A Proven History of Innovation in Advanced Process Control and Beyond

aspentech | White Paper

Executive Summary

Energy and chemical companies are recognizing the need to embrace new technologies as they face the energy transition and volatile and increasingly uncertain operating environments. A greater focus on remote operations and the desire for improved and consistent operational productivity and reliability is increasing focus on more autonomous operations and workflows. In addition, more organizations are looking at adaptive capabilities to address the need for greater resiliency in plants and value chains.

The AspenTech Production Optimization solution, enabled by Aspen Unified™, is designed to help Owner Operators tackle key challenges in Downstream Operations. As an example, it helps to reduce the gap which can commonly occur between planning, scheduling and operations. Advanced Process Control (APC) is a foundational layer in Production Optimization. AspenTech has consistently delivered significant innovations in APC over the last three decades and its APC technology has been widely deployed, delivering significant economic returns for companies around the globe.

Aspen DMC3™ is AspenTech's third generation APC technology. The software has many powerful capabilities, perhaps its most important is the ability to adapt to changing process conditions. Aspen GDOT™, short for Generic Dynamic Optimization Technology, represents the next layer in Production Optimization. The solution sends targets to APC systems running on specific process units and coordinates operations in real-time, taking account of economic objectives for broad process envelopes and driving significant added benefits. AspenTech has now embedded Industrial AI into its APC and Dynamic Optimization products, allowing customer to access these powerful new capabilities from within the product environments they are familiar with.

1. Vision for the Self-Optimizing Plant and the Smart Enterprise

AspenTech's vision for the Self-Optimizing Plant and Smart Enterprise is centered on the development and deployment of new technologies to support operators in dealing with the important challenges of remote operations, operational productivity, reliability and resiliency. It takes advantage of proven modeling and optimization technology, AI techniques, closed loop automation, ubiquitous, secure connectivity and cloud scale infrastructure to deliver powerful new capabilities to our customers.

AspenTech has pioneered 'Industrial AI' where physical first principles modeling and constraints provide the guardrails to Deep Learning technology to deliver pragmatic AI solutions. For example, online models and AI Agents will monitor and provide rich insights about process health and anticipate future process and equipment disruptions, turning unplanned downtime into planned and managed downtime.

Rapid feedback loops, whether closed-loop, or supporting manual decisions are enabled within the Self-Optimizing Plant and Smart Enterprise. Predictions from online models and AI agents running a range of scenarios will help to provide rich insights about the future.

We recognize that customer journeys to the Self-Optimizing Plant may take different paths and the components of the Self-Optimizing Plant must reinforce one another incrementally. Additionally, customers expect new technologies which are bringing increased automation to be explainable, so that they have the confidence to deploy them in operations. One of the first steps a customer can take in their journey to the Self-Optimizing Plant is the implementation of an integrated production optimization solution.

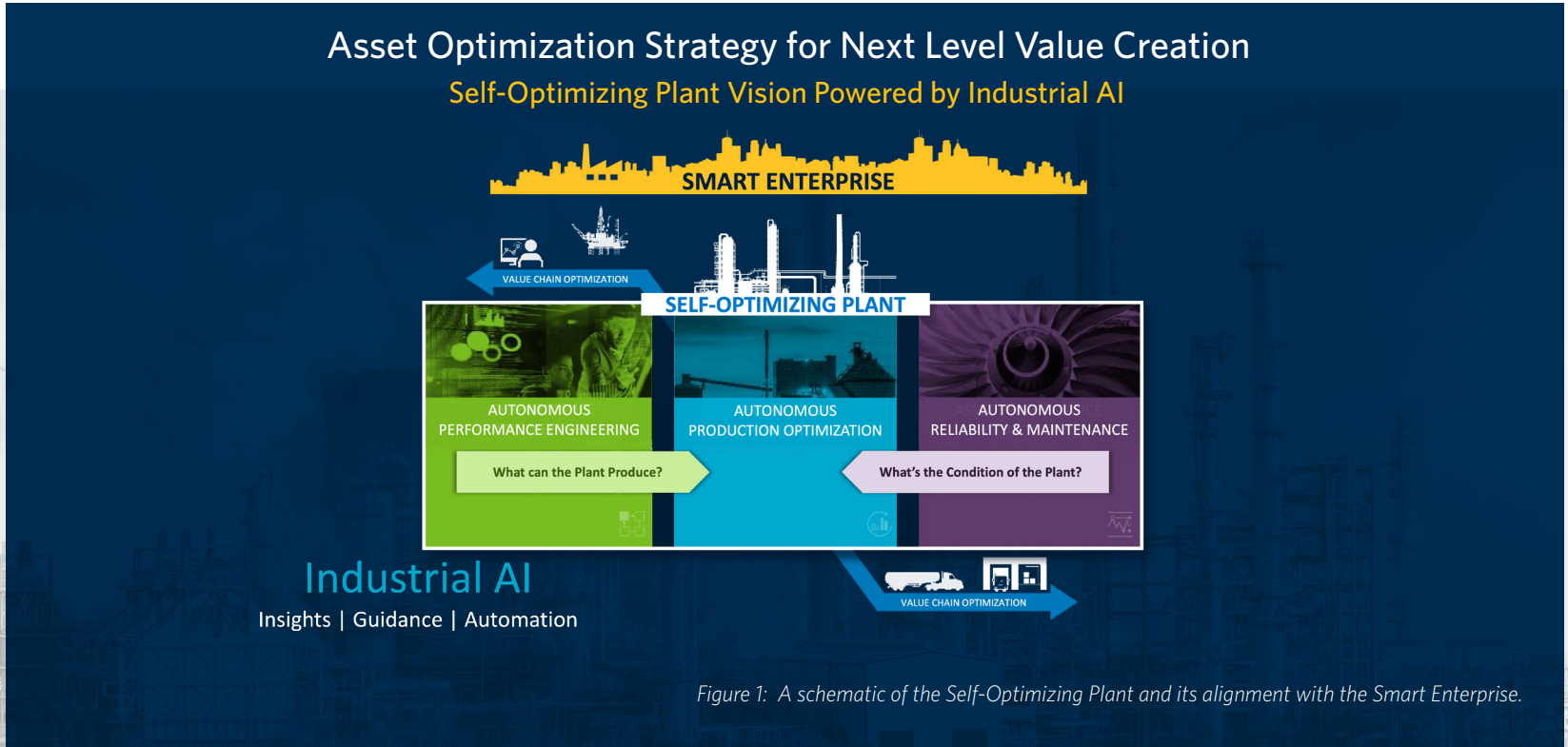


Figure 1: A schematic of the Self-Optimizing Plant and its alignment with the Smart Enterprise.

