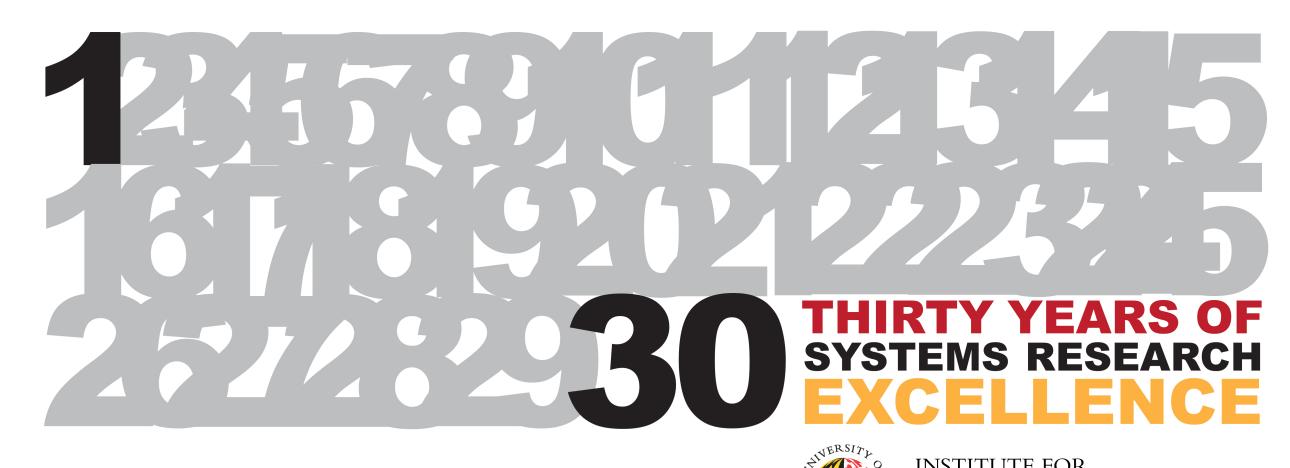# Model Based Systems Engineering (MBSE)

