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v1.1

Overview of Systems Engineering Research at Georgia Tech

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Georgia Institute of Technology

SYSTEMS ENGINEERING Research Center

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- Introduction
- Selected SE-related efforts
  - Professional Masters in SE (PMASE)
    Bishop, et al.
  - Tennenbaum Institute (TI)
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- Summary

Georgia Tech Fun Facts

Georgia Institute of Technology

1885

Founded
in
Atlanta

Faculty

5 Professors

5 Shop Supervisors

Students

129 undergrads in Mechanical Engineering

1903

First full-time football coach

John Heisman

1948

Renamed *Georgia Institute of Technology*

1996

Served as Olympic Village for 10,000+ athletes/staff

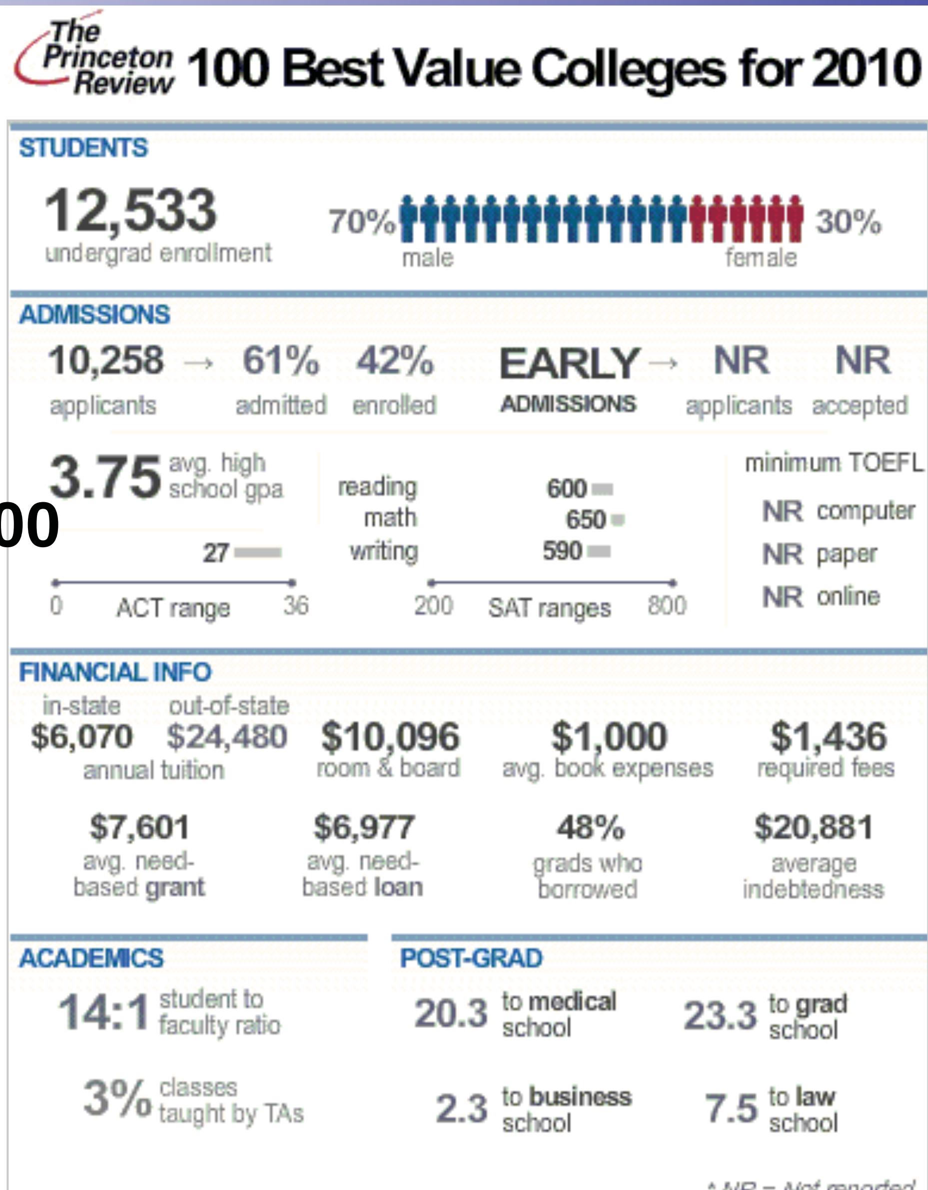
Mascots

Georgia Institute of Technology

Georgia Tech Statistics

Students
- undergrad: ~12,000
- grad: ~8,000
total: ~20,000

engineering: ~11,000



http://www.usatoday.com/news/education/best-value-colleges.htm

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Professional Masters in Applied Systems Engineering

www.pmase.gatech.edu

The degree program:

- **Targeted to working professionals (5+ years experience)**
- **Convenient format combining distance learning and onsite interactions**
- **An applied degree taught from an enterprise view**
- **Relevant tools for solving real world problems**

The PMASE Curriculum

Core Curriculum

ASE 6001: Fund in Modern SE

ASE 6002: Sys Design & Analysis

ASE 6003: M&S for SE

ASE 6004: Leading SE Teams

ASE 60X5: Advanced Topics in SE
- SysML
- HSI

ASE 6006: SE Lab

SE Processes & Techniques

Integrated SE Mgt

SE Tools, Standards, Languages

Domain Specific Engineering

Complex Systems

Complex Systems Curriculum

ASE 61X1: Domain Elective in Synthesis & Analysis
- Vehicles
- Sensors
- Info Systems
- HSI

