be tied to specific hardware vendors. Integrators will see reduced training costs for their staff, as they will not need to learn multiple proprietary systems. They will be able to build systems from multiple suppliers at a much lower cost. Standard interfaces will reduce or eliminate much of today's custom integration solutions.

#### SWOT Analysis

For the end user, the Open Process Automation approach expands the options for integrators and allows them to specify a "best-of-breed" solution. The Open Process Automation approach decreases the time and cost it takes to integrate different vendor elements. The Open Process Automation approach will also increase integrators' ability to bid on projects in which they would otherwise be uncompetitive.

A downside for integrators is the possibility for more competition for jobs. However, Open Process Automation acceptance will increase opportunities and make it more important for SIs to have production process knowledge, and understand end users' key pain points and hot button items.

A threat to integrators is low-cost competition using cloud and Internet-based services, that could compete against in-place integrators, siphoning off the high-profit elements and leaving the lower-profit wiring and checkout elements to local integrators.

### 4.1.3 Hardware Supplier Role

#### Current State

Hardware suppliers provide Level 0 up to Level 3 hardware to monitor, operate, control, and optimize process equipment. The hardware usually comes with its proprietary firmware, drivers (if applicable), and engineering software interfaces, which are provided to end-customer segments through indirect (e.g., SI and partner) channels. In the current state, hardware suppliers fulfill an "exclusive" service provider role for its systems (DCS, PLC, hardware, and software) because of the proprietary nature of the hardware architecture and hardware-related software. In addition, they take the position of an SI with third-party systems.

The hardware supplier's key activities are strongly focused on service and support, including product lifecycle management, building of DCS (if applicable), engineering of hardware/software, R&D, and third-party systems integration. Depending on which level of hardware/software will be provided, the hardware supplier's key partners range from hardware suppliers for electronic devices and/or computer equipment, software suppliers (e.g., operating system suppliers), and software development partners (e.g., enterprise suppliers).

Hardware suppliers' main resources are defined by sales and marketing, finance, system engineers, hardware engineers, third-party developers, and contractors.

The major costs incurred by hardware suppliers are resources (infrastructure and employees), components, and supplies.

Hardware suppliers deliver significant value with functional capabilities, innovation, performance, reliability, availability, security, and safety, driving four different revenue streams: hardware (e.g., components), licenses (e.g., I/O count), services, and projects (e.g., engineering and commissioning).

### Future State

The open system platform with interoperability, portability, certification of standards conformance, and a software marketplace brings significant changes to the hardware supplier:

- Although the open system platform creates the possibility to cover more customer segments, direct customer relationships will decrease; instead, Open Process Automation SIs, who take responsibility for full system integration from different vendors, will handle more direct customer relationships and will be the hardware supplier's main partners

- Hardware suppliers will no longer act as the exclusive hardware and service providers of their systems

  Proprietary interfaces will be replaced by certified standard interfaces, thus resulting in more competition (e.g., hardware, firmware, and services), and therefore replace traditional revenue models with new emerging business models.

- Some hardware suppliers might not be able to fulfill the Open Process Automation SI role; specialized Open Process Automation SIs will execute hardware supplier system integration with third-party components

- Increased competition on the hardware and service side will motivate hardware suppliers to differentiate themselves from their peers

  This should drive them to be more innovative and to put additional funding into R&D so they can deliver more value to SIs and customers. However, traditional bases of competition (e.g., quality, selling price, performance, maintenance service, availability, reputation, and brand-name awareness) will remain.

**Value Proposition**

Interoperability and portability will increase market competition and make it difficult to find unique differentiators between hardware suppliers. These differentiators have not been identified yet. However, new business opportunities can be seen in a software marketplace (e.g., cloud) to deliver "special" services for the hardware delivered.

