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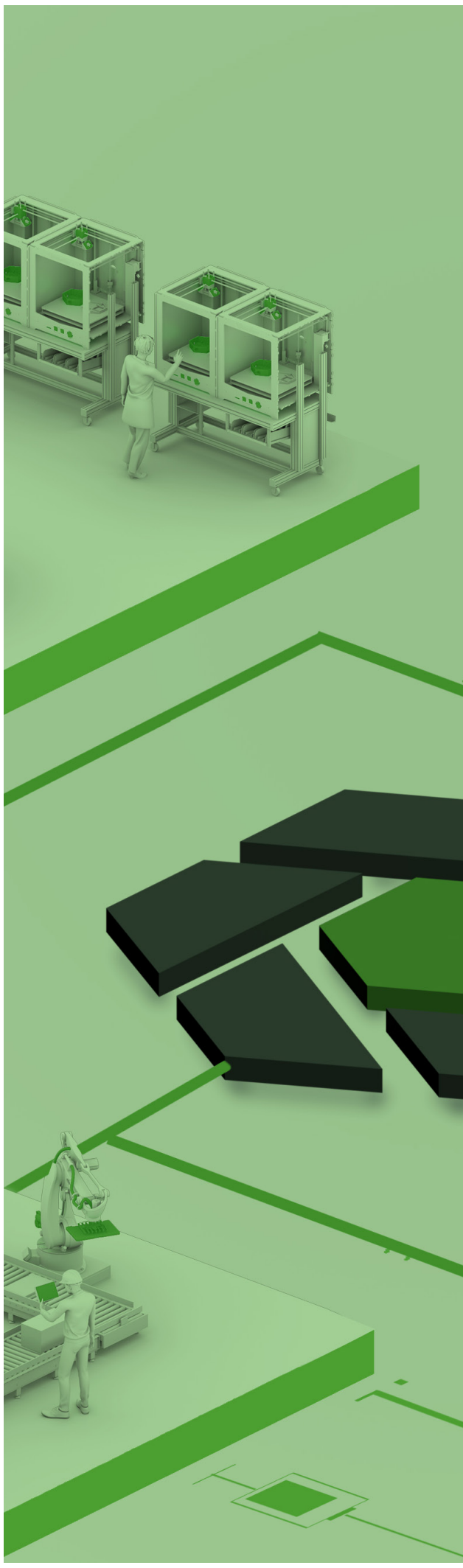
PLM and ERP: Their respective roles in modern manufacturing

WHITE PAPER

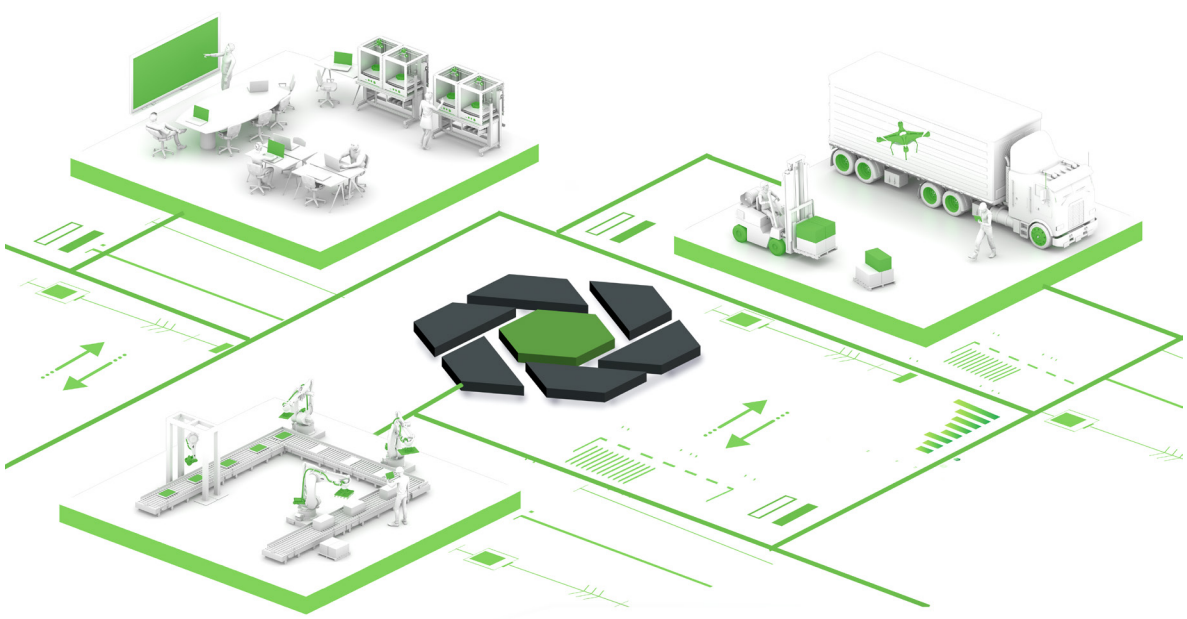


Introduction

> **Best in class companies are 1.5 times more likely to have processes that span PLM and ERP systems**
>
> Aberdeen Research

