# Multiplying MES Value with PLM Integration

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**Whitepaper by Dr. Michael Grieves**

# Introduction

Manufacturing Executions Systems (MES) have existed for decades to provide both planning and control of the manufacturing process and visibility of the actual states of material, labor and equipment on the factory floor. While MES point solutions remain, more sophisticated MES systems have evolved into platforms addressing different facets of manufacturer's overall operations requirements, including planning, controlling, monitoring and assessment. These applications include routings, sequencings, labor usage data collection, scrap reporting, production variance reporting and others.

MES platforms have, and continue to provide, significant opportunities to integrate manufacturing functions while reducing wasted time, energy, and material on the factory floor. The value of MES, however, can be greatly amplified if integrated into the Product Lifecycle Management (PLM) framework. PLM, with its product-centric perspective, provides an integrated framework for the different functions of create, build, support and dispose that have historically remained isolated and de-coupled.

To realize innovative products, they must first be built. This means that MES can benefit from the information created in the Digital Manufacturing (DM) process of PLM. DM consists of three phases:

1. Building the first product
2. Ramp up, and
3. Building the rest

In building the first product, DM creates a Bill of Processes (BofP) which specify the labor, material, equipment, routing and sequencing necessary to manufacture a specific product. These BofPs can be fully simulated in digital replications of the factory. These BofPs can be created, tuned, potentially optimized, validated and then sent on to MES, which will control and monitor the execution of BofPs on the factory floor.

MES is critical in closing the gap between inevitable gaps between simulation and reality on the factory floor. As production ramps up, MES information is critical in adjusting BofP. This information should then be fed back to engineering to improve their knowledge of the actual BofPs needed to produce desired results. MES is then needed to insure deviations do not occur when building the rest of the products after ramp-up.

MES is also critical to PLM in monitoring and reporting what actually occurred on the physical factory floor. For PLM to be effectively realized, the creation of "as-built" product information is a requirement. "As-built" product information is the creation of a virtual counterpart to the physical product. "As-builts" not only have information about what specific parts the product has, but will also need to have information about the BofP that created it, as well as the monitoring and quality control information as the product went through the manufacturing process.

Continuous Improvement initiatives will benefit from the collection of data when MES has access to "As-builts" product information. Production performance can easily be correlated with "As-built" product data to then evaluate which product component or process could be modified to improve output, increase product quality or improve product performance.

Finally, MES provides a link between PLM and the Enterprise Resource Planning (ERP) system. Once the product has been created in PLM, the actual transaction to call for the build of that product usually becomes the responsibility of an ERP system. ERP systems, being velocity transactions systems, do not and should not have the required detail to build complex products. Ideally, MES provides the interface between ERP specifying what should be built at the product level with PLM, which then specifies which components, processes and resources are necessary to build the product.

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## Defining PLM

Product Lifecycle Management (PLM) is an integrated, information-driven approach comprised of people, processes/practices, and technology to all aspects of a product's life, from its design through manufacture, deployment and maintenance—culminating in the product's removal from service and final disposal. By trading product information for wasted time, energy, and material across the entire organization and into the supply chain, PLM drives the next generation of lean thinking.

*Grieves, M. (2006). Product Lifecycle Management: Driving the Next Generation of Lean Thinking. New York, McGraw-Hill.*

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As part of this PLM framework, MES greatly magnifies the value it already brings, creating a major opportunity to eliminate cost by leveraging the use of this valuable information. And, MES provides data for valuable downstream support activities too.

# MES and PLM

Over the years, Manufacturing Execution Systems (MES) have evolved from point solutions into robust platforms to plan and control manufacturing resources. Specifically, MES controls labor, material and equipment, and the processes that use these resources to create products that meet exact quality standards. While these platforms have provided immense value to the manufacturing environment, the opportunity for MES to multiply its value arises when it can be integrated into a Product Lifecycle Management (PLM) framework.

PLM differs from MES in that it is a framework or approach that looks to "de-silo" the product information that has historically been locked away in functional silos. PLM then uses this information in an integrative way to reduce wasted time, energy, and material, especially between the interfaces of functional areas, such as engineering and manufacturing, while also fostering innovation.

