Using Digital Manufacturing for Designing, Validating and Documenting the Manufacturing Process

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PLM – Define, Monitor, Control the Physical World

VIRTUAL
Non Tangible Assets

Product & Process Knowledge

INTELLECTUAL PROPERTY

PHYSICAL
Tangible Assets

Production

REAL OPERATIONS
Process Development Approach

- Product Data Managed in PDM
- High Level Planning
- Detailed Geometric Based Planning
- DPM for Assembly
  - DPM Human Task
  - DPM Robotics
  - DPM Machining
  - DPM Inspect
- Quest
- Discrete Event Factory Modeling
- Work Instructions Sent to MES
- Electronic Work Instructions
- DPM Shop

Virtual Product Development Conference
2004 - Huntington Beach, California
High Level Planning

- Integrated Process Modeling (Multi-level of detail)
- MBOM Development
- Task sequencing / precedence at all levels of detail
- Build-plan authoring (Configuration/Effectivity)
- Reconcile EBOM-MBOM, & Process Plans
- Line Balancing
- Status reports
- Cost Tracking
- Implement Best Practices
Process Planning (EBOM/MBOM Reconciliation)
Process Planning (Defining the Process)
Discrete Event Factory Modeling

- Automated preparation of simulation model out of the data in the PPR Hub
- Anticipate the behavior of Plants in operation
- Determine throughput capacity with various product mixes and resource levels
- Evaluate material handling alternatives, number of machines required
- Determine impact of facility layout
- Analysis of:
  - Flow time
  - Bottlenecks
  - Throughput
  - Capacity
  - Utilization
Discrete Event Factory Modeling

Component Fabrication Facility

Final Assembly Line
Factory Simulation

Large Scale Assembly

Chinook Program

Orbiter Mod Center

CII658 Program

Crane & Tooling Limits

Space Management

**Programs:**
- Boeing Commercial Aircraft (BCA):
  - 737 / 747
- Aircraft & Missiles (A&M):
  - F/A-18E/F / UCAV / CII658 / Chinook
  - F/A-18EFF / DD-21 / C-17 / V-22
- Space & Communications (S&C):
  - Space Shuttle / Delta / NMD / CRV
  - Air Borne Laser / Wedge Tail

**Benefits:**
- Validates Floor Space & Factory Operations
- Validates Operation Sequences & Large Scale Tooling Concepts
- Highlights Capital Investment Requirements
- Identifies Assembly Anomalies
- Drives & Validates Design Release Schedule
Detailed Process Planning (Producibility Analysis)

- Usage of native CATIA-geometry
- Product- and assembly analysis
  - Creation of assembly sequences
  - Assembly optimization
    - Assembly analysis
    - Collision detection
- Design for Assembly (DFA)
  - Evaluation of product design from assembly perspective
- Design for Maintability (DFM)
  - Evaluation of product design from a maintainability perspective
- Process optimization in the context of product and resources
- Author Electronic Work Instructions
Benefits:
- Validates Design/Assembly Integrity Prior to Commitment
- Validates Operation Sequences & Tooling Concepts
- Identifies Assembly Anomalies
- Drives & Validates Design Release Schedule
- Enables Optimization of Assembly Processes
- Reduces Downstream Production Planning (Assembly)
- Creates Consistent Virtual/Simulation Based Work Instructions
- Captures Best Assembly Practices

Programs:
- Boeing Commercial Aircraft (BCA):
  - 737 / 747 / 777
- Aircraft & Missiles (A&M):
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  - F/A-18EFF / DD-21 / C-17 / V-22
- Space & Communications (S&C):
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  - NMD / CRV / Space Station
  - Air Borne Laser / Wedge Tail
Detailed Process Planning Producibility Analysis

Assembly Sequence Validation

Original Concept

Validated and Approved Concept

PRODUCT DEVELOPMENT CONFERENCE
Harness Assembly Simulation

Key Features

- Simulation of Cables designed in EHI/EHF in Process Document
- Simulate assembly of the electrical harness into final products
- Define processes and resources needed to assemble the harness into product
- Simulate assembly issues and maintenance tasks

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration</th>
<th>Start</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process</td>
<td>42.75</td>
<td>0.00</td>
<td>42.75</td>
</tr>
<tr>
<td>Start 1</td>
<td>0.66</td>
<td>0.00</td>
<td>0.66</td>
</tr>
<tr>
<td>Move</td>
<td>10.00</td>
<td>0.00</td>
<td>10.00</td>
</tr>
<tr>
<td>Switch 1</td>
<td>6.00</td>
<td>10.00</td>
<td>16.00</td>
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<tr>
<td>Change Viewpoint</td>
<td>20.62</td>
<td>16.00</td>
<td>36.62</td>
</tr>
<tr>
<td>Change Viewpoint</td>
<td>8.75</td>
<td>36.62</td>
<td>45.37</td>
</tr>
<tr>
<td>Show Text: dgt1</td>
<td>4.38</td>
<td>40.38</td>
<td>44.75</td>
</tr>
<tr>
<td>Step 1</td>
<td>6.00</td>
<td>44.75</td>
<td>50.75</td>
</tr>
<tr>
<td>Delay Activity 1</td>
<td>10.60</td>
<td>50.75</td>
<td>61.35</td>
</tr>
<tr>
<td>Move</td>
<td>0.38</td>
<td>60.00</td>
<td>60.38</td>
</tr>
</tbody>
</table>