2. Production Optimization Solution

In a recent article *'The Autonomous Plant: Entering a New Digital Era' (September 2021),* McKinsey noted, *"A fundamental element of the autonomous plant will be its ability to collapse and close the feedback loops between planning and scheduling and operational optimization technologies. This ensures that relevant insights are shared and that appropriate actions are identified and taken."* At AspenTech, we have brought the layers of production optimization closer together with our Aspen Unified™ technology. Planning, scheduling, dynamic optimization and advanced process control (APC) do not just deliver differentiated value separately, they now deliver even more value together. They now share model components and data as well as information about constraints.

AspenTech's APC and dynamic optimization technologies are adaptive as described later in this document. As the process changes, these technologies adapt. They have multiple synergies and components of feedback built into them. They can pass their estimates of changing model parameters to the planning and scheduling layer to keep the business processes synchronized. Overall, we think we can significantly close the gap between planned and actual performance; driving closer alignment between planning, scheduling and operations.

This also offers the possibility of integrated business processes which work over short timeframes and enable the plant to be more agile and responsive to smart enterprise demands.

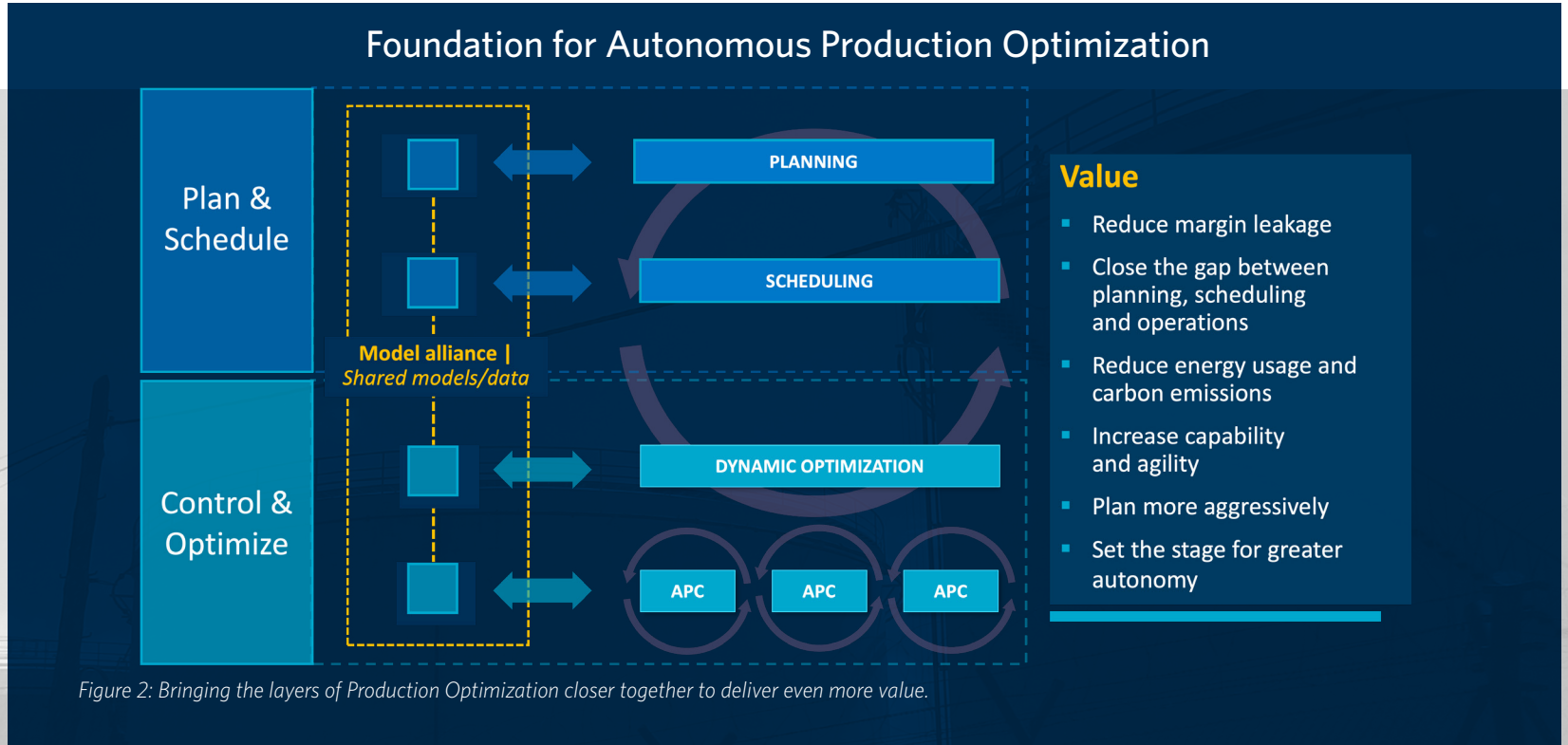


Figure 2: Bringing the layers of Production Optimization closer together to deliver even more value.

Production Optimization Value Summary

Closing the gap between planning, scheduling and operations enables us to reduce the margin leakage which often occurs between planning and execution. With greater alignment and agility, as well as integrated optimization, plants will have more capability. It will be possible to produce more diesel for the same crude feed diet for example. This, in turn, means we can plan more aggressively and set more ambitious goals.