In today's challenging environment, even designing the best product is not enough. You must enable designers, manufacturing and service planners, and other supporting roles like suppliers, logistics, and plant planners to work from anywhere. They must be able to flexibly manage supply chain disruptions, manufacture more variants with agility and speed, and continue servicing products everywhere. Companies are rewarded for doing this right and punished when things go wrong. Leading companies are aligning their people, processes, and tools from the initial state of product ideation through to manufacturing, device connectivity and field service. They are providing access to product and enterprise data – in the context that domain users are accustomed. However, uniting engineering with the factory and supply chain can be complicated, costly, and typically not user friendly. Information might be difficult to access, and systems frequently do not talk to one another.

In this paper, we will focus on two pillars of manufacturing, Product Lifecycle Management (PLM) and Enterprise Resource Planning (ERP). We will discuss best practices/methods and out-of-the-box software used to integrate them for data consistency and quality. This will help you master the production ramp-up and eliminate some of the biggest mistakes. Engineering, purchasing, and manufacturing can work concurrently even if they are spread across the globe and working from home offices – saving time, reducing costs, improving quality, and getting to market faster.



A historical perspective

In the early 1990s, manufacturers began to see the value of having a single, enterprise-wide software suite that integrated all the major functional areas of the business, including manufacturing operations, distribution, logistics, inventory, shipping, human resources and accounting. Vendors offering these suites – now known as ERP – promised better alignment of operations, improved planning and productivity, greater efficiency, and better visibility and control. Large manufacturers were quick to adopt ERP solutions, such as SAP, JD Edwards, PeopleSoft, Baan, MAPICS, Oracle Manufacturing, Microsoft Dynamics AX, etc. According to The McKinsey Quarterly, companies invested more than $300 billion in ERP solutions in the 1990s.

While companies were deploying ERP solutions to squeeze inefficiencies out of the manufacturing supply chain, PTC and other CAD/CAM-related vendors envisioned an equally far-reaching opportunity. As industries of all kinds embraced CAD tools, manufacturers were generating vast amounts of complex, ever-changing design data – data they wanted to make available to their suppliers and global collaborators.

Initially, Product Data Management (PDM) worked well to keep track of the product design information. PLM then emerged in response to the need for better management of engineering processes and improved workflows in global, distributed supply chains via web-based applications. The realization that engineering data could be repurposed throughout the enterprise and beyond, to help optimize product designs, shorten time-to-market, and streamline downstream processes such as manufacturing and service, transformed how products were developed.

Today, companies around the world are using PLM to leverage the data generated in the product design to accelerate innovation and improve productivity and efficiency – not only within the engineering department, but also across all ancillary and downstream functions involved in product development, manufacturing and service planning. Together with the Industrial Internet of Things (IIOT) platforms, PLM digitalization enables companies to better understand how the defined and planned processes are performing on factory shop floors for continuous improvement. PLM also helps to understand how the designed and the produced product is performing in the field, leveraging IIOT connectivity and the digital twin of the products or the processes in PLM.

The growing scope of PLM

Because they originated from different disciplines with different goals, and evolved at different speeds, ERP/MES (Manufacturing Execution System) and PLM have, until recently, existed as largely separate entities. However, these formerly discrete realms are drawing closer together. Today, in order to embrace promises of the Industry 4.0 revolution, manufacturers need to digitally transform. Both ERP/MES and PLM are the pillars of manufacturing. ERP systems consistently rely on product information and manufacturing planning deliverables (manufacturing bills of material (mBOMs), process plans, work instructions, 3D visualizations, numerical controls (NC) and additive manufacturing (AM) files, etc.) supplied by PLM, so much so, that several ERP/MES vendors have begun to incorporate PLM capabilities into their offerings or build interfaces that would allow better PLM integration. The objective is to help customers understand the impact of product design or manufacturing planning decisions in other areas, such as sales forecasting and labor resource planning. Meanwhile, PLM vendors see their value to the enterprise growing beyond the design engineering department, as PLM's strengths in collaboration and accelerated innovation have emerged as a strategic advantage, and major cost saver, for many manufacturers.

