WHITE PAPER

MODULAR PLANT AUTOMATION FOR SMART MANUFACTURING AND AGILE OPERATIONS

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Abstract

With the increasing adoption of Industry 4.0, industries require rapid scaling while enabling the integration of shopfloor, enterprise systems and the value network in the most efficient way. There is a growing demand for shorter product launch times, particularly in industry segments like fine chemicals, pharma/biopharma manufacturing, food & beverage, oil & gas, and energy & utilities. Although large-scale or traditional automation systems have been commonly used in the manufacturing process for decades, they lack the flexibility required to support the rapidly changing demands of the industry. The batch size can vary, and typically, a batch size of one is also targeted.

This requires a new approach to automation that provides increased flexibility and modularity to support quick changes. There is a need for a different approach towards automation that incorporates the plug-and-play concept and enables flexible integration and orchestration of processes.

Modularizing process automation solutions will enhance production operation flexibility, increase the efficiency of automation systems, enable faster time-to-market and reduce operating costs. This requires a standard way of information exchange between vendor systems, which enhances the interoperability of control systems while having vendor neutrality.

This white paper focuses on the approach to building modular automation solutions based on NAMUR standard Module Type Package (MTP - NE 187, VDI/VDE/NAMUR 2658) specifications for the manufacturing industry that has batch operations, require rapid delivery times and customized product offerings.

Overview of traditional plant engineering and challenges

In today's process manufacturing industry, businesses face a significant challenge arising from the lack of standardization across vendor systems (Figure 1)[2]. This issue directly affects the efficiency of plant operations and results in a high total cost of ownership (TCO). In traditional plant engineering, incorporating different technologies and equipment from various vendors introduces complexity and inefficiency due to the absence of standardized processes and interfaces. Plant operators and workers are burdened with integrating disparate systems, leading to increased efforts, system downtime and reduced productivity (Figure 2)[3].

These operational inefficiencies come at a substantial cost, including expenses for maintenance, system upgrades, training, and lost production opportunities.

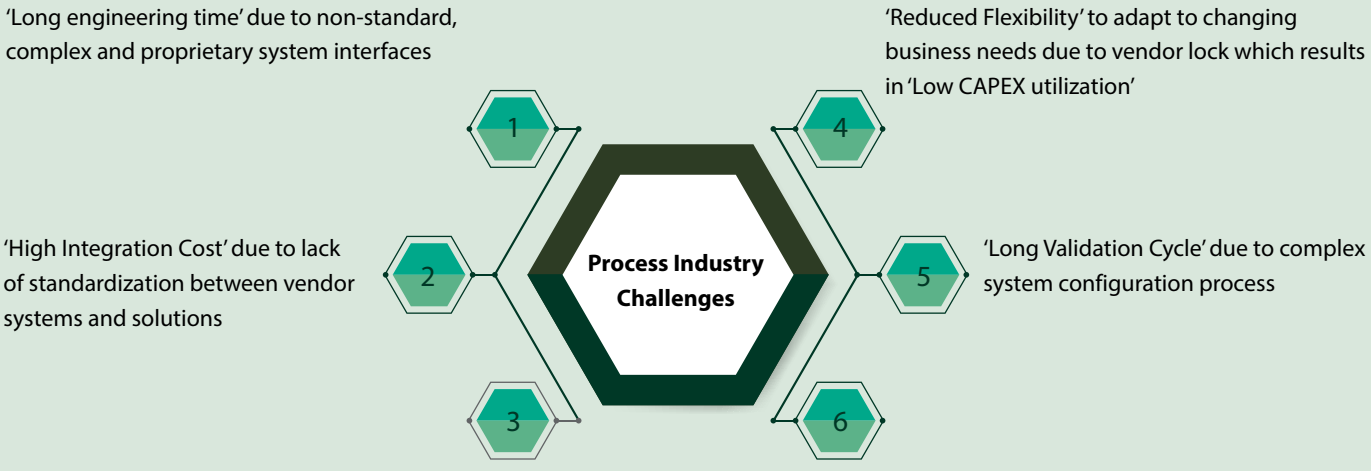


Figure 1 - Challenges of today's process industry

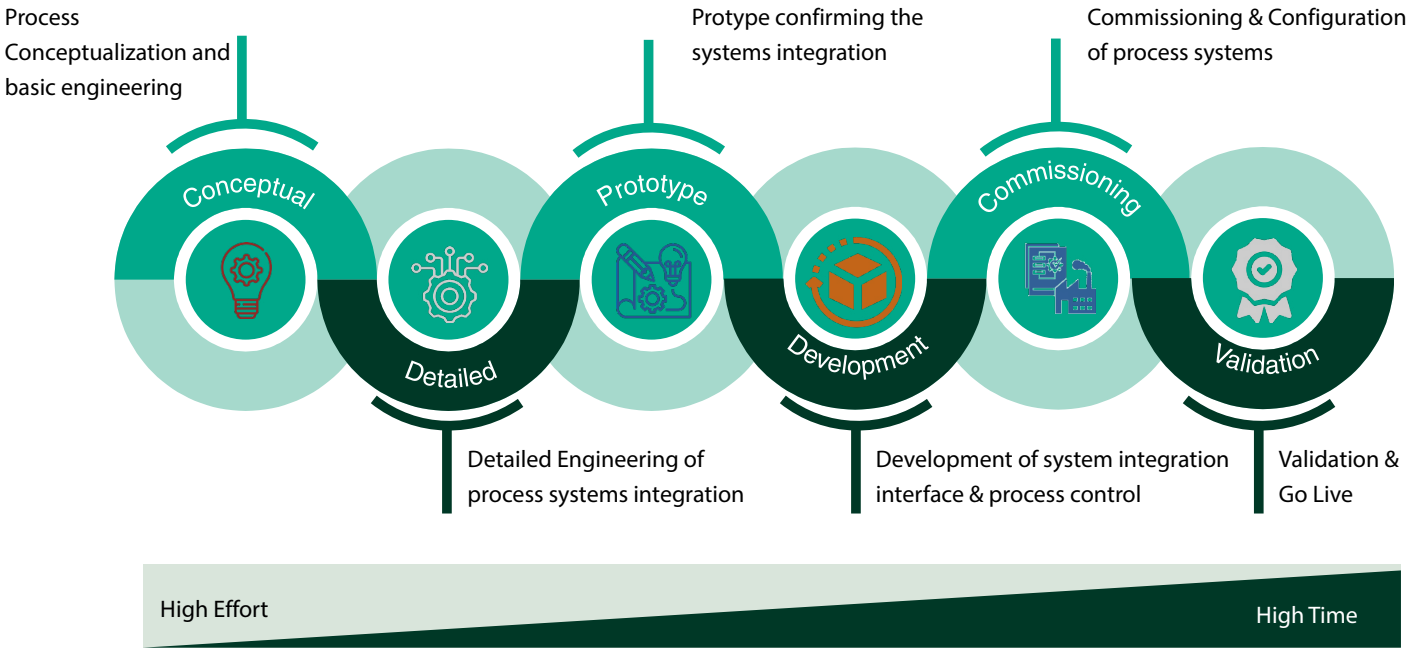


Figure 2: Traditional Plant Engineering

Addressing the integration challenges in the process manufacturing industry is essential for achieving operational efficiency and facilitating digital transformation. Recently, process manufacturing, especially in the life sciences industry, has required flexible and agile manufacturing systems to cater to smaller volumes of specialty products, which requires frequent changes in production setup. Figure 3 vividly illustrates the intricate web of obstacles posed by vendor lock, proprietary interfaces and non-standardized data models in legacy manufacturing systems. These challenges hinder seamless connectivity and interoperability among systems and components in the evolving digital manufacturing ecosystem. This fragmentation introduces bottlenecks and complexity and restricts the flow of critical information throughout the organization. Consequently, these inefficiencies lead to reduced productivity, missed optimization opportunities, and overall inefficiency in plant engineering, resulting in less flexibility in operations.

