



From Complexity to Autonomy: How UniversalAutomation.org Enables the Next Industrial Transformation

Openness is no longer optional.

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CONTENTS

Executive Overview	3
Why Industry Must Change	4
How Industry Is Responding.....	6
Enabling the Transformation: the Role of UAO.....	8
Conclusion and Recommendations	16

Executive Overview

Industrial automation is at an inflection point. Increasing operational complexity, tighter sustainability targets, workforce constraints, and volatile market conditions are exposing the limitations of closed, hardware-centric automation systems. These architectures were designed for stability, not continuous change, making them costly to adapt, difficult to scale, and increasingly misaligned with modern digital and autonomous ambitions.

A new automation paradigm is emerging - one that treats software as the primary driver of flexibility, resilience, and long-term value. By decoupling control applications from proprietary hardware, open and software-centric automation enables portability, interoperability, and reuse across diverse environments. This shift reduces lifecycle risk, protects existing investments, and allows organizations to modernize incrementally rather than through disruptive replacements.

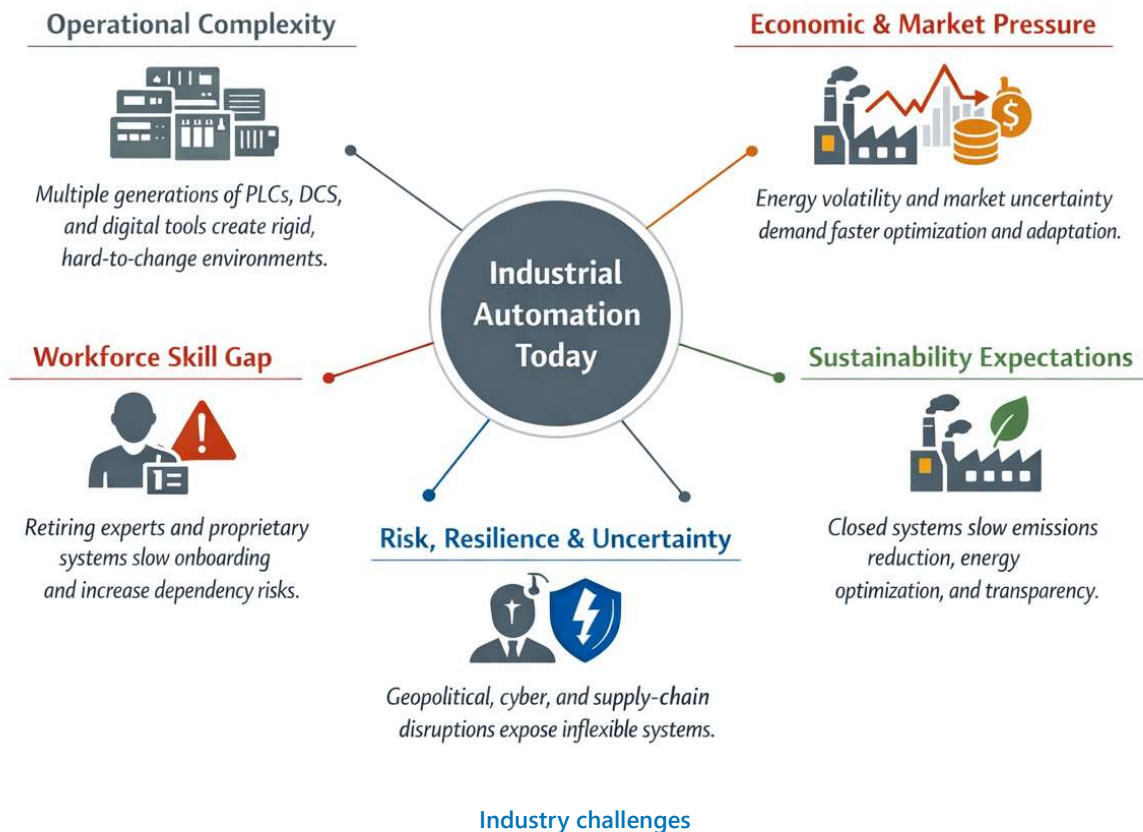
The international non-profit association UniversalAutomation.org (UAO) plays a critical role in turning this vision into operational reality. By providing a vendor-independent execution layer based on IEC 61499 and proven-in-use technologies, it enables scalable, interoperable control while supporting coexistence with legacy systems. Real world deployments across multiple industries demonstrate that open automation is not a future concept, but a practical pathway to higher autonomy, faster innovation, and sustainable digital transformation.