Faculty: John S. Baras, Mark Austin, Sarah Bergbreiter, Jeffrey Herrmann
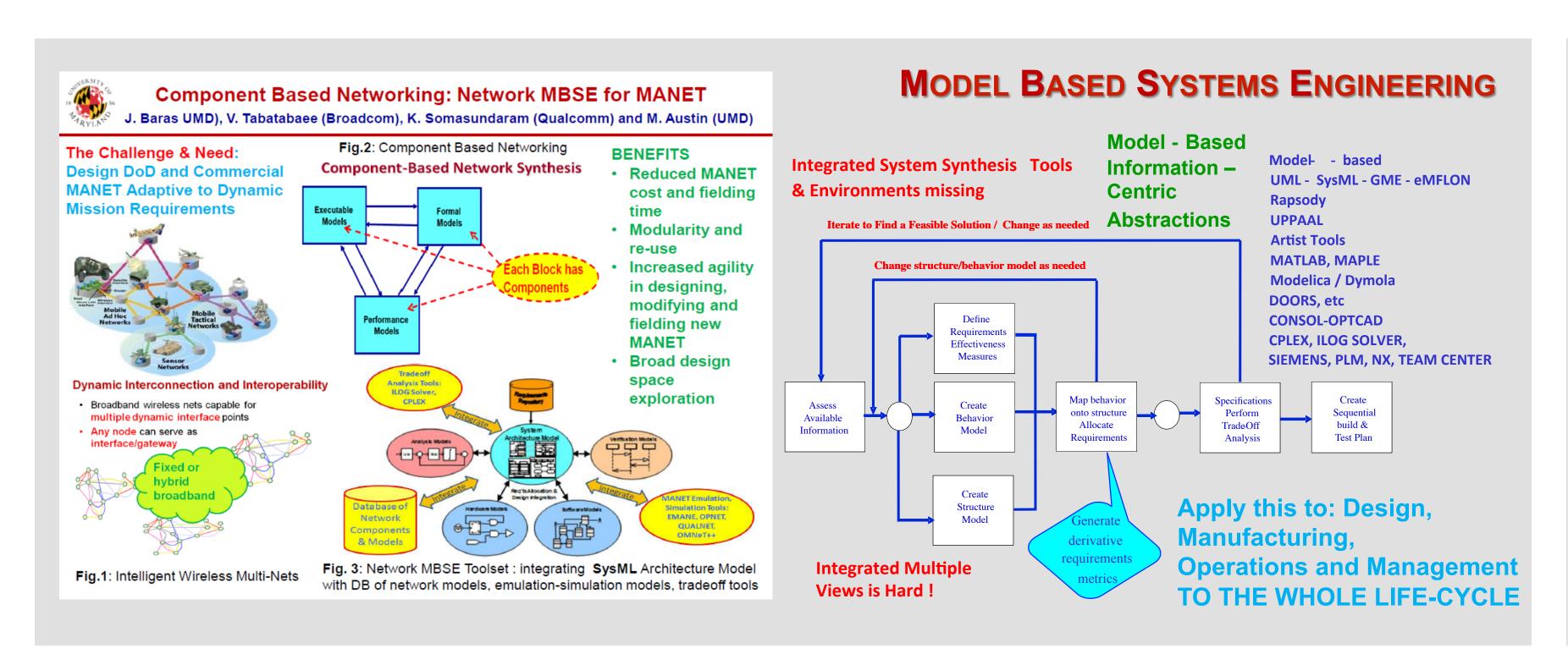Researchers: D. Daily, S. Jain, I. Katsipis, I. Matei, E. Paraskevas, L