Scope of the LCCC-ACCESS Workshop on Model-Based Systems Engineering and Model-Based Engineering Education

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The Next Frontier in Engineering Research & Education

First quarter of the 21st century will be dominated by advances in methods and tools for the synthesis of complex engineered systems to meet specifications in an adaptive manner

Evident from the areas emphasized by governments, industry and funding agencies world-wide:

- energy and smart grids
- biotechnology
- systems biology
- nanotechnology
- the new Internet
- collaborative robotics
- software critical systems
- homeland security
- materials design at sub-molecular level
- network science
- environment and sustainability
- intelligent buildings and cars
- customizable health care
- pharmaceutical manufacturing innovation
- broadband wireless networks
- sensor networks
- transportation systems
- security-privacy-authentication in wireless networks
- cyber-physical systems
- web-based social and economic networks

Economic, Market, Technology Drivers

- Rapid changes in technology
  - telecomm devices, the Internet, MEMS, biotechnology and bioengineering, microelectronics, DSP, software
- Fast to market most critical
  - moving niche markets; mass markets: winner-take all phenomena
- Increasing pressure to lower costs
  - standardization, open architectures, interoperable subsystems/components
- Increasingly higher performance requirements
  - communicate with multimedia to and from anyone, at any time, anywhere, data-driven mass-spectrometer, cellular networks with .9999999 availability
- Increasing complexity of systems/products
  - Lab on the Chip, cell telephone on the chip, materials with "on demand" physical properties, personal digital assistants, information networks, advanced aircraft, communication satellites
- Increasing presence of embedded information and automation systems
  - smart materials, smart spaces, wearable health monitors, electronically adjustable car suspensions, self-healing telecommunication networks, implantable precision drug delivery devices
- 70% of product/system failures due to bad or no SE effort

Engineering Complex Systems: Challenges

- Synthesis from modular components
  - not only in aerospace, defense and large government projects
  - in all commercial designs and operations
  - integration is key
- Teams of experts working together on complex problems
  - multiple disciplines
  - communication and interpretation problems
- Characteristics of scientific, technical, business data
  - large volumes, not all relevant
  - numerically intensive, parallel applications
  - multidimensional, heterogeneous, distributed
  - specialized search engines, multiple views

Specific Examples

- VLSI design and manufacturing
- Electromechanical systems design and manufacturing
- Virtual manufacturing/virtual companies
- Telecommunication networks design
- Telecommunication and information networks management
- Appliance design and manufacturing; PCs, DSPs, boards, micromechanical systems
- System on a chip
- Modular aircraft: Joint Advanced Striker
- Lean aircraft and aerospace design and manufacturing
- "Boeing's seventh wonder" IEEE Spectrum, 1995
- Air Traffic Control
- Network security
- System of systems
- Systems Biology

Educational Needs – Background

- **Need to "see the bigger picture" earlier**
- **Current undergraduates are different from past and heterogeneous**
  - Heterogeneity will increase; especially among the very best; the candidate "creators" of future engineering breakthroughs
- **Basic calculus, physics and chemistry already done at a very good level among the best high schools; AP courses; College bypass**
- **Computers as indispensable communication-modeling-experimentation tools**
- **Programming replaces calculus; a "representation" symbology**
- **The Internet; access to knowledge that is easily searchable; multimedia depositories of experiments**
- **Virtual 3-D Labs**
- **Easier to collaborate**