For industrial stakeholders, the message is clear: openness is no longer optional. Those who align early with open automation principles will be better positioned to adapt, collaborate, and compete in an increasingly dynamic industrial landscape.

Industry must change to manage complexity, and UniversalAutomation.org (UAO) provides the open foundation to make that change possible.

Why Industry Must Change

Industrial organizations are operating in an environment of unprecedented complexity and pressure. Structural shifts in technology, markets, workforce demographics, and societal expectations are exposing the limits of traditional automation and operational models. ARC research consistently shows that incremental improvements are no longer sufficient; the industry must rethink how systems are designed, integrated, and operated to remain competitive, resilient, and sustainable.



Industrial organizations face mounting pressure as traditional automation models struggle to keep pace with growing complexity, market volatility, and societal expectations. Many plants operate heterogeneous environments composed of multiple generations of PLCs, DCS platforms, and standalone digital solutions accumulated over decades. These fragmented, vendor-specific systems make even minor changes - such as adding optimization applications

or modifying control logic - slow, costly, and risky, a challenge further intensified by IT/OT convergence.

At the same time, economic and market pressures are forcing companies to operate closer to their limits. Volatile energy prices, fluctuating raw material costs, and supply-chain instability demand frequent operational adjustments, particularly in energy-intensive industries. However, rigid automation architectures designed for long-term stability limit the ability to rapidly reconfigure or optimize operations. Shorter product lifecycles and higher customization requirements compound this issue by driving up engineering and commissioning costs.

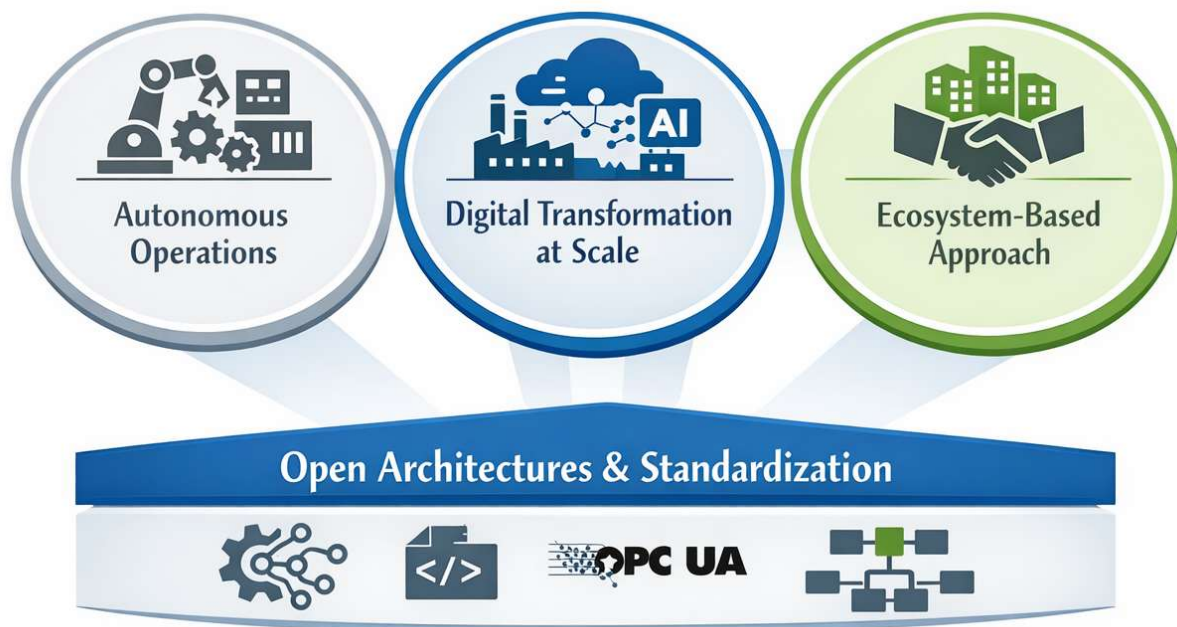
Workforce dynamics add another layer of risk. The retirement of experienced engineers is creating critical knowledge gaps, as expertise is often embedded in proprietary systems and custom integrations. Younger engineers are frequently deterred by closed, vendor-specific environments, leading to longer onboarding times, greater reliance on external specialists, and increased operational risk.

