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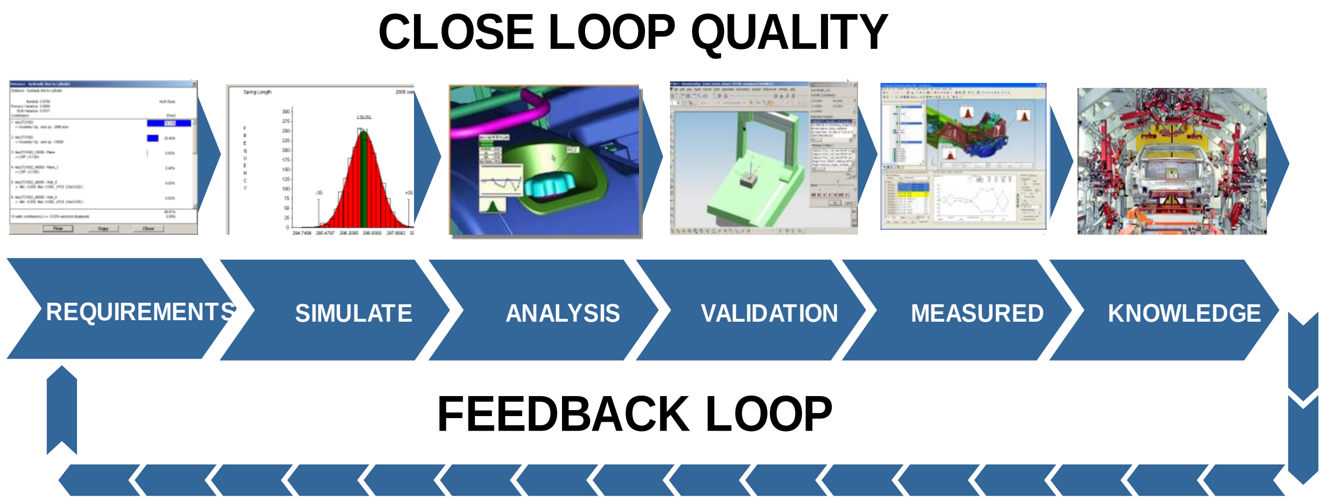
Siemens PLM Software Integrates Product, Process, and Quality Assurance with Dimensional Planning & Validation



