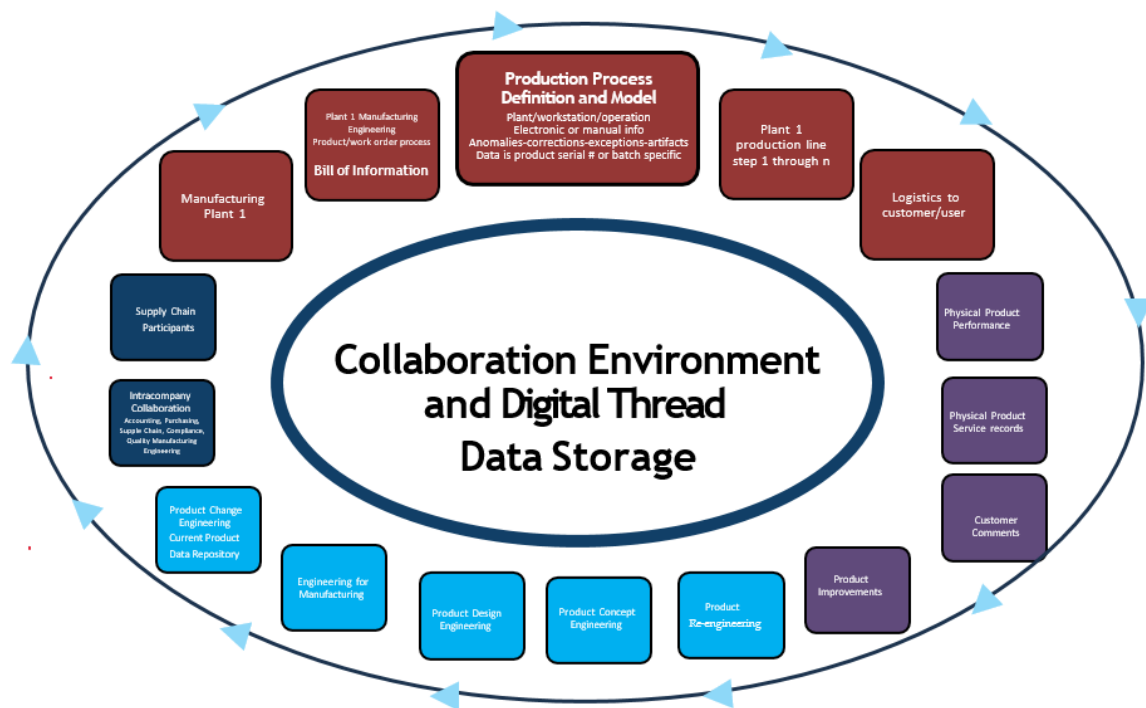


Applying Digital Thread Across Manufacturing



This illustration is intended to show the range of possible participants contributing to the digital thread. Although a sense of progression of product engineering to manufacturing to customer use is intended, each company will have their own workflow processes. Product Change Engineering is considered the source of finalized product data in this example. Illustration 1

US Department of Defense Definition:

A digital thread is an extensible, configurable, multi-directional integration of authoritative technical data, software, and information throughout a product's or system's life cycle, enabling the capture of decision-making information and knowledge.

A concise explanation is that the digital thread contains all the necessary information to build and update the digital twin. The digital thread establishes a framework that seamlessly connects business systems across the product lifecycle. The digital thread is created to convert disparate data into actionable information. It can provide data access, integration and transformation capabilities for the digital twin, a vital interface and an integrated global view of all data, models and product information.

What can Digital Thread do for you?

Digital Thread describes the concept of building and maintaining the digital history across the life of the product through engineering design, production/supply chain, and customer use.

Our approach to Digital Thread is based on an Enterprise Information Orchestration approach we call Production Process Management™ (PPM) that extends a product's Digital Thread from Engineering to, and through, Manufacturing to deliver and/or retrieve product digital information between all associated and designated information resources including PLM, ERP, value chain partners, MES, scheduling, etc., as defined by you. PPM provides multi-directional information capability that is workstation and workstation operation-centric, supporting electronic or manual data handling.

Production Process Management™ (PPM) plays a crucial role in forming the core of the Digital Thread by orchestrating the seamless flow of digital information related to a product throughout its entire lifecycle, from design and engineering to manufacturing, and even through service and maintenance. PPM contributes to this by managing and optimizing production processes and ensuring data consistency and accuracy across the product's journey.