Businesses are building a more sustainable future with a continued, concentrated focus on energy efficiency in refining—this makes sense in the current environment because it both reduces operating cost and also carbon footprint. Refiners are using advanced process control and dynamic optimization to reduce process variability and energy consumption, and support autonomous operations. Adaptive process control enables further optimization by using plant data to update process models and manage process responses to changing plant conditions.

The following sections focus on the APC and dynamic optimization layers of AspenTech's Production Optimization solution.

3. Aspen DMC3™: Third Generation APC Technology

At the foundation of the production optimization solution lies APC. Its value to the process industries has been established over three decades via thousands of applications across a large customer base with ROIs, sometimes in a matter of weeks. AspenTech has consistently delivered breakthrough innovations adding incremental value for our customers via increased process profitability, sustainment of APC benefits, speed and efficiency in deployment and adaptation to current operating and market conditions. See more detail in our APC Innovation timeline below. Consistent with the technology priorities we have for the Self-Optimizing Plant, we have embedded AI in our third generation of APC technology, Aspen DMC3™, to further improve the time to sustained value, lower the barrier for APC implementation and enable faster rollouts across the enterprise. We have also augmented the existing linear FIR and sub-space model identification algorithms with nonlinear Deep Learning in order to provide full nonlinear models for those variables in the control matrix that exhibit severe nonlinearities.

Some notable innovations over the last decade include the following patented technologies:

- Model Quality Analysis (MQA): Provides real-time control performance monitoring that measures progress continuously, pinpoints troubled model curves and root cause of poor performance.
- Calibrate mode and adaptive control: enables less-disruptive testing moves in closed-loop and provides model adaptation while still optimizing the process.

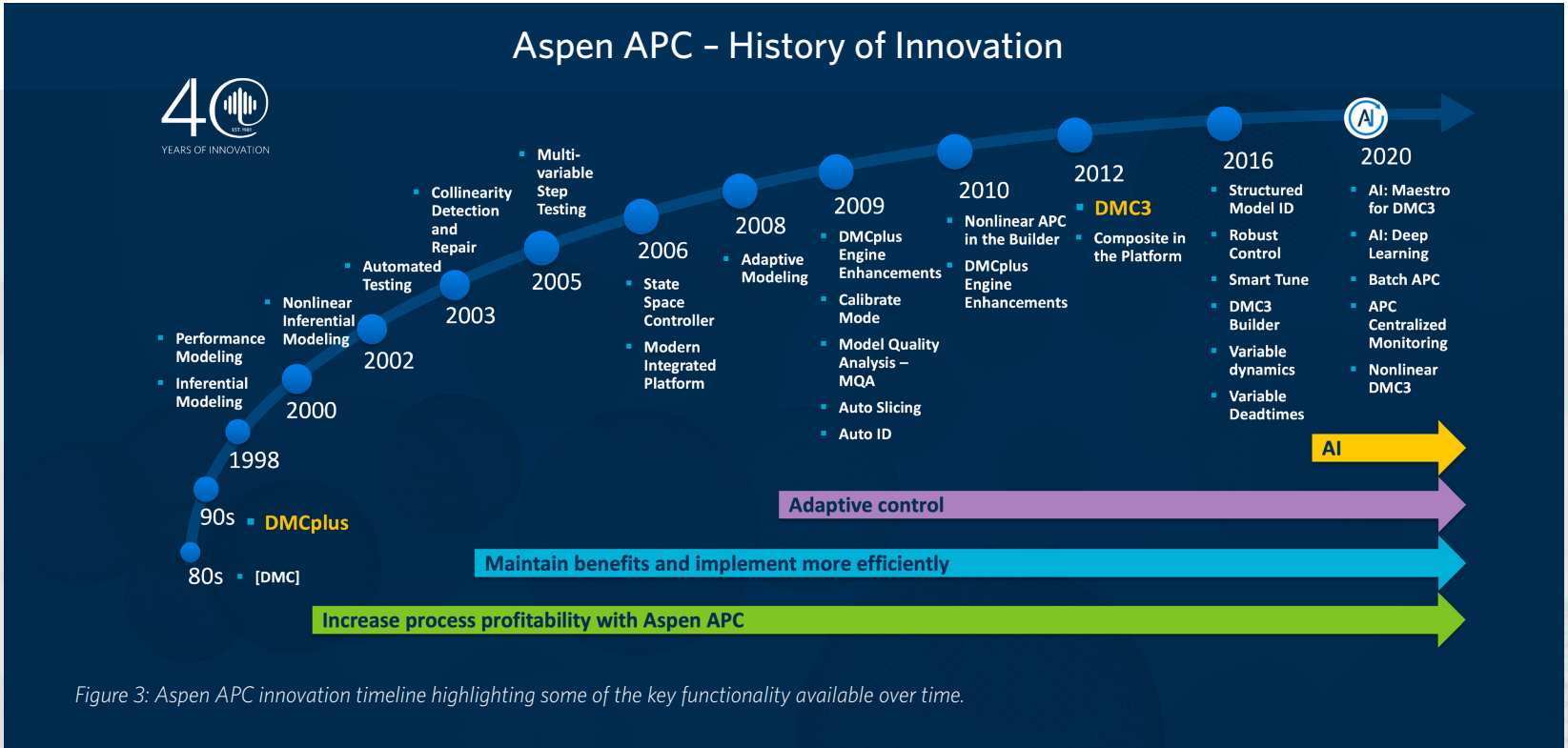


Figure 3: Aspen APC innovation timeline highlighting some of the key functionality available over time.

- SmartTune: Simplifies tuning as it allows the process engineer to explicitly specify variable priorities and optimization direction for the controller objective function.
- Robust control with economic relaxation: Makes the controllers more resilient to model quality issues and unmeasured process disturbances.