**SWOT Analysis for the Future State**

Interoperability, portability, and security standards will improve the product lifecycle process and lower the efforts associated with system upgrades for end users. However, hardware suppliers' existing revenue streams have derived from customers who today are "locked-in" to a hardware supplier's architecture that will have to be replaced with other emerging business models and opportunities (e.g., Open Process Automation software marketplace, software-based solutions of certain hardware functionalities). More competitors will drive innovation, which could result in lower prices for hardware. In addition to potentially fewer customer relationships, the Open Process Automation approach will make the hardware market more competitive due to the increased number of hardware suppliers. Certifications and conformance are critical and could lead to hardware supplier segmentation. In the future, uniqueness of hardware suppliers will have to be redefined.

### 4.1.4 Subsystem Integrator Role

**Current State**

Subsystem integrators provide software-enabled hardware components for integration into larger systems. Main Automation Contractors (MACs), EPCs, SIs, and DCS suppliers are the main consumers of these subsystems. These subsystems are used in skid-mounted, standalone processing modules, process analyzers, and major infrastructure components, such as turbo compressors and power-generation units.

Because of the availability of a large number of industrial control system offerings, a manufacturing plant composed of equipment subsystems can have a large number of independent control systems. Given the closed nature of these proprietary industrial control systems, cost-effective integration of subsystems across the plant is limited due to custom software solutions.

**Future State**

Subsystems built to conform to Open Process Automation hardware and software standards should allow subsystems and process control systems to be integrated with one another far more cost effectively. This system of systems concept will be enabled by the standardization of physical interfaces, data models, and APIs.

The IP of the subsystem integrators that is embodied in their algorithms, software, and hardware designs would be protected since only key interfaces would be standardized. It is not the intent to standardize the unique interfaces for various proprietary component designs within the major infrastructure subsystems such as analyzers, electric power generators, and turbo compressors.

#### Value Proposition

The goal of the Forum is to reduce the customization of subsystems across the process automation spectrum. Aspirationally, standardizing interfaces opens new markets to subsystem suppliers and reduces costs through effective reuse of design artifacts. For the end user, it provides more market options to implement control system functionality without costly customization. The ability to rapidly insert new capabilities into these subsystems using certified, standard software and hardware interfaces adds value to the installed base and opens new revenue streams for suppliers of all control applications.

#### SWOT Analysis for the Future State

The strength of the Open Process Automation approach is manifested in loosely-coupled business relationships with software suppliers and integrators, which should reduce part number counts and configuration management costs. The Open Process Automation initiative should also drive an open market for subsystems, which should reduce purchasing cost and spare parts inventory.

The drawbacks from tightly-coupled proprietary subsystems and the inherent inability to innovate are dramatically reduced through the Open Process Automation initiative.

The elimination of proprietary system lock-out should dramatically increase opportunities for suppliers. End users should be able to reduce operational costs resulting from obsolescence issues since the Open Process Automation approach enables incremental enhancements and updates. This has the potential to drive significant cost savings because it could eliminate the need for major upgrades, which often require turnarounds or shutdowns.

The threats to the success of Open Process Automation subsystems suppliers should be mitigated by a robust certification process that should ensure compliance with the standards. The certification system should prevent products that are not compliant with the Open Process Automation Standard from entering the market.

### 4.1.5 Software Supplier Role

#### Current State

Process automation systems software adds value by increasing capacity and utilization, lowering operating costs, improving product quality control, fulfilling regulatory requirements, and even by replacing expensive physical sensors or analyzers.

Software-supplier solutions implement the run-time infrastructure of the process automation system and monitor, operate, control, and optimize manufacturing processes and process equipment. These software products contain the IP of the software supplier.

Some software products are extended by application-specific configuration and the code needed to achieve operation objectives specific to the process and process equipment being monitored and controlled. This configuration and code is generally produced and maintained by end users, SIs, and service providers. Examples of application-specific configuration and code include: Proportional Integral Derivative (PID) controller parameters, PLC ladder logic or structured text code, and Advanced Process Control (APC) models. This application-specific configuration and code is the IP of the end user (in most cases).