ASE 6102: SOS & Architectures

ASE 6103: Lifecycle & Integration

ASE 6104: Complex Systems Capstone

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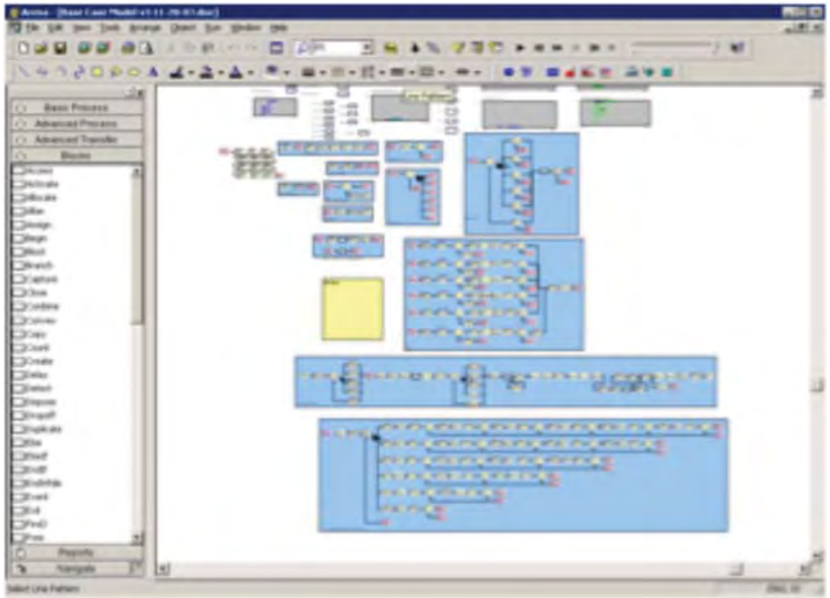
See also our work in RT16 and RT25 →

Tennenbaum Institute

- Interdisciplinary research
- Understand and enable fundamental change of private and public sector enterprises
- Defense acquisition
- Services
- Energy
- Enterprise integration
- Global manufacturing
- Health care

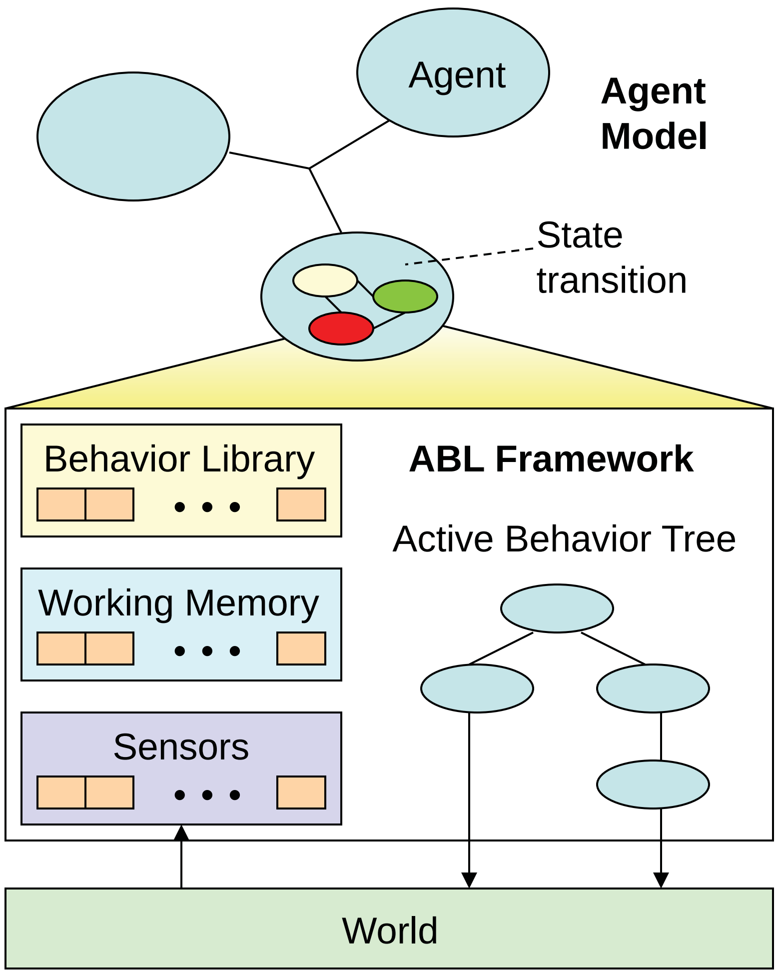
Defense Acquisition



Weapons systems progress through the acquisition lifecycle, including sustainment. The impacts on cost, schedule performance and risk are compiled.

- Goal – investigate relationships between evolutionary acquisition, system modularity and production level
- Findings
  - Evolutionary acquisition tends to reduce program costs but increase enterprise costs
  - Modularity tends to increase development cost and decrease sustainment cost
  - High modularity tends to lower overall acquisition cost and mitigates the overall cost associated with high production
- Sponsor – Navy/NPS