APC Project Methodology

The traditional APC project methodology, which has been fairly consistent for a number of APC vendors, involves a sequence of steps from pre-test activities to plant testing, model identification, application configuration, simulation and commissioning of the application. Sustaining the control performance of the APC application in order to ensure that APC continues to deliver the same benefits as the process conditions or/and market conditions keep changing, was also a time-consuming effort. Although this is a time-tested methodology, it can make the deployment and managing of APC controllers costly, disruptive and often needing experienced control engineers who, are also retiring at a rapid rate. What was clearly needed was a faster, easier, smarter APC solution that adapts and responds to changes in operating and market conditions in order to help drive real sustained results.

The DMC3 Adaptive Control technology enabled a new, more efficient methodology that reduced the time to application commissioning from months to weeks, delivering APC benefits much faster. A *seed model,* created in many cases from historical data, is put into the calibrate mode and the APC application runs in closed-loop, generating benefits, while the online model identification, running in the background, enables the engineer to refine and update the models. The persistent excitation provided by the less-disruptive calibrate moves ensures high model fidelity while operations do not experience significant process perturbations.

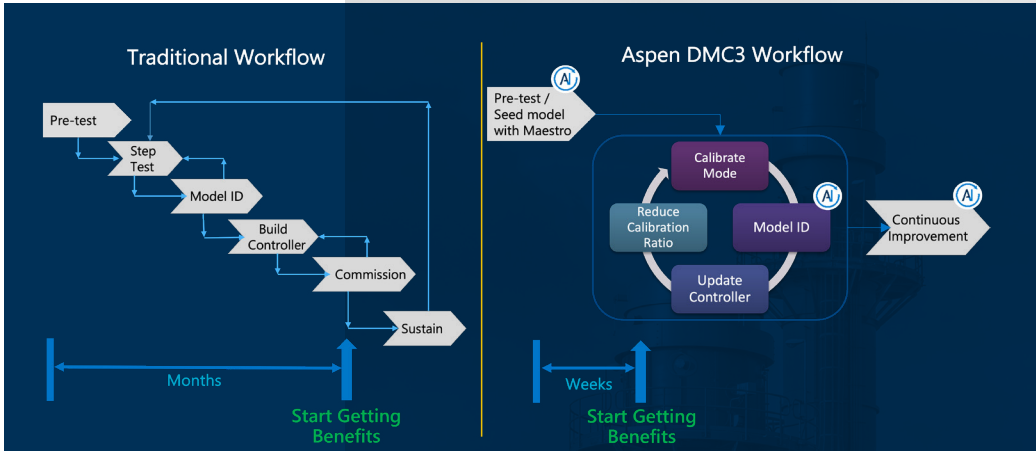


Figure 4: Traditional vs DMC3-enabled APC methodologies.

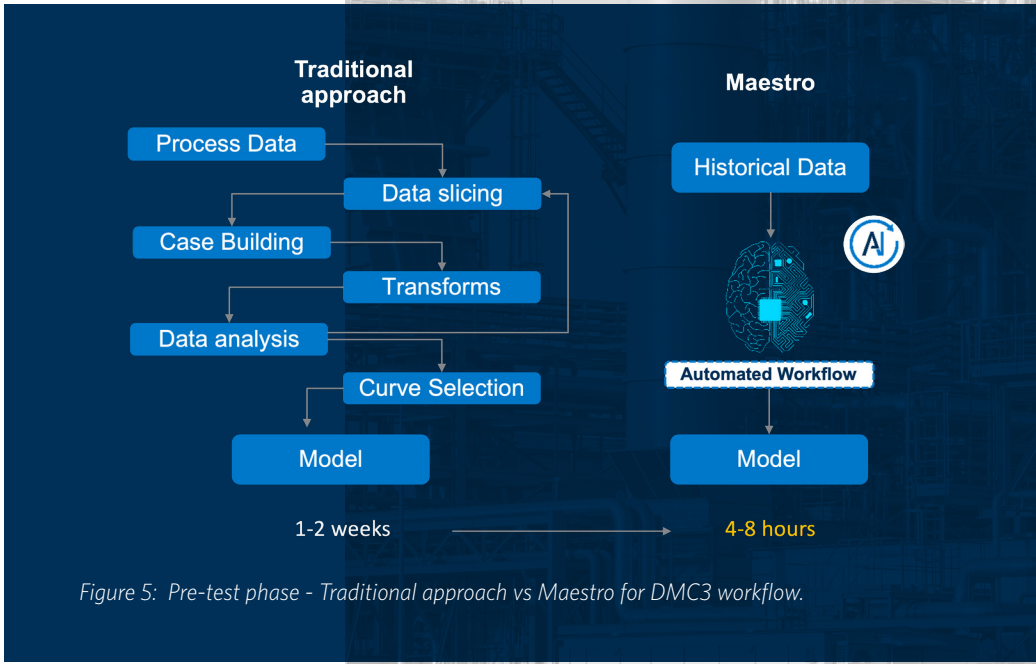


Figure 5: Pre-test phase - Traditional approach vs Maestro for DMC3 workflow.

Incorporating AI into Aspen DMC3

One of the most critical steps of an APC project is often the pre-test phase. The Maestro technology for DMC3 revolutionizes APC initial model-building as Machine Learning-powered algorithms are packaged with an easy-to-use, wizard-like workflow to enable building seed models from historical data. Data mining algorithms are combined with PID Loop detection to enhance automated data slicing. Automatic correlation analysis and automatic transformations detection help to obtain accurate models.