Software suppliers can be partitioned in two segments: integrated software suppliers, who produce products tightly bound to a vendor-specific process automation system, and independent software suppliers, who provide products that communicate with vendor-specific process automation systems through vendor-provided gateways. Software supplier revenue comes from licensing of the software. The major costs incurred by software suppliers are R&D, sales, and customer support.

### Future State

The Open Process Automation approach brings several significant changes for software suppliers:

- An open system platform
- Interoperability, portability, and security standards
- Certification of standards conformance
- The Open Process Automation marketplace

The combination of well-defined interoperability standards, an open platform, and a conformance certification program will allow independent software suppliers to deliver products that will fully integrate in an Open Process Automation system, significantly reducing the distinction between independent and integrated software suppliers.

The certification process and portability standards make it possible to create and operate a software marketplace for Open Process Automation software components. End users and SIs can use the marketplace to discover best-fit or best-in-class software components to build and maintain high-value process automation systems.

Independent software suppliers will see their customer segments expand as end users and SIs recognize that interoperability, portability, and standards conformance of the Open Process Automation platform remove impediments to adopting independent software-supplier products. Integrated software suppliers could grow by expanding their offerings across additional hardware platforms. Supplier relationships could develop among software suppliers, and integrated software suppliers might be able to reduce costs by collaborating with independent software suppliers. All existing software suppliers will see increased competition as new suppliers enter the market.

### Value Proposition

Software suppliers will continue to deliver significant value. The energized market and increased competition will drive greater innovation from software suppliers. Interoperability, portability, and security standards will lower the costs and risks associated with upgrading and replacing software, allowing end users and SIs to readily adopt best-in-class software components, leading to greater value for end users who are updating in-place process automation and deploying new process automation systems.

### SWOT Analysis for the Future State

The standardized, open platform will allow software suppliers to leverage their R&D investments across a growing number of conforming systems. This will enable them to pursue innovations that have been infeasible in the traditional process automation market. The open platform also encourages innovation by giving more software developers the ability to create solutions that take advantage of real-time, low-level interaction with automation systems and process equipment, and it enables solutions composed of interoperating components from multiple vendors.

Some software suppliers will be able to produce common components, toolkits, or frameworks that can be leveraged by many other software suppliers, lowering development costs and allowing each software supplier to focus on their specific area of expertise and value proposition.

Agile end users and SIs will be able to adopt new and improved software to realize greater value from their process automation investment. Standardized interoperability, portability, and security lower the risks of adopting and upgrading software products.

Certification will be critical to ensuring this energized software supplier market produces software that conforms to the Open Process Automation Standard and integrates well with Open Process Automation systems. Failures of conformance will erode confidence in the specification, segment the software suppliers, and damage the viability of the Open Process Automation marketplace.

### 4.1.6 Service Provider Role

#### Current State

The service provider offers post-installation hardware, software, algorithms, code, and configuration support for end users, usually under a service contract and sometimes via a project. The service provider maintains a local presence to respond quickly to the end user's needs with 24x7 availability. The service provider brings domain expertise around the end user's business processes. The service provider offers technical expertise in the end user's systems. The service provider often stocks hardware spares for the end user for emergency repair situations.

The service provider's key activities range from end-user standard engagements for hardware/software installation, ongoing support, and preventive maintenance (break/fix). The engagements could also be more advanced, including services such as Front-End Engineering and Design (FEED) studies for greenfield projects, data analytics, remote condition-based monitoring for corrective action, loop tuning, alarm management, and analyzer calibration. Some specialty service provider activities include comprehensive outsourcing of an end user's hardware/software platform for on-premise support at the IT/OT level.

The service provider's sales channels are usually direct to customer. However, some have more sophisticated integrated solutions with alliance partners. Service provider partners are usually hardware and software suppliers; some may align with application suppliers.