. Petnga, D. Spyropoulos, B. Wang, S-A. Yang, Y. Zhou
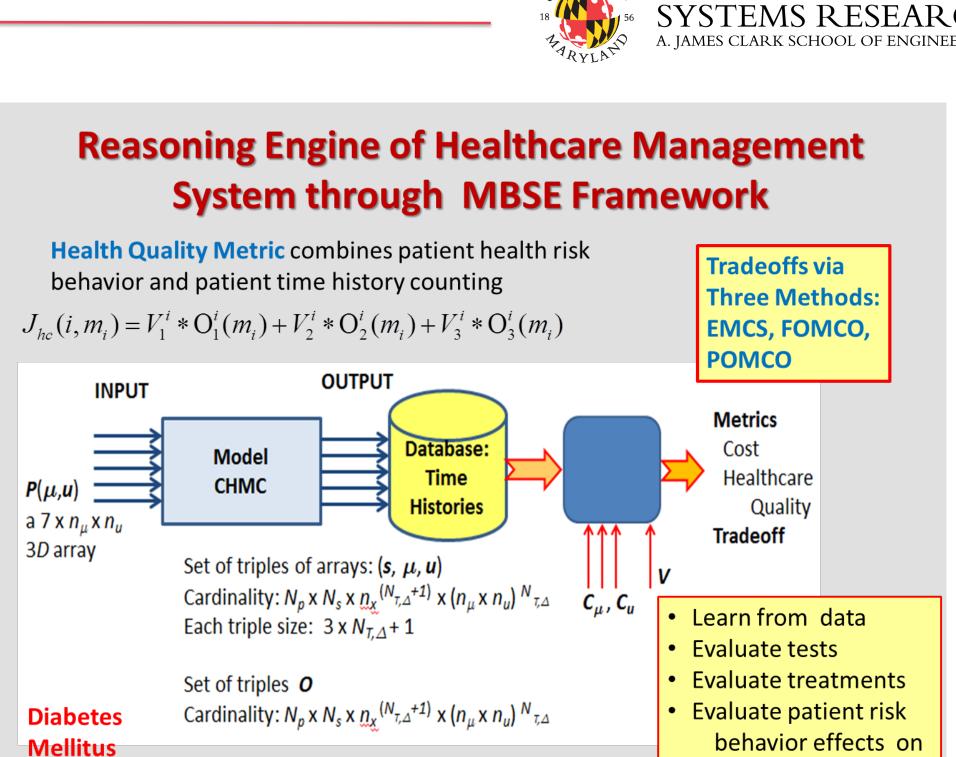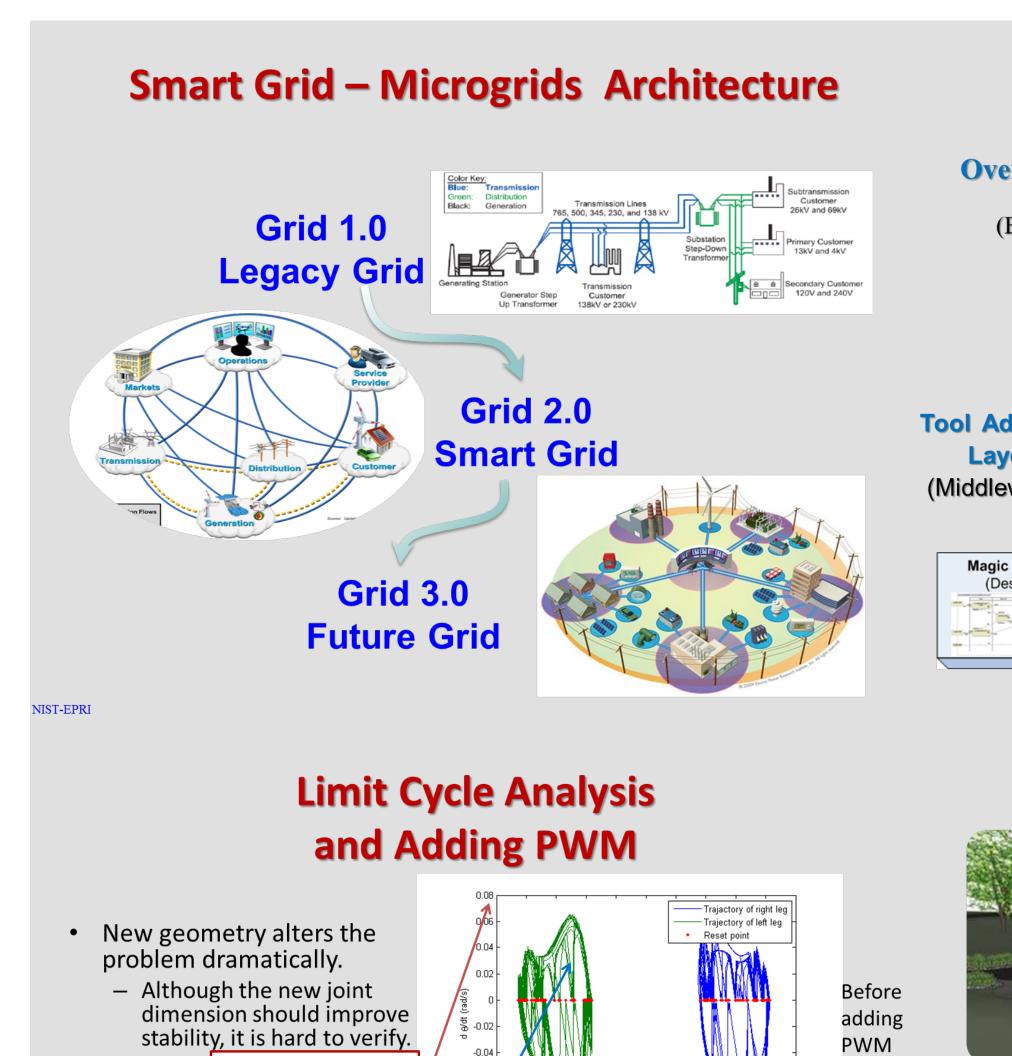
30 THIRTY YEARS OF SYSTEMS RESEARCH EXCELLENCE

