

DRIVING DIGITAL MANUFACTURING TO REALITY

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ABSTRACT

The goal of digital manufacturing is to provide the manufacturing community with solutions to create, validate, monitor and control agile, distributed manufacturing production systems geared towards build-to-order and lean production. The scope of Digital Manufacturing has evolved recently to include Computer Aided Process Planning (CAPP); Computer Aided Production Engineering (CAPE); a Manufacturing Data Base which contains product data, process data, manufacturing resources (PPR); generation of executable programs for automation; the generation of work instructions for workers on the shop floor and the feedback of manufacturing performance data from the shop floor. Digital Manufacturing is a 3D computer environment that has only become possible because the product data and tooling data are now available in 3D CAD. This paper discusses the methodology of applying Digital Manufacturing from the initial concept design phase of both product and production processes, through detail design and validation, to both implementation on the shop floor and the constant monitoring the shop floor performance data to support continuous improvement activities. Because up to 60 percent of the value of automobiles and fighter aircraft are sourced from suppliers, the Digital Manufacturing environment must be accessible across the supply chain to support today's B2B method of doing business.

1 FROM PROCESS ENGINEERING TO PRODUCTION

The more experienced users realize the value of utilizing Digital Manufacturing from the very earliest phases of the product realization process. The value continues after product launch as the feed back of performance data and maintenance history is used to constantly improve the processes.

Digital Manufacturing is broken up into ten methodologies:

1. Define all constraints and objectives of the production system.

2. Define the best process to build the product and its variants according to targeted constraints and objectives.
3. Define and refine the production system process resources and architecture, and measure its anticipated performance.
4. Define, simulate and optimize the production flow.
5. Define and refine the plant layout.
6. Develop and validate the control and monitor functions of the production system. Execute the schedule.
7. Balance the line, calculate costs and efficiencies of the complete production system and select the appropriate solution.
8. Download valid simulation results to generate executable shop-floor instructions.
9. Upload, accumulate and analyze performance data from actual production system operations to continuously optimize the production process
10. Support field operations with maintenance instructions and monitor maintenance history.

Following these methodologies, the entire enterprise has maintained complete control of the process planning, the PPR validation and the deployment to the shop floor and the field. The day-to-day process planning is conducted within the same environment to accommodate for late part delivery, machine breakdown, absenteeism, etc. By continuous monitoring of the shop and field, unforeseen problems can be addressed quickly and the performance data can be used in modeling future evolutions of new products using the same manufacturing processes. By keeping a current model of the PPR status on the shop floor, new products and processes can be quickly evaluated.

2 A DECISION SUPPORT TOOL

It is clear that Digital Manufacturing is a decision support tool. It provides the members of the concurrent engineering team, or Integrated Product Team (IPT), the environ-

ment to perform their iterations to reach the optimal combinations of product and process. The Manufacturing Data Base, shown as the PPR Hub in Figure 1, is a knowledge repository that is shared by all enterprise members via a web based Portal so that they have the right information at the right time to support their decisions.

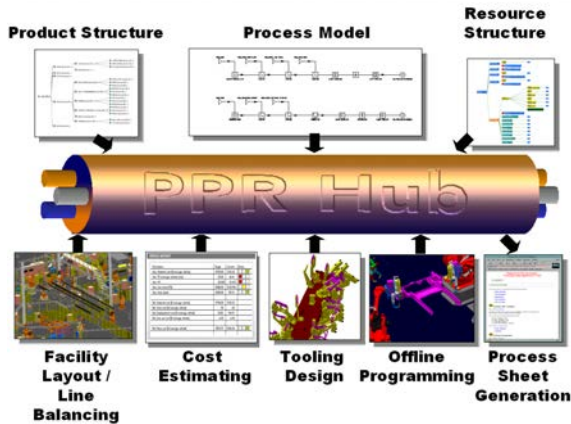


Figure 1: PPR Hub

The Manufacturing Data Base eliminates the re-entry of data for each study and provides the basis for configuration management of this data so that each participant is confident that they are using the most up to date data in their analysis. In a B2B environment vendors can access the continually revised data and update their price and delivery information to this database to position themselves as the potential vendors.

3 THE BUSINESS DRIVERS BEHIND DIGITAL MANUFACTURING

The industries that benefit the most from utilizing these methodologies are those with capital-intensive manufacturing and those with very complex products but very low production, even single unit production. For the capital intensive manufacturers, the ROI is calculated based on the value of reducing the time to market by 30-50 percent due to efficient concurrent engineering, reducing the product cost by 10-25 percent through multiple iterations of Design for Manufacturing and Design for Assembly, and reducing the costly engineering changes to product design and production tooling during launch by 80-90 percent. This is because each and every operation in the manufacturing process has been debugged in the Digital Manufacturing environment. For each task, the combination of product data, tools, fixtures, automation, material handling equipment and people have been validated in a physics based, 3D world. Customers such as DaimlerChrysler, General Motors, Boeing and Lockheed Martin have publicly declared that digital technologies have saved them

millions of dollars in just a few years. Similar savings have been realized in the semiconductor industry.