Aspen Maestro for DMC3 technology helps industries to:

- Lower the barrier for APC implementation
- Save time by automating recurrent tasks like data slicing and transformations
- Mine "seed" models from historical data which can be further refined online via DMC3 calibrate technology
- Drastically reduce the time to deploy APC models online
- Reduce engineering efforts to analyze data and build models
- Sustain peak plant performance when combined with DMC3 Adaptive Process Control

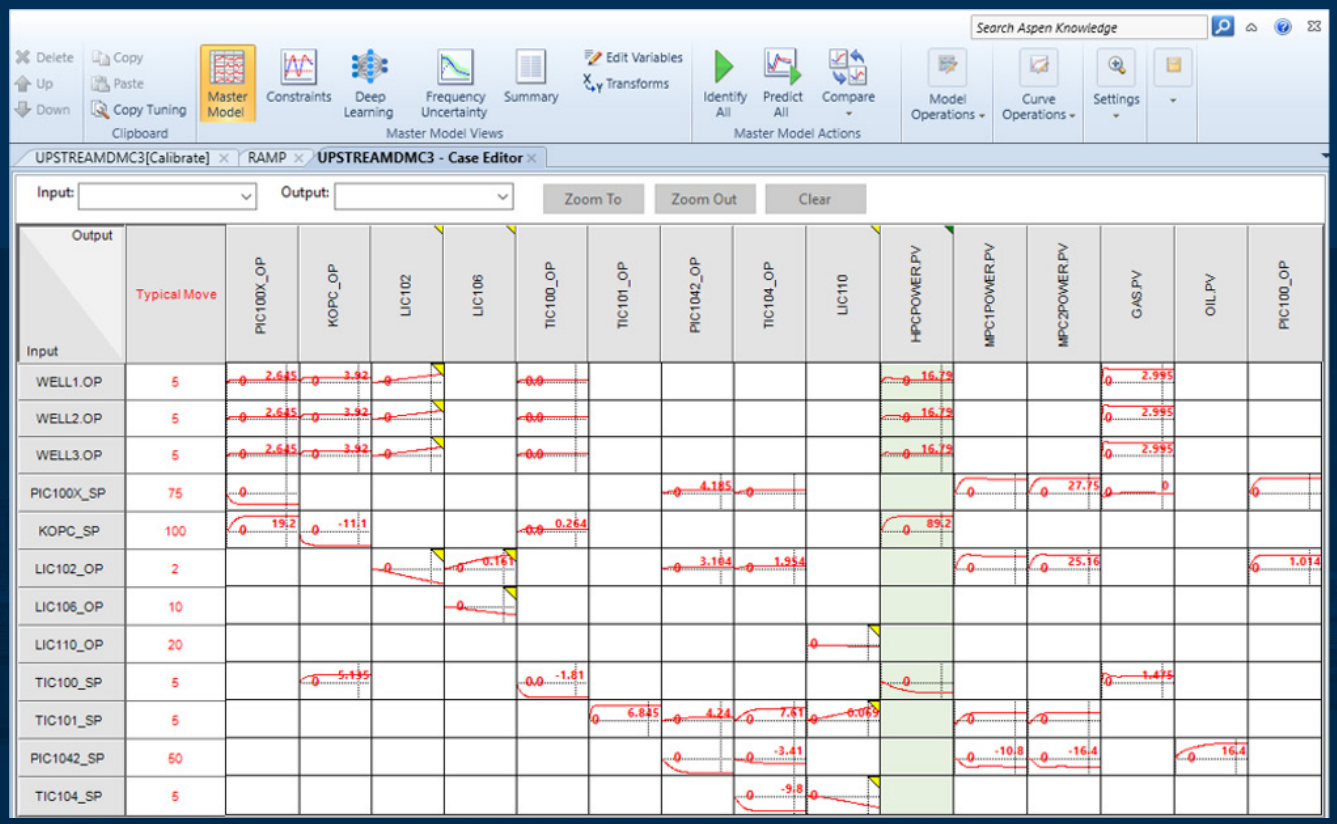
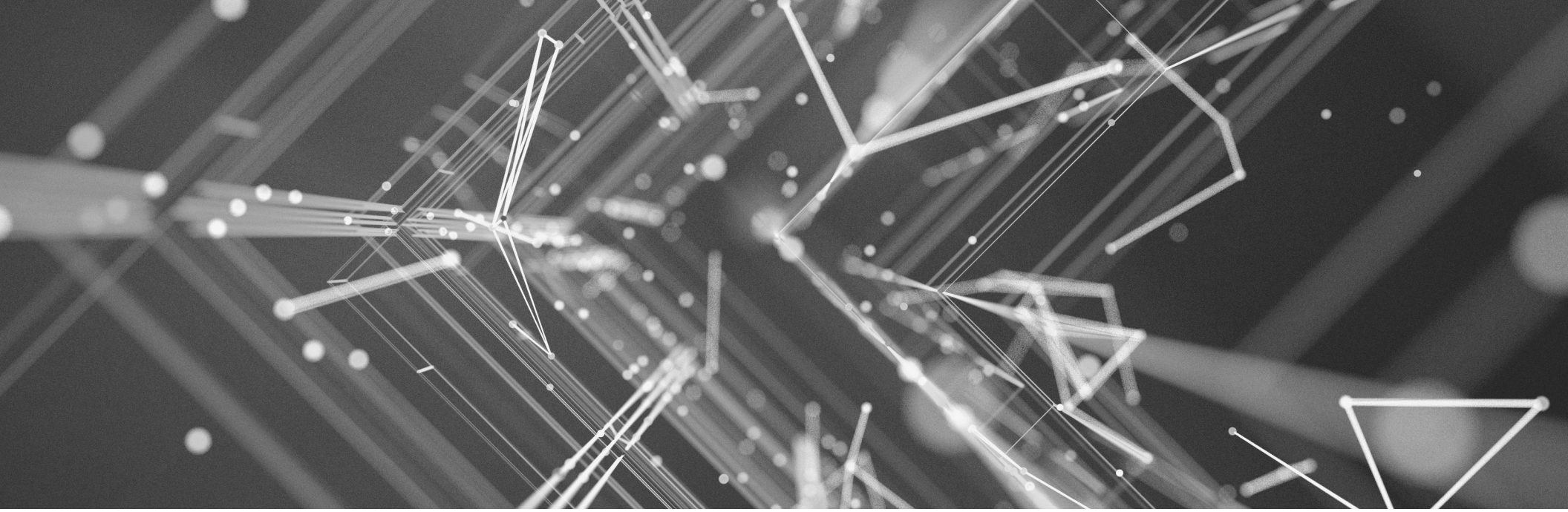


Figure 6: DMC3 model matrix combining linear, linearized (via transforms) and full nonlinear deep learning variables.