DPV Quality Assurance Feedback Loop

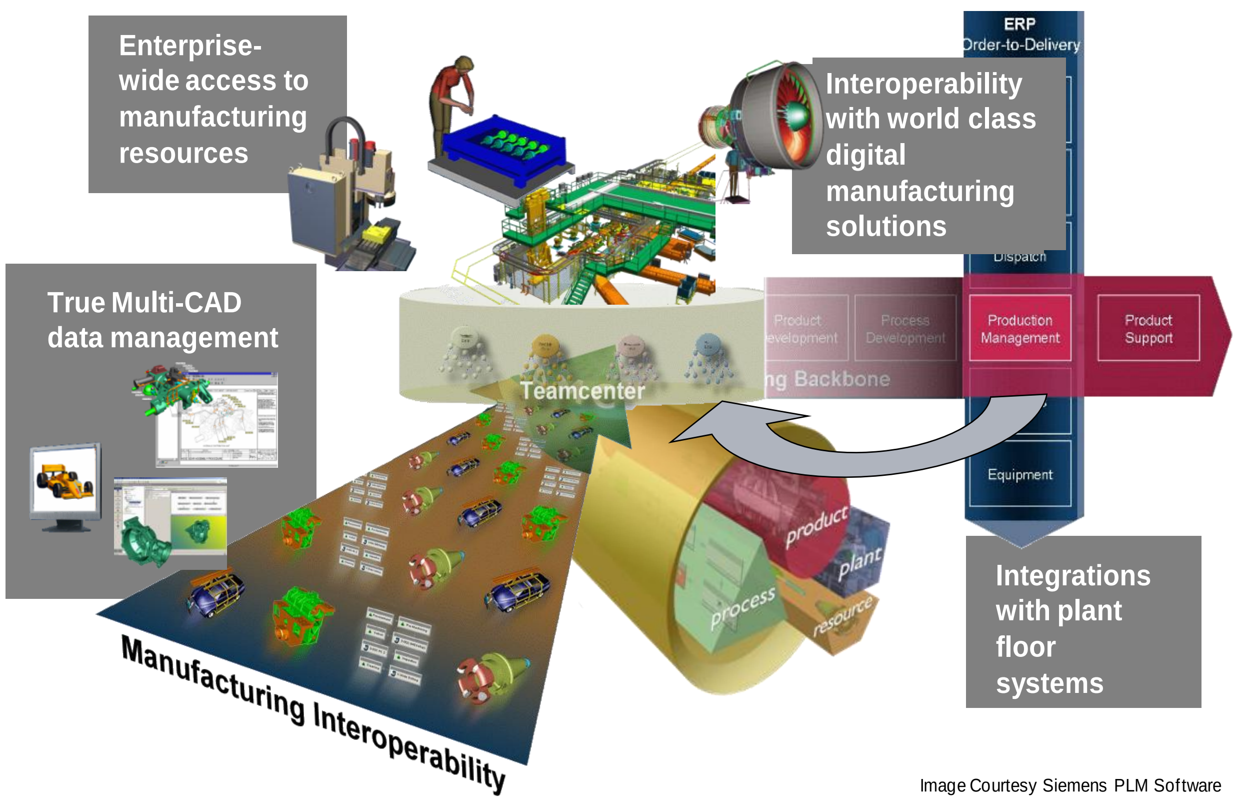


Image Courtesy Siemens PLM Software

Siemens PLM Software Manufacturing Backbone

Executive Overview

Clearly, manufacturing across all industrial sectors is being driven by a new set of business imperatives. Agile response to volatile markets, drastic reduction of time to market, and high product variability are just some of the challenges facing manufacturers. Along with the need for constant innovation, manufacturers continue to focus on reducing the cost and time for producing the product, the single most significant means of remaining competitive. Moreover, reducing the time to product launch while optimizing manufacturing processes will become even more significant as product lifecycles become shorter, market prices erode, outsourcing increases, and product models and variants multiply.

Along with the need for constant innovation, manufacturers continue to focus on reducing the cost and time for producing the product, the single most significant means of remaining competitive.

Manufacturers today are re-visiting the roles of Quality Assurance (QA) and Continuous Process Improvement (CPI) as essential methods for producing and delivering quality products as well as a business strategy for becoming and remaining competitive. The overall benefits of Quality Assurance programs can be manifested in a number of business initiatives that are essential to any company's success in their respective markets. Today, these business drivers include continuously improving production throughput while reducing costs, getting the product to the market faster, maintaining product reputation for quality, and identifying deviation in production systems.

In order to meet the demands of the evolving manufacturing environment, manufacturers must look to certain technology and process improvement enablers. One of these emerging game-changers is the next-generation of Product Lifecycle Management (PLM) tools that merge product design, manufacturing process design and simulation, and real-time metrics and data from shop floor production systems. Siemens PLM Software has combined and integrated PLM solutions from the design/build domains with production inspection systems to measure, analyze, and validate both the product and the manufacturing process. They are calling this new technology Dimensional Planning and Validation (DPV). DPV is an integrated set of tools that provides real time capture and analysis of production process data thereby enabling quick problem resolution, reduction of production down-time, and the overall improvement of in-depth analysis on the build process and the issues that arise.

Establishing a Quality Assurance Foundation

Companies, and the consumers they supply, need assurance that they can rely on their products to meet quality standards that foster both confidence and trust in their use and create an on-going demand for that product. Quality Assurance, as a discipline and a business strategy, consists of all those planned and systematic actions necessary to provide confidence that a product will fulfill requirements for quality.

QA should be differentiated from Quality Control which traditionally has focused on the end-item inspection of a product to discover defects that result in rejection of the product. Conversely, QA represents a systematic method to measure, analyze, and improve the manufacturing process in order to build the quality into the process. QA works because both customers and plant managers have a need for QA as they cannot oversee every detail of the manufacturing operations themselves. They need to place trust in the producing operations thus eliminating any need for constant intervention.