Industrial operations are also increasingly exposed to geopolitical, regulatory, cyber, and supply-chain disruptions. Monolithic, tightly coupled systems reduce resilience, making it difficult to isolate failures, replace components, or comply quickly with new regulations. In parallel, sustainability pressures are accelerating the adoption of energy monitoring, emissions tracking, and electrification initiatives, yet closed architectures hinder data access and integration across systems.

Together, these forces underscore the need for more adaptable, interoperable, and resilient automation architectures that can evolve without repeated large-scale redesigns.

How Industry Is Responding

Industrial companies are no longer relying solely on incremental optimization of existing systems. Instead, leading organizations are adopting new operational strategies, architectural principles, and collaboration models to regain agility, resilience, and long-term competitiveness. While these responses vary by industry and maturity level, several clear patterns are emerging across global industrial operations.



Industry Trends and Enablers

Organizations are increasingly aligning their automation strategies around three reinforcing objectives: autonomous operations, digital transformation at scale, and ecosystem-based innovation.

The shift toward autonomous operations reflects a growing recognition that traditional automation models cannot keep pace with today's operational complexity, workforce constraints, and sustainability pressures. Across industries and regions, companies are investing in architectures that support higher levels of autonomy through software-centric control, portability of applications, and lifecycle flexibility.

At the same time, companies are pursuing digital transformation at scale. Early digital initiatives often delivered local benefits but failed to scale due to fragmented systems and project-specific integrations. Organizations are now prioritizing common platforms, repeatable deployment models, and architectural consistency, moving from experimentation toward sustainable, enterprise-wide adoption.

Rather than relying on single-vendor systems, organizations are embracing architectures in which solutions are designed to be interoperable regardless of the underlying technology. This approach emphasizes the use of open standards, the separation of data from applications, and the availability of data through common or federated data layers that can be consumed autonomously by multiple applications.

By shifting the focus from tightly coupled solutions to principle-based design, companies can scale automation and digital capabilities more effectively while reducing lifecycle complexity and dependency. Achieving this vision requires solution providers to align with a clear set of principles that prioritize openness, technology agnosticism, interoperability, transferability, and data ownership.



Open Digital Ecosystem Principles

UAO provides the foundation beneath these trends through open architectures and standardization. By decoupling hardware, software, and applications and standardizing principles and interfaces rather than products, UAO enables interoperability, reduces lifecycle risk, and supports resilient, future-ready automation environments.

What Enables the Transformation and the role of UAO

The shift toward more autonomous, resilient, and sustainable industrial operations is enabled by a set of core technologies that changes how automation systems are designed and scaled. Industrial data platforms provide a common foundation for integrating operational and engineering data, while analytics, artificial intelligence, and machine learning enable advanced optimization and decision support. Edge, cloud, and hybrid architectures allow these capabilities to be deployed flexibly, balancing real-time control requirements with enterprise-level visibility.

