
Dr. Al Sanders
October 29, 2009
JCSEM M&S Sub-Committee

• Joint Committee for Systems Engineering & Manufacturing
  - Sponsored by NDIA Systems Engineering & Manufacturing Divisions
  - Chaired by Dr. Tom Christian (SE) and Mike Packer (Manufacturing)

• JCSEM M&S Sub-Committee Chartered in November 2008
  - Dr. Al Sanders – Chairman (Honeywell)
  - John Allen (Honeywell)
  - Kevin Fischer (Rockwell Collins)
  - Greg Pollari (Rockwell Collins)
  - Charlie Stirk (Cost Vision)
  - Dr. Gary Belie (LMCO)
  - Simon Frechette (NIST)
  - Tim Comerford (Missouri University)
  - Scott Frost (Anser)
  - Brench Boden (AFRL)
Early Producibility Focus Motivation

• Early decisions responsible for many production ramp issues
  - Actual costs exceed estimates
  - Quality levels below expectations
  - Low yield and delivery problems
  - Service and sustainability issues
  - Integration & assembly problems
  - Overall supply chain inefficiencies

• DoDI 5000.02 implemented to drive earlier knowledge-based decisions
  - Increased focus on SE discipline
  - Increased focus on manufacturing
  - Analysis-based approaches needed
  - Producibility most neglected “ility”
  - Producibility drives hidden costs

New Approaches Required to Address Producibility Risks
Many producibility issues driven by early SE & design decisions
- Producibility forgotten requirement
- Producibility hard to quantify early
- Producibility M&S tools immature

Most producibility analyses are CAD-based rule checkers
- Require nearly final design layout
- Occur too late to influence design
- Only as good as rules loaded in

Need quantitative low & high-fidelity tools for trade studies
- Balance performance/producibility
- Guide analysis-based decisions
- Shape design vs. verify problems

Void Exists in Current Producibility M&S Capabilities


**JCSEM Committee Objective**

- **Overall JCSEM Mission**
  - Integrate manufacturing and producibility considerations into early systems engineering activities

- **Policy sub-committee charter**
  - Identify and update key SE policy documents to drive early focus on manufacturing & producibility

- **People sub-committee charter**
  - Identify critical producibility engineering skills required for early manufacturing engagement in SE

- **M&S sub-committee charter**
  - Identify industry M&S analysis needs required to address producibility concerns in early design activities

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**Goal is to Move Manufacturing to the Left in Acquisition**
"Identify industry M&S *analysis* needs to facilitate the integration of producibility concerns into the earliest phases of the system engineering process”

**In- Scope:**
- Product & process centric analyses to guide design decisions
- Factory & supply chain analyses to guide industrial base design
- Methodologies to integrate producibility into SE trade studies

**Out-of- Scope:**
- Virtual collaboration tools and enhancements to existing software
- Data standards, protocols, and interoperability requirements
- Digital/IT type solutions to facilitate information sharing

*Focus is Identifying M&S Needs that do not Exist Today*
Sub-Committee Technical Approach

• Objectives and Focus Areas
  - Identification of product, process, and supply chain analysis needs
  - Identification of a producibility figure of merit “goodness” measure
  - Identification of viable approaches for SE trade study integration

• Technical Approach
  - Identify the key inputs that would go into a producibility figure of merit calculation to capture and quantify producibility concerns
  - Identify specific M&S focus areas where producibility analysis capabilities are needed to support system design activities
  - Define what type of information the analyses should provide at each step in the system design and development process
  - Identify potential system trade study approaches that enable producibility evaluations to be integrated into design activities

Goal is to Provide Investment & Implementation Guidance
Producibility Figure of Merit Elements

- Producibility definition used by sub-committee:
  - Producibility defined as ease and economy of manufacturing an item, or group of items, in large quantities in a production environment
  - Most producibility costs “hidden” in nature such as scrap, rework, missed deliveries, safety stock, and lead time buffers due to low yield

<table>
<thead>
<tr>
<th>Producibility Life Cycle Cost Drivers</th>
<th>Key Factory Metrics</th>
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<tbody>
<tr>
<td>Unit Product Cost (Material &amp; Conversion)</td>
<td>Cost</td>
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<tr>
<td>Manufacturing Capital Investment Cost &amp; Risk</td>
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<td>Development MRL Maturation Cost &amp; Risk</td>
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<td>Overall Manufacturing Cycle Time (WSCT)</td>
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<td>Item Long Term Sustainability Risks</td>
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Legend:
- Manufacturing Cost Currently Considered
- Manufacturing Cost not Currently Considered
- Hidden Factory Cost not Currently Considered