All QA activities are post-event activities with analysis and process improvement typically accomplished off line, establishing confidence in results, product claims, and most importantly that the process can produce the same quality product repeatedly and consistently. Thus, by establishing an effective QA program, a company is making a statement about how they intend to conduct business. Instead of merely measuring the quality of their products and assuring the quality of the business, manufacturers are able to insure their partners and customers that they can trust the quality of their products and services.

Assessing the Business Impact of QA

Quality Assurance methods and programs have become entrenched at most successful companies and are integral components of their business and manufacturing processes. The overall benefits of QA programs can be manifested in a number of business initiatives that are essential to any company's success in their respective markets. Today, these business drivers include continuously improving production throughput while reducing costs, getting the product to the market faster, maintaining product reputation for quality, and identifying deviation in production systems.

Building it Right the First Time Means Lower Production Cost

The reality for manufacturers was that traditional quality control methods usually caused production bottlenecks. A product quality inspection process needed to be put in place to detect part or assembly failure along with a corrective action process to deal with rejected products and components. This approach to quality control represented an inherent constraint to product throughput due to slow inspection methods, lack of quality resources, and ultimately the rework of the rejected parts and finished products.

The adoption of QA and Continuous Process Improvement (CPI) methods emerged as a way to address not only final product quality, but, equally as important, optimizing and streamlining the overall production process in terms of increasing throughput while reducing the cost of production resources. Moreover, by dealing with quality issues after the fact, manufacturers are unable to accurately assess the true cost of quality. Parts can continue to be rejected without the defects in the production process being identified. In other words, making the product right the first time can eliminate a significant amount of time and money from the production process.

Hitting the Market Window Is Critical to Business

In today’s global business environment, getting your product to market in a timely manner is more important than ever. In certain market sectors, such as consumer electronics and consumer packaged goods, missing the market window can mean product failure no matter how good the product is or how well it was conceived and developed. Moreover, this situation can now be applied to longer lifecycle products such as automotive, industrial equipment, and other more complex consumer products. Invariably, the root cause for not introducing a product to the market at the optimum time is due to production delays and product quality issues.

Applying QA and quality solutions that enhance rather than hinder production systems throughput and serve to speed up the overall production process are critical to remaining competitive in business. Further, insuring that when the product rolls off the production line it meets all quality requirements without rework or rejection, or worse yet, becomes subject to recall after it is delivered to the customer, means that the product is available to the market as well as meets customer satisfaction demands.

Maintaining a Reputation for Product Quality

One of the often overlooked benefits of an effective CPI program is the establishment of a "quality" leadership reputation in the marketplace across a company's product brands. Again, this brings into play a company's intention to not only insure their customers of a quality product, but to instill a sense of trust and reliability that is an embodiment of the company culture. Companies that have established effective QA and CPI best practices are not only insuring that products that roll off their production lines meet quality standards, but are demonstrably fostering a culture and image of excellence and reliability in the market place.

A well-studied example of a company that has done a very good job of fostering this type of image is Toyota. Moreover, they have accomplished this reputation for quality and confidence in their products through their pioneering work in areas of Lean Manufacturing, CPI, and Total Quality Management (TQM). These principles and methods have been accepted throughout the manufacturing community. Today, adoption and implementation of these methods denote the path to product quality and reliability.

Identifying Variation in Production Systems

In simple terms, variation represents the difference between an ideal and an actual situation. An ideal represents a standard of perfection—the highest standard of excellence that is uniquely defined by the stakeholder community including direct customers, internal customers, and suppliers. Excellence is synonymous with quality, and superior quality results from operational excellence (doing the right things, in the right way). Designing and building production processes that are able to identify variation, that is, a measurable deviance between product build and product design, before the build process is complete, represents a proactive approach of QA and CPI versus the reactive approach of quality control and part rejection. Reducing the variation stakeholders experience is the key to quality and continuous improvement.

If the yield and quality from production systems can be predicted by using virtual simulation technology to validate both the product and process, then it follows that variation can be anticipated and managed. A QA program that can leverage existing PLM technology such as digital simulation can offer a degree of reliability that enables the producer to have repeatable quality across all products.