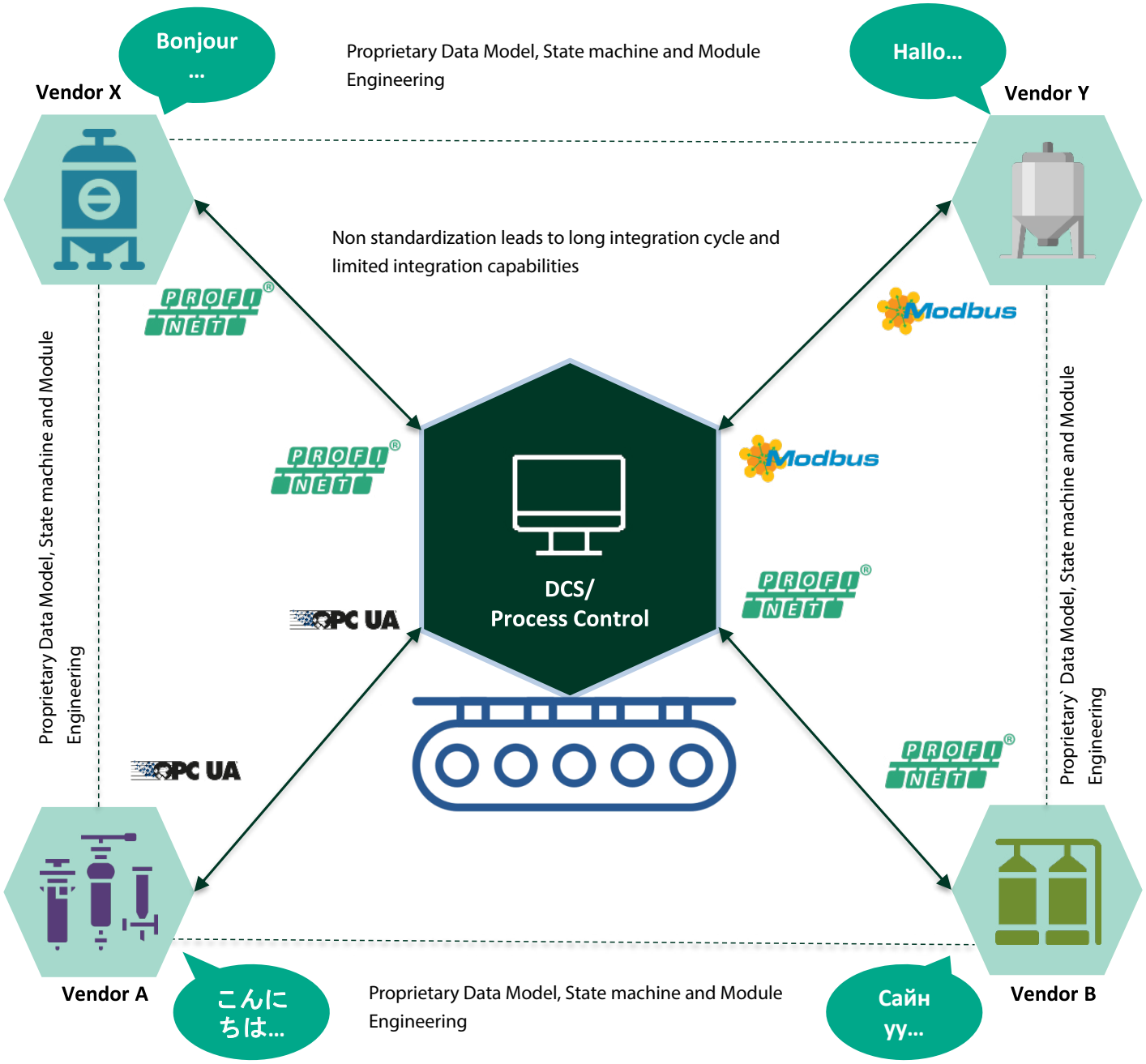


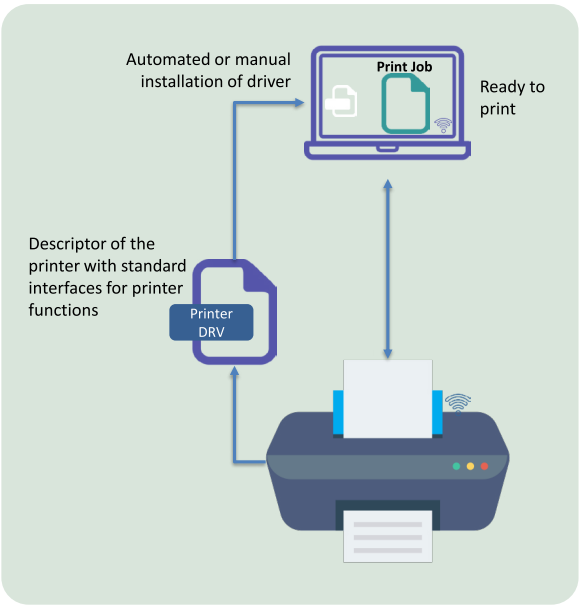
Figure 3 – Proprietary interfaces limit ease of integration.

For example, in the process industry, setting up a process line typically takes approximately 10-16 months due to limited interoperability between systems that require a DCS-like solution to engineer the integration and orchestration of connected process units. This process includes the integration, engineering, and development of process displays for the integrated process units, which involves a significant effort and cost for developing and validating such solutions. Once the process line is set up, it can only serve the purpose it was designed for. Adopting that solution to different process needs takes a long time, requiring manufacturers to invest in new resources since optimizing the existing design is costly.

It is imperative to address these integration challenges to unlock the full potential of process manufacturing. By doing so, collaboration between systems can be enhanced, enabling data-driven decision-making and improved operational outcomes. A typical approach involves employing a new standard "Module Type Package" for system interoperability. This approach will not only improve efficiency but also empower companies to seize the benefits of digital transformation and gain a competitive edge in the industry.

Overview of Module Type Package (MTP)

"Module Type Package" (MTP), an emerging industrial standard, defines specifications for building pre-automated modular units and enabling interoperability between modules, as well as process orchestration by interconnecting these modular units as required (Figure 4)[3]. The MTP specification provides a standardized way to describe the module's capabilities, interfaces, and operational behavior, allowing them to be easily integrated into a larger process system. This standardization will significantly reduce the time and effort required to integrate modules from different vendors, making it easier to build flexible, agile and scalable modular process plants.