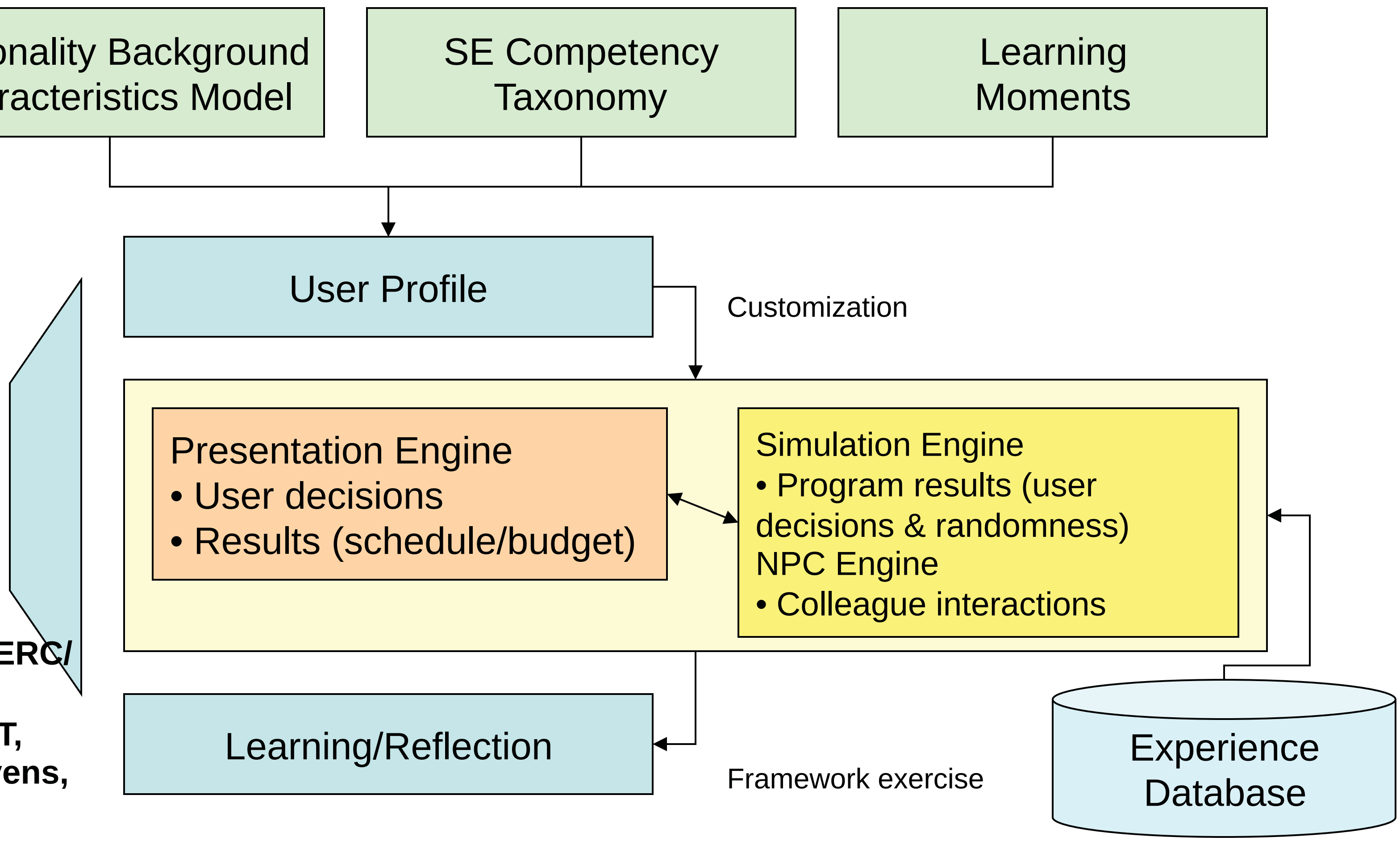
Defense Acquisition and Organizational Simulation



- Goal – represent organizational phenomena in simulation models (agent-based, discrete-event, system dynamics)
- Incorporate interactive computing concepts (character programming and drama management)
- Application to Predator acquisition:
  - Multi-actor decisions
  - Lead service selection
  - Military utility determination
- Sponsor – Air Force

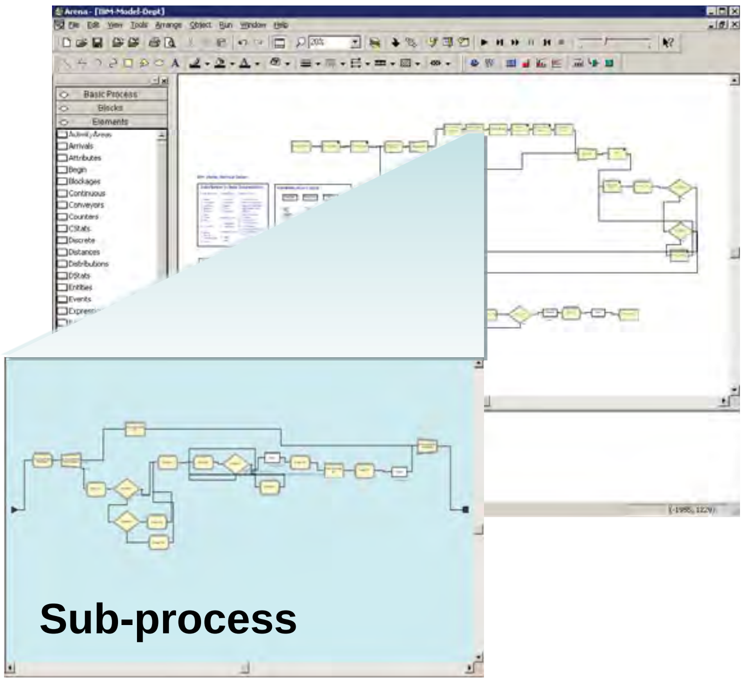
Defense Acquisition and Systems Engineering (RT-16)