PLM is concerned about the product information throughout its life, which also includes the specifics of how that product came into existence. Specifically, this is the labor, material, equipment and processes that created the product.

The key to successful manufacturing is to have defined, repeatable processes that minimize the use of resources: labor, material, and equipment. Therefore, for each product the company produces, the goal is to create a Bill of Process (BofP) that specifies each step that goes into creating the process while minimizing the use of labor, material and equipment.

# Three Phases of Product Manufacturing

As discussed in the Introduction, product manufacturing can be thought of as having three phases: Building-the-first-one, Ramping-up production, and Building-the-rest-of-them. While this viewpoint may appear at first glance to be an overly simplistic, it proves very useful – the tasks employed and the involvement of different

functional areas change depending on the phase the product is in. While making the "rest of them" may never really occur due to product changes, even after the product is in full production, the three phases of building the first one, ramp-up and building the rest of them helps us understand how MES fits within the PLM framework.

## *Building-the-first-one*

When building the first product in the past, manufacturing and MES were an afterthought. At best, they were brought into the process late. At worst, manufacturing was tossed blueprints and a prototype or two over the wall separating engineering and manufacturing and was expected to build the product. Either way resulted in delays, as iterative processes between engineering and manufacturing ensued in order to have a product design that could actually be manufactured.

Under PLM, this model is changing. The designs are being done digitally. The product is "virtualized." Companies are eliminating physical prototypes and digitally testing the product instead. Companies are using Digital Manufacturing tools to create BofPs that can be simulated. With Digital Manufacturing, companies can build simulations of entire factories down to the detail of individual machines along with their operators. With these simulations, companies can simulate the individual steps of the BofPs to see that those steps lead to the desired product. In addition, these BofP developers can try many different configurations in order to find the BofP that minimizes the use of labor, material and equipment.

If the goal was to build digital products, then the task would be completed. Unfortunately, the goal is to build physical products, which do not behave as nicely or consistently as their digital equivalents. There are gaps between the results of simulations and what actually occurs on the factory floor.

MES may be used to close or at least narrow those gaps. MES contains a wealth of information concerning actual labor, material, equipment, and time required to perform manufacturing operations execution. More importantly, MES has information on the variability of processes, which is important in two ways.

First, MES information can establish the normal variability of a process so simulations can be run not just at the ideal rate, but over the entire range of variability. For example, an assembly called Process "A" may ideally take 10 minutes, but the

variability range over a normal distribution is 10-15 minutes with an average of 12.5 minutes. The simulation needs to be run at the average with ways of looking for changes that will bring it down to the ideal time.

Second, MES information can describe variability over time. As machinery ages and dies wear, product tolerances may change. Simulations that only take into account initial conditions will show the product within tolerance; relying that this condition will remain in effect over time may produce products that eventually fall out of tolerance. There are numerous examples of product designs that fit well together when initially manufactured and assembled. However, over time, all the components moved towards their tolerance limits. Even though the components were technically within tolerance, they were all at their limits so the product could no longer be assembled. This type of information can only be obtained from previous experiences, contained within MES.

## *Ramp-up*

As Figure 1 shows, the ideal goal of PLM is to eliminate ramp-up. With simulation and Digital Manufacturing techniques, the goal is to digitally drive down the experience or learning curve. Only when simulations that build the digital product show that resource consumption is minimized should the first physical product be built. The resulting BofP is then shipped down to factory floor to be executed by manufacturing.

Again, this is an idealistic view that will never occur. Simulations never capture all variability in the real world. That is not to say, however, that some of the drive down the learning curve cannot be done digitally, saving time, effort and resources.

Today, most learning stays in the manufacturing area, never making it back to engineering, where a substantial number of BofPs are developed. As a result, BofPs delivered to the factory floor often need to be re-worked. In many companies the BofP in engineering does not match the BofP actually used in manufacturing to build the product.