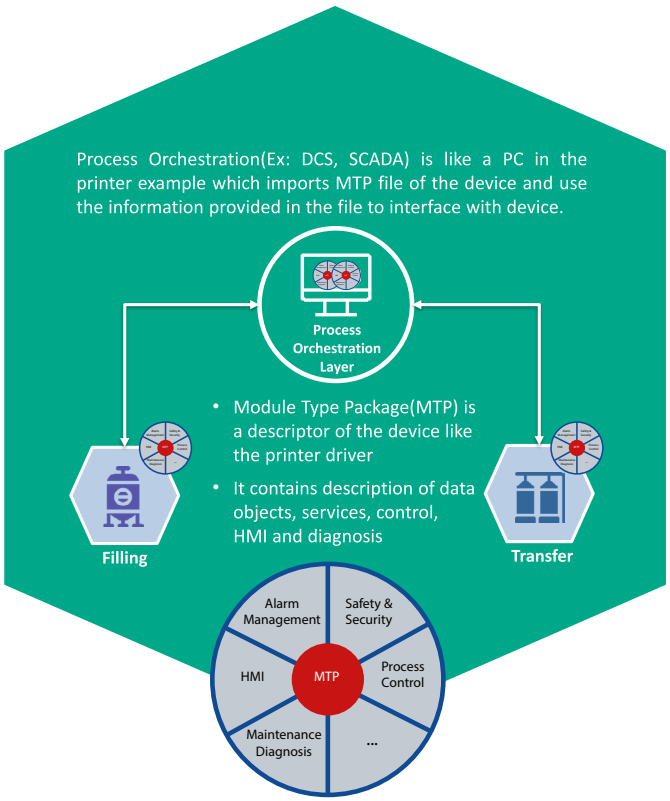


Figure 4 – Overview of Module Type Package

MTP is a modular-specific standard developed by NAMUR, an international user association of automation technology and digitalization in the process industry. The MTP standard provides a framework for equipment data models and includes various sections, from engineering and data aspects to human-machine interfaces (HMI). The standard is designed to be compatible with other industry recommendations, including the Reference Architecture Model for Industry (RAMI) 4.0.

MTP defines the specifications to build pre-automated modular units that enable interoperability between any module and orchestration of these modular units. The standard describes different aspects – Process Control, Communications, Alarms, Safety, HMI and Diagnostics, as shown in Figure 5[1] for each module leveraging OPC Unified Architecture (UA) for systems communication.

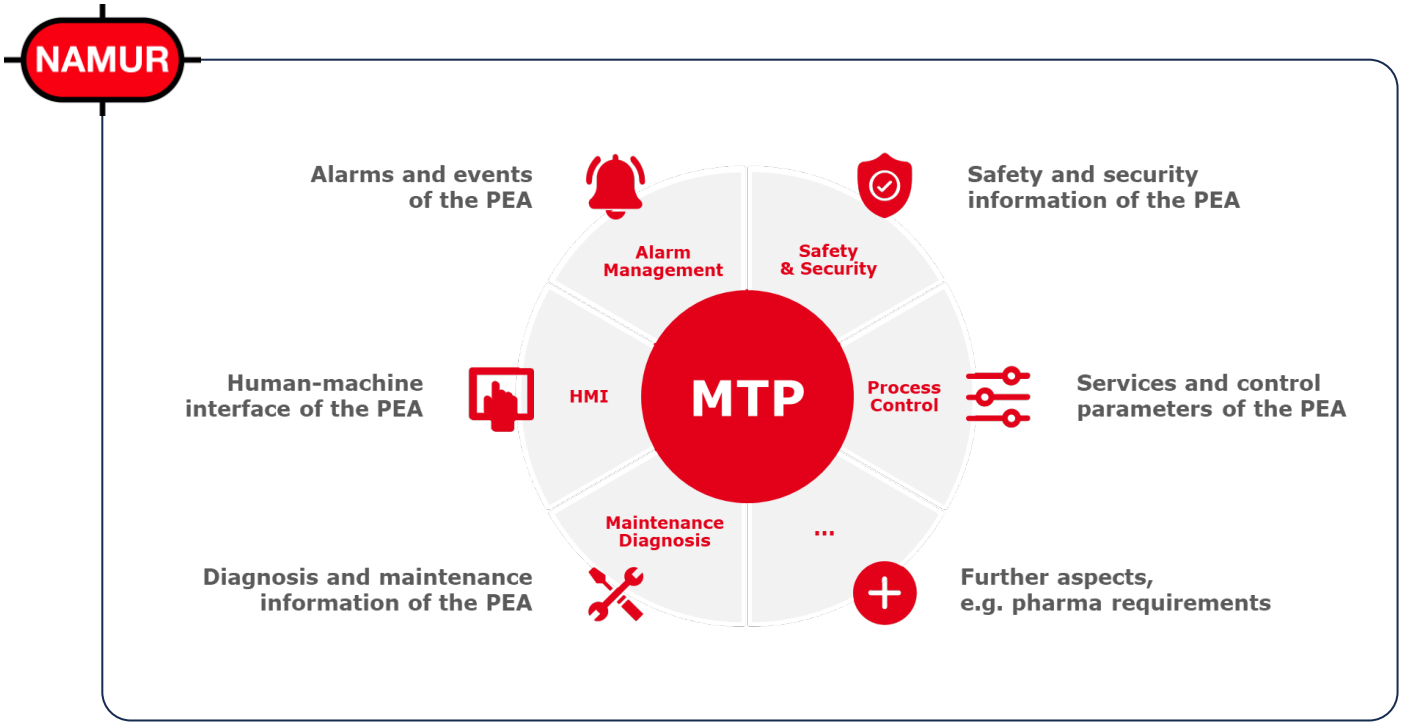


Figure 5 - Aspects of MTP

MTP is an advanced IEC standard that specifies the lifecycle of components in a facility. It prescribes that systems in the plant need to be modularized to make it easy to plug and produce or replace a module at any time. Additionally, the NAMUR Open Architecture (NOA) complements MTP by aiming to create production data that is easily and securely usable for plant and asset monitoring and optimization (Figure 6)[3].

