Modeling & Simulation Investment Needs for Producible Designs and Affordable Manufacturing

Systems Engineering Implications

NDIA JCSEM M&S Sub-Committee
Dr. Al Sanders (Chair)
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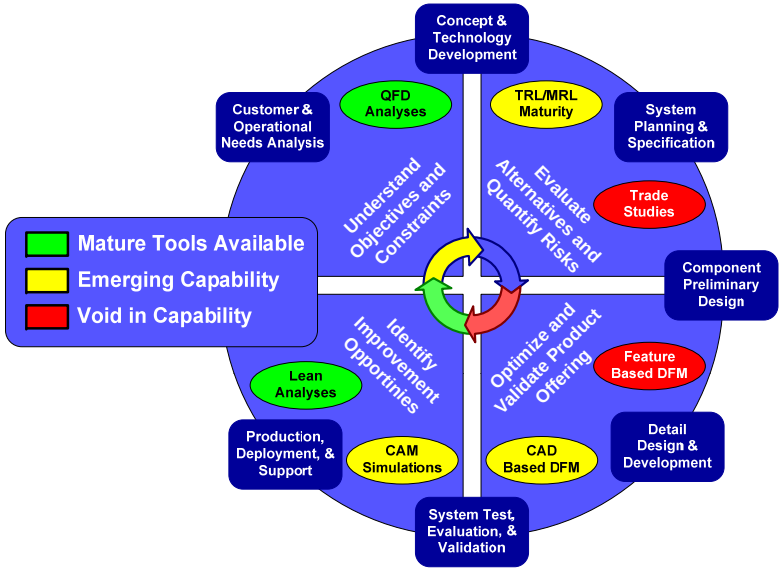
JCSEM M&S Sub-Committee Members

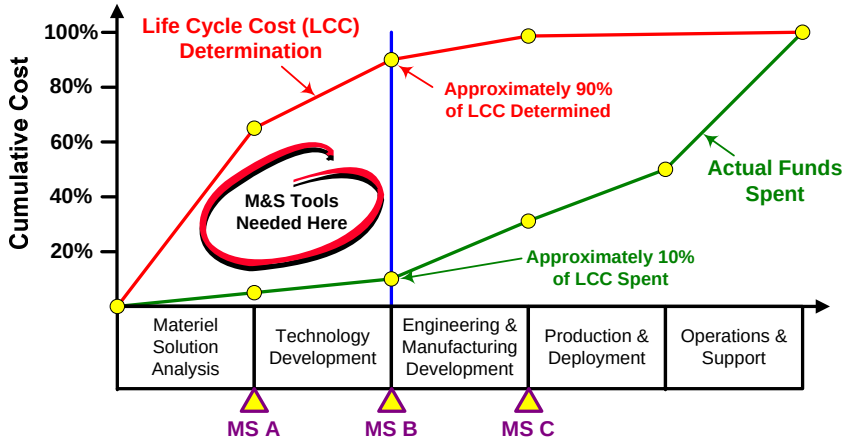
- **Joint Committee for Systems Engineering & Manufacturing**
  - **Sponsored by NDIA Systems Engineering & Manufacturing Divisions**
  - **Chaired by Dr. Tom Christian (SE) and Mike Packer (Manufacturing)**

- **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 of S&T)**
  - **Scott Frost (Anser)**
  - **Brench Boden (AFRL)**

Current State of Producibility M&S

- **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 M&S Sub-Committee Charter

"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 was Identifying M&S Needs that do not Exist Today

M&S Sub-Committee Objectives

Objectives and Focus Areas:

- Identification of product, process, and supply chain analysis needs
- Develop a producibility figure of merit "goodness" measure
- Identification of viable approaches for SE trade study integration

Technical Approach:

- Define the key inputs that would go into a producibility figure of merit calculation to capture and quantify producibility concerns
- Define 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
- Evaluate potential trade study approaches for ease of integrating producibility considerations into early system design activities