Georgia Tech Tennenbaum Institute



Sponsor – SERC/ DAU
Partners – GT, Purdue, Stevens, USC

Services

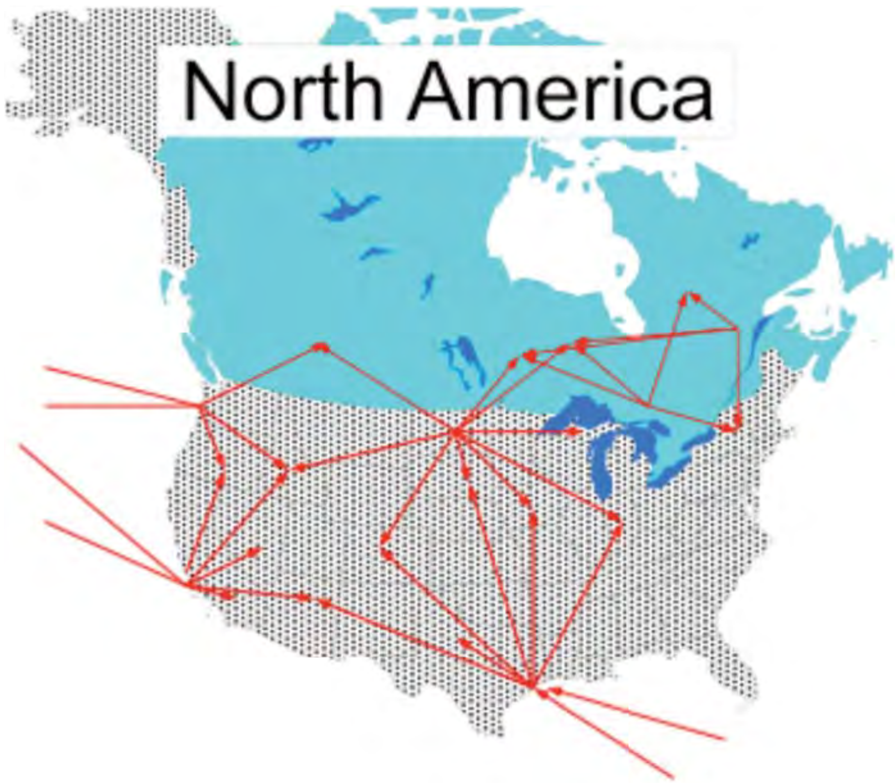


Requirements and designs are represented as information artifacts that evolve and change as they traverse processes

- Services constitute a majority of GDP
- Engineering design as a service – computer servers
- Time to market is key
- GT modeled and simulated computer server design processes
- Organizational designs and skill level mixes have a major impact on service effectiveness
- Sponsor – IBM

Energy

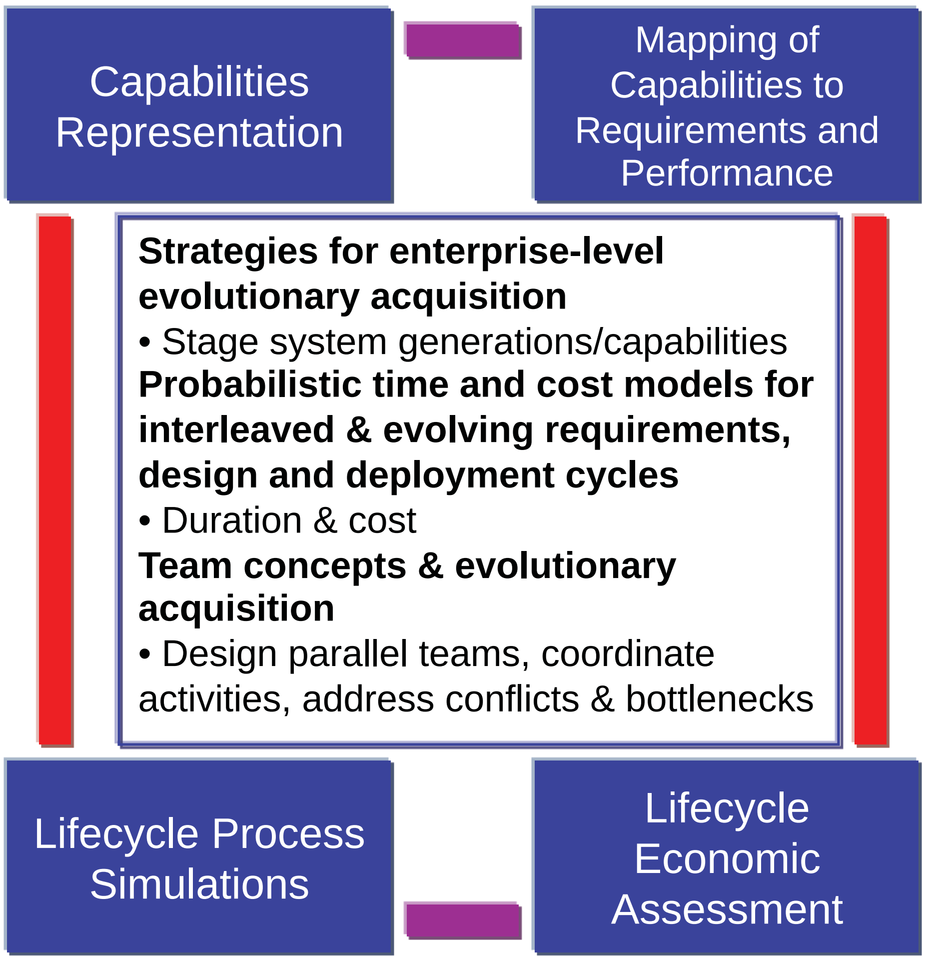
Georgia Tech Tennenbaum Institute



- Wind energy systems integrators face major cost issues in transport of components
- Multiples of $100M annually
- GT developed an optimization tool for sourcing and transport of components
- Spreadsheet-based with trade-offs between usability and speed
- 10-15% cost reduction on sample runs vs. manual approach
- Sponsor – GE Energy

Enterprise IT Integration (RT-25)

Georgia Tech Tennenbaum Institute



- Enterprises face new challenges, requiring new capabilities
- This involves integration of new capabilities
- How are these translated in a disciplined manner to IT requirements
- This occurs in an evolutionary environment
- Need for tools
  - Represent capabilities and requirements
  - Facilitate experimentation and what-if analysis
- Sponsor – SERC
- Partners – GT and USC