Typically, application of Six Sigma methods represents a management technique that aims to control variation and develop and deliver near perfect products and services. The term "Six Sigma" refers to statistical constructs that measure how far a given process deviates from perfection. Six Sigma is a process as well as a discipline that measures how many defects exist in a business process and then systematically determines how to remove them. Rigorous Six Sigma requires that a process produce no more than 3.4 defects per million occurrences of the process, but the primary goal should always be continuous process improvement.

Re-visiting Continuous Process Improvement

CPI is a strategic approach for developing a culture of continuous improvement in the areas of reliability, process cycle times, costs in terms of less total resource consumption, quality, and productivity. Deployed effectively, CPI increases quality and productivity while reducing waste and cycle time, thus embodying the most basic tenets of Lean Manufacturing. In simple terms, any company that produces products and/or delivers services should be viewed as agents of change for continuous process improvement and innovation with the pursuit of quality being a consistent and continuous quest.

> CPI and Lean Manufacturing can be adopted and instilled as a culture within manufacturing organizations. However, the actual implementation and derived benefits can depend on the tools and technology available to manufacturing operations.

While the principles of CPI and Lean Manufacturing can be adopted and instilled as a culture within manufacturing organizations, the actual implementation and derived benefits can depend on the tools and technology available to manufacturing operations. Starting in the early 90's, Statistical Process Control (SPC) methods and tools allowed manufacturers to collect and analyze production systems data and produce control charts (Pareto charts, histograms, etc.) in order to stabilize, control, and improve the production process. Later on, factory layout and production process emulation applications emerged that enabled manufacturers to produce rudimentary testing of control systems and factory operations by using throughput simulations.

Today, with 3D modeling technology, manufacturing engineers are able to create virtual factories and production systems that simulate the actual operations and controls in real time. Using these advanced virtual simulation technologies enables manufacturers to create real simulation not just emulation that allows for optimization and process improvement based on a digital factory model. Additionally, by using virtual simulation tools and methods, manufacturers are able to synchronize and validate production processes prior to physical commissioning.

Using Engineering Models to Validate Process Improvement

Today, through the use of Digital Manufacturing simulation tools, manufacturers have the ability to create a virtual environment of production operations that digitally and accurately represent the physical production environment. Moreover, using these virtual simulations, manufacturing engineers are able to validate production systems such as assembly lines, machine tools, robots, conveyors, and controls that actually operate as planned and designed prior to physical commissioning.

Product engineering designs are integrated with manufacturing process design by placing digital product models within the virtual simulation of production systems to synchronize and validate the design/build process. The next logical step in the evolution of the design/build process would be to extend the integration of this process to quality assurance methods, metrics, and analysis that validate that the product is being built per engineering design.

Closing the Loop between As-Built and As-Designed

It is on the factory floor where the product design, manufacturing processes, material, production equipment, labor, and, most importantly, knowledge associated with the culmination of the build process all come together. It is at this point in the design/build process that the design and manufacturing engineers, along with production operations, determine whether they've made the product they set out to make and if they have made it in the way that was intended.

It is critical to capture the knowledge at the point of manufacture that will either validate the process design and planning or detect deficiencies that need to be corrected.

In order to truly optimize a company's manufacturing process, it will be critical to capture the knowledge at the point of manufacture that will either validate the process design and planning or detect deficiencies that need to be corrected. The production knowledge needed to validate the as-built to the as-designed can include a combination of production process planning, production execution methods, and actual verification data comprised of inspection metrics. Moreover, this knowledge can then be captured, stored, and routed back to engineering for process improvement.

One of the most significant elements of a comprehensive Product Lifecycle Management (PLM) solution set is the ability to enable and engender a collaborative environment for knowledge capture. Today's end-to-end PLM solution set provides an environment for the creation and management of digital information for both product and production processes resulting in integration of product design with manufacturing, business systems, and factory floor production systems. Within this context, production processes can be created, planned, and validated.

Production management solutions are becoming integrated with PLM solutions and thereby support design/build solutions by interfacing with, capturing, and storing real-time manufacturing events that represent the production processes and determine "how" a product is made. Further, this integration has been extended to shop floor inspection systems to capture metrics that validate the build process. This provides the transition from "as designed and planned" information associated with PLM systems to the "as built" records of production management systems. By including production management solution sets as integral components of PLM, manufacturing operations can create a closed loop system that can determine if the product was made the way it was planned, and if not, provide answers by accessing the real-time data and event repository.