Weight factors would be assigned to each element of the figure of merit based on relative cost impact and risk for critical systems, sub-systems, & components

Figure of Merit Links Producibility to Key Factory Metrics
Matrix focus areas:

- Should cost analyses
- Yield prediction models
- DFX analyses
- Manuf process modeling
- Production line modeling
- Physics based analyses (casting, solder flow, etc.)
- System integration, assembly, & test modeling
- Operator assembly & test modeling, e.g., ergonomics
- Obsolescence modeling

**M&S Analysis Output for each Design Phase Identified**

<table>
<thead>
<tr>
<th>SE Design &amp; Analysis</th>
<th>Prelim Design</th>
<th>Detail Design</th>
<th>Proto Manuf</th>
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<tr>
<td><strong>Electronics Yield Prediction</strong></td>
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<td>* sensitivity analysis of component key characteristics limits</td>
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<td>* identification of critical components driving yield fallout</td>
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<td>* identification of design simplification and yield improvement opportunities</td>
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<td>* analysis of component type and processing alternatives on yield</td>
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<td>* analysis of component yield classification (reworkable vs. scrap)</td>
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Supply Chain Design & Analyses

Analysis focus areas:

• Distribution aspects
  - Infrastructure complexity
  - Business strategy alignment
  - Logistics/queuing delays
  - Environmental events

• Technical aspects
  - Product complexity
  - Material availability/maturity
  - Process learning curves
  - Technology maturity
  - Work force maturity
  - Sustainability impact
  - Contract/policy constraints
  - Trend analysis & diagnostics

System Modeling Approach for Industrial Base Design
Producibility M&S Linkage

Producibility Figure of Merit Integrates M&S Tool Output into a Single “Goodness” Measure for Trade Evaluations

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Program Planning & Risk Management Tools & Approaches Apply Here

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Weight factors would be assigned to each element of the figure of merit based on relative cost impact and risk for critical systems, sub-systems, & components.
SE Trade Study Integration

- Manufacturing VOC to be included in trade study process
  - Responsible for long-term production of the proposed system
  - Provides input on production cost, quality, delivery, & inventory goals
  - Establishes process capability, cycle time, and yield flow down targets

- Quality Function Deployment (QFD) based methods
  - Most common trade study tool to down select alternative concepts
  - Help translate customer needs into system specs and design criteria
  - Correlate key technical performance measures to acquisition cost
  - Mature approach that can be easily adapted to include producibility

- Value Driven Design (VDD) based methods
  - Integrates systems engineering, optimization, and economic principles
  - Leverages requirements flexibility, optimization, and value models
  - Helps balance among competing TPM’s to produce best system offering
  - Emerging research area that addresses limitations of QFD approaches

**Producibility M&S Capability Enables Trade Integration**
DoD and Industry Benefits

- Several GAO studies conducted around acquisition cost overruns
  - Systemic issue was excessive design, technology, & manufacturing risk
  - Successful programs exhibited earlier design & producibility knowledge
  - Recommendation is adoption of knowledge-based decision processes

- Producibility analysis capability generates critical knowledge early
  - Provides means to influence and validate requirements feasibility
  - Provides means to identify, quantify, and proactively plan for risk
  - Provides manufacturing analysis capability comparable to engineering

- Producibility figure of merit provides means to quantify concerns
  - Provides means to quantify “hidden costs” during early design studies
  - Provides means to guide industrial base solutions and minimize risk
  - Provides means to down select most producible design alternatives

Producibility M&S Enabler for Early Knowledge Integration
Summary & Recommendations

• Producibility is neglected “ility” due to lack of analysis capability
  - Producibility issues are difficult to predict and drive “hidden” costs
  - Manufacturing VOC needs to be included in requirements definition
  - SE trade studies need to incorporate producibility considerations

• Producibility M&S is a critical research area that has been missing
  - M&S tools required to drive manufacturing to left in acquisition
  - Product, process, & supply chain centric analyses are needed
  - Requires focused research attention and investments to mature

• Top level framework established for SE trade study integration
  - Producibility figure of merit developed as “goodness” measure
  - Current QFD-based methods can be extended to address producibility
  - More research is needed to develop and mature VDD-based approaches

Final Report to Document Committee Recommendations