Since manufacturing actually makes the product, it only makes sense that manufacturing should own the BofP. The logical residence for BofPs is within the MES system. As manufacturing modifies their processes to become more efficient, BofPs are updated to reflect the latest, actual process used to manufacture the product.

Within the PLM framework, a BofP not only benefits manufacturing, but also engineering. With MES owning the BofPs, engineering can create new products using the actual BofPs used to create products. This is a feedback mechanism, illustrated in Figure 2, that has been missing from many if not most companies. The result is a better design for manufacturability with less change orders, freeing up engineering time better spent on innovation.
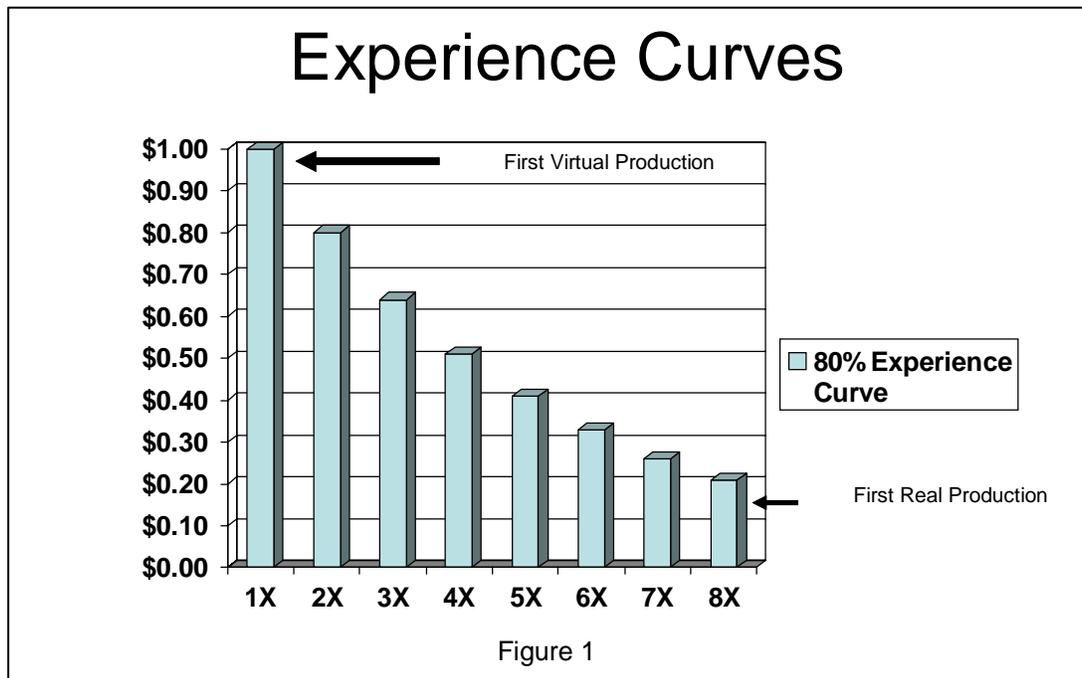


Figure 1

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Ramp-up is also the period in which scale issues rear their ugly heads. While simulations can and should be done at different levels of production, there will continue to be gaps between virtual and real production. MES, as owner of BofPs, will need to make the necessary adjustment to BofPs, and then feed these scale issues back to engineering.

efficiently, using proven, standard trouble-shooting processes which may be replicated not only throughout the plant, but across multiple plant locations. Finally, and most importantly, quality measurements need to be collected to insure the product meets specifications.

# BofP Feedback Loop

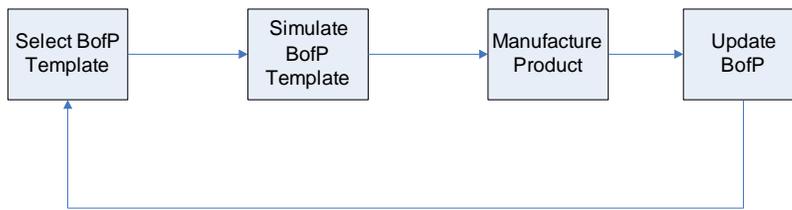Select BofP Template → Simulate BofP Template → Manufacture Product → Update BofP

Figure 2

These product measurements are not only used for performing quality tests resulting in a pass/fail for the product, but the data collected on actual results compared against specifications is invaluable in assessing manufacturing validity of new designs, as noted in "Building-the-first-one." By providing a feedback loop, the engineering / manufacturing divide can be bridged, reducing the slow iterative process of trial-and-error typically performed by manufacturing companies.