All Sub-Committee Objectives met and/or Exceeded

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**

	System Producibility Elements	Key Factory Metrics			
	Producibility Score: $Y=f(x_1, x_2, \ldots, x_n)$	Cost	Quality	Delivery	Inventory
x_1	Unit Product Cost (Material & Conversion)	X			
x_2	Manufacturing Capital Investment Cost & Risk	X	X	X	
x_3	Development MRL Maturation Cost & Risk	X	X	X	
x_4	Overall Manufacturing Cycle Time (WSCT)			X	X
x_5	Item Scrap & Rework (COPQ)	X	X		
x_6	Item Rate & Shipment Risks (OTTR)			X	X
x_7	Item Assembly, Test, & Integration Complexity	X		X	
x_8	Item Long Term Sustainability Risks	X	X	X	X

Legend
Manufacturing Cost Currently Considered
Manufacturing Cost not Currently Considered
Hidden Factory Cost not Currently Considered

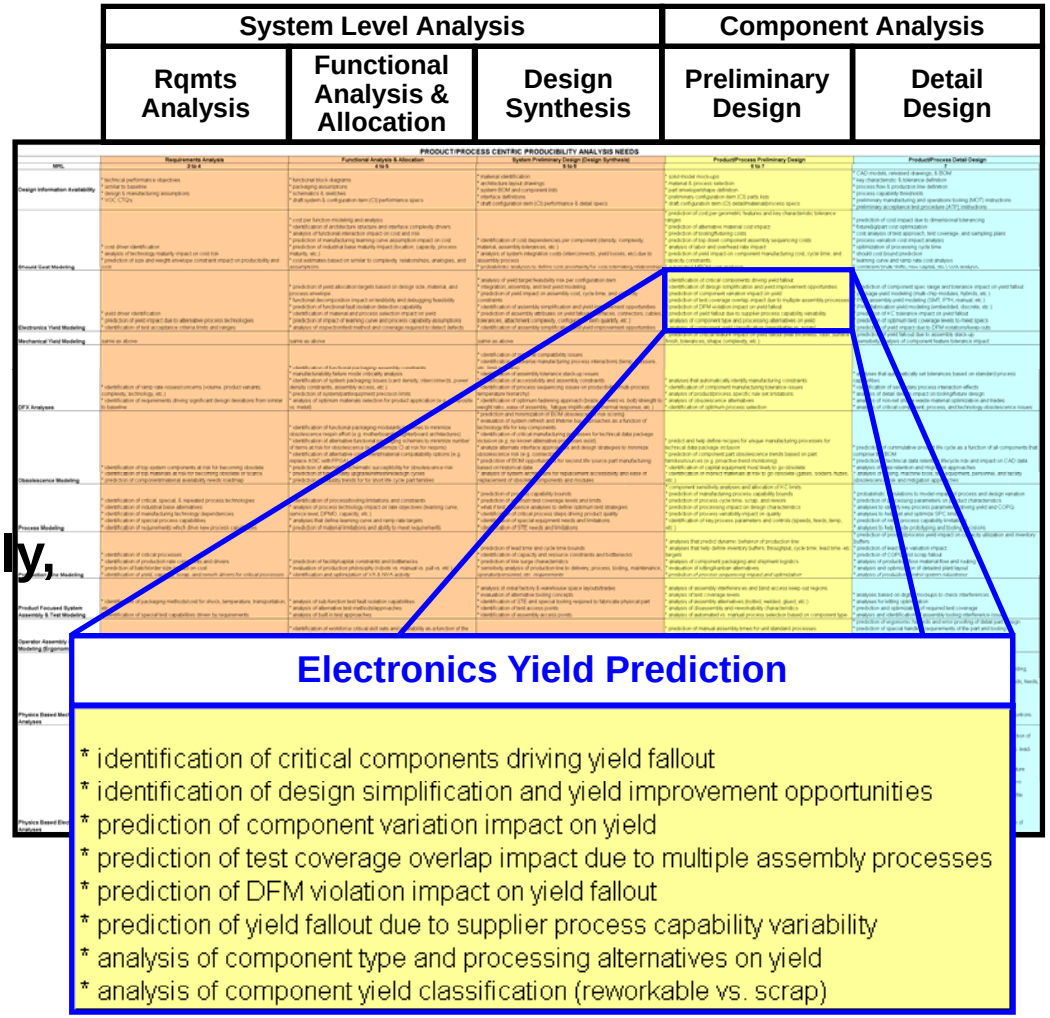
Weight factors would be assigned to each element of the figure of merit based on relative cost impact and risk for critical systems, sub-systems, & components

