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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

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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**

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The Changing Role of Simulation

- **<u>Today,</u> 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
- **<u>Tomorrow,</u> simulation will become part of the design process -- Synthesis.**

The Model Will Be The Specification

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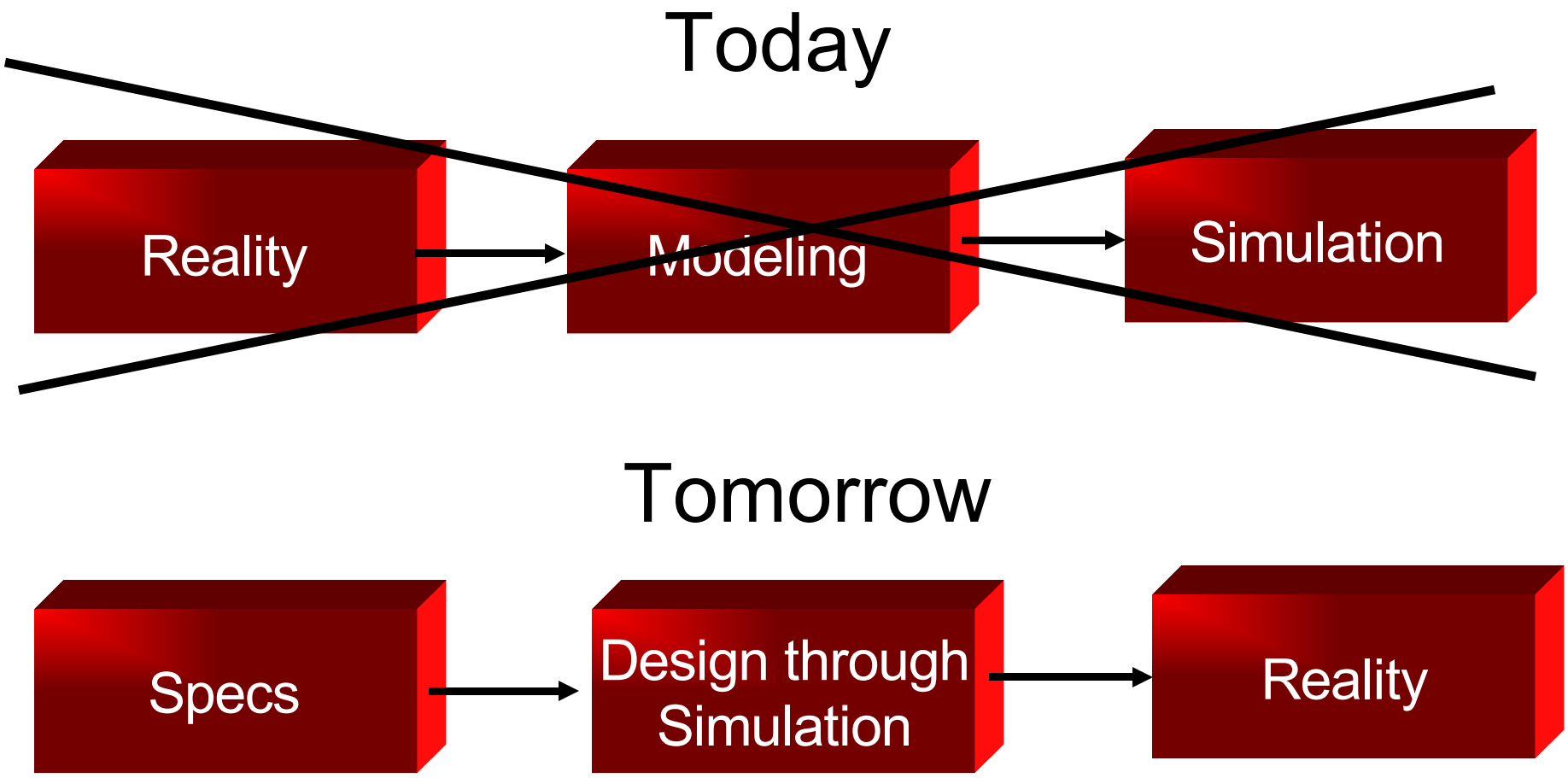
Future Design Process