Measure, Analyze, and Validate the Product & Process

An integral component of the PLM solution set today is CAE and the tools that enable realistic testing of the product design. These tools and testing methods provide the means to validate that the product design will meet physical requirements in actual use. CAE tools validate, in a virtual environment, that the product will meet fit, form, and functional requirements in use in the real world.

The product testing analogy that works for the manufacturing processes is Digital Manufacturing, a technology that can provide a means to measure, analyze, and validate that the product is being built per the engineering design. This can be accomplished by accessing CAD design geometry, CAE data models, product tolerance information, and other dimensional measurements to perform a comprehensive dimensional analysis of the as-built completed part or assembly. Additionally, this will also require access of real-time measurement and product inspection data from measurement devices, systems, and machines that can validate the as-planned production processes conform to the product design.

Integrating Product & Process Design

Design for Process is becoming an accepted approach in the overall design/build process. Simply put, this means designing the product to facilitate the build process. The concept of concurrent development of both the product and process to produce the product was introduced with concurrent engineering. It was based on the notion of designing a part not only to meet fit, form, and functional criteria, but also designing to meet manufacturability requirements. The idea was to foster a design environment that involved collaboration between the design engineer and manufacturing engineer early in the design process. While this concept worked well for designing some parts and assemblies, there remained a fundamental disconnect between the design process and the complex set of manufacturing processes.

The more effective approach, and one that fits with the concept of a more holistic function of PLM, is to design the product that facilitates the manufacturing processes from a best practices perspective. The goal would be to create an innovative design for a part or assembly that meets the requirements for fit, form, and function, and also adheres to best-practices criteria for manufacturing efficiency and quality assurance.

Capturing Process Knowledge: Best Production Practices

Today, manufacturing technology and processes represent a significant portion of a company's intellectual property (IP) which now competes with product innovation and design in importance to manufacturers for remaining competitive in their respective markets. Capturing manufacturing process knowledge and making it available and accessible for reuse is quickly becoming a critical business strategy for companies. Moreover, the manufacturing processes that define a company's core competency and IP must represent the best practices in terms of the creation, execution, and ultimate reuse of these processes.

The caveat to all of this is the availability of technology that will enable manufacturing processes to be created, simulated, validated, analyzed, and finally captured into a single knowledge repository that allows access for reuse. PLM technologies such as virtual simulation for both product and production process, along with collaborative data management solutions for product and process, will be the means to achieving both knowledge management and preservation of best manufacturing practices.

PLM Solutions Provide End-to-End Product & Process Integration

Clearly, manufacturers are beginning to regard the design/build/support/maintain domains of the product lifecycle with a holistic view of product, process, and automation. From product conception and development through the creation and implementation of manufacturing processes to the design and commissioning of production systems and the automation that run them, manufacturers will benefit from an end-to-end set of solutions that address the entire scope of the product lifecycle. While an end-to-end PLM strategy along with the technology and applications that support it focus on the integration of product and processes, there remain gaps and disconnects that must be addressed in order to truly close the loop between product build and product design.

One of the basic elements of a completed design/build lifecycle is quality, both in terms reliability of the product and of the assurance of continually improving processes.

One of the basic elements of a completed design/build lifecycle is quality, both in terms of reliability of the product and the assurance of continually improving processes. Quality must be an integral component of an end-to-end PLM strategy beginning with the digital design and continuing through the manufacturing process. Moreover, this must include the capture of the as-built record, inspection metrics, and production data that confirms the product is built per design and the manufacturing processes are both correct and performing optimally.

Validation and Analysis Tools Control Variation

Design engineers have traditionally been able to determine parts and assembly mating, fit, and interference through digital mockup methods and techniques. Similarly, they can assign dimensional tolerances to parts and assemblies that accommodate fabrication and assembly processes like hole drilling, machining, and mating surfaces. Product engineers can assign tolerances and assembly criteria, but it is incumbent upon the manufacturing and tooling engineers to devise production processes and tooling fixtures that meet these tolerances and produce a product that conforms to product design.