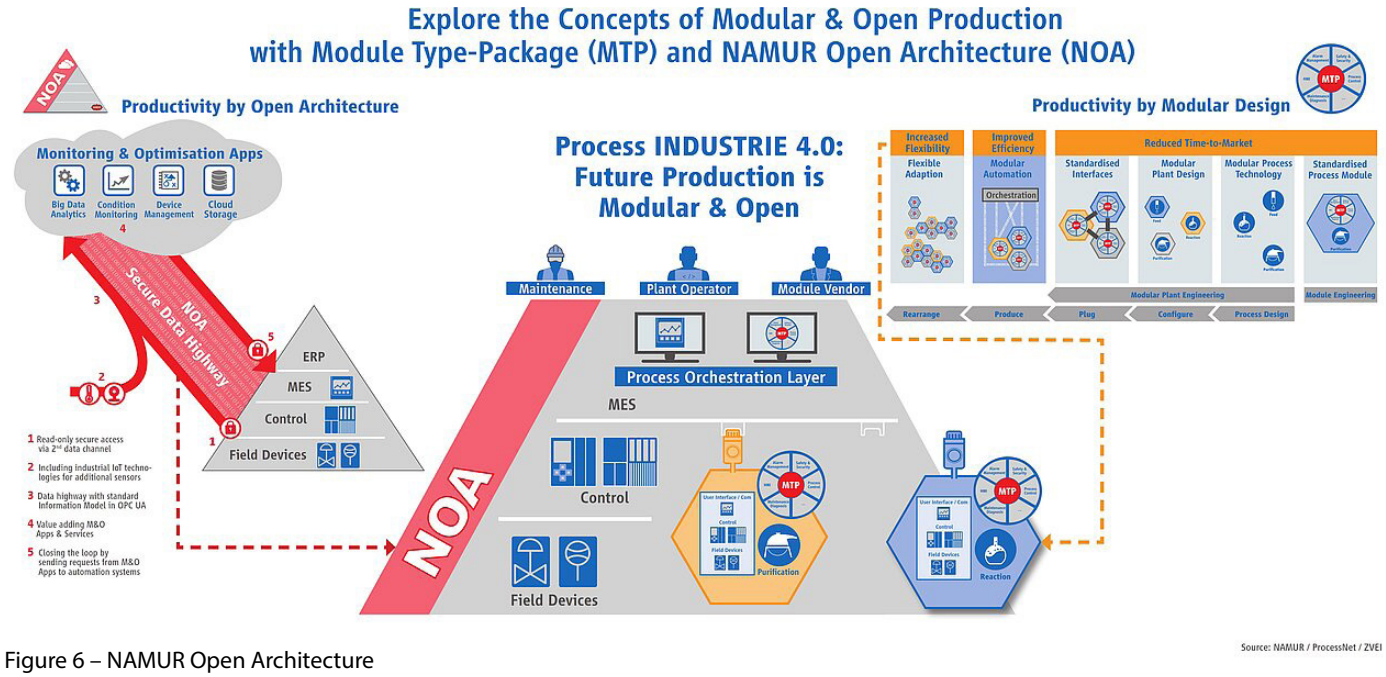


Figure 6 – NAMUR Open Architecture

The MTP specification defines the core aspects that should be present in a system and allows for adding more elements to support industry needs. For instance, the pharmaceutical industry may require additional services beyond the core specification for quality control. To define each piece of equipment, MTP files use an automation-specific XML data format called Automation Markup Language (AML), an internationally standardized format (IEC 62714).

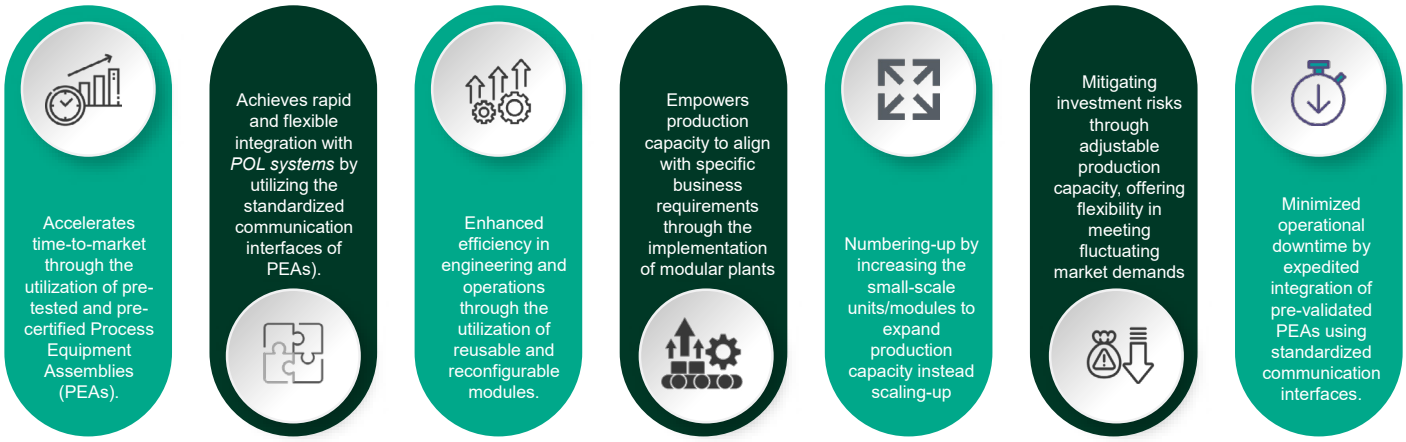


Figure 7 – Key Advantages of Modularization using MTP

Key concepts of MTP

MTP utilizes the following key concepts to define and build plant systems:

1. Process Equipment Assemblies
2. Modular Plant
3. Process Orchestration

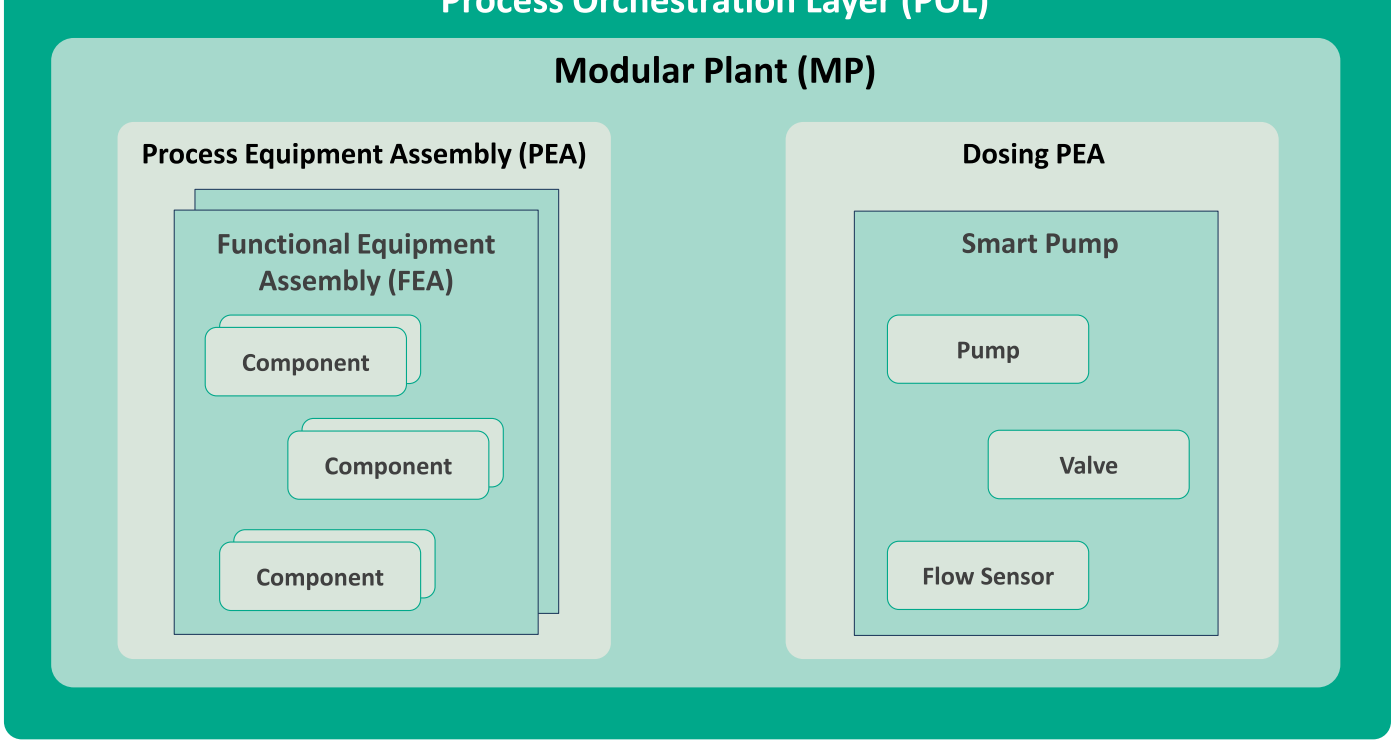


Figure 8 - Key MTP concepts

Process Equipment Assembly (PEA): Defines an autonomous or semi-autonomous unit of process equipment comprising functional equipment assemblies (Figure 8)[3]. These assemblies (E.g., Dosing PEA) include equipment and control modules (e.g., Smart Pump) of a modular plant designed based on the standard specifications to provide required services and data assemblies for further upstream integration.