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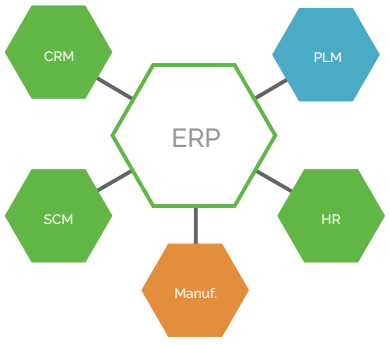

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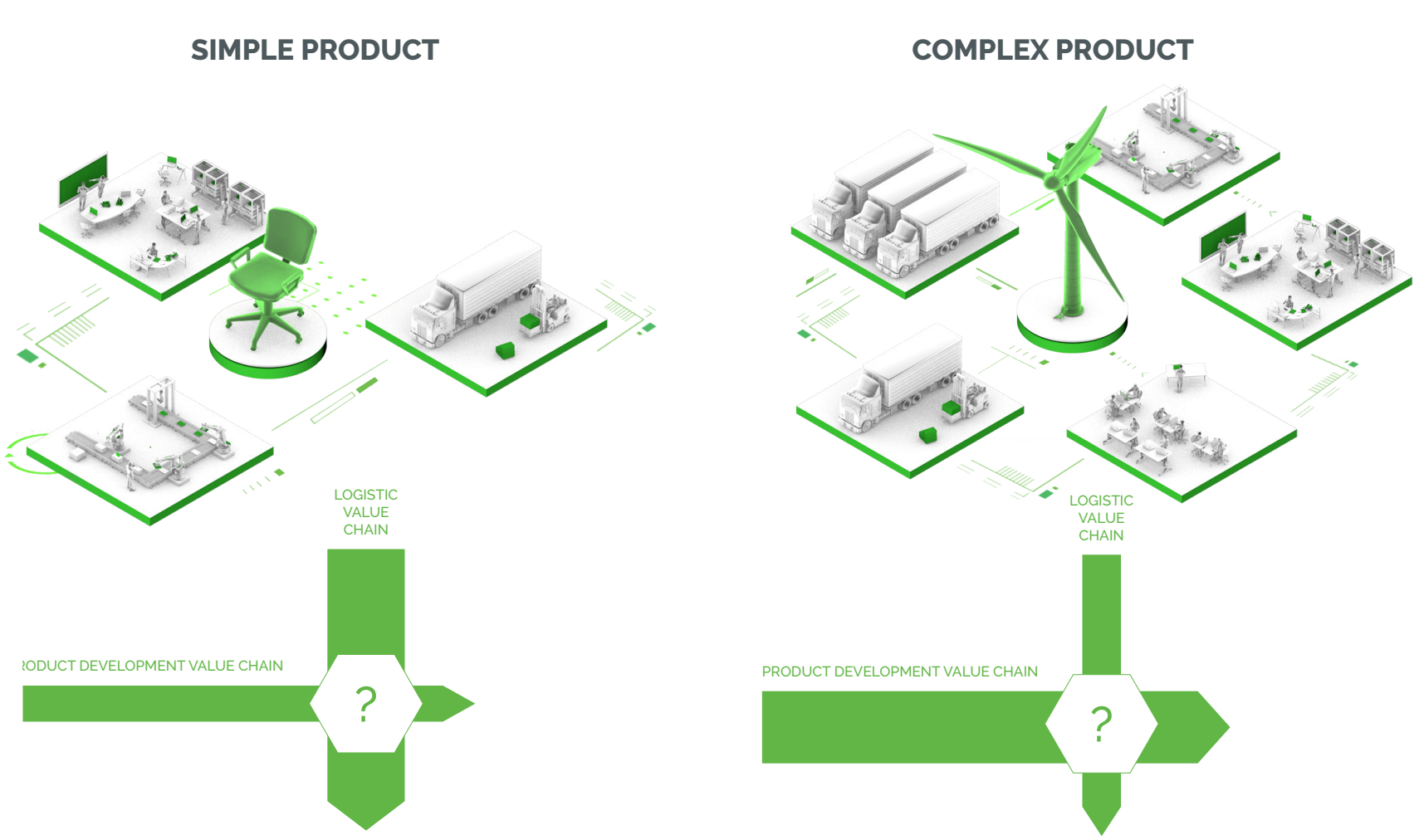
The Roles of PLM, ERP and MES

IDC analysts Jeffrey Hojlo and Kevin Prouty put it this way in their Digital Transformation for New Product Development and Introduction (NPDI) Plan Scape in 2019, “There has been considerable time in the past decade invested by manufacturers from multiple industries rationalizing, cleansing, and unifying data in product development, engineering, and R&D; supply chain and manufacturing; and service planning and execution. The next step is to connect these areas through the NPDI process, for faster response to demand, market, value, and innovation and to establish a closed loop of information and analysis that enables faster change, more effective innovation, and assurance of high levels of product, asset, supply chain, manufacturing, and service quality.”

As the definition of PLM has broadened along with its impact, many manufacturers are unclear about how to develop and implement a strategy that enables their companies to derive maximum benefit from both ERP/MES and PLM. PTC believes they both have critical roles to play, and that the proper coordination and calibration of these roles can add value beyond what either one can deliver alone.



Value Chains

In order to properly coordinate cross-system processes in both PLM and ERP, customers need to investigate both the Product/ Manufacturing Process development value chain versus the logistic value chain. The more complex a product, the more complex the design, manufacturing, and the service planning process. For example, to manufacture a watch or a bearing, there is huge variability of the product and increasing complexity in the manufacturing processes. In those situations, the product/process development chain is very important compared to the logistic value chain. Hence, the design, manufacturing and service strategies should be handled in PLM to ensure a digital continuity and associativity as well as facilitate great enterprise collaboration.