The service provider's cost structure traditionally includes employee training, hardware, software, and application support platforms with simulation to maintain expertise specific to application, equipment, or industry. The service provider's primary direct cost is skilled labor; but significant labor costs also include recruiting, traditional sales, and marketing. For more hardware-focused service providers, spare parts inventory for emergency service can be a significant cost.

The service provider’s revenue streams include end-user service and support contracts and typical end-user “run and maintain” or Operating Expense (OPEX) projects.

### Future State

In the future state, the service provider will deliver industry vertical solutions, applications, and services including:

- Preventive maintenance
- Self-diagnosing, self-learning, and automated software updates
- Managed remote services
- Alarm management
- Infrastructure management

These services can be based on an outcome (pay for performance) revenue model that requires an ecosystem of partnerships and alliances between the service provider, system integrator, software and hardware vendors, and subsystem providers. Through direct sales channels and open marketplaces, the service provider domain experts, open system experts, and freelance (crowdsourced) resources will have a chance to commercially engage end-user stakeholders directly for a more “agile” service model. In addition, a transformation in legal and liability requirements will allow for mutually beneficial service or project-based contracts that utilize “as-a-service” subscriptions.

### Value Proposition

Long-term outcome-based (pay for performance) revenue models will shift domain expertise roles and responsibilities from the end user to the service provider allowing for both unconventional revenue and service add-on opportunities. Significant data exchange between key partners and end-user asset data will enable new digital services on hardware and software products. The service provider may offer equipment and/or subsystem providers new innovative services such as remote asset/location monitoring, usage-based licensing and maintenance, system and process optimization, and analytics. Through these future service partnership and alliance opportunities, the ecosystem will generate shared revenue streams.

### SWOT Analysis for the Future State

With a standardized, open platform, other service providers may now compete for the end user’s support contract as technical expertise will become more universal. Outcome-based (pay for performance) service contracts incentivize the service provider to innovate to deliver better performance. An Open Process Automation marketplace may alleviate one of the service provider’s key resource constraints – skilled technical talent. Crowdsourcing and open source development could level the playing field by removing the competitive advantage typically held by hardware/software manufacturers (OEMs) who have a significant advantage in the marketplace when it comes to their proprietary systems.

# 5 Principles, Quality Attributes, and Goals

The Forum is developing a standard of standards and business practices to implement the Open Process Automation approach for industrial control systems of the future. The Forum is following a structured approach for the development of these standards and processes. The structured approach is based on members acknowledging key governing principles and associated quality attributes. The goal is to closely associate the Open Process Automation technical requirements and business processes to the quality attributes that define the underlying principles.

## 5.1 Key Principles

The key Open Process Automation principles were derived from the needs of the end users, the capability of current state-of-the-art technology, and recent advances in published certifiable open standards development. The genesis of the Open Process Automation approach is that current industrial standards and business practices cannot support these principles. The key principles that guide the selection of the technical standards and business practices associated with the Open Process Automation approach are listed below.

- Extensible and evolvable standards
- Maximum leverage of the best components of existing industry standards and development of new standards only when none exist
- Resiliency and cybersecurity enablement
- Abstraction of software processing environments with respect to processing hardware
- Abstraction of applications with respect to processing software environment
- Standardized logical interfaces and data models
- Defined physical, electrical, logical, and data interfaces for hardware components
- Accommodation of simple through complex systems
- Accommodation of small through large systems
- Modularity of physical and logical interfaces
- Interchangeability and reuse enabled by a robust certification and product discovery process
- Decreased initial investment and TCO of industrial control systems
- Decreased time-to-market and time-to-deployment of new capabilities to the end user
- Increased competition amongst the industrial supply base

The key principles cannot be coherently realized without a set of attributes that reflects the stakeholders' views of what the architecture should enable. These attributes are defined as quality attributes.