Today, there are digital validation tools that enable manufacturing and tooling engineers to simulate tolerance stack-ups, analyze variation, and validate assembly and tooling. These tools allow a dimensional engineering approach that enables both design and manufacturing engineers to optimize part tolerances by simulating the characteristics of parts and assemblies with embedded 3D variation analysis. By being able to determine the variability of these characteristics, they can predict process behavior and capabilities thereby helping to determine the design and process factors that contribute to variation. Engineers will then be able to conduct a comprehensive dimensional analysis that includes design geometry, product tolerances, assembly attachments and sequences, actual measurements, and even Finite Element Analysis (FEA) that predicts sheet metal distortion.

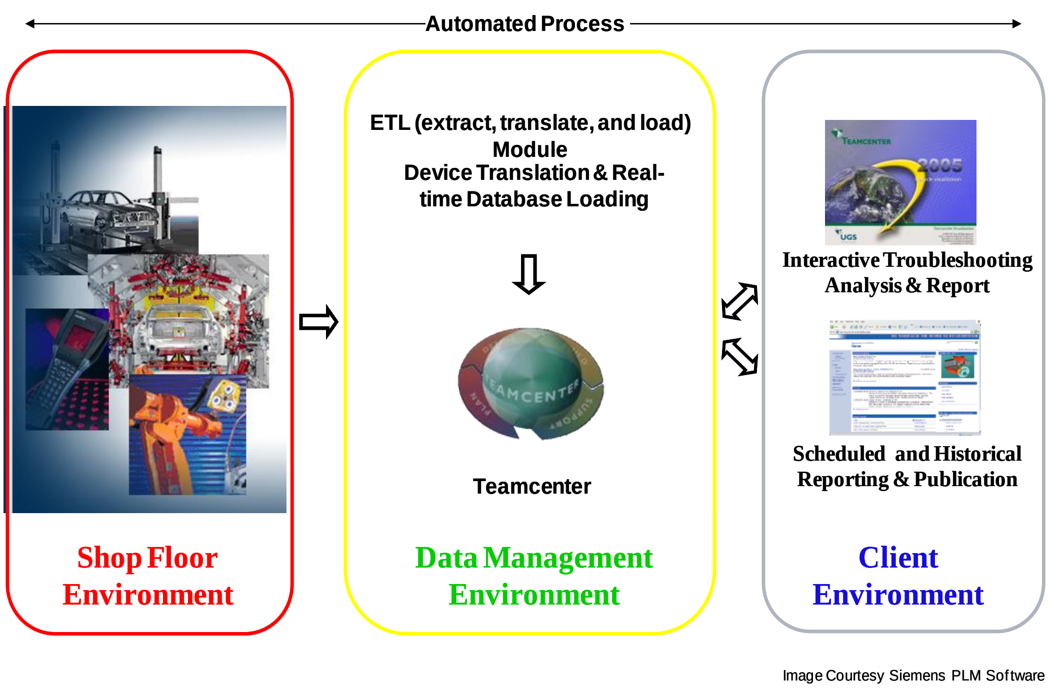
Dimensional Planning and Validation

Siemens PLM Software has combined product design and production process measurement technologies to address the issue of closing the loop between the as-built to as-designed, as well as providing new technology to validate and extend quality assurance methods. They have introduced a much needed solution set based on existing PLM technologies such as product testing (CAE) realistic simulation and Digital Manufacturing simulation technologies that are capable of analyzing and validating production processes. Importantly, they have also integrated the ability to access data generated by state of the art inspection systems and production measurement systems. Siemens is calling this new technology Dimensional Planning and Validation (DPV). DPV is an integrated set of tools that provides real time capture and analysis of production process data thereby enabling quick problem resolution, reduction of production down-time, and the overall improvement of in-depth analysis on the build process and the issues that arise.

Merging Production Validation with Predictive Simulation

One of the primary goals of DPV is combining production process validation together with predictive simulation tools within a collaborative design/build environment. Much of the respective production process data, product engineering and test data, along with process simulation information, have traditionally been isolated and un-accessible to manufacturing engineering and factory floor operations. DPV brings together product engineering and production process execution and resulting in a common platform to validate the as-built to the as-designed.