Services: Services are the core part of a PEA and represent a set of capabilities associated with one or more control modules and equipment assemblies. Examples of MTP services include Transfer, Dosing, Filling, Heating, Mixing, and Emptying. These services are defined in the MTP file and use an automation-specific XML data format (AML).

Control Module: A control module is usually a collection of sensors, actuators that can be operated as a single entity such as temperature control, pressure control or flow control. Control modules are defined as part of the MTP specification and are used to build up the services.

Functional Equipment Assembly: An equipment assembly is a logical or physical grouping of controls modules and subordinate equipment assemblies used as part of a PEA to perform a specific function in the process. Examples of equipment assemblies include pumps, valves and sensors. Like control modules, equipment assemblies are defined as part of the MTP specification and are used to build up the services.

Data Assembly: A collection of data elements is used to provide information about the process or equipment. Data assemblies are defined as part of the MTP specification and are used to build up the services used to control a process.

The Modular Plant (MP) is a flexible and pre-designed unit that can be easily integrated into a larger process plant. It consists of standardized modules or packages that are self-contained and pre-engineered with specific functionalities (Figure 9)[1]. These modules can be quickly assembled, interconnected and integrated into the overall plant design, allowing for faster project execution, reduced construction time, and improved flexibility in adapting to changing production requirements.

The Process Orchestration Layer (POL) is a critical function that operates at the intersection of automation and information technology in modular plants. Its purpose is to ensure the smooth and efficient coordination of different modules, subsystems and applications. In effect, POL acts as a conductor, coordinating and synchronizing the various parts to create a harmonious whole. It uses standardized communication protocols and interfaces to seamlessly integrate process equipment assemblies (PEAs) and services, ensuring they work together to achieve the desired outcomes (Figure 9)[1].

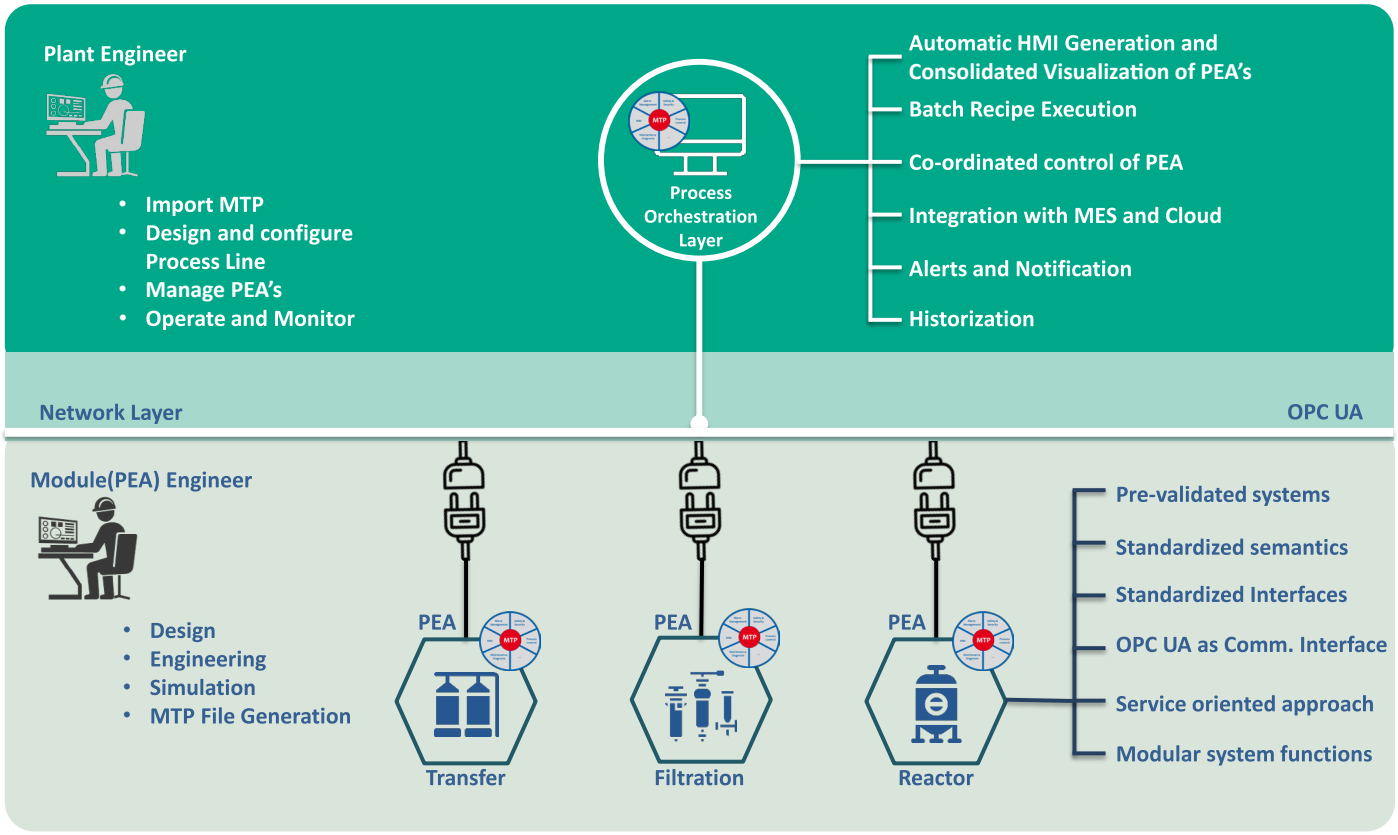


Figure 9 - Process Orchestration (POL)

At the heart of the MTP standard is the MTP file in AML, which the equipment vendor supplies for each skid or piece of equipment. This file contains the necessary information for the Process Orchestration Layer (POL) to establish its communications, tags, services, and HMI, enabling it to monitor and control the Process Equipment Assembly (PEA). The MTP file is crucial for interfacing with the PEA and forms the backbone of the MTP standard (IEC 62714) (Figure 10)[1].

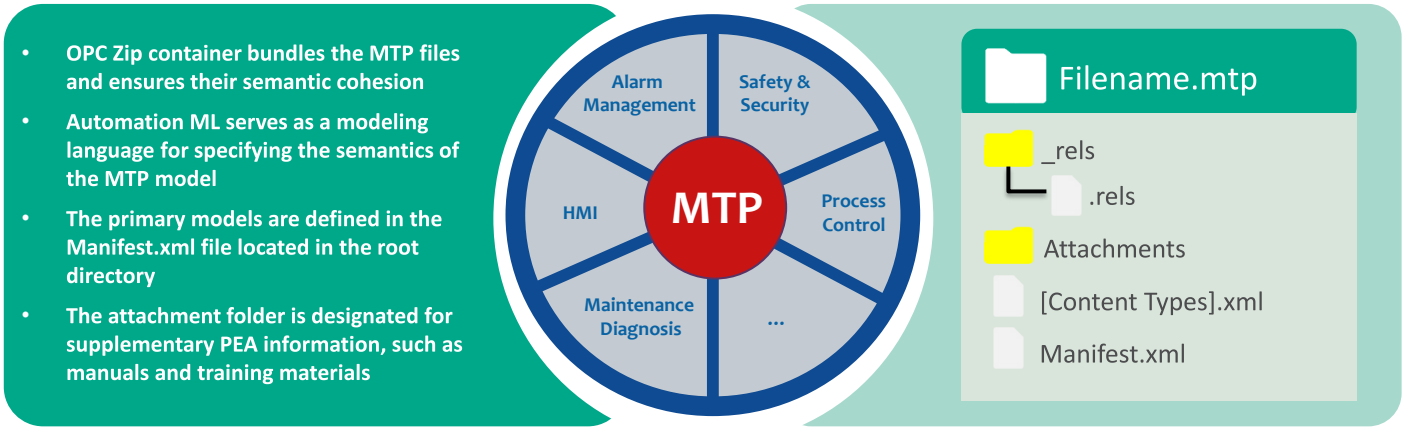


Figure 10 - Description of an MTP file

It lays the foundation for a new service-oriented approach to engineering and automation segments for process and manufacturing industries. In this approach, MTP services are the key aspects of a PEA and serve as the interface with the POL system for executing the engineering functions.