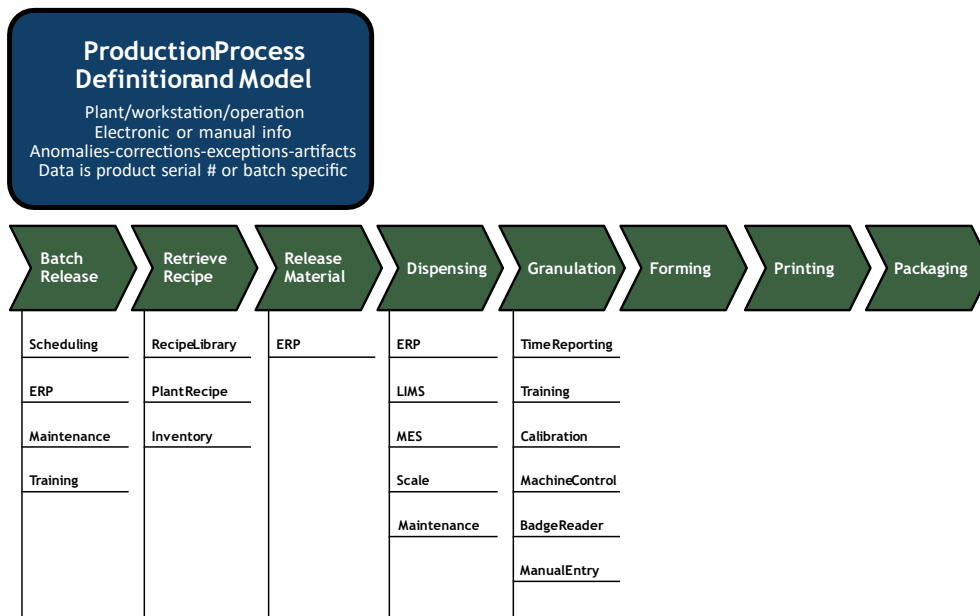
Here are a few ways PPM improves your manufacturing processes and forms the Digital Thread:

- A. **Improved Operational Efficiency:** Enables the modeling, automation, and optimization of business processes, leading to streamlined and more efficient operations. This provides a unified view of data and processes across the organization, reducing data silos and redundancy.

- B. **Enhanced Visibility and Traceability:** Ensures that all relevant data and information related to products or processes are connected and accessible in real-time. Provides process visibility, allowing organizations to view and track the progress of tasks and activities at various stages.
- C. **Futureproofing:** As technologies and market conditions evolve, PPM can be adapted and extended to incorporate new capabilities and data sources. The product-driven process is easily updated to incorporate product or plant environmental evolution such as workstation and production equipment upgrades. Each information resource is treated as a node on your network that can be easily revised.
- D. **Better Decision-Making:** Access to real-time data and analytics within the Digital Thread enables data-driven decision-making and provides tools for process monitoring and reporting, aiding in identifying bottlenecks and areas for improvement.
- E. **Reduced Errors and Improved Quality:** Automation capabilities help reduce manual errors in processes. The process execution ensures that product data is accurate and up to date, contributing to better product quality.
- F. **Faster Time to Market:** Accelerate process execution, enabling organizations to bring products and services to market more quickly.
- G. **Compliance and Governance:** Facilitates the enforcement of compliance rules and regulations within processes. Ensures that data and product information adhere to industry standards, regulatory requirements and address the latest product changes.
- H. **Enhanced Customer Experience:** Streamlined processes and quicker response times lead to a better customer experience. Your Digital Thread enables you to provide customers with accurate product information and status updates.
- I. **Cost Savings:** Automation through the Digital Thread reduces manual labor and operational costs by eliminating data redundancies and inefficiencies in processes leading to significant cost savings.
- J. **Agility and Adaptability:** The Digital Thread supports adaptability by providing a real-time view of product data and processes and allows for agile process design and modification to respond to changing business needs.
- K. **Collaboration and Communication:** Digital Thread platforms include collaboration features, facilitating communication and collaboration among teams and departments. Collaboration is promoted by providing a sole source of truth for data and information.
- L. **Competitive Advantage:** Organizations that implement Digital Thread strategies are better positioned to stay competitive in the digital age. They can innovate more rapidly, respond to market changes effectively, and deliver higher-quality products and services.
- M. **End-to-End Process Integration:** Your Digital Thread integrates various stages of the production process, from product design and engineering to manufacturing and beyond. There is a unified platform for managing and optimizing these processes, ensuring that data and information flow smoothly throughout the entire product lifecycle.