INSTITUTE FOR SYSTEMS RESEARCH — A. James Clark School of Engineering

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Component Based Networking: Network MBSE for MANET

J. Baras UMD), V. Tabatabaee (Broadcom), K. Somasundaram (Qualcomm) and M. Austin (UMD)

The Challenge & Need: Design DoD and Commercial MANET Adaptive to Dynamic Mission Requirements

Fig.2: Component Based Networking Component-Based Network Synthesis

Each Block has Components

BENEFITS
- Reduced MANET cost and fielding time
- Modularity and re-use
- Increased agility in designing, modifying and fielding new MANET
- Broad design space exploration

Dynamic Interconnection and Interoperability
- Broadband wireless nets capable for multiple dynamic interface points
- Any node can serve as interface/gateway

Fixed or hybrid broadband

Fig.1: Intelligent Wireless Multi-Nets

Fig. 3: Network MBSE Toolset : integrating **SysML** Architecture Model with DB of network models, emulation-simulation models, tradeoff tools

MODEL BASED SYSTEMS ENGINEERING

Integrated System Synthesis Tools & Environments missing

Iterate to Find a Feasible Solution / Change as needed

Change structure/behavior model as needed

Define Requirements Effectiveness Measures

Assess Available Information

Create Behavior Model

Create Structure Model

Map behavior onto structure Allocate Requirements

Generate derivative requirements metrics

Specifications Perform TradeOff Analysis

Create Sequential build & Test Plan

Model - Based Information – Centric Abstractions

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

Integrated Multiple Views is Hard !

Apply this to: Design, Manufacturing, Operations and Management TO THE WHOLE LIFE-CYCLE

Rigorous Framework for Requirements Engineering

- **How to represent requirements?**
  - Automata, Timed-Automata, Timed Petri-Nets
  - Dependence-Influence graphs for traceability
  - Set-valued systems, reachability, … for the continuous parts
  - Constraint – rule consistency across resolution levels
- **How to automatically allocate requirements to components?**
- **How to automatically check requirements?**
  - **Approach:** Integrate contract-based design, model-checking, automatic theorem proving
- **How to integrate automatic and experimental verification?**
- **How to do V&V at various granularities** and progressively as the design proceeds – not at the end?
- **The front-end challenge**: Make it easy to the broad engineering user?

Reasoning Engine of Healthcare Management System through MBSE Framework

Health Quality Metric combines patient health risk behavior and patient time history counting

$$J_{hc}(i, m_i) = V_1^i * O_1^i(m_i) + V_2^i * O_2^i(m_i) + V_3^i * O_3^i(m_i)$$

Tradeoffs via Three Methods: EMCS, FOMCO, POMCO

INPUT / OUTPUT

$P(\mu, u)$ a 7 x n_μ x n_u 3D array

Model CHMC → Database: Time Histories

Set of triples of arrays: (s, μ, u)
Cardinality: N_p x N_s x $n_\mu (N_{\tau,\Delta}+1)$ x $(n_\mu$ x $n_u) N_{\tau,\Delta}$
Each triple size: 3 x $N_{\tau,\Delta} + 1$

Set of triples O
Cardinality: N_p x N_s x $n_\mu (N_{\tau,\Delta}+1)$ x $(n_\mu$ x $n_u) N_{\tau,\Delta}$

Diabetes Mellitus

C_μ, C_u V

Metrics
Cost
Healthcare Quality
Tradeoff

- Learn from data
- Evaluate tests
- Evaluate treatments
- Evaluate patient risk behavior effects on treatment

Smart Grid – Microgrids Architecture

Grid 1.0 Legacy Grid

Grid 2.0 Smart Grid

Grid 3.0 Future Grid

NIST-EPRI

MBSE for Microgrids --SysML and Consol-Optcad Integration

Overview

Meta-modeling Layer
(Enterprise Architect + eMoflon, Eclipse development environment)