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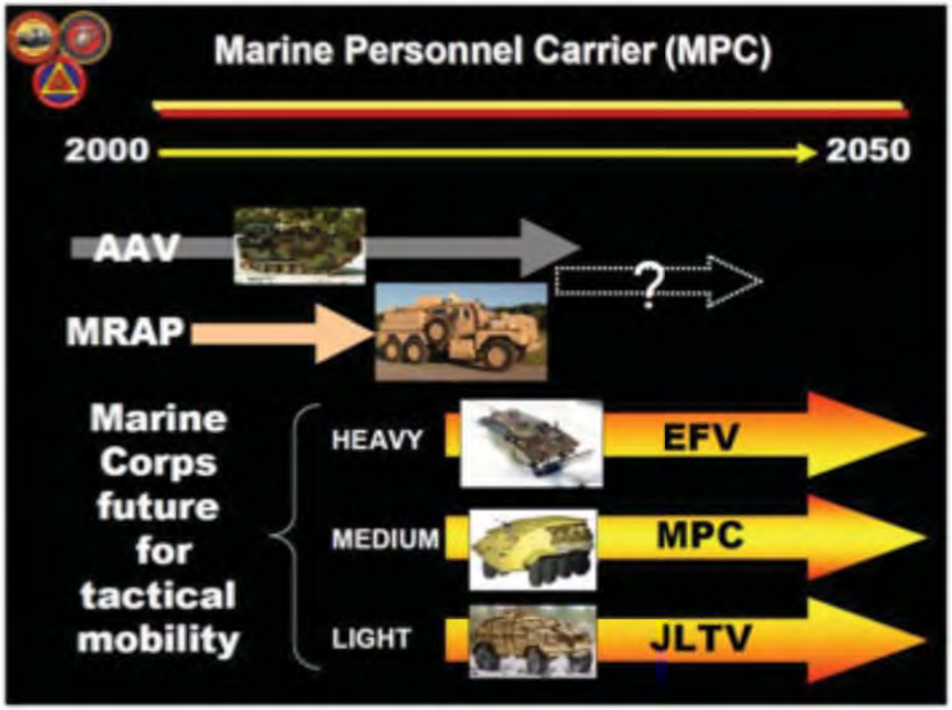
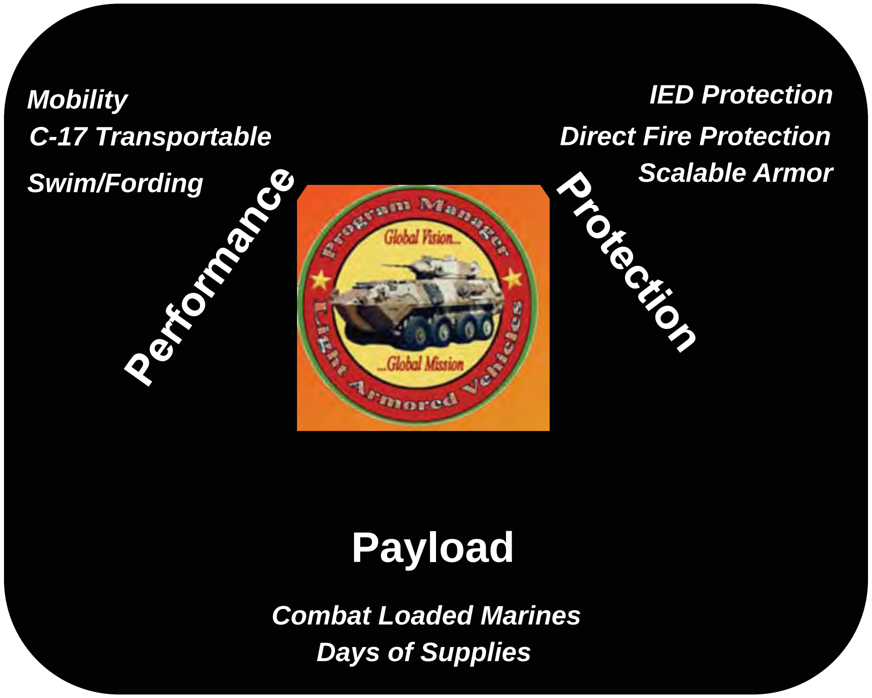
Collaborative Decision Making

Decision-makers afforded novel real-time, panoramic view of trade-offs and parametric sensitivities via advanced visualization features

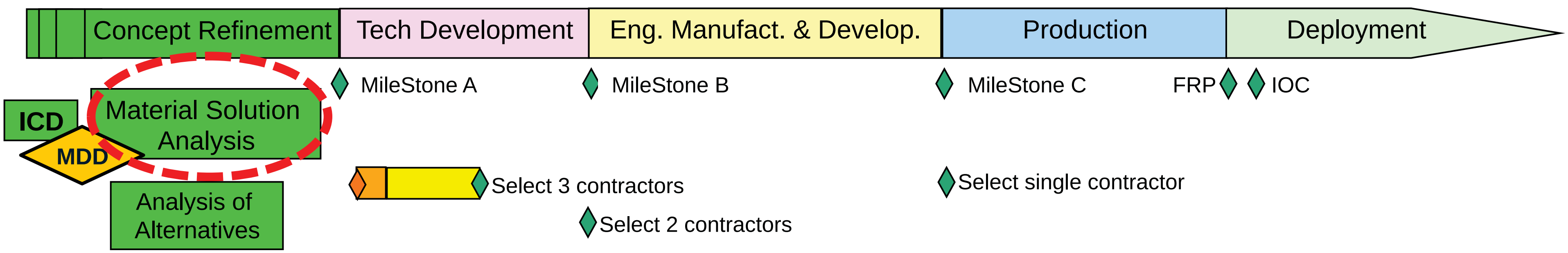
Research conducted on capability-focused and inverse design to identify solutions that meet dynamic requirements

Real-time collaboration and decision making in a secure environment to solve real-world problems





performance payload protection



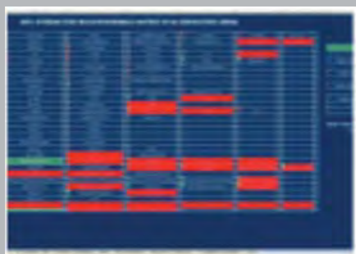
Requirements Definition
Current toolset used to analyze selected mobility requirements and associated costs

Source Selection
Current toolset may be used to assist source selection planning

Outcomes

- Better defined requirements with enabling performance
- Getting proposals that are closer to our goals, reducing risk to cost and schedule
- Guidance towards source selection

