Hidden Costs of Producibility and the Potential ROI of Developing Advanced Manufacturing M&S Capabilities

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Dr. Al Sanders
Honeywell Aerospace
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- Key findings from 18 month study on current DFM practices*
  - Producibility is a neglected “ility” due to the lack of analytical tools
  - Many costly producibility issues inadvertently designed-in
  - Current commercially available DFM analysis tools inadequate
  - Focused M&S research and investments needed to close gaps

- Roadmap development underway for key M&S focus areas
  - Systems engineering trade study and design methodologies
  - System integration, assembly, and test modeling
  - Enterprise level supply chain design and analysis methods
  - Electrical, mechanical, and assembly yield modeling
  - Quantitative DFX analyses including complexity characterization
  - Life cycle cost modeling including uncertainty and risk analysis


NDIA Committee Goal is to Influence S&T Investments
Why Focus on Producibility?

- Cost of Goods Manufactured
  - Direct material and labor costs
  - Manufacturing overhead costs

- “Producer” life cycle cost drivers
  - Low yield & process inefficiencies
  - Manufacturing process complexity
  - Excessive quality specs/controls

- Product cost reduction strategies
  - Post-NPI value engineering
  - Factory lean transformation
  - New material/process technologies
  - Strategic sourcing & material mgmt
  - Commodity “should cost” analysis

Because Producibility Drives Significant “Hidden Costs”
But is there a Business Case?

- Most legacy fielded systems have known producibility issues
  - VE changes to improve design almost always cost prohibitive
  - Significant sustaining engineering costs incurred year-after-year

- Aerospace-wide producibility improvement initiative launched
  - Cost-benefit criteria developed based on factory financial impact
  - Focus is reducing “producer” LCC drivers impacting the factory

**2009-2011 Financial Savings Dashboard**

<table>
<thead>
<tr>
<th>Year</th>
<th>Projects</th>
<th>AVE Yield Improvement</th>
<th>Normalized Total Savings</th>
<th>Average ROI</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>50</td>
<td>21.0%</td>
<td>1.29%</td>
<td>9.9</td>
</tr>
<tr>
<td>2010</td>
<td>74</td>
<td>21.0%</td>
<td>0.69%</td>
<td>8.6</td>
</tr>
<tr>
<td>2011</td>
<td>82</td>
<td>26.0%</td>
<td>0.92%</td>
<td>5.8</td>
</tr>
<tr>
<td>Cumulative</td>
<td>206</td>
<td>23.0%</td>
<td>0.96%</td>
<td>7.8</td>
</tr>
</tbody>
</table>

Estimate 4-5X Greater Opportunity for Save due to 80-20 Rule

**1% of Total Aero Conversion Costs**

*Producibility Directly Impacts Cost of Goods Manufactured*
Why is Manufacturing M&S the Solution?

• Once design is “locked-down” producibility is “locked-in”
  - Lack of relevant M&S tools prevents factory impact prediction
  - Inadvertently “designed-in” inefficiencies can persist for years

• Producibility issues primarily impact factory overhead costs
  - Root cause affinity mapping used to understand origins of issues
  - Analysis substantiates proposed M&S research focus areas

**Problem Duration Histogram**

- Ave Problem Duration 11.1 Years

**Producibility Driver Breakdown**

- Design Robustness: 16.1%
- Process Optimization: 15.8%
- Process/Supplier Selection: 16.9%
- DFX/Complexity: 16.6%
- Integration/Test: 19.1%
- Manufacturing Yield: 9.2%
- Other: 6.2%
Common Themes but Different Priority Focus Areas for Mechanical vs. Electronic System M&S Tool Development

Mechanical vs. Electronic System M&S Needs

Mechanical Producibility Breakdown
- 49.1% of Total Savings
- Common Themes but Different Priority Focus Areas

Electronic Producibility Breakdown
- 50.9% of Total Savings

Ave Problem Duration
- Mechanical: 15.5 Years
- Electronic: 7.4 Years

49.1% of Total Savings
- Design Robustness: 9.3%
- Process Optimization: 22.0%
- Process/Supplier Selection: 17.0%
- DFX/Complexity: 4.6%
- Integration/Test Yield: 12.3%
- Manufacturing Yield: 11.4%
- Other: 23.3%

50.9% of Total Savings
- Design Robustness: 9.3%
- Process Optimization: 28.8%
- Process/Supplier Selection: 9.8%
- DFX/Complexity: 21.7%
- Integration/Test Yield: 21.1%
- Manufacturing Yield: 6.2%
- Other: 3.2%
“Real World” Producibility Examples

- Avionics RF transponder
  - Circuit architecture drove trial & error frequency tuning of individual cards

- Display graphics PBA card
  - Functionality upgrade for a dense design drove yield into single digits

- Engine controller chassis
  - Size constraint drove compact design requiring blind PBA installation

- Advanced alloy impeller
  - Material developed that current cutters cannot efficiently machine

- Advanced heat exchanger
  - Weight drove non-optimal joint design susceptible to braze erosion

Many Producibility Issues Inadvertently “Designed-In”
Current Model-Based Approach Limitations

“Function Centric”

“Geometry Centric”

“Operation Centric”

“Virtual Wall”

“Virtual Wall”

Same Producibility Problems now just Happen “Virtually”
Design-Manufacturing Interdependence

- Early design decisions lock-in cost
  - Trade studies focus on performance
  - Use of exotic materials to save weight
  - Design thrown across the “globe”

- Moving manufacturing to the “left”
  - Concurrent engineering teams
  - Early supplier involvement
  - Design for Manufacturing (DFM)

- Quantitative analysis tools lacking
  - Manufacturing knowledge mostly tacit
  - High level DFM guidelines/checklists
  - Rule-based CAD/CAM occurs too late