Challenges facing manufacturing today

To understand the proper roles and respective strengths of ERP/MES and PLM, it's helpful to begin by looking at the critical challenges that companies are trying to solve with these solutions. These challenges include the need to:

- Increase productivity
- Improve asset utilization
- Develop higher quality products at lower cost
- Decrease time to production ramp-up
- Increase the number and variety of products, without driving up costs and negatively affecting delivery schedules
- Deliver products that meet customers' demands
- Coordinate the work of global, diverse, cross-functional development teams
- Enable and accelerate innovation
- Comply with corporate standards and procedures
- Implement company initiatives across the enterprise
- Ensure regulatory compliance
- Support sustainability initiatives

Both ERP/MES and PLM can, and should, play key roles in addressing these challenges, but it's important to understand their respective strengths. And to do that you must first look at their different origins.

The DNA of ERP

ERP was developed in response to the "islands of automation" problem. Companies had deployed a variety of stand-alone departmental software products that were not integrated. This lack of integration caused major inefficiencies in business operations, particularly in the area of supply chain management, which depends on a smooth and reliable flow of materials data from one functional area to the next. Without this integration, organizations could not plan and schedule resources properly, leading to inventory overages and shortages of parts and finished products, procurement difficulties, manufacturing scheduling issues, order fulfillment and distribution problems, and so on throughout the supply chain.

ERP filled a serious need in the marketplace by providing an enterprise-wide solution that spanned and linked all the key operational functions and departments. This linkage has enabled manufacturers to integrate their manufacturing and supply chain processes to reduce delays and increase efficiency. ERP systems specialize in driving financially auditable transactions like purchasing, manufacturing, sales, and service. This is ERP's primary source of value.

ERP solutions, which grew out of accounting software products, are primarily focused on physical assets and the flow of materials; this "DNA" is reflected in the attributes and requirements of ERP solutions. ERP solutions perform particularly well when managing recurring transactions. And, since ERP solutions are geared toward planning and accounting for production, they only require whatever information is necessary for production. For example, if a lawn-tractor manufacturer purchases fully assembled engines for its tractors from an engine supplier, its ERP solution does not need to know all the details about the individual components that comprise the engine. For the ERP solution's purposes, the engine is a single part. The ERP solution can perform its planning and accounting functions perfectly well without further detail.

These attributes and requirements make ERP especially effective at executing and optimizing manufacturing and distribution processes involving well-defined physical assets. However, as its common characteristics suggest, ERP is less effective than PLM at managing design changes and is unsuited to enterprise activities that involve less tangible, but more strategically vital, assets, such as the intellectual capital typically found in product data and the product's bill-of-materials (BOM).

Common attributes of ERP include:

- Execution-focused
- Repeated transactions
- Inventory/order lifecycles
- Controlled, well-defined business processes
- Flat BOM
- BOM to procured part/assembly level
- Released versions
- Central theme of control
- Order/supply/demand-focused
- Rigid data model
- Structured data
- Hierarchical data relationships
- Data mining
- Text-based with some static 2D and 3D images

The DNA of PLM

PLM arose in response to the growing needs of product design organizations, as they struggled to manage, synchronize and share increasingly complex, interdependent CAD files among global teams involving both internal and external members. They needed a powerful tool to keep the teams collaborating effectively and required capabilities beyond those of PDM to serve as a "data vault" for product designs. PLM enabled product engineers to work and rework products to optimize designs – and with the rise of the Internet, to collaborate on that goal globally, in real time.

As product-development solution vendors, most of whom came from a CAD software background, created solutions to enable better collaboration on a global scale involving distributed supply chains, new needs were revealed. Vendors realized that all the data generated in the process of developing products had to be captured, continuously updated, and made accessible to all team members in usable formats. Because of the iterative nature of design, and the complexity of products incorporating many mechanical, electrical

and software components, the product data vaults of these organizations had to be powerful and flexible enough to link multiple layers of data, as well as robust and dynamic enough to support frequent change.

In addition, as the nature of product development became truly global in response to low-cost outsourcing and emerging market opportunities, vendors had to accommodate demands for more product configurations, and be able to manage the multiple CAD systems used in increasingly complex product structures. Today, PLM solutions have been extended to Manufacturing and Service planning in order to meet Industry 4.0 or Smart Manufacturing initiative goals. PLM is the backbone for digital transformation, creating a digital thread of product data starting from the design process to downstream and back.

In the process of providing these capabilities to global engineering teams, solution vendors also became aware that the digital product data being captured throughout the design cycle was of tremendous value to upstream processes and to future design work. Furthermore, the PLM paradigm they were developing could act as both a platform and an engine to guide the entire product development process as well as the manufacturing and service planning processes.