By adopting a service-oriented approach, the industry can define process engineering as a set of services abstracting low-level engineering functions, enabling efficient and effective coordination among different modules, sub-systems, and applications. This approach enhances the flexibility and scalability of automated modular systems, enabling the integration of new technologies and functionalities as needed. For example, the functional aspects of equipment control, valve operation, transfer of material, heating and mixing can be defined, and necessary inputs/parameters can be obtained through MTP specifications.

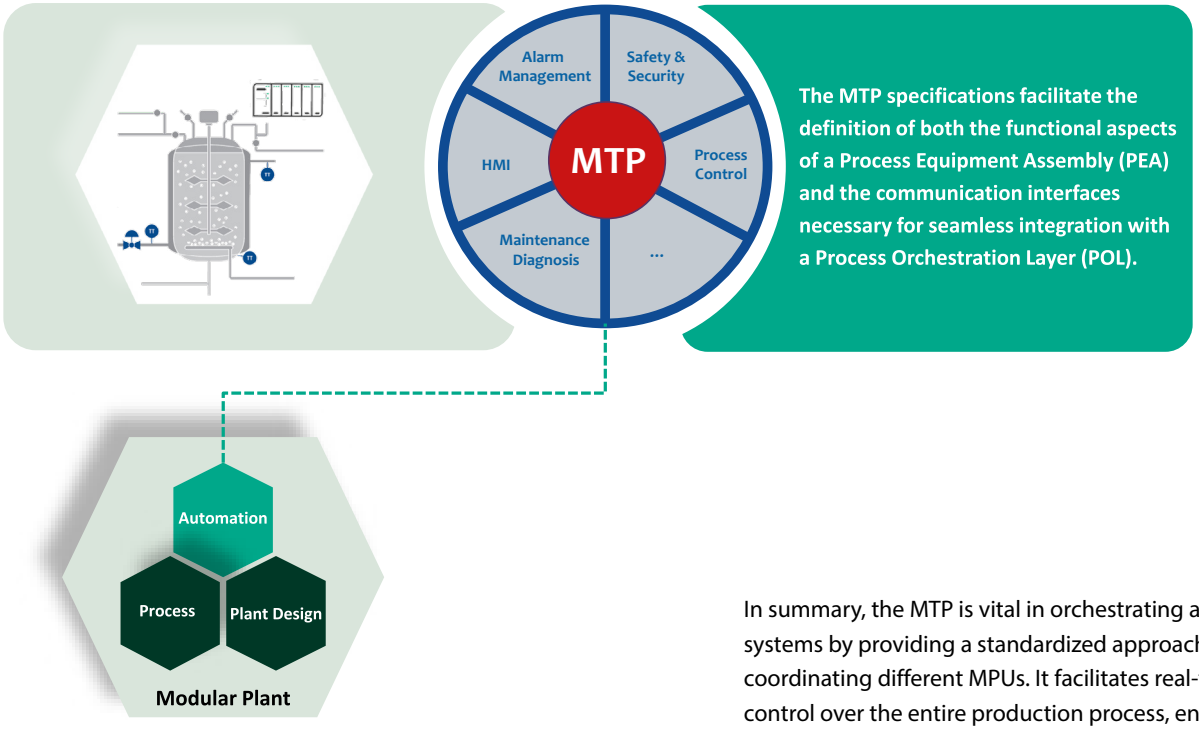


Figure 11[1] – MTP Aspect Overview

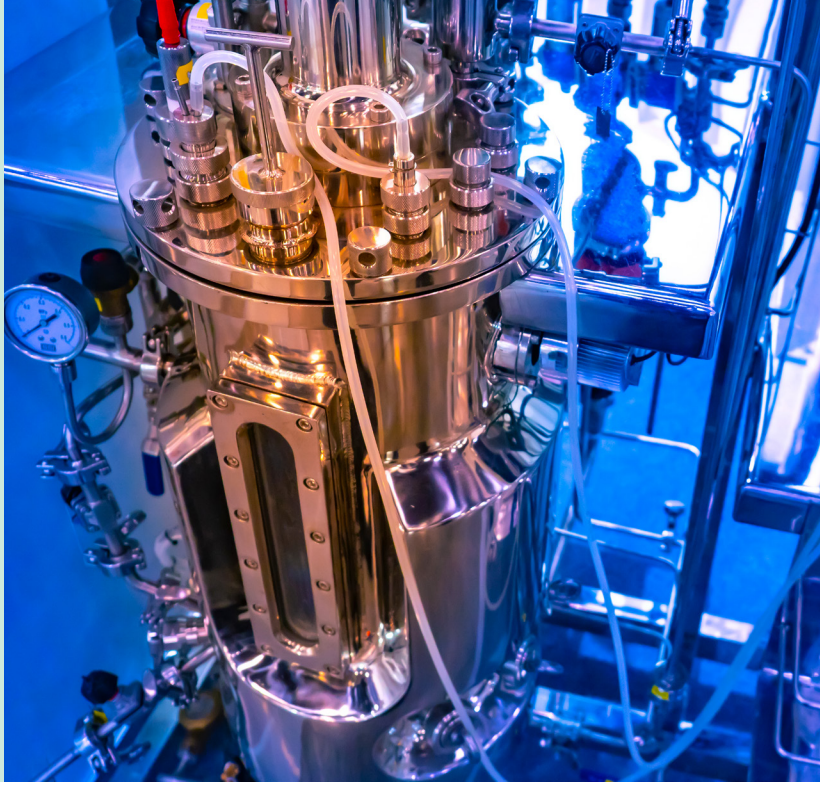
In summary, the MTP is vital in orchestrating automated modular systems by providing a standardized approach to integrating and coordinating different MPUs. It facilitates real-time visibility and control over the entire production process, enabling effective decision-making critical for optimizing the performance of the plant and achieving desired business outcomes.

Orchestrating Plant Processes leveraging MTP

Process Engineering:

Building a modular plant begins with the Module Engineering phase, during which plant assets are engineered based on MTP standards. System vendors are critical in engineering their systems following MTP specifications and guidelines to ensure system autonomy and interoperability. Systems that adhere to MTP specifications can generate an MTP file, which provides a detailed description of the system's interfaces and functionality.

It includes the operating screen and functionality of the module, together with alarms and diagnostics. Leading companies in the control software industry, including Siemens, ABB, Rockwell, Emerson, GE, Honeywell, Yokogawa and Beckhoff, have officially announced support for MTP in their control and process engineering software roadmaps. These modules with standard MTP interfaces can then be consumed for plant engineering, making it easier to plug and produce.