DPV can support the overall production build process of manufacturing operations and the data involved. This would include assembly process planning, process simulation and validation, process detailing and documentation, and product launch support. Dimensional planning and subsequent validation is accomplished by creating a virtual predictive state through quality simulation and validating this with a physical reactive state provided by real quality metrics. All of this product, process, resource, and plant data can reside on the Teamcenter manufacturing data backbone which provides a common and collaborative environment for the access and exchange of all information necessary for the execution and validation of the production processes, including quality assurance and product



DPV High Level Environment

reliability. Production operation data in the form of actual inspection data and metrics becomes an integral component of the validation process provided within the DPV environment. Product launch is supported through simulation of production systems, equipment, and the inspection systems themselves, all of which provide a virtual validation prior to any commissioning of these systems.

Associative Reporting & Analysis

One of the important aspects of DPV is the ability to provide analysis of the production processes based on deviations and deltas (differences) between the virtual simulation and the physical execution of production systems and operations. The results of the DPV analytics can then be provided as associative reporting of the production processes, where deviation build metrics can be reported on and accessed through a shared environment between organizations, plants, suppliers, and customers. Stakeholders across the design/build lifecycle will be able to share engineering design and test data, product and process simulation information, DPV analysis, and, most importantly, deviations in product and process that can be discovered before finished assemblies and products reach customers or OEMs.

DPV as a Component of Harmonized Lifecycles

Siemens PLM Software is currently focusing on the first generation of project Archimedes where they are combining key products and technologies to address certain high level use cases that target end-to-end product introduction processes, from product design through manufacturing and automation. One of these high level use cases is Harmonized Lifecycles where the intent is to extend and integrate the PLM collaborative backbone with the factory floor and production systems. One example is to link shop floor programming and simulation used in machine parts fabrication directly to quality inspections systems such as coordinate measuring machines (CMMs) and shop floor production management systems. The goal is to achieve bi-directional integration between PLM product and process information systems/shop floor automation and production management systems.

The DPV approach is an integral component example of the overall Harmonized Lifecycle, leveraging Teamcenter and the manufacturing data backbone. DPV, within the Harmonized Lifecycle environment, helps to provide multiple benefits including:

- Streamlines production by leveraging actual production measured data with product, process, automation, and inspection information.
- Provides continuous process improvement by validation of nominal (simulation) to actual production quality metrics.

- Increases production throughput by providing access to PLM information to the shop floor.

- Insures product quality and process reliability by providing product data to production systems.

DPV Component Overview

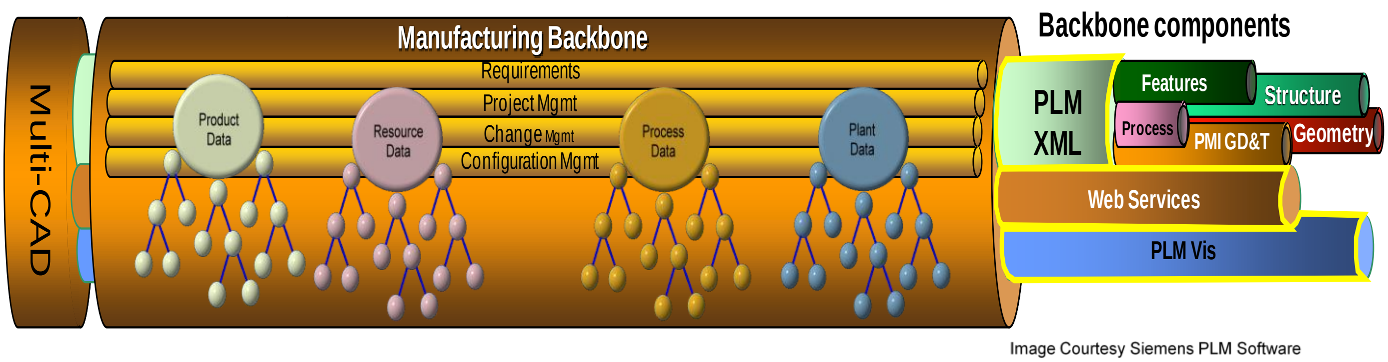
The DPV platform is comprised of six key components that combine to deliver the complete functionality for a dimensionally-based planning and production solution. At the shop floor level, physical **Measurement Systems** and inspection devices represent the point at which real-time metrics and inspection data is captured and stored. Typically, these measurement systems could include laser gap analysis, CMM, optical and digital measurement devices, hand held devices and any number of physical inspection systems. Next, the dimensional inspection data is translated and a **Data Load** component is used to populate the Teamcenter manufacturing data backbone with inspection metrics.

