Hidden Impacts of Producibility on System Affordability and Design-Manufacturing Interdependence

NDIA Systems Engineering Conference
October 26, 2011

Dr. Al Sanders
Chairman NDIA AMEC Committee
AMEC Charter & Mission

Move Manufacturing to the Left

Advanced Manufacturing +

Engineering Capabilities =

Modeling & Simulation

New Design Methodologies

AMEC
Based on 18 month study on current DFM practices*

- Analytical producibility analysis tools lacking
- Many producibility issues inadvertently designed-in
- Current commercial DFM analysis tools inadequate
- Manufacturing M&S a critical missing research area

Roadmap development underway for key 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 impact

Why Focus on Producibility?

• Production cost components
  ➢ Direct material and labor costs
  ➢ Factory overhead/burden costs

• Producer vs. user LCC drivers
  ➢ Low yield & process inefficiencies
  ➢ Manufacturing process complexity
  ➢ Excessive quality specs/controls

• Product cost reduction strategies
  ➢ Post-NPI value engineering
  ➢ Lean out existing processes
  ➢ New material/process technologies

Inadvertently Designed-In Producibility Issues Drive Significant “Hidden” Costs
Design-Manuf Interdependence

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

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

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

**M&S Enabler to Move Manufacturing Left**
Role of Systems Engineering

It All Starts with Requirements....
Current Model-Based Approaches

“User” Needs

Systems Eng

Design Engineering

Manufacturing

Requirements Analysis
Conceptual Design
Preliminary Design
CAE/CAD/CAM Based Design
Test & Evaluation
Production & Deployment
Operations & Sustainment

MBSE

MBE

MBM

“Virtual Wall”

“Virtual Wall”

“Function Centric”

“Geometry Centric”

“Operation Centric”

“Same Problems now Happen Virtually...”
M&S-Enabled Concurrent Eng

Current State

"User" Needs

"Geometry Centric"

"Operation Centric"

"Virtual Wall"

"Virtual Wall"

Transforming the Design Space

Future State

"Fit-Form-Function-Operation Centric"

"Physical World"

“Re-Engineering” Design & Manufacturing
Role of Producibility in Trade Space

Producibility a Critical “x”
Driving the Big “Y” of Affordability
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: 
\[ R(t) = \int_0^\infty f(t) \, dt = e^{-\lambda t} \]

\[ f(t) = \frac{1}{\theta} e^{-t/\theta} \quad \lambda = \frac{1}{\theta} \]

MTBF \[ = \frac{1}{\lambda} = \frac{\text{total operating hours}}{\text{number of failures}} \]

Modeling Relationships

\[ R = 1 - (1 - R_A)(1 - R_B)(1 - R_C) \]

\[ R = (R_A)(R_B)(R_C) \]

Physics of Failure Analysis

RAMS

Reliability Availability Maintainability Safety

Trade Off Evaluations

Focus is Early Detection of Failure Modes
What About Producibility?

Merriam-Webster.com

Producibility: noun
pro·duc·ibil·i·ty
\pra,\d(y)u\sa\bil\t\n
Definition of PRODUCIBILITY
: the character, state, or fact of being producible

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.
State-of-the-Art DFMA Analysis

Reduce part counts…
Standardize components…
Simplify assembly operations…

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

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

Stapler

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

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

Electric Wok


Simple DFMA Approaches Work for Simple Products
A&D Producibility Analysis Needs

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

• Producibility is a “design characteristic”
  ➢ Ease and economy of making item(s) at rate
  ➢ Drives manufacturing inefficiencies and risk
  ➢ F(fit, form, function, complexity, capability,..)

• Need quantitative analytical design tools
  ➢ Make “hidden factory” costs & risks visible
  ➢ Shape design vs. verify rule adherence

M&S Enabler for Producibility Prediction
Manufacturing Paradigm Shifts

• Manufacturing is more than a constraint on design
  ➢ Need to define, allocate, and flow down producibility rqmts
  ➢ Conflicting “user” vs. “producer” needs require trade-offs
  ➢ Producibility the “kingpin” of system affordability and cost

• Design for manufacturing needs to become a science
  ➢ Analytical basis needed for producibility similar to reliability
  ➢ Design attributes drive manufacturing complexity & yield fallout
  ➢ Methods needed to balance assembly vs. part complexity

• System integration and test are now part of manufacturing
  ➢ Encompasses mechanical, electrical, and software disciplines
  ➢ Extensive testing currently used to detect and contain defects
  ➢ Bulk of component producibility problems discovered here....

Scope of Manufacturing has Changed
Summary and Conclusion

• Producibility issues drive significant “hidden factory” costs
  - Neglected “ility” due to lack of analytical predictive tools
  - M&S capabilities needed to move manufacturing to the left
  - Primary lever to attack affordability during early design

• Advanced manufacturing M&S a critical research area
  - Quantitative product-centric analyses to guide design decisions
  - Supply chain analysis tools to predict industrial base behavior
  - Design methods that integrate manufacturing into trade space

• Vision is to create a “virtual manufacturing” environment
  - Fusion of marketing, engineering, & manufacturing disciplines
  - Manufacturing enterprise designed in parallel to the product
  - Producibility predicted, optimized, and traded as design evolves
Thank You

Questions?

Dr. Al Sanders
Honeywell Aerospace
602-231-1886
Al.Sanders@Honeywell.com