These solutions could also provide management with visibility into product development processes for better-informed decision-making, earlier in the lifecycle.

The ability to make changes early, while the products are in a digital state in the PLM system, results in tremendous savings when compared to the cost of making changes once the product is released to manufacturing and in production.

Over time PLM evolved into a flexible, dynamic environment adept at managing both product knowledge and data from a variety of sources, while making it accessible across the enterprise.

PLM systems specialize in collaborative iterations of engineering artifacts like CAD designs, BOMs (eBOM, mBOM, sBOM, etc.), process plans, and work instructions. Through a digital thread of product data, PLM is enabling the digital twin for the next generation of products and manufacturing processes.

By capturing and synthesizing complex and diverse volumes of data generated throughout the design and engineering process, PLM provides a means for better understanding and aiding innovation, collaboration, and their related functions.

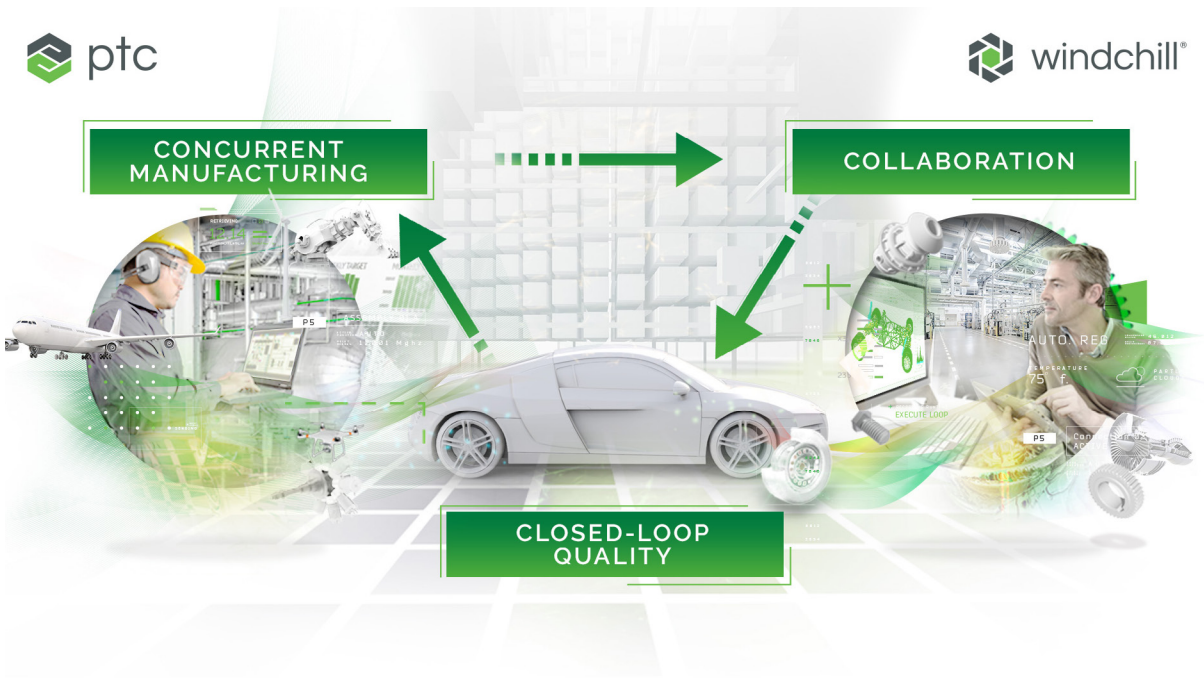
The ability to plan and validate the manufacturing process changes early, while the products, the resources and the processes are in a digital state in the PLM system, results in tremendous savings and reduced time to production ramp-up.

Common attributes of PLM include:

- Innovation-focused
- Creation, design, iteration and revision
- Dynamic change management with visibility across the entire product lifecycle
- Disciplined, but flexible design processes
- Complete BOM management (combined MCAD, ECAD, and software data in a single product structure) spanning as-designed BOM, as-planned BOM, as-serviced-BOM, as-built BOM
- Full product structure to component or raw material level
- Product and process iterations, revisions, and decision history
- Central themes of speed and managed creativity
- Focus on design/requirements/configuration/ project/program
- Flexible data structure for documents, structured and unstructured information, metadata
- Quality management: Non-conformances, CAPA, risk & reliability management (prediction, FRA-CAS, FMEA, fault tree analysis, etc.)
- Manufacturing deliverables: Numerical Controls (NC), additive manufacturing (AM), work instructions, tool design
- Complex design relationships; dynamically related, networked data relationships
- Knowledge search and retrieval; geometric search, 3D visualization, animation, augmented, virtual and mixed reality data.

What PLM brings to ERP customers

For manufacturing companies that have deployed ERP successfully, many areas of product and manufacturing process development are still done outside of ERP because of the complexity and dynamic nature of iterative engineering data. PLM solutions are home to those processes such as design engineering, but also to the ones of related functions such as manufacturing, quality, purchasing, and service. PLM allows all those roles to work concurrently, collaborate and address issues before production even begins, resulting in both time and expense savings and a higher quality product.