Harness assembled in the vehicle DMU
Robots

Interactive design, simulation and off-line programming of robotic workcells

- Collision avoidance
- Cycle time analysis
- RRS
- Calibration
- Post processors
- Spot welding
- Arc welding
- Cutting
- Painting
- Polishing …/…
Ergonomics

Ergonomic design and improvement of manual or semi-automated workplaces

- Worker simulation
- Predict human performance
- Maximize operator comfort
- Evaluate manning level alternative
- Optimize Tasks performance
- Optimize Workcell design
- Analyze human interaction with:
  - Robots
  - Devices
  - Processes
Ergonomics

Anthropometry

Postural analysis

Vision

Ergonomic analysis

Workplace Layout

Worker simulation

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2004 v[pd] • Huntington Beach, California
Ergonomics

Manufacturing Process Validation

Maintenance Scenario Validation

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MSC Software® Virtual

2004 v[p d] • Huntington Beach, California
Machining Process Planning

Multi-model and design features

Stock design

Product design

Machinings

NC Coding

Specific applications

Inspection

Process planning

Machining features

Tolerance & Drafting

NC simulation
NC Program Simulation/Verification

Ensure NC machining process reliability and productivity off-line

- NC Process prove-out
- Machining process optimization
- Check for all collisions
- Machined part validation
- Verify NC code
- Cycle time analysis
- Machine tool, tooling, setup and devices validation
- Document job setup with 3d definition (snapshots AVI’s, etc.)
Quality Assurance

Interactive programming and simulation of CMM's

- Targeting a complete coverage of the end to end Quality Assurance process
- Inspection product line will be composed of 3 configurations:
  - Inspection Off-line programming and simulation
  - Inspection On-line and tolerance evaluation
  - Inspection Reporting

Quality Assurance
Electronic Work Instructions

- Integrated with MES and/or Maintenance Execution System
- Easy-to-use, intuitive GUI, touch-screen
- Reduce erroneous work instructions, ambiguity, wrong drawings, etc.
- Generate non-conformance reports
- View job data in 3D, textual, and PERT chart formats
- Collect As-Maintained data, manage inspection buy-offs

PRODUCT DEVELOPMENT CONFERENCE - 2004
### Summary of Benefits Achieved

*Listed in Order of % Improvement (1 of 2)*

<table>
<thead>
<tr>
<th>Benefit Achieved</th>
<th>% Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in Search Time for Data</td>
<td>80%</td>
</tr>
<tr>
<td>Reduction in Number of Design Changes</td>
<td>65%</td>
</tr>
<tr>
<td>Better Understanding of Requirements</td>
<td>50%</td>
</tr>
<tr>
<td>Shortened Manufacturing Planning Process</td>
<td>40%</td>
</tr>
<tr>
<td>Reduction in Number of Workstations</td>
<td>40%</td>
</tr>
<tr>
<td>More Optimized Material Flow</td>
<td>35%</td>
</tr>
<tr>
<td>Reduction in Time to Market</td>
<td>30%</td>
</tr>
</tbody>
</table>

(Average value for varying number of responses)
## Summary of Benefits Achieved

*Listed in Order of % Improvements (2 of 2)*

<table>
<thead>
<tr>
<th>Benefit</th>
<th>% Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savings due to Improved Labor Utilization</td>
<td>30%</td>
</tr>
<tr>
<td>Savings in Tool Design</td>
<td>30%</td>
</tr>
<tr>
<td>Improvements from Better Plant Layout</td>
<td>25%</td>
</tr>
<tr>
<td>More Quickly Identify Areas for Improvement</td>
<td>15%</td>
</tr>
<tr>
<td>Improved Validation of Processes</td>
<td>15%</td>
</tr>
<tr>
<td>Increase in Collaboration/Communication</td>
<td>15%</td>
</tr>
<tr>
<td>Increase in Production Throughput</td>
<td>15%</td>
</tr>
<tr>
<td>Overall Reduction in Product Cost</td>
<td>13%</td>
</tr>
<tr>
<td>Decrease in Product Design Time</td>
<td>10%</td>
</tr>
<tr>
<td>Reduction in Inventory</td>
<td>10%</td>
</tr>
</tbody>
</table>
# ROI study for Digital Manufacturing

<table>
<thead>
<tr>
<th>Factor</th>
<th>Implementation Size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small</td>
</tr>
<tr>
<td>Initial Investment</td>
<td>$200K</td>
</tr>
<tr>
<td>Annual Investment</td>
<td>$200K</td>
</tr>
<tr>
<td>Annual Savings</td>
<td>$1M</td>
</tr>
<tr>
<td>Annual Return on Annual Investment</td>
<td>5 to 1</td>
</tr>
</tbody>
</table>
Conclusions

• Single integrated PPR database and application suite
• Build-to-Package derived from PPR database
• Reduced cost of Engineering Change Orders
• Reduced time to market
• Decreased program risks
• Increased Mfg. innovation
• Increased first time quality
Lockheed Martin JSF Program Focuses on Maintainability with DELMIA Solutions

“The timing, flexibility and affordability of simulations gave us a significant amount of influence over the air-system design. The designers are willing, and even eager, to address these concerns while their work is still in its preliminary stages… DELMIA’s most important contribution is to make maintainability assessable in the beginning of a design effort, where the payoff is significantly better.”

Michael T. Golas, Manager, Lockheed Martin Maintainer–In–Loop Program
Thank You!

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