Model-Based Specification and Simulation-Based Design and Procurement

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“System of Systems” Design Challenges

**Today**
- Rule Based Design
- Standard Parts
- Increasing Complexity
- Specifications, Documents
- Small Samples Statistics

**Tomorrow**
- Relational Based Design
- Standard Processes
- Increasing Detail
- Model is the Specification
- Physics Based Analysis
- Statistics from All of Industry
Complexity

(From “Modeling and Simulation in System Engineering: Whither Simulation Based Acquisition?” By Andrew P. Sage and Stephen R. Olson, George Mason University)

- The more identical that a model must be to the actual system to yield predictable results, the more complex the system is.
- Complex systems “…have emergence … the behavior of a system is different from the aggregate behavior of the parts and knowledge of the behavior of the parts will not allow us to predict the behavior of the whole system.”
- “In systems that are ‘complex,’ structure and control emanate or grow from the bottom up.”
- A system may have an enormous number of parts, but if these parts “interact only in a known, designed, and structured fashion, the system is not complex, although it may be big.”
- Although a physical system maybe not be complex, if humans are a part of the system, it becomes complex
Example: The Electrical System and The Power Electronics Thesis

• Present electrical power systems are complex.
  – At equilibrium, 60Hz. Supplies power to 60Hz loads the system is stable and predictable.
  – If perturbed, the system can become unstable and unpredictable – bifurcation can occur.
  – Humans are needed to operate the system

• Future PEBB based power electronic systems will not be complex.
  – Automation is possible -- reduced operating costs
  – Progressive integration -- reduced system costs
  – Higher availability due to physics-based health prediction – reduced maintenance costs
  – Increased reliability and life by controlling overstresses
  – Increased applications and technologies
The Changing Role of Simulation

• **Today**, simulation is used for evaluation -- Analysis.
  – Simulation programs require detailed design information
    • Circuit parameters are entered before simulation begins.
    • Variations in design can be analyzed

• **Tomorrow**, simulation will become part of the design process -- Synthesis.

*The Model Will Be The Specification*
Future Design Process

**Today**

Reality → Modeling → Simulation

**Tomorrow**

Specs → Design through Simulation → Reality

Roger Dougal & Antonello Monti, University of South Carolina
The Design Cycle

Customer Designer

Mission: Performance, Life, & Cost

Supplier Designer

Products

Requirements
Physics-Based Models are Required

- Product models must be specific
- Requirement models can be general
  - In fact, requirement models with very specific details, in the design phase, can lead to an overly constrained problem.
Validation, Emulation, and Incremental Prototyping

- Validation of models
  - Controller In the Loop
  - Processor In the Loop
  - Hardware In the Loop

- Real-time simulation is needed for real hardware

- High speed real-time simulation is needed for high-speed controllers

- Multi-rate simulation for distributed simulation environments
Needs

• Modeling Standards
• Benchmark Models
• Public Library of Models
• A body of international volunteer experts for all of the above
• And …