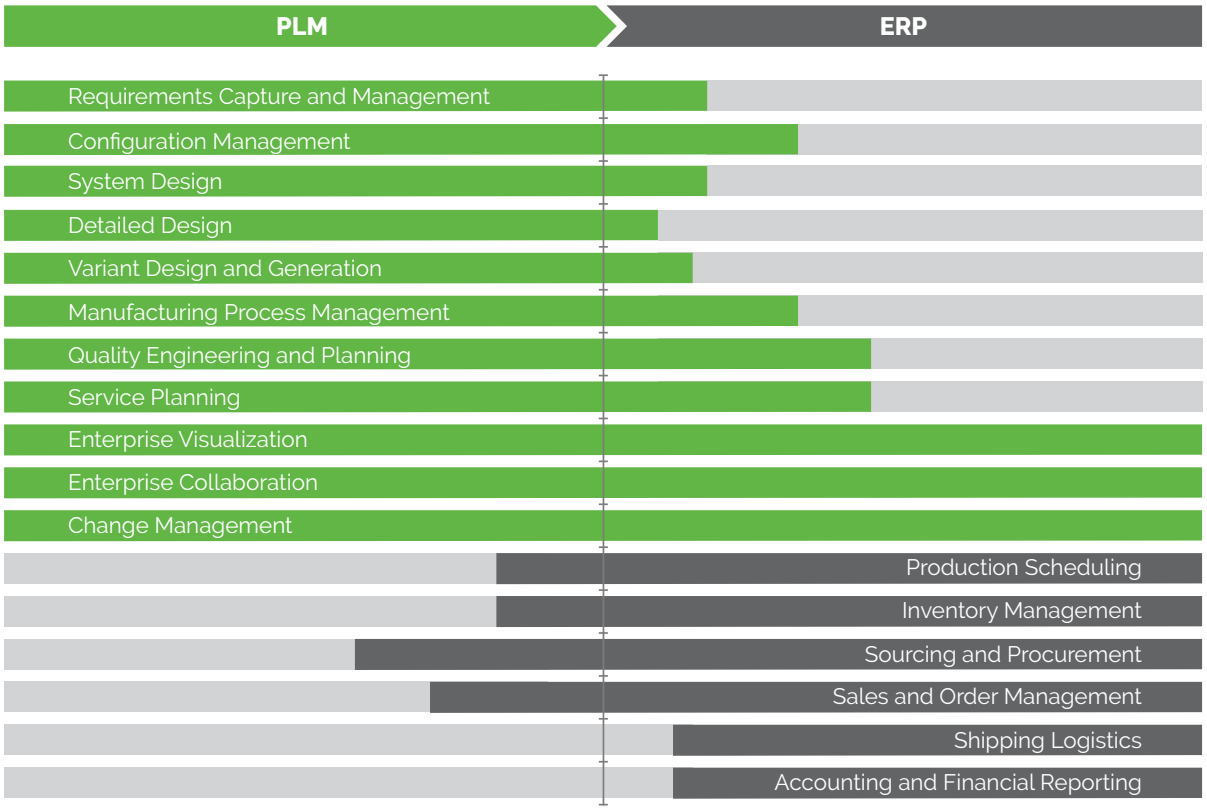


The Digital Thread is managed and orchestrated by PLM

Another major area that PLM is bringing to ERP customers is the ability to have and maintain a digital thread between the design and the factories by ensuring associativity between design and manufacturing deliverables in the factories.

How PLM works with and improves ERP

Traditionally, ERP solutions had to wait until product designs and process plan definitions were finalized before information could be shared with downstream functions or suppliers. By enabling companies to develop and maintain a digital thread for product and manufacturing processes from PLM to ERP, companies will enjoy streamlined procedures and processes, as well as high quality data in downstream production systems.



Distribution of ERP and PLM processes and responsibilities, with particular focus on PLM

Why is it beneficial to integrate PLM and ERP systems?

The integration of PLM and ERP links together the critical upstream and downstream processes and data between classically disparate user groups who work in different enterprise systems. This results in:

- Closed-loop quality: Manufacturing consumes accurate and up-to-date PLM-sourced artifacts like mBOM, sBOM, process plans, and work instructions. In return, engineering receives nonconformance and problem feedback from factories, and field service
- Data-driven design: Engineering leverages factory and field performance data to inform design decisions

An ideal integration environment provides a bi-directional framework and reliable closed-loop transaction management. This allows for the release of all the PLM deliverables that are required by ERP to run the material requirements planning (aka MRP) processes. Those deliverables (mBOM, process plans and processing resources) need to be created in ERP from corresponding released data in PLM, seamlessly, without human intervention.