M&S a Critical Enabler to Move Manufacturing to the Left
Sate-of-the-Art DFMA Analysis

Reduce part counts…
Standardize components…
Simplify assembly operations…

**Stapler**

- **“As Is” Design**
  - 29 Total Parts
  - Assy Time 204 sec

- **“To Be” Design**
  - 11 Total Parts
  - Assy Time 88 sec

**Electric Wok**

- **“As Is” Design**
  - 33 Total Parts
  - Assy Time 233 sec

- **“To Be” Design**
  - 13 Total Parts
  - Assy Time 91 sec


Simple DFMA Approaches work for Simple Products
Aerospace & Defense DFM Analysis Needs

• A&D productibility challenges
  - Maximum functionality in smallest package
  - Highly 3-D shapes with intricate features
  - Exotic hard to machine/fabricate materials
  - Tightly controlled dimensions & tolerances

• Producibility a design characteristic
  - Ease and economy of making item(s) at rate
  - Manufacturing-Assembly-Inspection-Test
  - F(fit, form, function, complexity, capability,..)

• Need quantitative analytical design tools
  - Make “hidden factory” costs & risks visible
  - Predict design-driven manuf inefficiencies
  - Shape design vs. verify rule adherence

Complex Product Designs Require Advanced DFM Tools
Honeywell Producibility Analysis Toolkit

Analysis Based Approach to Identify Manufacturing Risks

What design attributes are driving the design to be complex?

Is there significant hidden factory rework due to low first pass yield?

Do suppliers have experience making designs of similar complexity?

What are the top manufacturing risk areas requiring mitigation plans?

Are producibility trades being conducted in early NPI activities?

What is the design strategy to minimize DFM violation impact?

Does the “similar to” baseline have DFM violations and how severe?

What alternative design options increase yield and minimize re-work?

What is the DFM Scorecard Analysis?
“Virtual Manufacturing” Frontier

Current State Reality

Future State Vision

Transforming the Design Space

Need to “Re-Engineer” Product Development Processes
Summary and Key Takeaways

• Producibility issues drive up the Cost of Goods Manufactured
  - Neglected “ility” due to lack of analytical predictive tools
  - Inadvertently “designed-in” inefficiencies can persist for years
  - M&S tools needed to help guide product-process improvements

• Advanced manufacturing M&S is a potential “game changer”
  - Quantitative tools to predict system producibility characteristics
  - Supply chain analysis tools to predict industrial base behavior
  - Design methods integrate manufacturing into SE trade space

• National research agenda needed for “virtual manufacturing”
  - Improving A&D system affordability is an industry-wide problem
  - No single company has resources to solve this problem alone
  - Focused research & investments needed to develop capabilities

M&S is a Transformative Technology of the Future for the Advanced Manufacturing Discipline
Questions?

Contact Information
Dr. Al Sanders
Al.Sanders@Honeywell.com
Reliability Engineering Discipline

Reliability Theory

Reliability: Probability that a device will perform its intended function during a specified period of time under stated conditions.

Analytical Basis

Reliability: Probability that a device will perform its intended function during a specified period of time under stated conditions.

Physics of Failure Analysis

Trade Off Evaluations

Focus is Early Detection of Failure Modes and System Safety
What About Producibility?

Merriam-Webster.com

Producibility: Ease of manufacturing an item (or a group of items) in large enough quantities. It depends on the characteristics and design features of the item that enable its economical fabrication, assembly, and inspection or testing by using existing or available technology.

BusinessDictionary.com

Producibility: Ease of manufacturing an item (or a group of items) in large enough quantities. It depends on the characteristics and design features of the item that enable its economical fabrication, assembly, and inspection or testing by using existing or available technology.

Air Force Research Lab

Producibility: A design characteristic which allows economical fabrication, assembly, inspection, and testing of an item using available manufacturing techniques. The relative ease of manufacture of an item or system.

Defense Acquisition University

Producibility: The measure of relative ease of manufacturing a product. The product should be easily and economically fabricated, assembled, inspected, and tested with high quality on the first attempt that meets performance thresholds.

Analytical First Principles Basis Needed for Producibility
Yield Improvement Impact Prediction

\[ \text{ADD}_{\text{rework}} = (\text{Yield}_{\text{actual}} - \text{Yield}_{\text{target}}) \times \text{Demand} / \text{Manuf}_{\text{days}} \]

\[ \text{COPQ}_{\text{savings}} = \text{ADD}_{\text{rework}} \times \text{Rework}_{\text{time}} \times \text{Manuf}_{\text{days}} \times \text{Burden}_{\text{rate}} \]

\[ \text{WIP}_{\text{savings}} = \text{ADD}_{\text{rework}} \times \Delta \text{Cycle Time} \times \text{Std Cost} \]

- \text{ADD}_{\text{rework}}: average daily demand for the rework operations driven by low yield
- \text{COPQ}_{\text{savings}}: projected annual cost of poor quality savings due to yield improvement
- \text{WIP}_{\text{savings}}: projected inventory savings due to yield improvement
- \text{Yield}_{\text{actual}}: actual yield of the process step where the defect(s) are generated
- \text{Yield}_{\text{target}}: target yield of the process step where the defect(s) are generated
- \text{Rework}_{\text{time}}: conversion processing time associated with the rework loops
- \Delta \text{Cycle Time}: additional manufacturing cycle time associated with rework loops
- \text{Demand}: projected forward 12 month demand for savings calculations
- \text{Std Cost}: standard cost of the part/item being reworked
- \text{Manuf}_{\text{days}}: number of actual manufacturing days in a calendar year
- \text{Burden}_{\text{rate}}: labor burden rate associated with the rework operations

\[ Y = f(x) \] Formula Links Product Yield to Factory Financials