Sub-system Technology Selection Tool

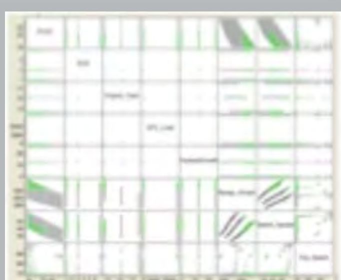


Compare and prioritize technology

Vehicle Performance Generation Tool (VPGT)

Generate valid design solutions

Statistical Data Analysis



Design space exploration

Vehicle Comparison Tool (VCT)

Compare valid design solutions

Output : Recommendations for a **balanced, achievable** requirements document for MPC

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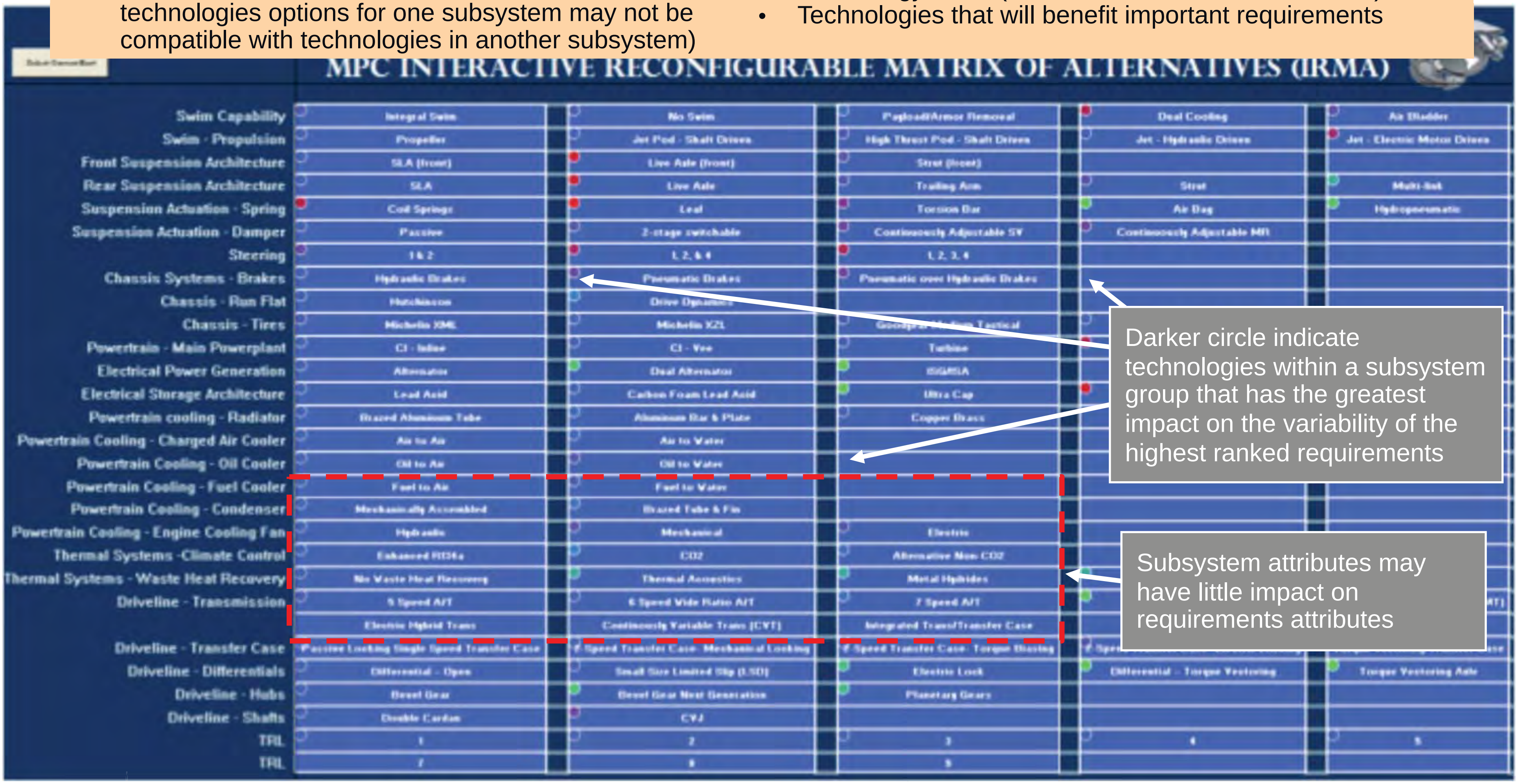
Navigate through the possible combinations through:

- A series of technology compatibilities (i.e. some technologies options for one subsystem may not be compatible with technologies in another subsystem)
- Technology filters (i.e. all must be at least a TRL = 8)
- Technologies that will benefit important requirements



Darker circle indicate technologies within a subsystem group that has the greatest impact on the variability of the highest ranked requirements

Subsystem attributes may have little impact on requirements attributes

Navigate through the possible combinations through:

- A series of technology compatibilities (i.e. some technologies options for one subsystem may not be compatible with technologies in another subsystem)
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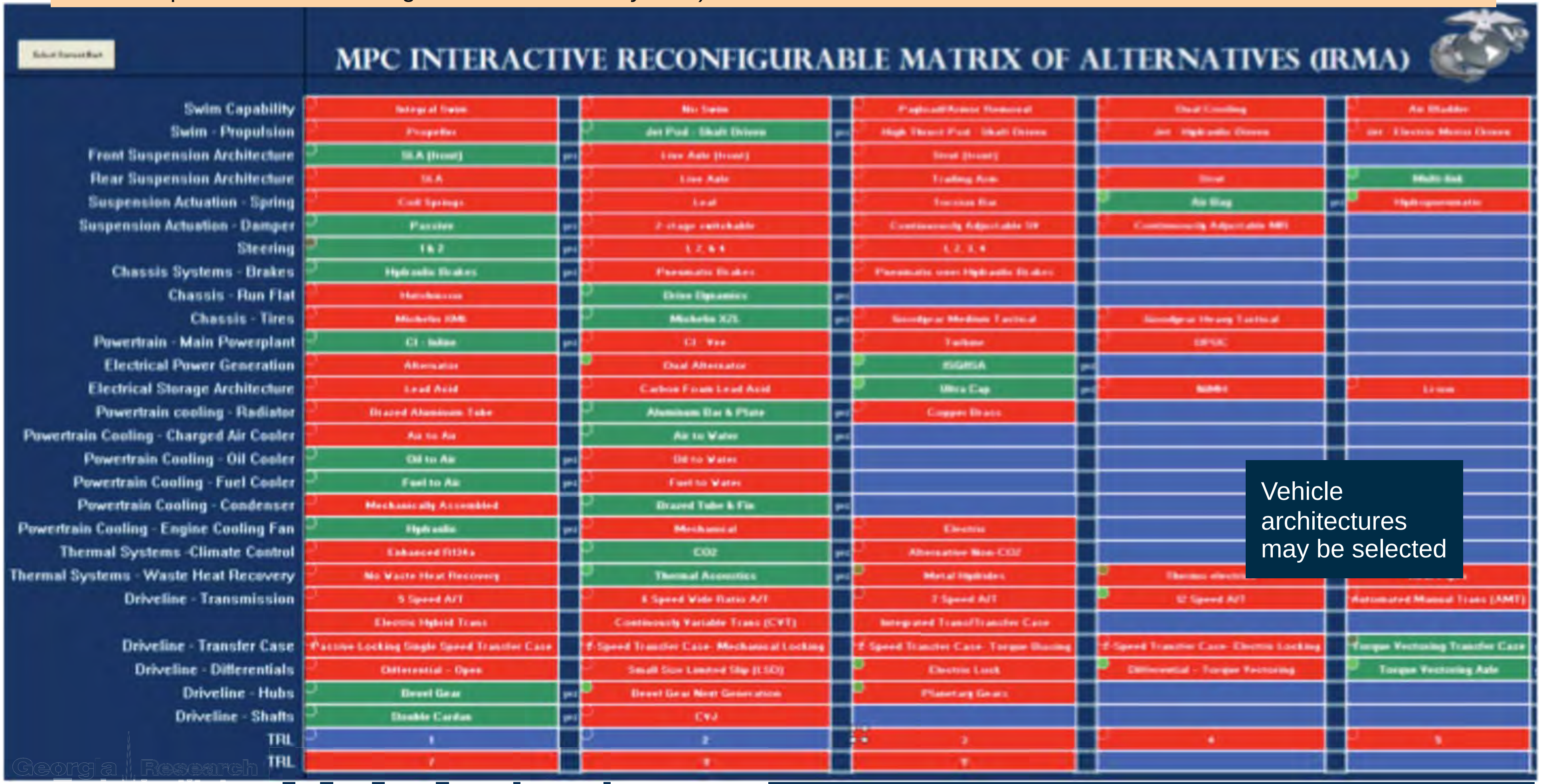
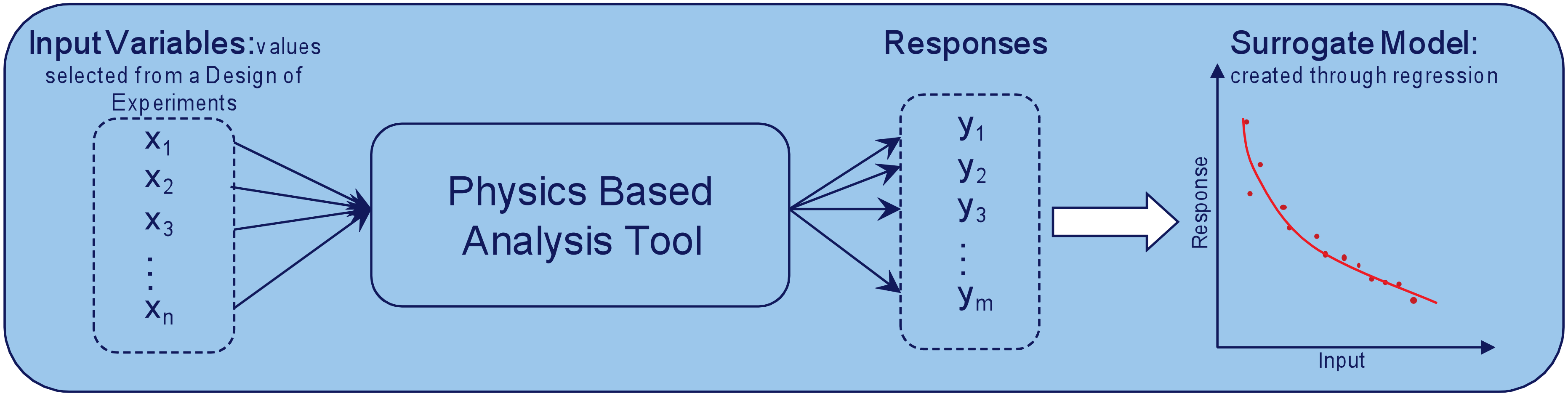
- Technologies that will benefit important requirements