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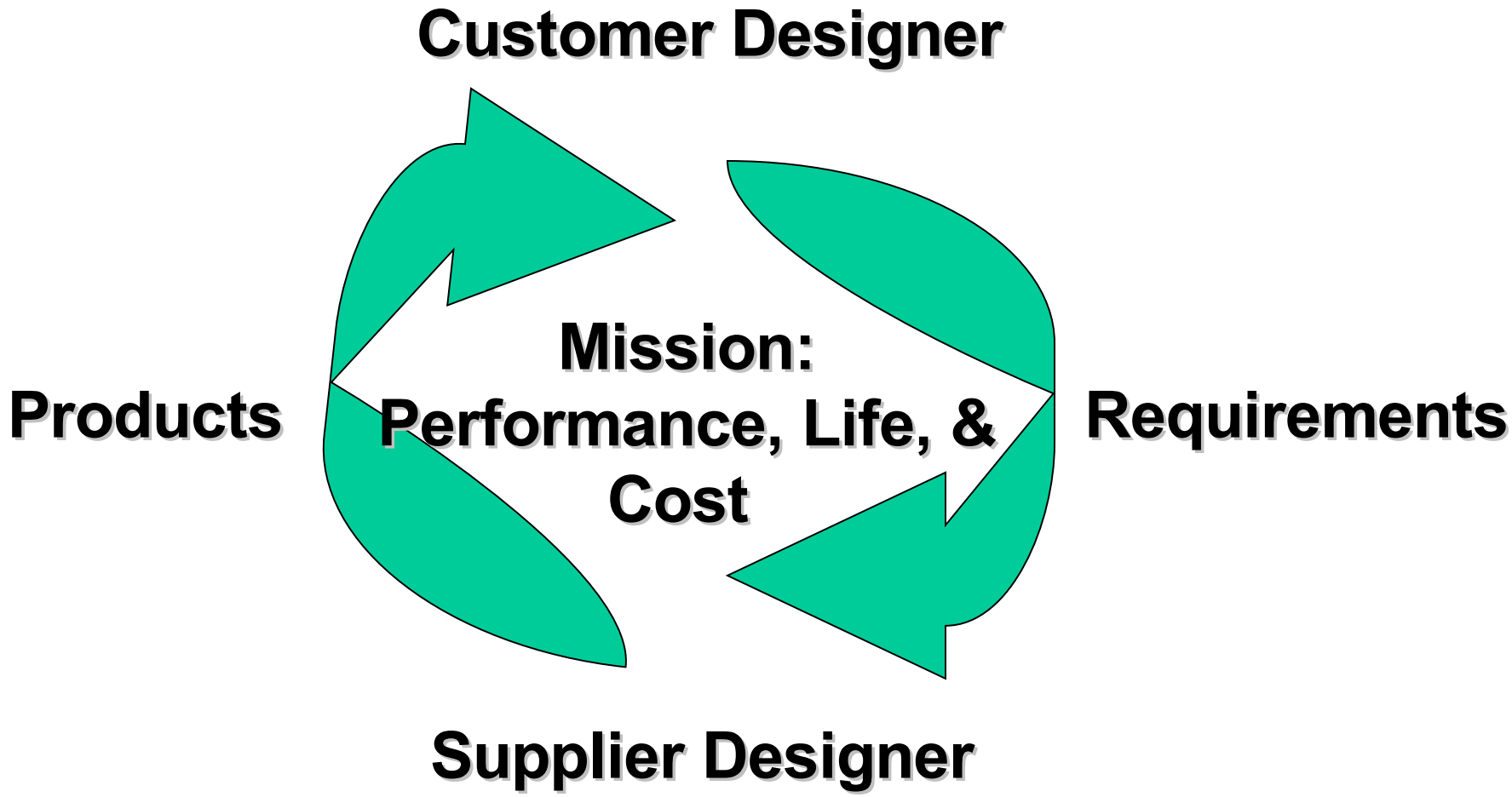
The Design Cycle



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.

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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 need 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 …