Engineering System Design and Synthesis, Manufacturing, Life-Cycle Management

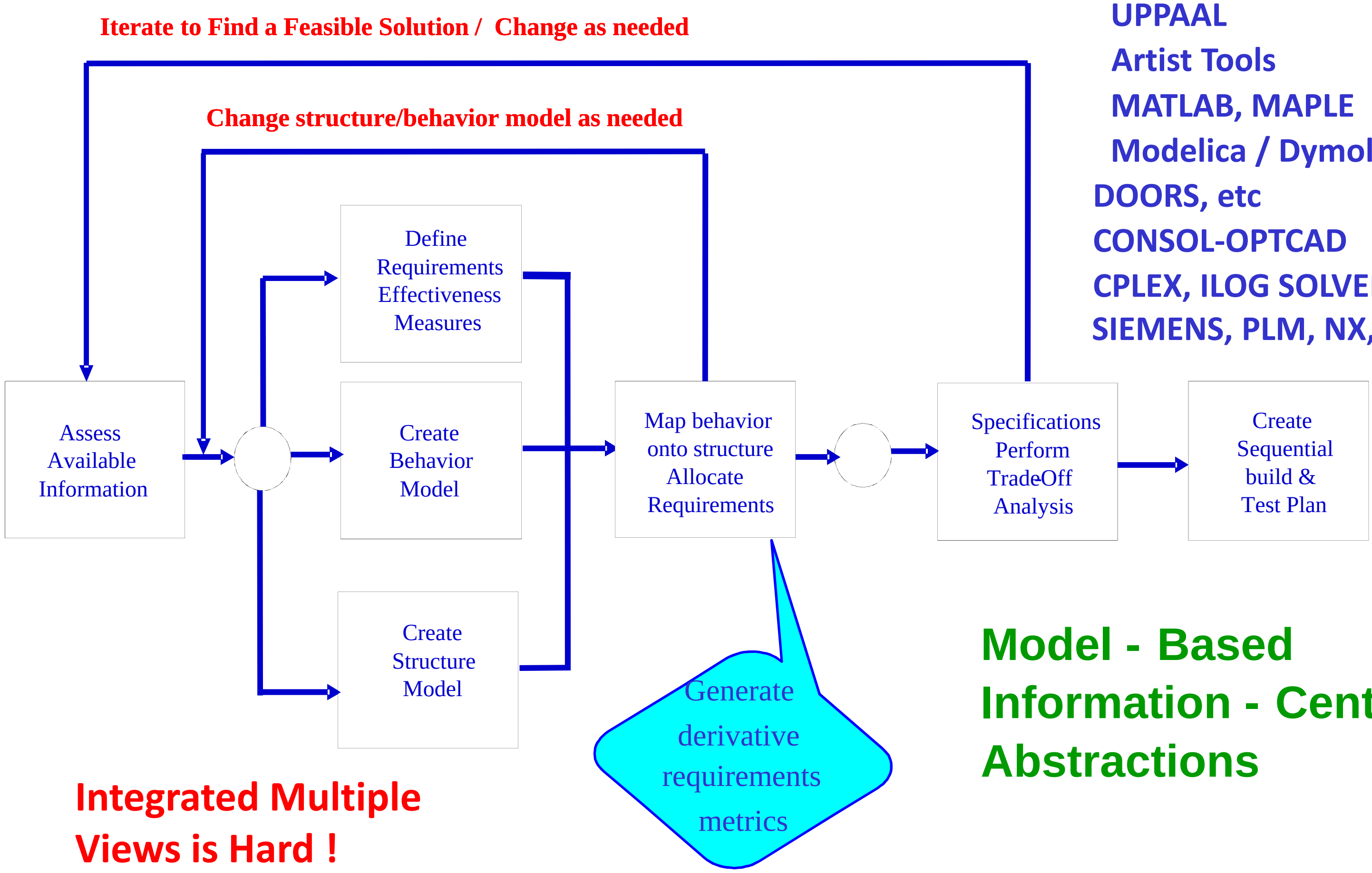
- **System Synthesis requires the following steps (at least)**
  - **Collection of Requirements**
  - **Construct System Structure (what the system consists of)**
  - **Construct System Behavior (what the system does)**
  - **Map Behavior onto Structure and vice a versa (what components will perform a specific part of behavior)**
  - **Allocate requirements to Structure and Behavior**
  - **Trade-Off Analysis**
  - **Validation and Verification (i.e. Test Plan)**
- **In this process implementation technology must be specified at some point (c.f. silicon, dimension, MEMS, ?)**
- **Reducing Design (read Synthesis) to compilation requires understanding and characterization of design rules and their incorporation in the synthesis process**

MBE-MBSE-PROCESS

Integrated System Synthesis Tools - & Environments missing

Model- - based
- UML - SysML - GME - eMFLON
- Rapsody
- UPPAAL
- Artist Tools
- MATLAB, MAPLE
- Modelica / Dymola

DOORS, etc
CONSOL-OPTCAD
CPLEX, ILOG SOLVER,
SIEMENS, PLM, NX, TEAM CENTER



Model - Based
Information - Centric
Abstractions

Integrated Multiple Views is Hard !

Transforming Engineering

- Move from a ***reductionist*** scientific approach to an ***integrative*** scientific approach
- **The challenge is to synthesize engineering systems so as to be able to generate predictable system behavior and performance by integrating behaviors and performance of system components**
- ***Compositional synthesis, manufacturing and life-cycle management*** of complex engineered systems
- This compositional synthesis advances engineering to the next frontier, **way beyond 'plug and play synthesis'**

Key Questions

- What are the common elements?
- How to best prepare Engineering students?
- How early to introduce what?

Scope of Workshop on MBSE and MBE Education

- **Interact**
- **Summarize where we are**
- **Identify and summarize what we need**
- **Describe key and fundamental challenges, approaches**
- **Establish collaborations**

- ***At what level is best to start? Mode? Hands on?***
- ***Graduate Education: MS?, PhD?***
- ***Undergraduate Education?***
- ***Pre-University? Post-University? Life-long?***
- ***Role of the Internet? Self-Learning?***
- ***Role of Industry? What and How? Equivalent of Clinics?***

Thank you!

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Questions?