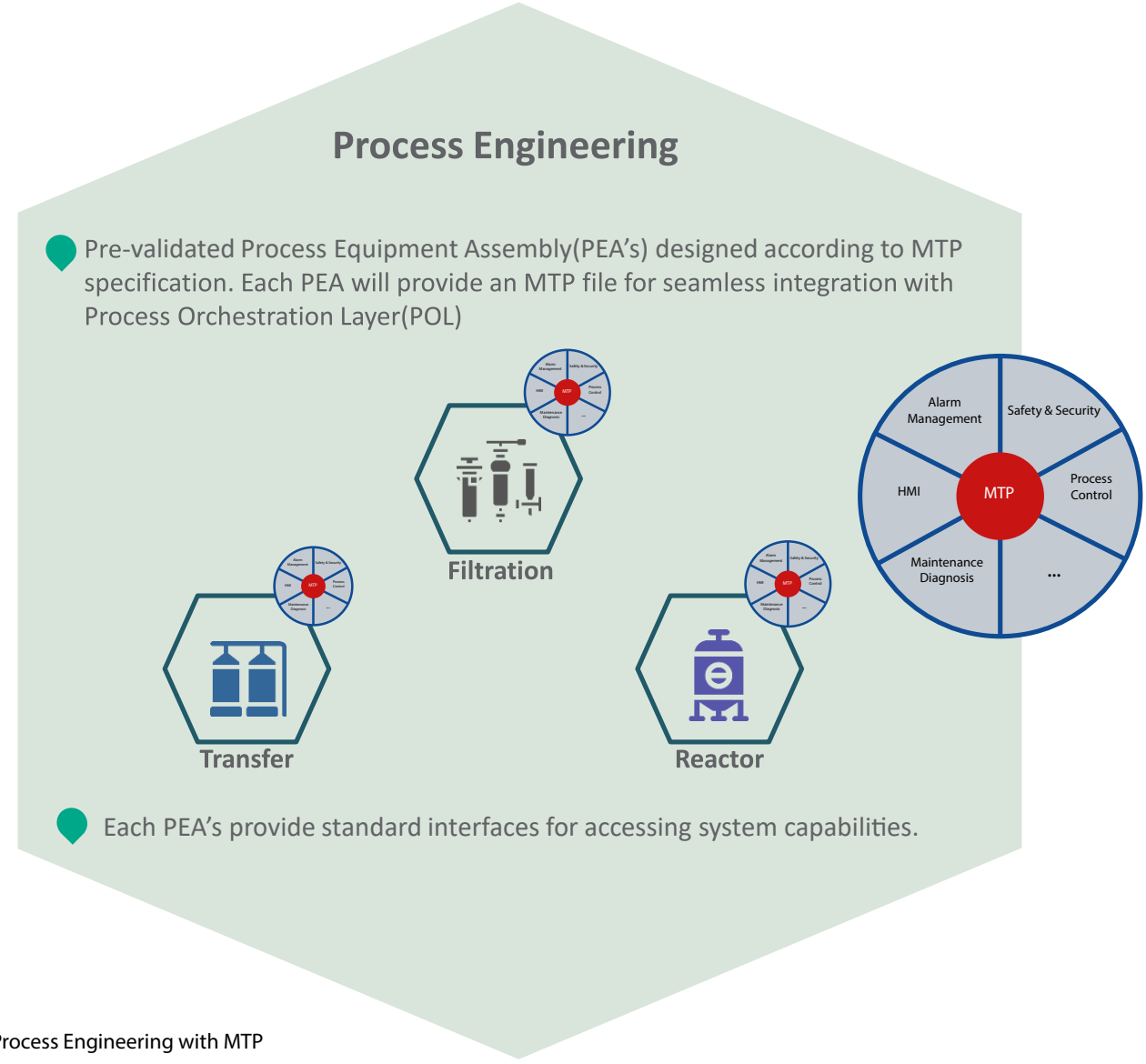


Figure 12[1] - Process Engineering with MTP

Plant Engineering

Plant engineering integrates the MTP file of an autonomous or semi-autonomous modular system, also known as a PEA, into the POL. The POL system is designed to understand the interfaces and aspects defined in an MTP file and use them to establish a connection and exchange data with the PEA using the OPC UA protocol. POL is a control software that can automatically generate PCS objects, graphics objects, and service metadata, as well as use communication protocols to enable a two-way exchange of information.

As the centralized control system, POL orchestrates the process by invoking the Services, Procedures and Data Assemblies exposed by the PEA, through which the system can autonomously handle a process operation. POL integrates PCS data from all connected PEAs, providing a single pane of glass view with centralized alarm management, P&ID, recipe orchestration, reporting, historicization, process configuration and control.