- N. **Data Management and Consistency:** The system maintains access to each repository of product-related data, ensuring that information is consistent and up to date. This includes design specifications, bills of materials (BOMs), work instructions, quality control data, and all other operational information you deem necessary and essential for a continuous Digital Thread.
- O. **Product Lifecycle Management (PLM):** Digital Thread is a focal point in delivering PLM product information, allowing organizations to manage the complete lifecycle of a product. This includes capturing design changes, managing revisions, and tracking the history of a product from its initial concept to disposal or recycling.
- P. **Collaboration and Communication:** The systems can facilitate collaboration among various stakeholders, including design teams, engineers, production managers, workstation operators, quality control personnel, and value chain partners. This collaborative environment ensures that everyone can access the latest information and work together efficiently.
- Q. **Workflow Automation:** The system can automate and manage workflows and processes related to production, ensuring that tasks are executed in a structured and efficient manner. This includes automating manufacturing work instructions, quality checks, and change management processes.

Illustration 2 The Digital Thread is built through the execution of a product/plant specific BPMN process orchestration workflow that is managed across the production steps. The following is an example of a solid dose pharmaceutical product.



The workflow includes retrieving the current Bill of Process Information (BPOI) production step data artifacts from a library, plant, or value chain resource to support the workstation information requirement and simultaneously, collecting the data to build the Digital Thread. Each instance of a Production Process is archived for absolute traceability, analytics, failsafe restart, and future reference.

- R. **Real-time Monitoring and Control:** The Digital Thread can provide real-time visibility into production operations, allowing organizations to monitor progress, track performance against targets, and make timely decisions. This real-time data contributes to the continuous effort to improve performance.
- S. **Traceability and Compliance:** The Digital Thread enables pinpoint traceability of products, materials, and components throughout the supply chain and production process. This traceability is critical for compliance with industry regulations and quality standards.
- T. **Analytics and Continuous Improvement:** These systems often include analytics capabilities to analyze historical data and identify areas for process improvement. This supports the organization's ability to refine processes and enhance product quality.
- U. **Scalability and Adaptability:** Digital Thread solutions are designed to scale with the organization's needs and adapt to changes in production processes, making them suitable for both small-scale and large-scale manufacturing operations.

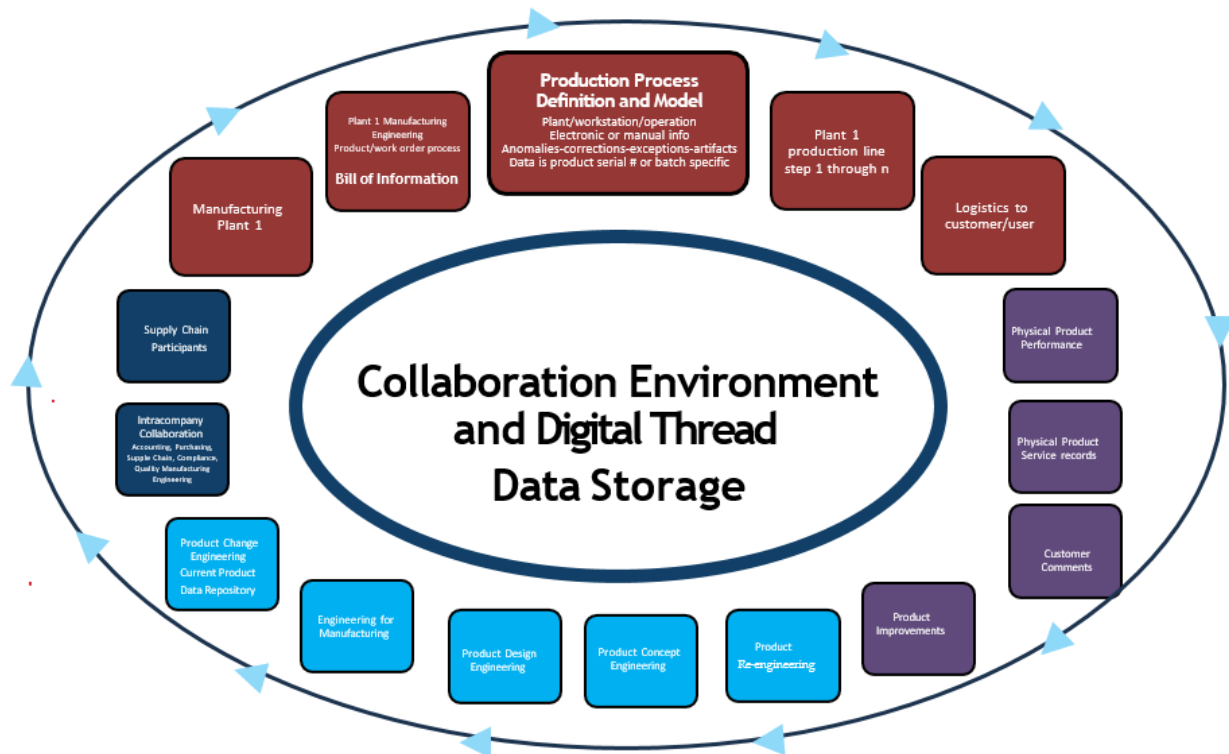


Illustration 3 The typical functions are described.