Regarding model development, Deep Learning technology has also been introduced for both inferentials (in Aspen IQ) and control (in DMC3). For inferentials, Deep Learning provides more accurate predictions for process and quality variables across a wide range of operating conditions or nonlinear regions. For control applications, Deep Learning provides the additional capability of including nonlinear variables in the same DMC3 model matrix combined with linear variables. The familiar DMC3 Builder workflow is used to build and deploy Deep Learning dynamic models—with minimum additional expertise required. Although technically possible, there is no need to utilize Deep Neural Networks for all variables in the DMC3 matrix.

It is the merger of the linear (e.g. sub-space) and nonlinear Deep Learning technologies that adds tremendous value, more than the individual technologies on their own. This is especially true when it comes to the crucial aspect of explainability of the APC actions, which is key for the adoption of any technology in control rooms. For example, in Figure 6, only one variable, which was identified as highly nonlinear, is modelled via Deep Learning, establishing a best practice of adding nonlinear variables only when it adds significant value to the overall solution. For the rest of the linear variables (or linearized variables via automatic transform) the powerful linear sub-space model identification is used.

AIoT: Cloud-Based Solutions for Performance Monitoring and Model Development

The Aspen Artificial Intelligence of Things (AIoT) Hub™ provides a Cloud-ready, Industrial AI infrastructure that opens up more possibilities for remote performance monitoring and model building. Aspen Enterprise Insights (AEI) is a hybrid-cloud-based product available in the AIoT Hub with a flexible enterprise visualization and workflow management solution that delivers real-time decision support across the enterprise. Flexible dashboards provide powerful visualization, reporting as well as drill-down capabilities for root cause analysis workflows available across functional areas. Process data are broadcasted securely one-way-only outside of the process network for AEI and AIoT to provide the guided analytics and actionable insights

Aspen AIoT hub also opens up other possibilities, for example, containerizing APC applications and AI Agents in order to be agnostic of the deployment environment. Another example is running the APC applications via microservices so that it is easy to deploy new functionality quickly and integrate with other applications seamlessly.

4. Aspen GDOT™: Dynamic Optimization

Aspen GDOT (Generic Dynamic Optimization Technology) is a crucial component of production optimization as it addresses the long-standing challenge of optimizing broad envelopes of refinery and petrochemical plants in closed loop by aligning planning/scheduling models, objectives and economics with actual operations. GDOT coordinates multiple process units in closed-loop by adjusting targets for many APC controllers on process units and blending systems.

With its large envelope scope, GDOT can exploit a broad set of degrees of freedom across multiple process units to optimize performance objectives (for example product yield or quality) in real-time. It then sends optimized targets down to underlying APCs.

Aspen GDOT Models

Aspen GDOT models can be a combination of fundamental, planning-like and AI driven Hybrid models. These models provide the consistency needed to optimize a large scope. Additional granularity of process constraints and dynamics needed to run in closed loop are incorporated into GDOT by including models derived from APC.

GDOT models are configured, for example, via templates that cover the middle distillate/Naphtha envelope for refining and for Ethylene sites. In addition to planning and APC models, GDOT also has some proprietary models included in the templates.

Online Optimization Revisited

In the past a key barrier to real time optimization systems was the skillset required to build and maintain optimization systems. The modeling approach and technology available in GDOT has enabled APC engineers to maintain large scope GDOT optimizers for over a decade with very high uptimes. Optimizing a broad scope, e.g., an entire a refinery middle distillates system, has much larger benefits compared to a unit level optimization. However, modeling of the entire middle distillates scope requires rethinking of the traditional modeling and optimization approach. With the combination of process templates that have embedded process knowledge and patented data reconciliation technology, engineers with an APC skillset can easily configure and maintain unit level or broad scope optimizer applications in refining and Olefins applications.