Yet technology alone is not enough. Open standards and open architectures are essential to overcome the limitations of closed, vendor-specific systems. By separating data, applications, and infrastructure, open architectures enable interoperability across heterogeneous environments, reduce lifecycle complexity, and allow incremental modernization. This openness accelerates innovation, improves resilience, and supports collaboration across an increasingly diverse industrial ecosystem.

UniversalAutomation.org builds directly on these principles. By decoupling automation software from proprietary hardware and standardizing how control applications are developed and deployed, UAO enables portability, reuse, and long-term flexibility. It provides a practical pathway toward software-centric, interoperable automation while protecting existing investments and supporting the gradual evolution toward autonomous operations.

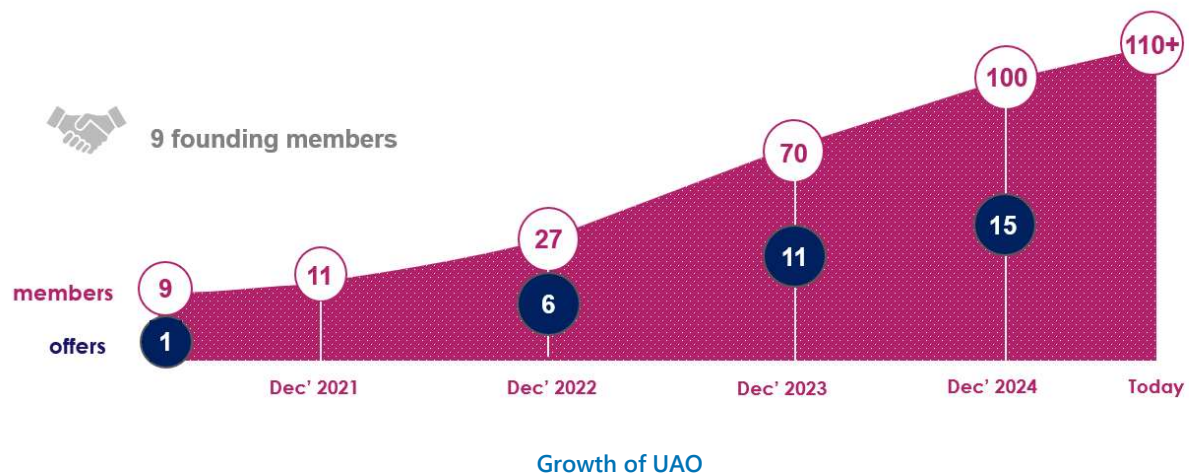


UniversalAutomation.org in a Nutshell

The mission of UniversalAutomation.org is to enable a shift toward open, software-centric industrial automation by decoupling control applications from proprietary hardware. UAO promotes portability, interoperability, and reuse of automation software, helping industrial organizations reduce vendor lock-in, manage lifecycle complexity, and adopt modern digital technologies at their own pace. Its vision is to establish a common, vendor-independent automation foundation that delivers greater flexibility, resilience, and long-term sustainability.

UAO was established as an independent, non-profit association to address the limitations of traditional hardware-centric automation. Rather than acting as a formal standardization body, it brings together end users, technology vendors, system integrators, and academics to accelerate real-world adoption of IEC 61499-based automation through shared implementations and proven-in-use technologies.

Founded in 2021, the organization has grown from nine founding members to more than 100 members worldwide, reflecting strong industry alignment around open, vendor-independent automation.



Member Profiles

UniversalAutomation.org brings together a diverse and balanced membership that reflects the full industrial automation ecosystem.

- End users play a central role by defining real operational requirements and validating the practical value of open, software-centric automation in brownfield and greenfield environments.
- Technology vendors contribute automation platforms, hardware, and software solutions, collaborating on shared implementations that enable portability and interoperability across systems.
- System integrators and EPCs apply UniversalAutomation.org principles to design, integrate, and deploy scalable solutions, helping translate open architecture into operational reality.
- Academic institutions and research organizations support long-term innovation by advancing IEC 61499 knowledge, developing skills, and preparing the next generation of engineers.

