“Virtual Manufacturing Frontier”
Path-Forward

AMMEP Planning Workshop
Georgia Institute of Technology
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Chairman NDIA AMEC Committee
### The World has Changed.....

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<th>20th century paradigms</th>
<th>21st century realities</th>
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<td>Orig Equip Manuf (OEM)</td>
<td>System integrators</td>
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<td>Domestic industrial bases</td>
<td>A global industrial base</td>
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<td>Static supply chains</td>
<td>Dynamic supplier networks</td>
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<td>We design what we build</td>
<td>We design what others build</td>
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<td>Large complex systems</td>
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<td>Discipline centric designs</td>
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<td>Collocated design teams</td>
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<td>Paper-based environments</td>
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<td>Balancing handful of “ilities”</td>
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<td>Technology at any cost</td>
<td>Cost is a key requirement</td>
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<td>Profit on the aftermarket</td>
<td>Minimize life cycle costs</td>
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**Cost is the new King of the A&D Industry**
Our Culture Hasn’t….

- Engineering invents and creates....
  - Rocket scientists and engineers dream up new technologies
  - Mathematical and scientific principles used to solve problems
  - Performance enhancing technologies developed at any cost

- Manufacturing builds and mass produces....
  - Semi-skilled labor uses machine tools and jigs to make parts
  - Experience and judgment used to develop/optimize processes
  - Automation and lean used to make processes more efficient

Need to Change a Century of Perceptions
Changing the Paradigm

Current State

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Changing the Paradigm
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Future State

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Changing the Paradigm
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Transforming the Design Space

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Changing the Paradigm
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“User” Needs

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Changing the Paradigm
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“Producer” Needs

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Changing the Paradigm
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Manufacturing

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Changing the Paradigm
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“Re-Engineering” Design & Manufacturing
Producibility Trade Space Focus

AMEC M&S Focus “Fuzzy Front-End”

80% “Hard” Science
20% “Soft” Science

Marketing Requirements

20% “Hard” Science
80% “Soft” Science

Complex System Design and Development

“User” Needs
Size Weight Power Efficiency
Reliability Maintainability Operability
“User” LCC

Need to Balance and Trade Off Numerous Conflicting Design Requirements

Producibility

“Producer” Needs
Cost Quality Delivery Inventory
Reusability Serviceability Upgradeability
“Producer” LCC

Manufacturing Enterprise Design and Development

Producibility “Kingpin” of Affordability
Honeywell Developed Enabling DFM Tools

**Manufacturing Complexity Model**
- What design attributes are driving the design to be complex and what can we do to simplify?
- Do potential suppliers have experience making products of similar complexities?

**CCA Yield Prediction Model**
- Is there significant hidden factory rework due to low first pass assembly yield?
- What design changes are we examining to increase the yield and minimize re-work?

**DFM Score Card Analysis**
- Does the “similar to” have DFM violations and if so how severe?
- How can we eliminate the DFM violations in the new design?

**Productivity Metric**
- How severe is the productivity concern?
- What are we doing to mitigate the risk?

**Analysis Based Approach to Quantify Productivity Risks**

Example Producibility Design Tools

Manufacturing Complexity Model

Available Complexity Models
• CCA, MEMS, Composite, Injection Molding
• Casting, Joining, Machining

Processes in Development
• Supplier Capability/Complexity Alignment

Model Identifies Top Design Simplification Opportunities

CCA Yield Prediction Model

Key Inputs:
- Total number of SMT components
- Total number of SMT pads
- Total number of PTH components
- Total number of PTH pads
- Fine pitch IC component quantity
- Fine pitch IC pads/pitch quantity
- Test coverage (AOI, AXI, ICT)

Key Outputs:
- First pass assembly yield off line
- AOI cumulative yield after re-work
- AXI cumulative yield after re-work
- ICT cumulative yield after re-work

Model Allows “Up-Front” Prediction of CCA Yield Targets

Yield = f(complexity, capability)
Yield = exp(-OFD*DPMO/10^6)
OFD = number defect opportunities
DPMO = manuf process capability

Example Producibility Design Tools

DFM Score Card Analysis

Application based score card
- Criteria based on best practices
- Quantifies DFM violation impact

Captures 1st order DFM drivers
- Key design & process attributes
- Differentiates violation severity

Three producibility classes
- “Green” : preferred capability
  mild concerns: score > 85%
- “Yellow” : challenging capability
  moderate concerns: score 70-85%
- “Red” : limited/special capability
  significant concerns: score < 70%

Available DFM Score Cards
- CCA Power Supply, Processor/IO/Analog, RF
- Navigation/Tactical/Automotive Grade MEMS
- Sand Cast Housings, Investment Cast Vanes
- Heat Exchanger Fabrication and Joining
- Injection Molded Electronic Enclosures
- Hand Lay-Up and RTM Composites

Score Card Quantifies DFM Goodness of Design Concept

Fundamental Research Thrusts

- Analytical tools to quantify and predict producibility
- Methods to define, allocate, flow down producibility rqmts
- Prediction of theoretical process capability thresholds
- Design methodologies that cope with uncertainty and risk
- Design decision aides to cope with scale and complexity
- Architecture design approaches that allow adaptability
- Frameworks that make the exploding state space tractable
- Supply chain “design and analysis” methods and tools
- Benchmark experimental data sets to validate M&S tools
Next Steps in the Journey

• Cultural – changing paradigms....
  ➢ Redefining the boundary between engineering & manufacturing
  ➢ Not letting current methods and tools constrain our thinking
  ➢ Make advanced manufacturing a core “engineering” discipline

• Technical - developing roadmaps....
  ➢ Leverage industry team to identify critical gaps and needs
  ➢ Leverage academia to develop solutions to reach future state
  ➢ Invitation only think-tank/workshop of SME’s to draft roadmaps

• Policy/Funding - finding sponsors....
  ➢ Make developing new design methodologies a research priority
  ➢ Influencing S&T investments to include manufacturing M&S
  ➢ Industry-government-academia collaboration key to success

Continue to Build Critical Mass & Support
AMEC M&S White Paper

• 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


Maintain Focus on Critical Few Areas
“Identify industry M&S analysis needs to facilitate the integration of producibility considerations into the earliest phases of the system engineering process for complex aerospace and defense system design”

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

- **Out of Scope**
  - Development of M&S data standards & interoperability rqmts
  - Virtual collaboration tools and enhancements to existing SW
  - IT-enabled PLM software and modeling language improvements

**Limit Scope to M&S “Analysis” Capabilities and “Design Methods”**
Thank You
Questions?