This integration should also make sure that PLM information needed for consulting in downstream processes, but not mandatory to running the MRP, is also accessible on time and up to date without duplicating them in ERP for downstream consumption. For example, this is the case for 2D drawings, 3D models, manufacturing (NC and AM) files, work instructions, and any relevant documents. Conversely, an ideal integration should also make sure that ERP information required for consulting in upstream processes, but not mandatory to PLM processes, is also accessible on time and up to date without the need to duplicate them in PLM for upstream consumption. This is the case, for example, in the inventory level or cost of items that may influence the design

or changes initiated in PLM.

In conclusion, the best integration should allow information to move from one system to another and ensure that the information master in one system is always integrated in the other system. It should also allow to engage data where it resides without the need to duplicate in the other system, while ensuring the data is relevant and up-to date when accessed. Also, it is important to synchronize only relevant data that is needed for workflows and calculations.

PLM/ERP integration going forward

Today, many manufacturers are integrating PLM and ERP to improve efficiency and quality. While these organizations may be initially motivated by a desire to eliminate the inefficiency of re-entering data, along with the human error that can accompany it, the benefits go well beyond that. Organizations can also ensure that BOM data and supporting product development data, captured by the PLM system, is made available to all functions that need it. And, because the PLM system can provide routing and manufacturing process plans as well, critical upstream and downstream processes are linked and made more efficient and productive.

For most manufacturers, the question should be - how to most effectively implement and integrate these two solutions? Choosing the right ERP and PLM systems for the business is crucial, and manufacturers should not have to compromise on the benefits to fully realize the value in both. The value begins when product and process plan development, as well as production processes, are no longer implemented as islands, and the functions of PLM and ERP are deployed in a seamless, end-to-end solution.

Through the well-executed integration of ERP and PLM, companies can develop a smooth flow of major innovations such as new and more highly differentiated products, as well as ongoing business innovations like continuous cost and quality improvements.

Integrated ERP and PLM systems help deliver value across the entire range of innovation, while providing the continuous controls a modern manufacturing enterprise requires. This integration can provide a significant competitive advantage, as it drives nimble manufacturing, enabling manufacturers to quickly and confidently make the most of every significant and niche market opportunity.

When selecting PLM and ERP systems, manufacturers should heavily consider the integration capabilities. They should focus on PLM and ERP systems that

implement the two types of integrations discussed earlier (move data from one system to another and allow the systems to engage the data where it resides).

At PTC, we have built Windchill PLM, which allows for streamlined integration of both processes and data with downstream system like ERP and MES. Following are the major integration capabilities that Windchill PLM provides: The capabilities described above allow manufacturers to easily integrate Windchill as described in the example below:

Windchill Enterprise Systems Integration (ESI) module is a turnkey solution for publishing deliverables authored in Windchill to SAP and Oracle Manufacturing (BOM's, ECN, documents, drawings, CAD, NC, work instructions, process plans, control characteristics, processing resources).

> Nidec Global Appliance, the largest manufacturer of compressors for refrigeration, achieved signifi cant reductions in double work through their Windchill integration with SAP. Prior to the integration, developers had to input their work into segregated Windchill and SAP systems, doubling effort and increasing the likelihood of mistakes. Data in SAP was different from Windchill. What was the source of truth? While this did not disrupt individual project teams, it failed at an enterprise-level, as the lack of process control, supplier control, and inspection/test governance caused further delays in getting products to market. For example, a single part might have two places where it could be inserted, or a single assembly step could potentially use two different parts. Now, moving designs from development into production is seamless as the BOM and related work instructions are consistent.
>
> Vaillant Group, a global market and technology leader in the field of heating, ventilation, and air-con ditioning (HVAC), automatically transfers changes to product data, including manufacturing BOMs, to SAP via Windchill's ESI. Workflow functionalities are provided by Windchill and SAP MDG-M with automatic and transparent cross-systems status tracking of changes. Critical functions such as pre-defined rules are automatically generated. Before the integration between SAP and Windchill, 50% of first physical samples required re-work. After the implementation, where there is a hard link between both approvals in Windchill and SAP, there were no deviations at the start of series production. Further, the average process run time reduction was 25% from January 2019 to December 2019!

ERP Connector allows Windchill customers to interface with any other downstream system other than SAP or Oracle Manufacturing (e.g. Microsoft Dynamics AX) or hook a customer's existing middleware to start orchestrating the publication of Windchill data to other systems.

> **Yamazaki Mazak Corporation**, a global leader in machine tool production, replaced their legacy CAD and PLM software in 2019 to tighten their key in-house operations, enabling design, engineering, and manufacturing to work seamlessly together with their home-grown tools and Microsoft Dynamics. The goal was to decrease in-process inventory, manufacturing lead time, and indirect processes.

ThingWorx Navigate Apps allow users in downstream systems like ERP or MES to access Windchill data without the need to transfer or duplicate the data into the other system, ensuring up to date information is made available every time it's needed.