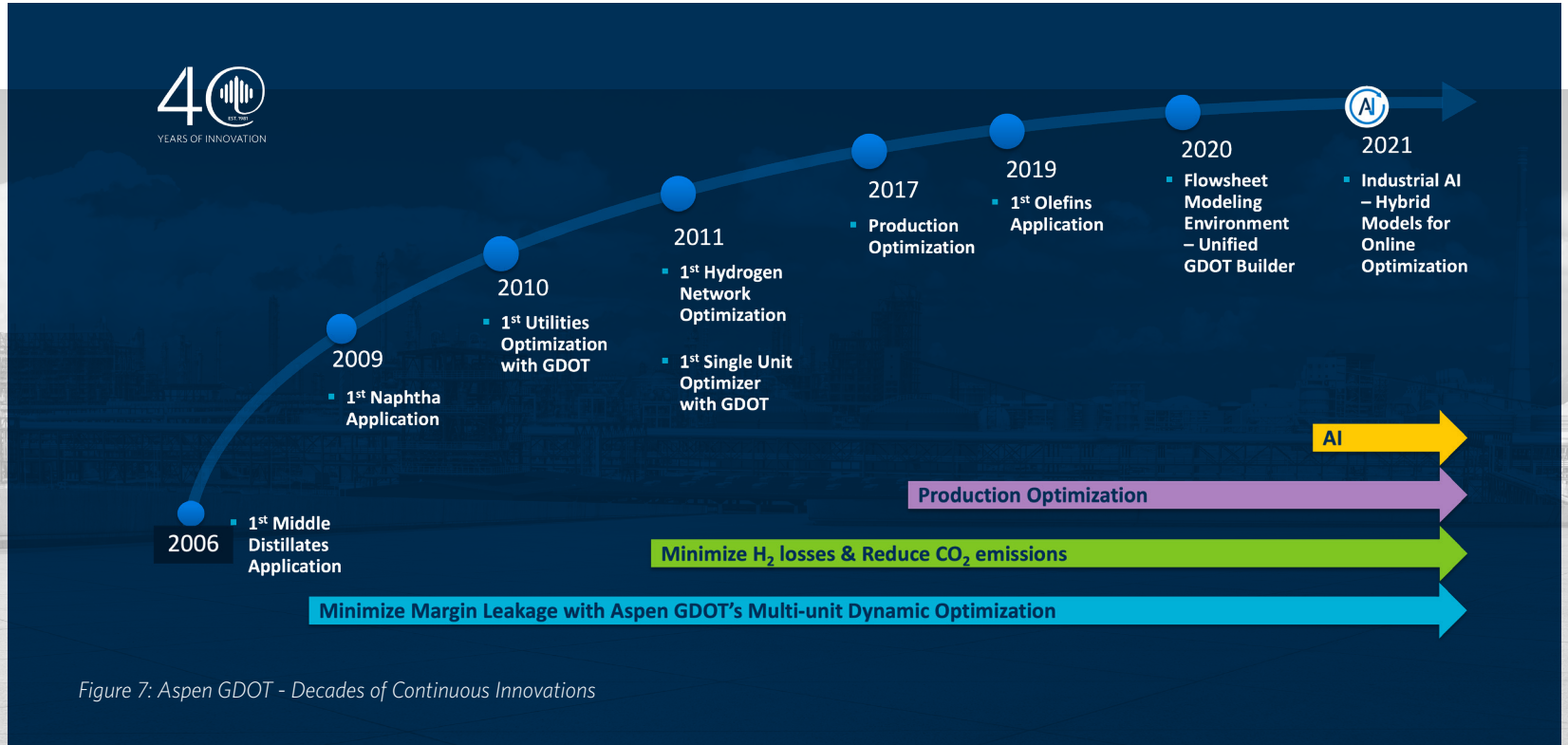


Figure 7: Aspen GDOT - Decades of Continuous Innovations

A New Era of Embedded Industrial AI

Aspen GDOT provides support for Hybrid Modeling technology. These hybrid models combine Industrial AI with AspenTech's widely used first principles models (for example, Aspen Plus® and Aspen HYSYS®). The resultant hybrid models make it possible to capture the behavior of the asset over a broad operating range and can be reconciled within GDOT, just like templated models can. These models can be incorporated into a closed-loop optimization environment like Aspen GDOT and be shared with Aspen Unified PIMS models. The AI-based hybrid models can be used to optimize complex process units like an FCC and can also be included in broader envelope models to drive multi-unit envelope optimization.

Benefits

GDOT is a proven technology that has enabled global companies to significantly improve margins over and above those delivered by APC, planning and scheduling solutions alone.

With GDOT, refining sites can expect to improve margins by $0.40/bbl. The benefits vary by size and complexity of the site. Some typical post audit benefits and areas of improvement achieved by mid-size refineries may include:

1. **Naphtha and aromatics processing.** Increase of aromatics yield by 5% and reduce gasoline giveaway.
2. **Middle distillates.** Increase middle distillate production by 5% to 10%.

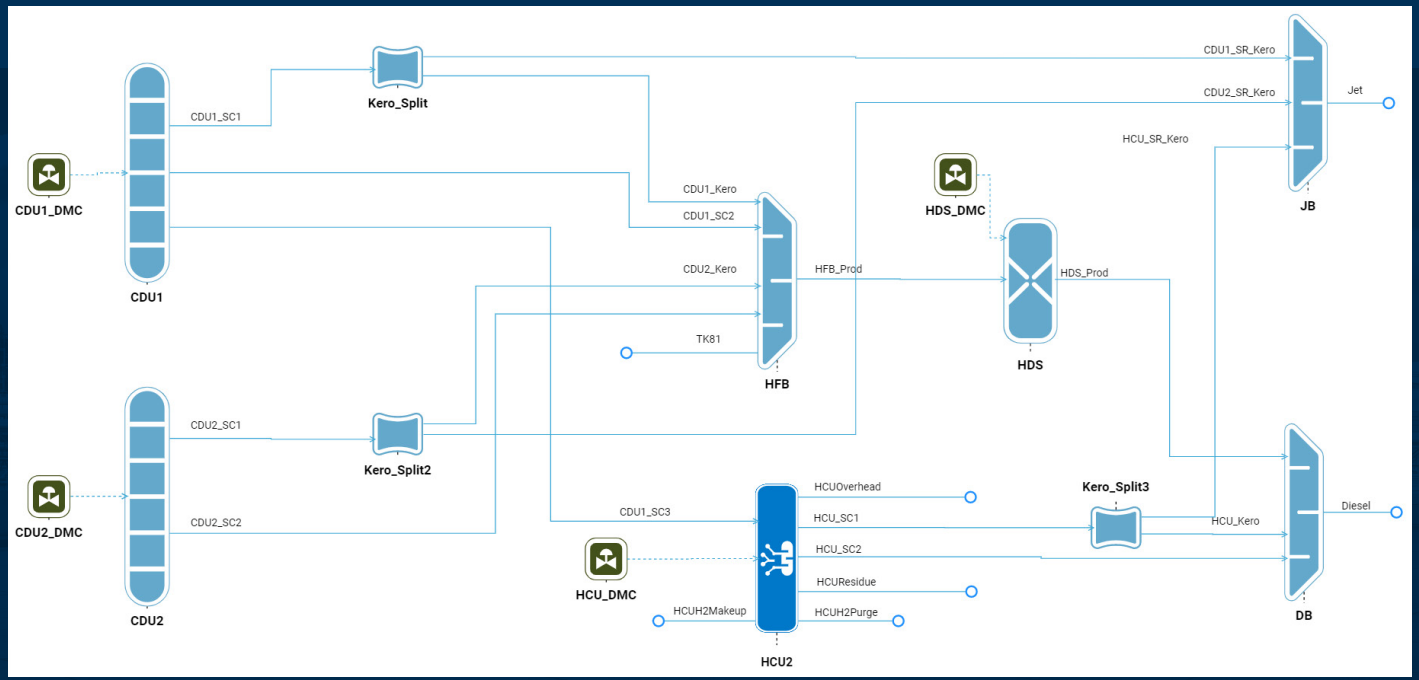
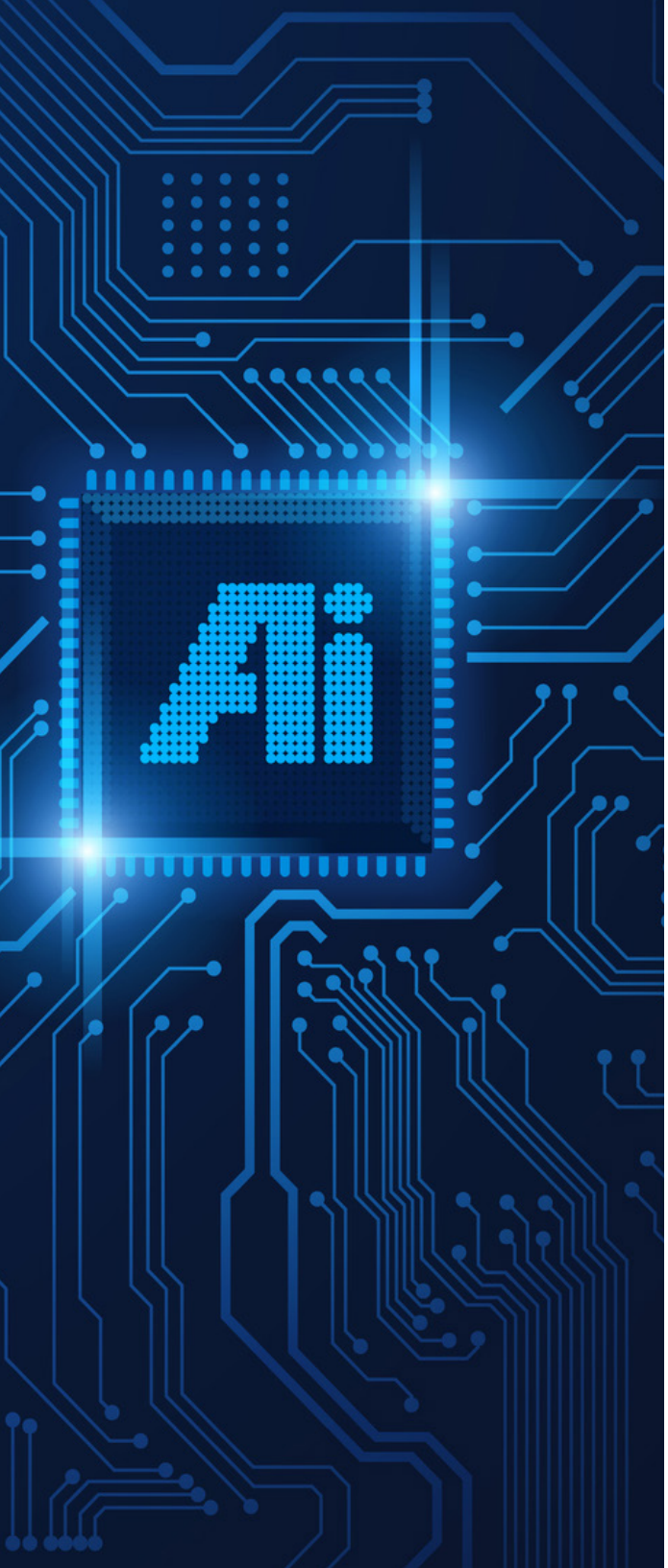