Together, these member groups form a collaborative ecosystem that accelerates adoption, reduces risk, and ensures that UniversalAutomation.org evolves in line with both industrial needs and technological progress.



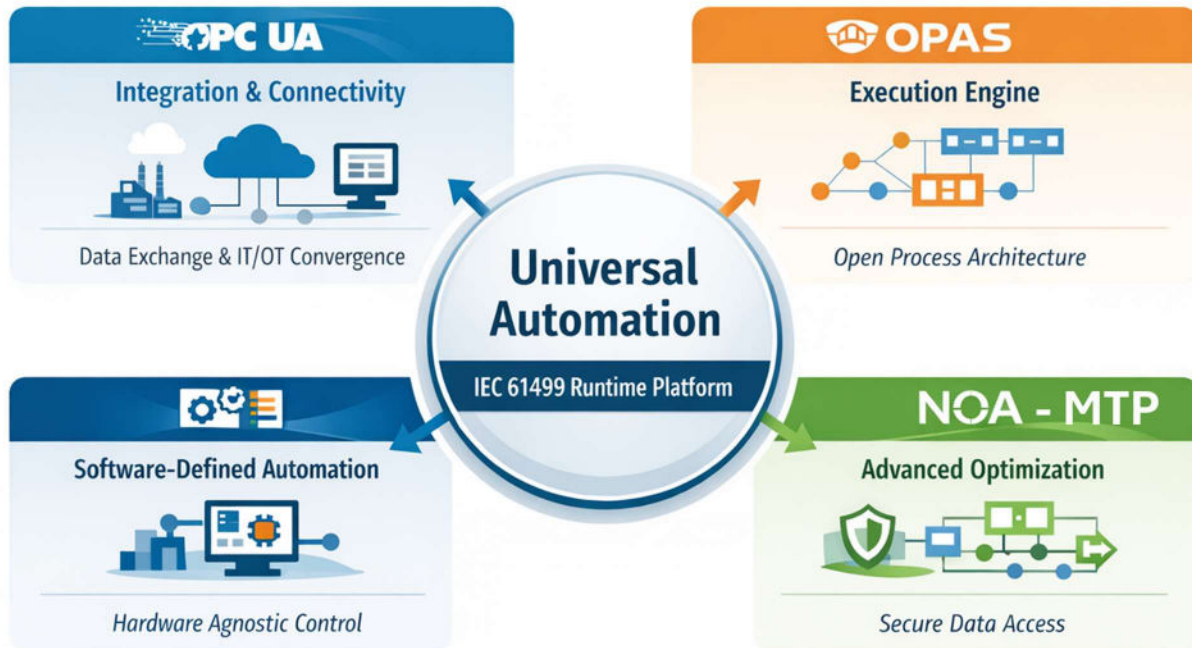
Overview of current members

How UAO Complements Other Industry Initiatives

UniversalAutomation.org is designed to complement and not replace existing standards and initiatives by providing a practical execution and deployment layer that turns architectural concepts into deployable systems. Here are some examples:

- **OPCUA** provides standardized and secure communication across OT and IT. UAO leverages OPCUA for connectivity and data exchange while focusing on the control and orchestration layer, enabling IEC 61499 applications to expose data and services without binding them to specific controllers.
- **Open Process Automation Standard (OPA-S)** defines open, vendor-agnostic process control architectures. UAO complements OPAS by providing a shared, proven-in-use IEC 61499 runtime execution engine, helping bridge the gap between architecture and implementation while reducing risk and accelerating deployment.
- **Open software-defined automation** is a core UAO principle. While software-defined automation can decouple software from hardware, it does not automatically eliminate proprietary dependencies; in some implementations, the runtime, tooling, and interfaces remain vendor-controlled, preserving lock-in. UAO's focus is on open SDA: enabling portability and interoperability through a vendor-independent execution layer, which also supports virtualization and edge deployment so applications can move across platforms from different vendors.
- **NAMUR Open Architecture (NOA) and Module Type Package (MTP):** UAO complements NAMUR's work not only through the NOA wrap-and-reuse strategies that allow advanced automation to coexist with legacy systems, but also by aligning with the MTP approach for modular, vendor-independent integration of process modules.