Digital Manufacturing is just as valuable for analyzing existing production lines during lean manufacturing initiatives and the introduction of new product variations or process improvements. One automotive supplier claims a 20 percent reduction in re-tooling time for a reworked line.

For those companies building very complex, one-of-a-kind products, the Digital Manufacturing environment enables them to climb up the learning curve before actual manufacturing. They can develop assembly sequences and tooling to increase their productivity and avoid unforeseen complications or shortfalls. Compared to their historical performance, customers in aerospace and shipbuilding have claimed efficiencies normally associated with the third ship on the first. This is extremely important when you are only building one or two units. One aerospace manufacturer claims that on their first piece production they had a 58 percent reduction in time and labor. A second aerospace project claimed a 42 percent saving in producing the first set of parts. These productivity gains and the related cost savings may mean the difference between a profit and a loss on the entire project.

Companies in the automotive and aerospace industries often have to prepare and submit large, high-risk proposals. They have realized the benefits of using Digital Manufacturing methodologies during the proposal phase. Since they have validated the manufacturability of their design and have a detailed estimated cost, they can quote a competitive price with confidence. In many instances they have developed innovated products or processes in the digital environment and used the simulations to communicate these innovations to their customers. This has won the confidence of their customers and award decision.

4 ENTERPRISE IT ENVIRONMENT PLACES HEAVY DEMANDS ON DIGITAL MANUFACTURING

In order to be effective in today's extended enterprise environments, the Digital Manufacturing solutions must be compatible with multiple CAD systems, multiple Product Data Management (PDM) systems, and be easily interfaced a numerous legacy systems that will continue to survive. Figure 2 outlines the complexities of this IT environment.

5 BROAD SET OF SOLUTIONS AVAILABLE IN A DIGITAL MANUFACTURING ENVIRONMENT

Fifteen years ago computer graphics became powerful enough to support the beginnings of Digital Manufacturing. Today, the PC engineering workstation and some laptops have the computer graphics power to provide high levels of productivity in Digital Manufacturing applications. Over these years a rich arsenal of solutions have

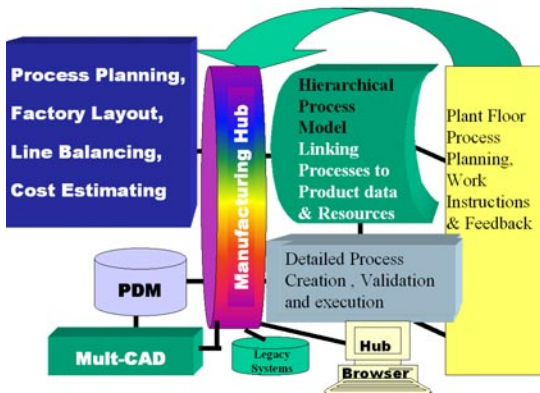


Figure 2: Digital Manufacturing IT Environment

STATUS REPORT			
Parameters	Target	Current	Status
Abs. Material cost (\$/average vehicle)	2750.00	2125.25	● ● ●
Abs. TE (average vehicle) [min]	25.00	45.61	● ● ●
Abs. HC	20,000	22,423	● ● ●
Abs. Line invest (T\$)	5000.00	5120.706	● ● ●
Abs. Area [sqm]	2500.00	193.15	● ● ●
Rel. Material cost (\$/average vehicle)	2750.00	2125.25	
Rel. Area cost (\$/average vehicle)	.78	.06	
Rel. Employment cost (\$/average vehicle)	57.50	104.91	
Rel. Line use cost (\$/average vehicle)	6.25	6.40	
Rel. Piece cost (\$/average vehicle)	2813.75	2236.56	● ● ●

Figure 4: Cost Estimation Report

been developed to attack time to market, cost and first piece quality. Since 70-80 percent of the cost of a product is determined by the product design, it is imperative that these solutions be applied early in the product realization process so that Design for Manufacturing and Design for Assembly studies can impact the product design while it is still digital and before any prototypes or production tooling have been ordered. Below is a thumbnail outline of some of the solutions available today.

Geometry based process planning, shown in Figure 3, is one of newest solutions available in Digital Manufacturing. It provides the linkage between each process step and the product and resource data related to that operation.

The ability to constantly measure the “Current” versus the “Target” for all the cost elements provides a very effective management tool in cost driven design situations (see Figure 4).

Plant layouts, such as the one shown in Figure 5, can be designed and continuously updated and validated as the fidelity of the process and resource models increase during the project.

Discrete event simulation tools validate the process plan, resource allocation and schedule in a stochastic 3D environment. An example is shown in Figure 6.