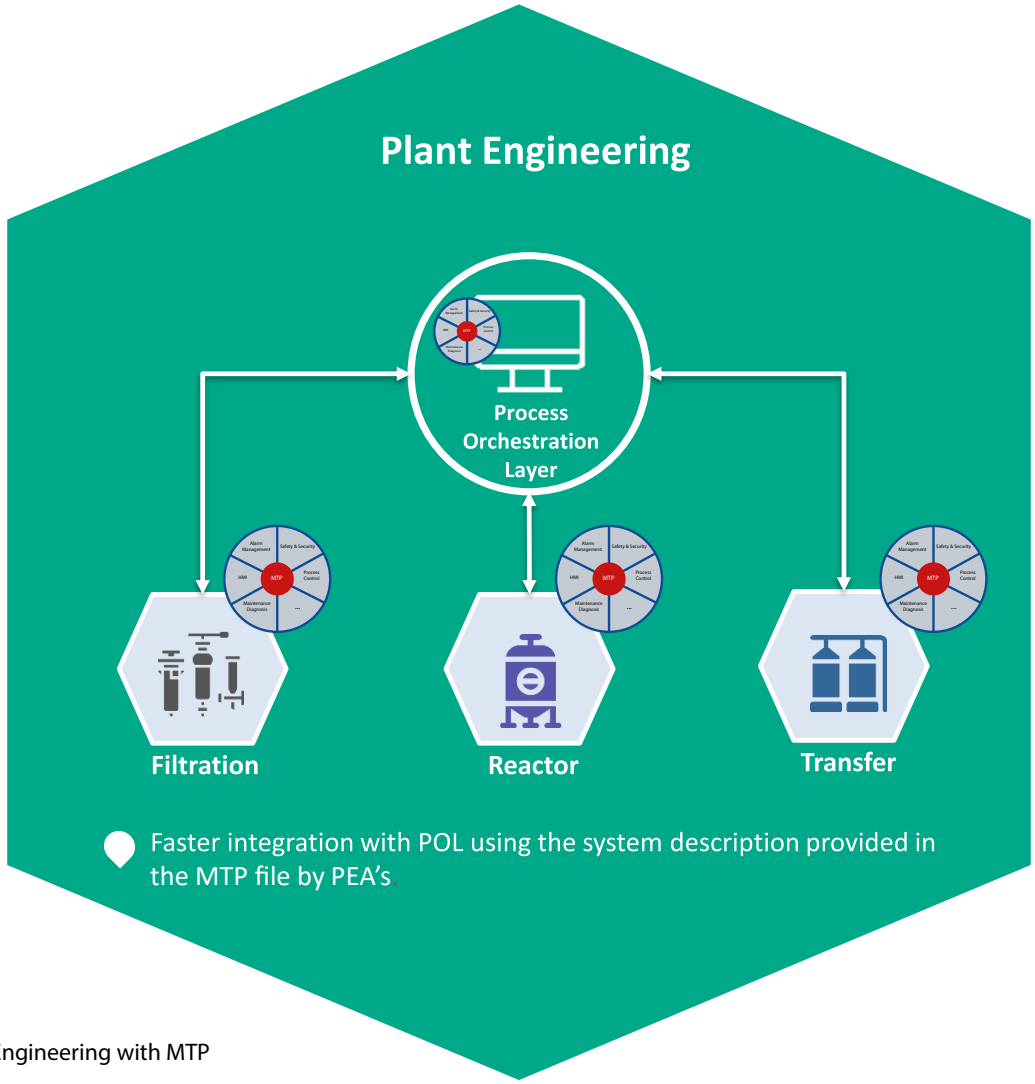


Figure 13[1] - Plant Engineering with MTP

Once the MTP file for a PEA is ingested into POL and configured for the process, the system can be seamlessly connected to POL without any further configuration. This enables plug-and-produce capabilities, where PEAs can be placed anywhere in the plant process and quickly onboarded by POL for the assigned process. This significantly reduces commissioning time from several months to just a few weeks.

Realizing flexible smart manufacturing architecture with MTP

PEAs designed using the MTP standard can be seamlessly integrated with vertical systems like POLs to enable the orchestration of the overall process by managing individual PEAs through their exposed services and data assemblies. Standardization of automation systems using MTP enables PEAs from different original equipment manufacturers (OEMs) to connect to vertical POLs and other vendor systems without additional configurations. Figure 14[1] shows how an MTP enabled system from vendors X and Y can be integrated with the POL solution from vendor Z through standard MTP interfaces. This helps to reduce complexity and streamline the process of integrating different equipment and systems in the plant. By promoting standardization and interoperability, MTP helps improve efficiency, reduce costs, and increase flexibility in process industries.

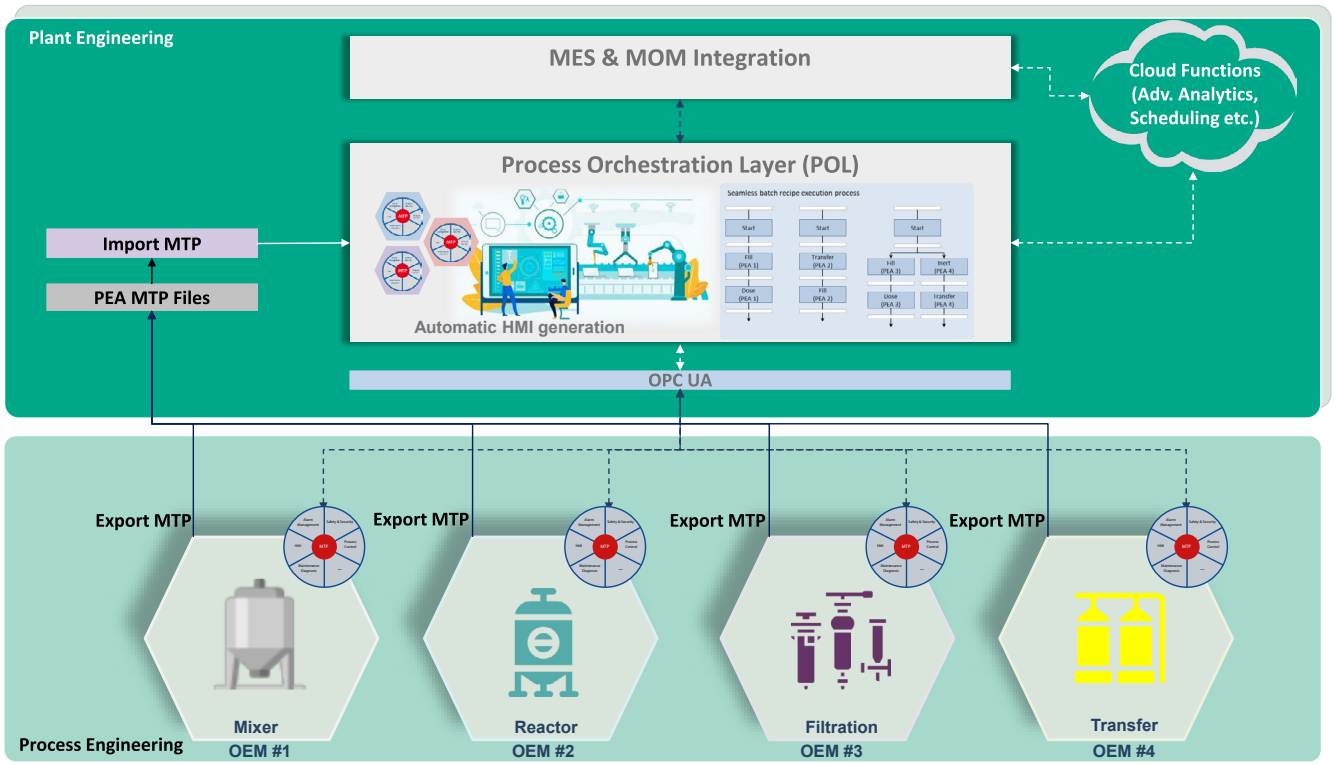


Figure 14 - Modular Production using MTP

HMI aspects defined in an MTP file enable the POL system to generate P&ID using HMI definitions dynamically:

The HMI aspect of an MTP file contains information about objects such as ports, graphics, connectors, topology, pipes and thickness. This information enables the POL system to dynamically generate a Piping and Instrumentation Diagram (P&ID) object that represents the PEA. The PEA vendor will define generic HMI objects based on the IEC 62424 and CAEX standards, which can be processed by any POL system that supports MTP. By standardizing the HMI aspect in MTP, the PEA's HMI can be automatically generated and integrated into the P&ID of the plant without the need for additional engineering effort. This enables plant operators to easily monitor and control the PEA through the central POL system, providing a unified view of the plant.

Figure 15 highlights the persona-based benefits the industry can achieve by adopting MTP for modular production. These advantageous outcomes encompass enhanced flexibility, improved performance and increased operational efficiency.

Figure 15 - Segment wise benefits of modular production using MTP

Conclusion

In the Industry 4.0 era, flexible and economic production is the target of many industry segments, be it fine chemicals, biopharmaceuticals, pharmaceuticals, food & beverage, oil & gas or energy & utilities. These segments spend significant efforts and costs to set up assembly lines for their demanding process needs. A potential solution to the challenges faced by the industry is to modularize the production process with modular automation systems that utilize MTP. MTP enables standardization across process systems and automation solutions with a modular architecture. Each module will have its own control capability, automation ML data format and OPC UA networking for plug-and-play. This approach will better meet industry demands as it builds the 'Factory of the Future.

The implementation of modular plants will help achieve this vision.

The Industry 4.0 vision also includes plug-and-produce capability to address growing customer needs. Standardization of plant assets with flexibility and interoperability enables the concept of plug-and-play to support plug-and-produce. With plug-and-play capability, plant assets can adopt changes in process configuration without requiring re-engineering efforts. This reduces the integration time by up to 50% compared to monolithic or traditional production systems. Modular production assets with

plug-and-play capability will lead the way to the Factory of the Future as envisioned by Industry 4.0.

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