Together, these initiatives form a coherent ecosystem, with UAO providing the execution backbone for open industrial automation.



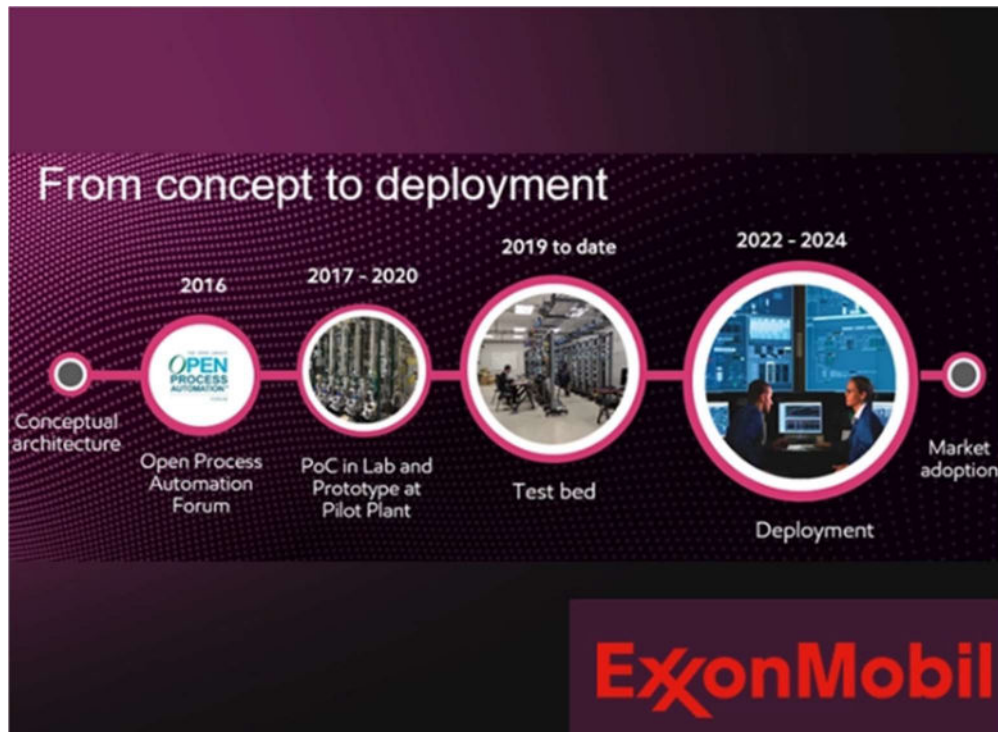
Connected Open Automation Ecosystem

Industry Use Cases Enabled by UAO

The value of UniversalAutomation.org has already been proven through multiple real-world use cases across diverse industries. Below are some highlighted examples.

ExxonMobil (Energy & Chemicals)

ExxonMobil leveraged UniversalAutomation.org to adopt an open automation platform that avoids dependency on a single vendor. Using the UAO runtime execution engine within an Open Process Automation (OPA) test bed since 2018, ExxonMobil has validated the portability of control applications built from best-in-class software components supplied by multiple vendors. The approach enables consistent execution aligned with open automation standards, reduces engineering and commissioning time, and accelerates innovation through proven-in-use software. A field deployment is underway to replace existing DCS and PLC systems, covering approximately 800 IO points and more than 90 control loops using UAO runtime and OPC UA.