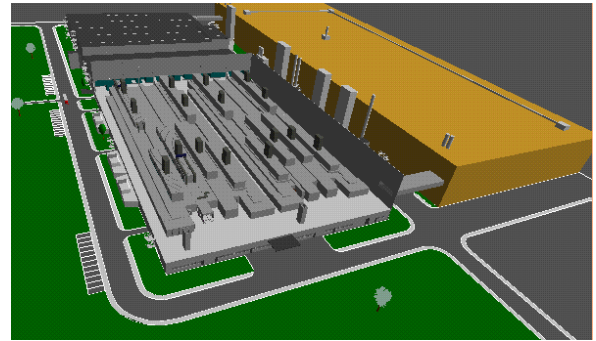


Figure 5: Facility Layout

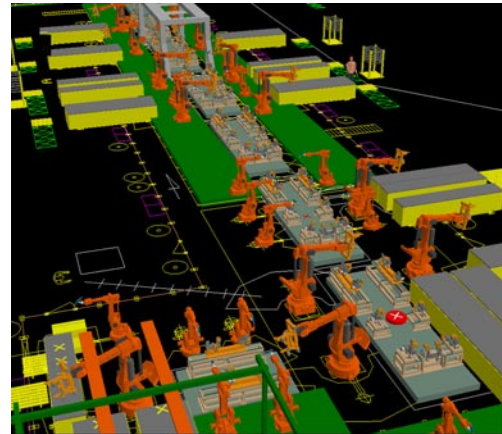


Figure 6: 3D Material Flow Simulation

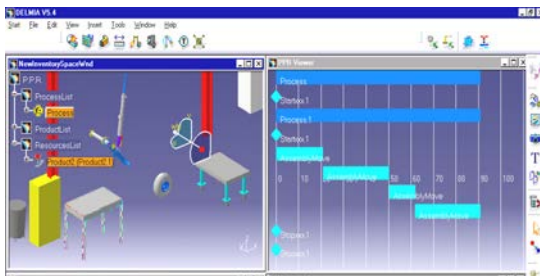


Figure 3: Geometry Based Process Planning

Accurate ergonomic simulations, see Figure 7, validate the human / machine interfaces of the manual work stations and analyze whether it can accommodate a variety of male and female workers without creating a hazardous or stressful condition.



Figure 7: Manual Assembly Simulation

The 3D simulation environment is capable of validating and generating robot programs in 50 percent less time than teach pendant programming and does not require that the robot be taken out of production for teaching the program. Figure 8 shows that multiple robot programs can be generated and validated.

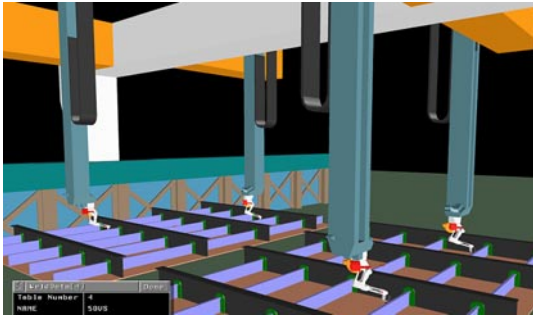


Figure 8: Welding Ship Sections

The ability to prove out programs at your desk instead of taking machine tools out of production plus the available analysis tools that have been used to reduce existing programs by 25 percent in cycle time makes NC program verification the easiest Digital Manufacturing solution to cost justify. This does not include the cost avoidance from eliminating crashes. Figure 9 shows that entire machine tool is used in this validation.

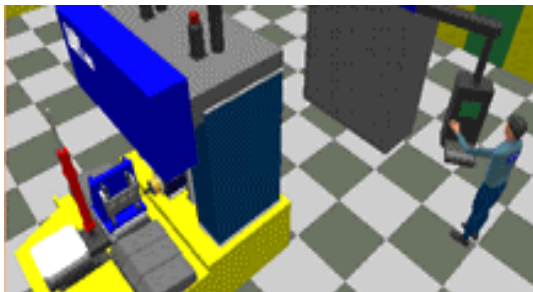


Figure 9: NC Program Validation

One of the latest developments in Digital Manufacturing is the rule-based generation of inspection plans from CAD features and having the inspection plan be fully

associative so that if the dimension, location or tolerance of feature changes, the inspection plan will change. See Figure 10.



Figure 10: CMM Program Generation from CAD Data

The same Digital Manufacturing Database that was developed during the product, process and resource development phases is used after product launch to support day-to-day process planning and generate 3D electronic work instructions. An example is provided in Figure 11.



Figure 11: Decision Support Tools for Process Execution

AUTHOR BIOGRAPHY

ROBERT G. BROWN has been president of DELMIA Corp. (formerly Deneb Robotics, Inc.) since he joined the company in 1992. He has over 30 years of experience in management, modeling and simulation, robotics, product development and manufacturing. He has served as president, ABB Flexible Automation, Inc., the U.S. operations of one of the largest industrial robot and robotic systems supplier in the world; Vice President and General Manager of the Automotive Division of ABB Flexible Automation; president, Aloyco, Inc., manufacturer of stainless steel and higher alloy valves; and division general manager, Watts Industries, a fluid controls manufacturer. He was also a consultant at Andersen Consulting. He holds a master of business administration degree from

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