## 5.2 Quality Attributes

The Open Process Automation quality attributes are those non-functional characteristics that influence system quality and drive architectural decisions. Quality attributes are the properties of an architecture, the merits of which can be judged by stakeholders. Quality attributes were developed in workshops attended by Open Process Automation end users and suppliers representing the industrial automation ecosystem. This engagement early in the architecture development process was designed to:

- Discover the driving quality attributes of the system
- Identify and prioritize the "goodness" stakeholders need
- Discuss specific constraints/thresholds for each attribute
- Discuss short "quality scenarios" to provide guidance and understanding of the quality attributes
- Document the key quality with ranking and definition

The Open Process Automation quality attributes apply to both the technical standards and business practice work products. These work products establish a standard common operating environment to support portable industrial automation capabilities and hardware implementations across domain-specific industrial automation systems. The Open Process Automation Standard defines the requirements for architectural segments, the key interfaces that link the subsystems together, and the hardware interfaces required to configure a system. These standards enable the reuse of capability-based software components and function-block configurations across different hardware computing environments. The idea is to avoid "reinventing the wheel" for every new system implementation. When programs reuse more, they save more. It also enables rapid replacement of older software and hardware, thus reducing TCO. The business practices assure a highly conformant certification program backed with a means of product discovery and contracting guidance.

The key quality attributes of *safety*, *resilience*, and *maintainability* are fundamentally intrinsic to Open Process Automation systems.

The following top ten quality attributes, applicable to the Open Process Automation approach, are listed in ranked order. The definitions of the ranked quality attributes were derived from several published reference sources and were extensively discussed and debated by the Forum membership workshop on quality attributes.

1. Interoperability (ISO/IEC/IEEE 24765:2010(E)) – The ability of two or more systems or components to exchange information and to use the information that has been exchanged.
2. Modularity (ISO/IEC/IEEE 24765:2010(E)) – The degree to which a system or computer program is composed of discrete components such that a change to one component has minimal impact on other components. The degree to which a system's components may be separated and recombined.

3. Standard Conformance – The process of developing and certifying systems or components to meet 100% of the Open Process Automation Standard.

4. Scalability – The degree to which a system can have its capacities adjusted to meet system requirements.

5. Securability – The ability of a system or component to protect against unauthorized access or modification throughout its lifecycle.

6. Reliability (ISO/IEC/IEEE 24765:2010(E)) – The ability of a system or component to perform its required functions under stated conditions for a specified period of time.

7. Affordability – A characteristic of design, expressed as a solution that meets a customer's needs or requirements at an acceptable price (to include recurring and non-recurring cost).

8. Portability (ISO/IEC/IEEE 24765:2010(E)) – The ease with which a system or component can be transferred from one hardware or software environment to another.

9. Availability (ISO/IEC/IEEE 24765:2010(E)) – The degree to which a system or component is operational and accessible when required for use. The ability of a component or service to perform its required function at a stated instant or over a stated period of time.

10. Discoverability – The ability of a configuration item or its information to be found. The ability to find an item and understand its information exchanges and capabilities.

## 5.3 Quality Attribute Goals

The goals to be achieved through using the quality attributes in Open Process Automation development are:

1. The quality attributes guide the membership in the selection of technical requirements and business practices based on stakeholder needs.

2. The quality attributes form the basis of Open Process Automation requirements traceability for the enumerated technical requirements and business processes.

3. The quality attributes shall have a correspondence with one or more of the enumerated Open Process Automation technical and business requirements embodied in the Standard and respective business practice publications.

The traceability of technical requirements and business processes to the respective quality attributes provides the basis for demonstrated stakeholder legitimacy. The historical reference point created by mapping the technical requirements and business processes to the quality attributes is of immeasurable value, providing continuity of Open Process Automation decision criteria. This continuity must be preserved as the Forum matures and new contributors join.

# 6 Conformance, Certification, Contracting

## 6.1 Conformance and Certification

Open Process Automation conformance means that a given software or hardware component completely satisfies the requirements of the Open Process Automation Standard. Certification is a formal recognition of a product's conformance to the Open Process Automation Standard. Suppliers will be able to certify that their products conform to the Standard. End users will be able to procure certified components that are backed by warranty.