There are two more uses for MES information.

## *Building-the-rest-of-them*

MES systems are most critical within this phase of manufacturing. While it is easy to say, "build the rest of them just like this one," it is much harder to do. "Building-the-rest-of-them" not only refers to creating the product so that it looks and performs the same, but it needs to be created using specified amount of resources: labor, material and equipment.

In a global economy, building the rest of them generally entails building products at different geographic locations. The concept of "duplicate exactly", originating form the semiconductor industry, requires duplicating manufacturing conditions and processes. MES has the information and controls to enforce that concept.

MES needs to provide and control the resources used throughout the manufacturing process. There needs to be complete visibility of the manufacturing process so that any deviations from the plan can be addressed immediately. There needs to be visibility of inventory both at the work stations and in plant inventory. Labor and material need to be tracked and compared to plan. Equipment maintenance must be managed so equipment is available as scheduled, so unexpected equipment outages are dealt with effectively and

1. Manufacturing verifiability
2. "As-built" data collection repository

The first use is critically important to all manufacturing companies; the second use is becoming more important as PLM matures.

Manufacturing verifiability is defined as the data collected during the processes used to manufacture the product. Examples of this data are torque readings on bolts used to install automobile seats or gas tanks, coordinate measuring system (CMM) readings of jet engine components and voltage tests of pacemakers.

While the primary use of this information is to insure quality control, its benefit extends beyond this use. MES functions as an alerting system prompting supervisors if data is missing or falls outside of specified ranges. Problems in this area are not typically attributed to weak quality specifications, but rather to employees bypassing these specifications. MES enforces these standards cost effectively, as the most cost efficient time to address these kinds of problems is at the source.

"As-built" data collected within MES is an excellent defense for product liability or

governmental regulatory actions. Product liability suits cost manufacturers billions of dollars every year. Without the ability to present data about the manufacture of a specific product, companies are at the mercy of plaintiff attorneys who raise doubt about the manufacturing process by asking, "Isn't it possible that the bolts holding my client's seat were not tightened properly?" The only way to answer such a question with certainty is to have the specific torque readings from those bolts, indicating that they **were** manufactured to the appropriate specifications. Only MES can provide this information.

MES is becoming increasingly involved in "as-built" information. This data specifies which components were contained within a product as well as which processes were used to build that product. "As-built" information is required to fully implement PLM because this information is required in the support and disposal phases of PLM.

In the support phase, the product can be much more efficiently repaired if the repair facility has knowledge of specific components. Otherwise, the costly process of disassembly and inspection must be undertaken to determine specific components. Recalls generally involve a wider range of products than actually required because companies do not have sufficient information to identify the specific products with defective components.

While the collection of "as-built" information has been limited to very expensive products such as jet fighter planes, the trend now is to do more data collection as technology advances and costs of collecting, maintaining and storing this information declines. MES is the logical choice to be the keeper of this information since it is being collected already as part of the manufacturing process.

## MES and ERP

Enterprise Resource Planning (ERP) systems are primarily transaction-driven Order-to-Cash (OTC) systems. These systems receive product orders from customers, control and track the order through the shipment process, at which point the order turns into an invoice until ultimately it turns into cash when the customer pays. The transaction is then marked complete and removed from active transactions.

With such a wide scope of enterprise requirements, ERP systems are ill equipped to handle assembly, let alone manufacture of complex products. What ERP systems can do is tell manufacturing that a certain product needs to be made, and can receive notice that the product has been manufactured, with status updates along the way.