Teamcenter-Based Lifecycle Management represents a key component in the overall DPV solution. It functions as the broker for all real-time production metrics and data with the reporting and publishing activities that provide the visibility and analysis functions for DPV. From Teamcenter, the outward facing components provide collaboration, access, and visibility to the Teamcenter Community. The **Root Cause Analysis & Report Creation** component directly addresses Quality Assurance requirements by taking shop floor metrics and related information and generating analysis of variation and its root causes. A quality information bridge provides a link from Teamcenter to the Root Cause Analysis component which in turn creates a report of the analysis.

All reports created from the DPV environment are scheduled and generated from the **Report Scheduler & Historical Reporting** component which is linked to Teamcenter Lifecycle Management via a publishing bridge. The output of these reports can then be disseminated across the Teamcenter Community through the **Web-Based Publishing & Collaboration** component of DPV.

DPV Platform Integrates Quality Assurance with PLM

Clearly, the primary advantage offered by DPV is the integration of quality assurance and continuous process improvement methods across the design/build PLM solution domains. Moreover, DPV establishes quality as a part of the overall digital design and manufacturing processes, enables the capture of production build data, and provides a means to validate the as-built process to the as-designed product.



DPV Connects Product, Process, Resource, and Plant Data

Quality Assurance, both as a discipline and a set of methods, is maturing from the perspective of predictability and as a measured and quantifiable technology. With DPV, Siemens PLM Software is establishing a connection and interface between product design, process design, and the shop floor production systems, domains that heretofore have been disconnected and isolated. The discrete manufacturing community across all industrial verticals will be able to benefit directly through enhanced product quality and reliability, production process improvement, and significantly improved market presence and reputation.

Conclusion & Recommendations

It is clear that the business drivers receiving the most focus today from manufacturers are:

- Reducing the Cost of Producing Product
- Shortening the Product Launch Lifecycle
- Flexible Manufacturing Systems

- Common Processes and Reuse
- Process Optimization

Manufacturers are competing for market share in a fiercely competitive environment by offering ever-expanding product lines to meet customer demands for more variability and selection, as well as maintaining product quality and delivering their product in a timely manner. This means operating in a flexible manufacturing mode where production must respond to more changeable markets, shorter product lifecycles, and a more sophisticated buyer that demands high quality.

Given the intense competition for market share and the absolute necessity to get products to market in time to hit the market window for consumer acceptance, companies are looking for any competitive edge that they can leverage including the optimization of their manufacturing processes. Manufacturers now have the opportunity to use next-generation PLM tools like DPV to help them meet the requirements mandated by these business drivers. That is, take quality delays and issues out of the time-to-market equation.

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Acronym Reference: For a complete list of industry acronyms, refer to our web page at www.arcweb.com/Community/terms/terms.htm

API Application Program Interface
APS Advanced Planning & Scheduling
B2B Business-to-Business
BPM Business Process Management
CAGR Compound Annual Growth Rate
CAS Collaborative Automation System
CMM Collaborative Manufacturing Management
CNC Computer Numeric Control
CPG Consumer Packaged Goods
CPI Continuous Process Improvement
CPM Collaborative Production Management
CRM Customer Relationship Management
DCS Distributed Control System
EAI Enterprise Application Integration
EAM Enterprise Asset Management
ERP Enterprise Resource Planning
HMI Human Machine Interface
IT Information Technology
MIS Management Information System
MRP Materials Resource Planning
OpX Operational Excellence
OEE Operational Equipment Effectiveness
OPC OLE for Process Control
PDM Product Data Management
PLC Programmable Logic Controller
PLM Product Lifecycle Management
RFID Radio Frequency Identification
ROA Return on Assets
SCM Supply Chain Management
WMS Warehouse Management System

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