The Certification Authority will legally authorize the originator of a certified Open Process Automation conformant software or hardware component to use the trademarked Open Process Automation logo to indicate certification. These certified conformant components are also mandatory for listing in the Open Process Automation Registry.

End users and Open Process Automation SIs need to ensure the interfaces and data models for software, and the form, fit, and interface data for hardware modules are conformant to the Open Process Automation Standard. Open Process Automation conformance does not certify functional capability or safety certification. These requirements are covered in the end users' and/or SIs' respective functional and safety specifications, which are outside the scope of the program.

The detailed Open Process Automation conformance process will be specified in the Open Process Automation Certification Policy and the Open Process Automation Conformance and Certification Guide. The technical requirements for conformance will be specified in the respective software and hardware technical requirements documents, the Reference Implementation Guide, and the Certification Verification Matrices.

In general, the originator of an Open Process Automation software or hardware component is responsible for ensuring it meets Open Process Automation conformance requirements. This responsibility is managed by the SI in the deliverables to the end user.

The end user shall structure Open Process Automation contracts to levy the responsibility for creating and maintaining Open Process Automation conformant products on the SI. The SI shall structure Open Process Automation subcontracts to levy the responsibility for originating and maintaining Open Process Automation conformance on the software or hardware originator.

The Open Process Automation Registry is an open, discoverable, non-proprietary listing of key metadata describing the certified software or hardware component. It will contain a set of searchable fields that allows for the rapid discovery of certified software or hardware components and provides a point of contact for further business transactions to learn more about or procure the component.

## 6.2 Contracting for Open Process Automation Components

The Forum is creating standards for a set of modular, interoperable, secure, certified software and hardware components. These components are created by both vertically-integrated and third-party suppliers. The Open Process Automation standardized components and systems will be integrated into control systems for continuous, batch, or hybrid processes.

Contracting for these components and systems from multiple suppliers will require contractual terms and conditions that balance two factors. The first is the customers' requirements for open interfaces and data models required to achieve open, interoperable systems. The second is protecting IP and ensuring a robust marketplace for the suppliers.

The BWG will create a Contract Guide to provide guidance to the buyers and sellers of Open Process Automation specified systems. The documentation will provide generic contract language for use in Requests for Proposals (RFPs) and the corresponding proposal responses.

# Acronyms and Abbreviations

| | |
|---|---|
| APC | Advanced Process Control |
| API | Application Programming Interface |
| BWG | Business Working Group |
| CAPEX | Capital Expenditure |
| DCN | Distributed Control Node |
| DCS | Distributed Control Systems |
| EAWG | Enterprise Architecture Working Group |
| EPC | Engineering, Procurement, and Construction |
| FACE | Future Airborne Capability Environment |
| FEED | Front-End Engineering and Design |
| HMI | Human-Machine Interface |
| IIoT | Industrial Internet of Things |
| I/O | Input/Output |
| IP | Intellectual Property |
| IT | Information Technology |
| MAC | Main Automation Contractors |
| MES | Manufacturing Execution Systems |
| MOM | Manufacturing Operations Management |
| MPC | Model Predictive Control |
| OEM | Original Equipment Manufacturer |
| OPAF | (The Open Group) Open Process Automation Forum |
| OPEX | Operating Expense |
| OT | Operational Technology |
| PID | Proportional Integral Derivative |
| PLC | Programmable Logic Controllers |

| | |
|---|---|
| RFP | Requests for Proposals |
| RTAC | Real-Time Automation Controller |
| SFC | Sequential Function Charts |
| SI | System Integrator |
| SIS | Safety Instrumented Systems |
| SOP | Standard Operating Procedure |
| SWOT | Strengths, Weaknesses, Opportunities, and Threats |
| TCO | Total Cost of Ownership |
| TWG | Technical Working Group |

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