ExxonMobil Light House Project

J&W Smart Logistics Center with ASRock Industrial (Logistics)

J&W Smart Logistics Center, in collaboration with ASRock Industrial, implemented a hybrid automation system to overcome manual processes, low throughput, and limited system flexibility. The solution is based on ASRock Industrial's iEP-5000G Industrial IoT Controller running IEC61499 from UniversalAutomation.org. The system integrates human-robot collaboration, modular conveyor loops with smart sensors and RFID/NFC, vision-based control gates, autonomous mobile robots, and a maintenance station for non-disruptive updates. This architecture enables real-time coordination across components, improving operational efficiency, scalability, energy performance, and system uptime while reducing errors and labor dependency.

"I see UAO technologies as the catalyst for open SDA and vendor-agnostic automation, enabling smarter and truly human-centric factories."

Mauro Mazzolini, Co-Founder, J&W

Gr3n (Advanced Plastic Recycling)

Gr3n has adopted UniversalAutomation.org to enable modular expansion of its depolymerization plants while retaining ownership of its software intellectual property and

flexibility in supplier choice. Reactor unit controls are implemented as intelligent, vendor-independent automation objects that encapsulate process control, HMI, and IT services such as track-and-trace. This modular approach supports scalable engineering, reduces costs during market scale-up, and improves total cost of ownership. By integrating OT and IT and enabling advanced data analytics, the solution also creates new optimization opportunities and supports Gr3n's long-term innovation strategy.

"UAO technologies unlock interoperable, vendor-agnostic automation, accelerating innovation, reducing integration costs, and creating scalable business opportunities across industries."

Franco Cavadini, CTO, Gr3n

Kongsberg Maritime: (Energy)

Kongsberg Maritime implemented IEC 61499 and OPC UA to automate offshore well barrier testing, replacing manual, time consuming, and inconsistent procedures. By using server side, event driven IEC 61499 logic with standardized OPC UA interfaces, the solution enables centralized orchestration, dynamic HMIs, and seamless OT/IT integration. This approach delivers consistently high-quality test execution, improves efficiency, reduces maintenance effort, and allows operators to focus on safety critical decisions rather than manual test coordination.

""Kongsberg Maritime's UAO app shifts automated oil well barrier testing from controllers to server, providing one single application for all wells and simpler deployment and maintenance. The app features OPC UA communication and an easy-to-follow HMI. Successfully put in operation in 2025. Operators found it easy to use and can focus on other tasks while the tests are running."

Merethe Gotaas, Department Manager, Kongsberg Maritime

Opportunities for Vendors and Integrators in an Open Ecosystem

While technology vendors may initially perceive open standards as a source of risk, experience shows that the opportunities created by openness, interoperability, and reuse significantly outweigh the challenges.



Opportunities for Technology Vendors and Integrators

Conclusion and Recommendations

Industrial automation is entering a phase where traditional, closed, and hardware-centric approaches can no longer meet rising demands for agility, resilience, and sustainability. Across industries, organizations are recognizing that openness, interoperability, and software portability are essential to manage complexity, reduce lifecycle risk, and enable digital transformation at scale.

UniversalAutomation.org fundamentally changes how automation systems are designed and evolved by decoupling control software from proprietary hardware, reducing vendor lock-in, and enabling reuse and portability across heterogeneous environments. In this context, UAO acts as a catalyst by providing a practical, proven in use execution layer based on IEC 61499, bridging the gap between architectural vision and real-world deployment while protecting existing investments.

To capture these benefits, end users should align future automation strategies with open principles, prioritize data ownership, and adopt incremental modernization paths. Technology vendors, system integrators, and EPCs should invest in software-centric, interoperable solutions and actively engage in collaborative ecosystems such as UAO to accelerate adoption, reduce integration risk, and unlock new business opportunities.



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