MES handles the job of actually initiating, controlling and monitoring the manufacture of the product. MES, as part of PLM, concerns itself with all the product information to provide the interface with ERP. In its ideal form, the only product information that ERP really needs to maintain is product number and quantity. As noted above, MES contains the BofP that is required to take the product number and turn it into the actual product represented by a product number. At the end of the manufacturing cycle, MES sends to the ERP system confirmation that the product is completed and ready for shipment.

ERP Systems and MES are complimentary, each with its own role to play in building products that customers order. Figure 3 shows this relationship.



Figure 3

Source: Purdue PLM Center of Excellence
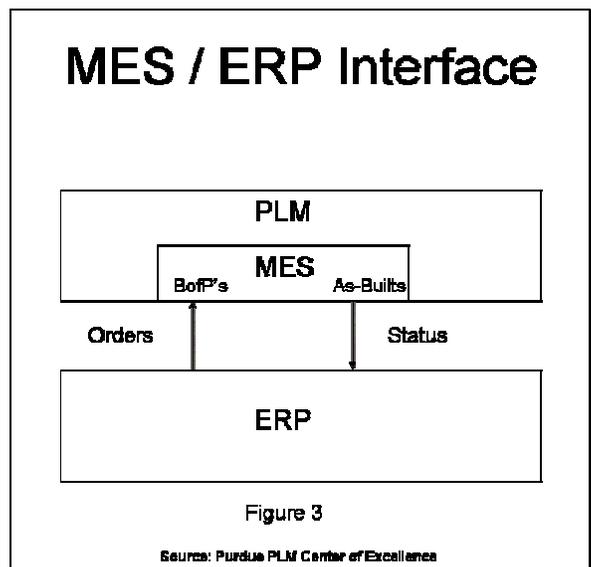
## Conclusion

MES has evolved over the years from a point solution to a robust execution platform for initiating, monitoring and controlling manufacturing resources: labor, material and equipment. The value of MES is multiplied when part of an overall PLM framework. An MES platform that is embedded within not only production, but maintenance, warehouse, quality and labor is even better.

Separating the phases of manufacturing into Building-the-first-one, Ramp-up and Building-the-rest-of-them, MES plays a critical role in all three phases. In Building-the-first-one, MES history can

guide product design into creating products that not only meet design requirements, but with specifications that can actually be met on the factory floor. In Ramp-Up, MES can affect steeper learning curves by capturing discrepancies between simulated builds of virtual products and actual experience of building physical products. MES can then feed modified BofPs back to engineering.

Finally, in Building-the-rest, MES should maintain the BofPs because they reflect the actual build of the product, collecting the data that verifies BofPs have been followed. MES should be the repositories of the "As-builts" since that information is collected during the manufacturing process.

MES, as part of PLM, is the interface between PLM and ERP. As complimentary systems, MES and ERP deliver value to the organization by providing both OTC transactions and the detailed information necessary to actually produce the product. The collective value of the entire manufacturing system grows as more processes are integrated and more data is shared. This 'unified data model' approach to MES and PLM can ultimately lead to a manufacture's 'nirvana'. In this scenario, all data is collected, standardized and available to each employee within all divisions, ending information 'silos' forever, increasing efficiency and optimizing manufacturing operations.

MES provides value by not only significantly reducing wasted time, energy and material in the manufacturing function, but by facilitating waste reduction in all aspects of the product lifecycle. MES serves as an invaluable information repository, including BofPs and "As-built" information.

## About Dr. Michael Grieves

Dr. Michael Grieves is a world renowned authority on Product Lifecycle Management (PLM). Dr. Grieves has written and lectured extensively on the topic and is a frequent keynote speaker on PLM. Dr. Grieves' works include the seminal work on PLM, Product Lifecycle Management: Driving the Next Generation of Lean Thinking (McGraw-Hill, 2006).

Dr. Grieves splits his time between the business world and the academic community. Dr. Grieves is Director of Industry Research at the University of Arizona MIS Department, a Visiting Professor at Purdue University College of Technology, and Chairman Emeritus of the Board of Visitors at Oakland University's School of Business Administration. Dr. Grieves co-founded the PLM Development Consortium at the University of Michigan College of Engineering.

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