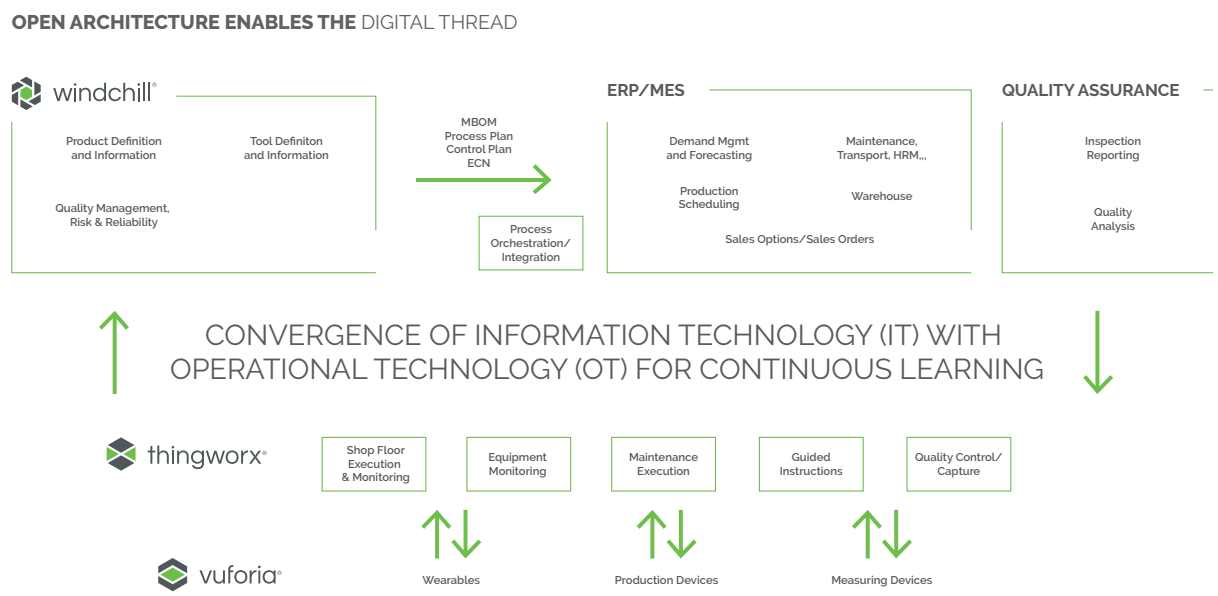
> **Bosch Rexroth**, a global manufacturer of drive and control technologies, created a simple user inter face that combines parts lists loaded directly from SAP with information stored in Windchill (torque, pressure, etc.) including an interactive 3D model that supports selecting, highlighting, annotations, and animations.

ThingWorx Operator Advisor App is a specialized app that allows access to work instructions from Windchill ensuring that the shop floor always has 3D based, rich, and up-to-date work instructions coupled with work order information from the ERP or MES system.

> VCST, a world-class automotive supplier of powertrain and brake components, leverages ThingWorx Operator Advisor App for shop floor execution and monitoring, equipment monitoring, maintenance execution, quality control/capture, and guided instructions for a PLM/ERP/MES experience linked to master data management.

RESTful API's are modern web services / APIs available for Windchill customers who need to engage data in Windchill from outside systems like ERP or MES for any use cases that may be required.

The capabilities described above allow manufacturers to easily integrate Windchill as described in the example below:



Below are important use cases that Windchill PLM and the ThingWorx platform can enable when integrated as shown above:

- **Synchronize published PLM content with ERP/MES.** ERP needs some PLM-sourced content to drive its transactions. Manufacturing resource planning needs part, mBOM, process plans, and routing information. Service procurement needs the service bill of materials (sBOM).

- **ERP users view PLM/IoT information to inform decisions.** ERP/MES doesn't need to store this content to drive workflow logic, but instead access it directly from PLM/IoT, particularly for dynamic visualization (e.g. factory and service workers need work instructions and sensor readings.)

- **PLM users view ERP information to inform decisions.** PLM doesn't need to store this content to drive workflow logic, but instead access it directly from ERP (e.g. engineers accessing part cost and quantity).

- **Synchronize IoT content with ERP's Asset Management.** Asset Management is the system-of-record for asset events that may originate in ThingWorx applications or connected devices that report through ThingWorx.

Enable the digital thread with ERP and PLM together

From the beginning, Windchill has been designed as the first web-based PLM solution that provides the openness needed for a great integration with systems like ERP and MES. ERP customers should find in Windchill PLM, a system that will complement existing ERP and MES solutions in order to help master the production ramp-up when there is a new product or a change. With Windchill's out-of-the-box integration to SAP and Oracle Manufacturing, its interface that is ready to connect to any another type of ERP or MES solution, and its integration to PTC's IIOT ThingWorx platform, you can create a digital thread from design to the shop floor and vice versa.

Visit https://www.ptc.com/en/technologies/plm for more information.

PTC, Inc.

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