Figure 8: Aspen GDOT flow sheet with templated, Hybrid and APC models integration.



3. **Residue processing.** Increase conversion on feed by 3%.
4. **Hydrogen and utilities.** Reduce fuel gas and H_2 losses by 50%+. Benefits are higher if the refinery has a shortfall of hydrogen.

The expected benefits of using Aspen GDOT for Ethylene sites include an increase in throughput of 2%-5%, yield increases of 1%-2%, and reduction in energy usage. GDOT applications optimize the feed allocation and conversion/severity for individual cracking furnaces, taking into account any process or production constraints and the overall site economics.

Conclusion

The Role of APC and Dynamic Optimization in Production Optimization

APC and Dynamic Optimization play a crucial role in supporting more autonomous operations and are at the center of our integrated Production Optimization solution, helping to align planning, scheduling and operations via shared model and data components and information about constraints. Aspen Unified technology brings these components together, enabling companies to take advantage of synergies with digital twins and providing the flexibility to support new objectives like sustainability.

Digital Twin

To roll out a new advanced process controller (APC) or re-tune an existing one, most plants conduct step tests on the actual asset, which requires engineering and operations expertise and may impact production. Performing the step-tests on a digital twin reduces production impact and saves time implementing APC. Control engineers can collaborate with process engineers to leverage existing simulation models based on actual operating conditions, leading to faster deployment for new APC units and less impact on production. This approach has been adopted for development of APC in upstream operations.

Sustainability

To achieve energy efficiency, operators need to concentrate on reducing the environmental footprint from resources consumed by their own business activities. Digital twin monitoring systems, dynamic optimization, and multivariable process control (APC) solutions can collectively save 5-15% energy use, as well as reduce carbon emissions by a proportional amount. Planning models can track, predict and optimize CO_2 emissions to meet sustainability targets and understand economic impact of carbon taxation.

Today, process industry organizations are facing unprecedented challenges, and must map a path forward amid demand uncertainty, feedstock and crude price volatility, sustainability pressures and global competition. AspenTech's goal is to continue to innovate, with an emphasis on delivering value faster over time. Now is the time to embrace digitalization and AI in a way that provides a smooth path forward, building on the powerful tools you have used for decades, enabling more automation, insights from models, and remote use of these tools.

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About Aspen Tech.

Aspen Technology (AspenTech) is a leading software supplier for optimizing asset performance. Our products thrive in complex, industrial environments where it is critical to optimize the asset design, operation and maintenance lifecycle. AspenTech uniquely combines decades of process modeling expertise with machine learning. Our purpose-built software platform automates knowledge work and builds sustainable competitive advantage by delivering high returns over the entire asset lifecycle. As a result, companies in capital-intensive industries can maximize uptime and push the limits of performance, running their assets safer, greener, longer and faster.

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