Integration Framework

Tool Adapter Layer (Middleware)

Magic Draw (Design)

Consol Optcad (Trade studies)

Tool Layer
(Magic Draw, Consol Optcad)

MBSE for Sensor Networks

System Specifications
WSNs Model Libraries (SysML)
Environment Models (Simulink/Modelica)
Control System Models (Simulink/ Modelica)

Simulink to SysML Transformation

Model Integration (BDD/ IBD/Parametric Diagrams) <<SimulinkBlock>>

<<StructuredSimulink Block>>

SFunction/Simulink Model Generation

C/C++ Codes Generation
C/C++ Source Codes

SFunction and Simulink Model

Panel Diagrams

Matlab/Simulink Simulations

Optimization Tools or Parametric Diagram Solvers

Interative Simulations
Statecharts Animations

Bridges
Snowpack
Soil liquefaction
Smart buildings
Traffic
Vineyards

Application to Microrobotics

- Micro-robots design and manufacturing require control algorithm and physical layer (material and geometry) co-design.
- This insect-like robot is modeled in Modelica language using Differential Algebraic Equation.
- We are working on a Model-Based Systems Engineering approach to perform analysis, modeling and tradeoff for robotics and its material and control parameters.

Siemens Tools Utilization
- Design and analysis CAD model at the design phase
- Guide requirement to implementation from CAD design to physical simulation

CAD design and process management
<<Modelling Hub>> SysML
Siemens TeamCenter & NX
Refine Model
Trade Off
Code Generation & Synchronization
Model linking
Modelica Model
<<FEA>> Comsol
Co-simulation

Limit Cycle Analysis and Adding PWM

- New geometry alters the problem dramatically.
  - Although the new joint dimension should improve stability, it is hard to verify.
  - However, Note decreases in limit cycle size in derivative direction used, t high tension between joints, unless motor output is increased dramatically. So no comparison is given here.
  - By ch Note changes in reset points of limit find th cycles helpful jumping behavior.

Before adding PWM

After adding PWM

MBSE for Energy Efficient Buildings

Simulation Results

Tradeoff analysis and Design Space Exploration via Multi-objective optimization

A Rigorous Framework for Model-based Systems Engineering

The Challenge & Need: Develop scalable holistic methods, models and tools for enterprise level system engineering

Multi-domain Model Integration via System Architecture Model (SysML)

System Modeling Transformations

BENEFITS
- Broader Exploration of the design space
- Modularity, re-use
- Increased flexibility, adaptability, agility
- Engineering tools allowing conceptual design, leading to full product models and easy modifications
- Automated validation/verification

APPLICATIONS
- Avionics
- Automotive
- Robotics
- Smart Buildings
- Power Grid
- Health care
- Telecom and WSN
- Smart PDAs
- Smart Manufacturing

Update System Model
(ILOG SOLVER, CPLEX, CONSOL-OPTCAD)

"Master System Model"
Tradeoff parameters
ADD & INTEGRATE
- Multiple domain modeling tools
- Tradeoff Tools (MCO & CP)
- Validation / Verification Tools
- Databases and Libraries of annotated component models from all disciplines

DB of system components and models

A Bold Experiment

Starting early in the education chain

Undergraduates working with industry and government mentors on Systems Engineering projects

NEW FOR FALL 2010
ENES 489P
SPECIAL TOPICS IN ENGINEERING
HANDS-ON SYSTEMS ENGINEERING PROJECTS

Capstone Course

- Systems Thinking up front
- Groups of 3-5 students on projects hands-on
- Industry as customers, co-workers, judges
- Learn concepts, methods, tools on the "job"
- 7/24 open SEIL lab

"The Nation that has the System Engineers has the Future"
J. S. Baras, *Systems and Signals*, Vol. 4.2, May 1990

SEIL Systems Engineering & Integration Laboratory

ARC Lab