Figure of Merit Links Producibilty to Key Factory Metrics

Product & Process Centric Analyses

Matrix focus areas:

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

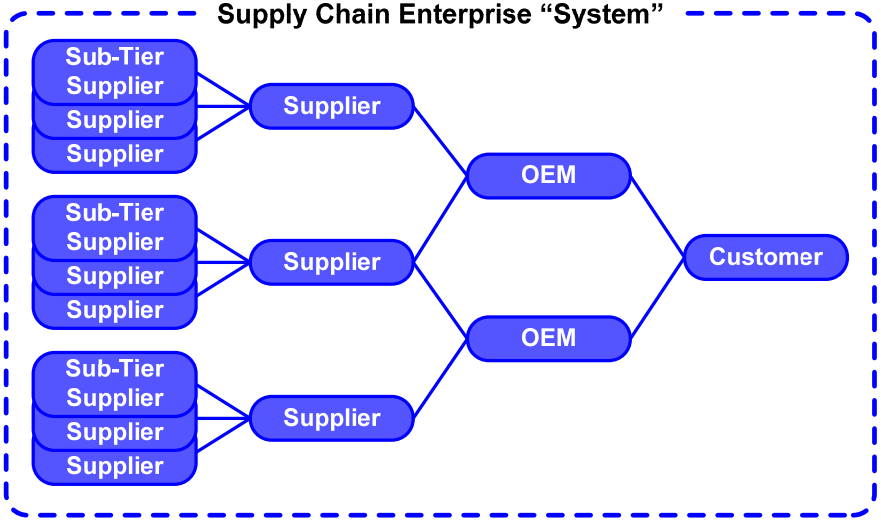


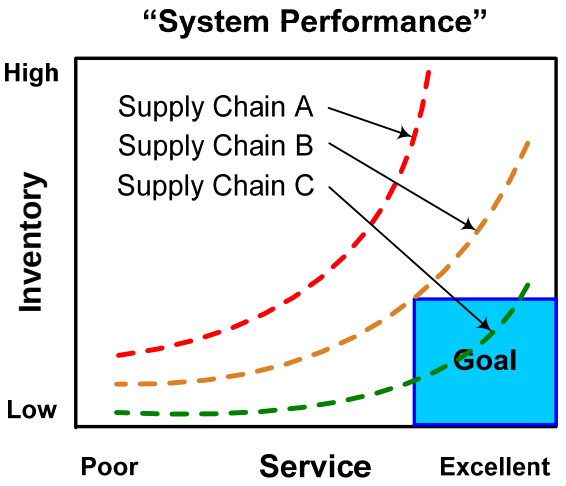
M&S Analysis Output for each Design Phase Identified

Supply Chain Design & Analysis

Analysis focus areas:

- Distribution aspects
  - Infrastructure complexity
  - Contract/policy constraints
  - Logistics/queuing delays
  - Environmental events
- Technical aspects
  - Product complexity
  - Material availability/maturity
  - Process learning curves
  - Technology maturity
  - Work force maturity
  - Sustainability impact
  - Business strategy alignment
  - Trend analysis & diagnostics





System Modeling Approach for Industrial Base Design

Producibility M&S Linkage

Producibility Life Cycle Cost Drivers	Should Cost Modeling	Yield Modeling	DFX Analyses	Process Modeling	Production Line Modeling	Physics Based Process Simulations	System Integration Assembly & Test Modeling	Operator Assembly & Test Modeling	Obsolescence Modeling	Supply Chain Design & Performance Modeling	Supply Chain Trend Analysis & Health Monitoring
	Product, Process, & Supply Chain Producibility Analysis Tools										
Unit Product Cost (Material & Conversion)	■			■		■					
Overall Manufacturing Cycle Time (WSCT)					■						
Item Scrap & Rework (COPQ)		■	■			■					
Item Rate & Shipment Risks (OTTR)		■	■		■		■			■	■
Item Assembly, Test, & Integration Complexity							■	■			
Item Long Term Sustainability Risks									■		■
Development MRL Maturation Cost & Risk	Program Planning & Risk Management Tools & Approaches Apply Here										
Manufacturing Capital Investment Cost & Risk											

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

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

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 Documents Committee Recommendations