The functions include:

- **Product Concept Engineering:** This is the initial stage of the product development, where the engineering team defines the product concept, requirements, specifications, and design. This step is also the initiation point for reengineering to accommodate product improvements.
- **Product Design Engineering:** This is the stage where the engineering team creates the detailed design of the product, including the bill of materials, drawings, models, simulations, and tests.
- **Engineering for Manufacturing:** This is the stage where the engineering team collaborates with the manufacturing team to ensure that the product design is feasible, efficient, and compliant for production.
- **Product change Engineering and Management:** This is a central core activity to formally initiate, confirm, manage, and track product changes. The published current product revision level and data reside here.
- **Intracompany Collaboration:** This category of activities includes the defined interaction between intracompany departments and value chain participants.
- **Supply Chain Participation:** It is likely there will be core suppliers that will be included in any new product development or product change. The digital thread should include digital information supporting each supplier's contribution.
- **Where to manufacture:** Identifying where in the multi-plant enterprise the product is to be manufactured might be the next management decision. This can be an extensive business consideration that includes marketing, logistics, intra-company transfers and facility capability upgrade.
- **Selected Plant Manufacturing Engineering:** This part explains how manufacturing engineering defines and models the production process for each plant/workstation/operation, using electronic or manual information that is product serial # or batch specific.
- **Product/Work Order Process:** This is the stage where the manufacturing team executes the production process, following the work order instructions for each product batch or product serial number. The data flow includes each workstation of the production process and collects any anomalies, corrections, exceptions, or defined artifacts during the production cycle. The execution of the work order works from and generates the digital information specific to the serialized component of manufacture or the product batch.

- **Logistics to Customer/User:** This is the stage where the product is delivered to the customer or user, following the logistics and distribution channels.
- **Physical Product Performance:** This is the stage where the product performance is monitored and measured, using sensors, data analytics, and feedback mechanisms.
- **Physical Product Service Record:** Many products can now be connected via the internet to show service and point of use records.
- **Customer Comments:** Companies want and need input regarding their products. Your complaint might be the evidence necessary to point out unseen design defects that suggest product reengineering.
- **Product Improvements and Re-engineering:** This is the stage where the product is improved based on the performance data and customer feedback, using engineering change management and continuous improvement methods.
- **Product Concept Engineering:** We are back at our starting point where the product is designed or redesigned.
- **Collaboration Environment and Data Storage:** This depicts the breadth of collaboration and workflow between multiple departments across the value chain to produce and maintain the product and its digital thread and data storage system.

In conclusion, the Digital Thread is a critical component in managing engineering and production processes related to each product in your company. It integrates and optimizes production processes, ensures data consistency, and enables end-to-end visibility and collaboration. By managing the entire product lifecycle and supporting data flow from design to production and beyond, our systems approach helps organizations achieve a seamless and continuous Digital Thread for improved efficiency, quality, and competitiveness.

CSI wants to be your Digital Thread source. Our experience in the engineering and production environment is extensive and aimed at the operations workstation level. Our approach is to start small with a proof of concept based on a limited number of products in your facility. Once your team feels comfortable with the concepts we will go forward at your pace, proving each step in your deployment roadmap. This approach allows a minimum cost of entry and a chance to work out issues well before they become cast in concrete. Another major advantage is your ability to provide quick and obvious beneficial use within weeks rather than months.



Michael McClellan has over 30 years of experience serving and managing manufacturing enterprises. He has held several positions in general management, marketing, and engineering, including President and CEO for 3 manufacturing companies supplying capital equipment and material management systems. In addition to numerous articles and white papers on manufacturing systems, he has written two books: *Applying Manufacturing Execution Systems*, the first book to define and explain manufacturing execution systems and *Collaborative Manufacturing: Using Real-time Information to Support the Supply Chain*, the first definitive examination of collaborative manufacturing concepts. He is also a major contributor to a book on business process management titled, *In Search of BPM Excellence*. Mr. McClellan has served over six years on the Manufacturing Enterprise Solutions Association (MESA) Board of Directors. He can be reached at 503 880 6345 in Camas, Washington.