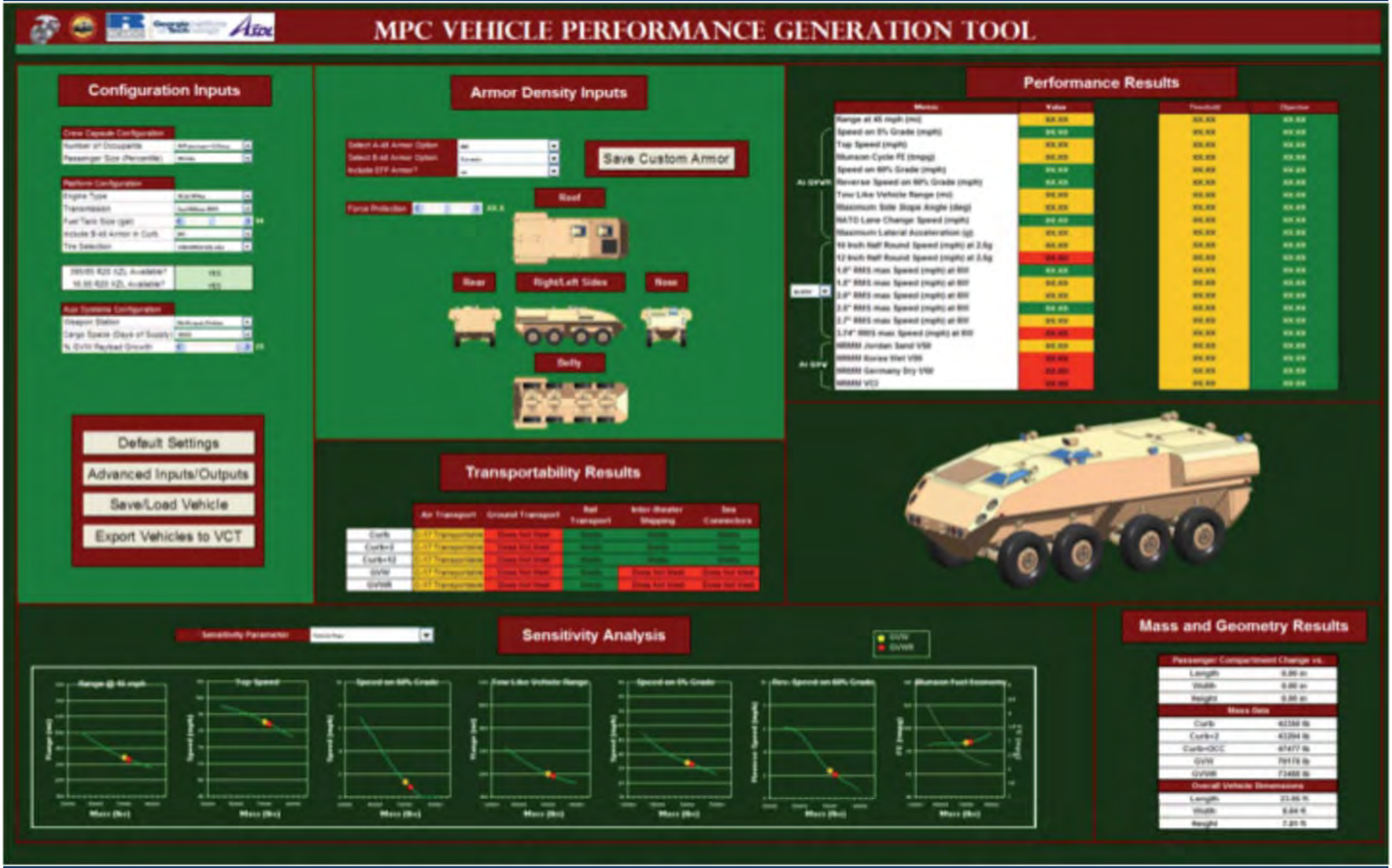


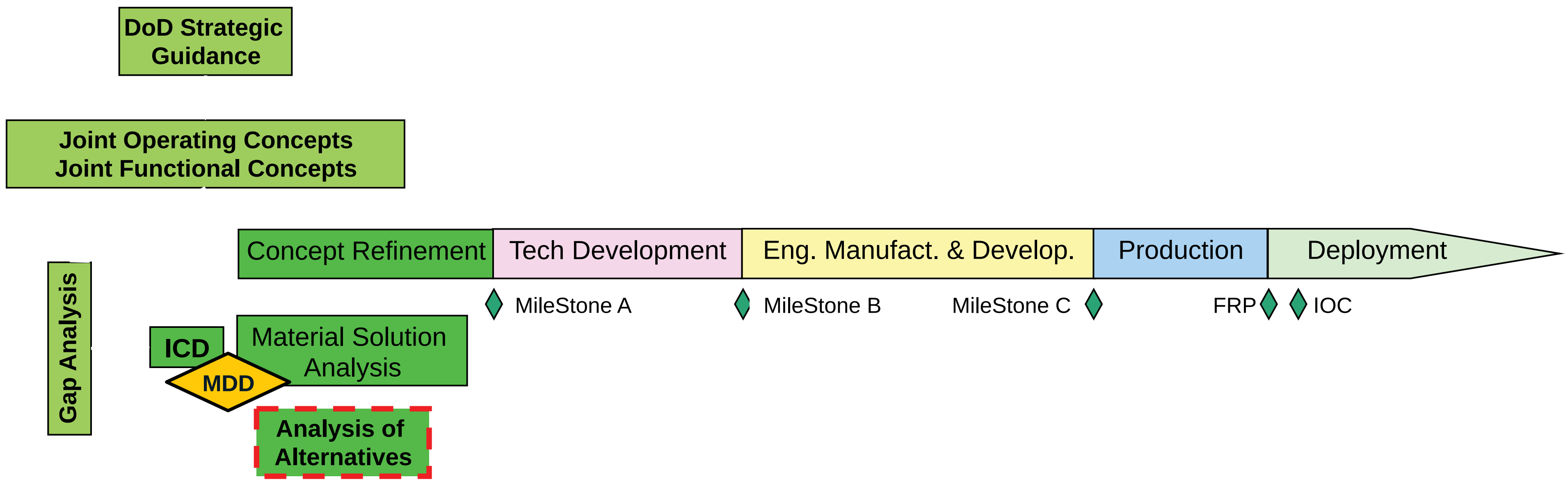
Vehicle architectures may be selected

Surrogate models

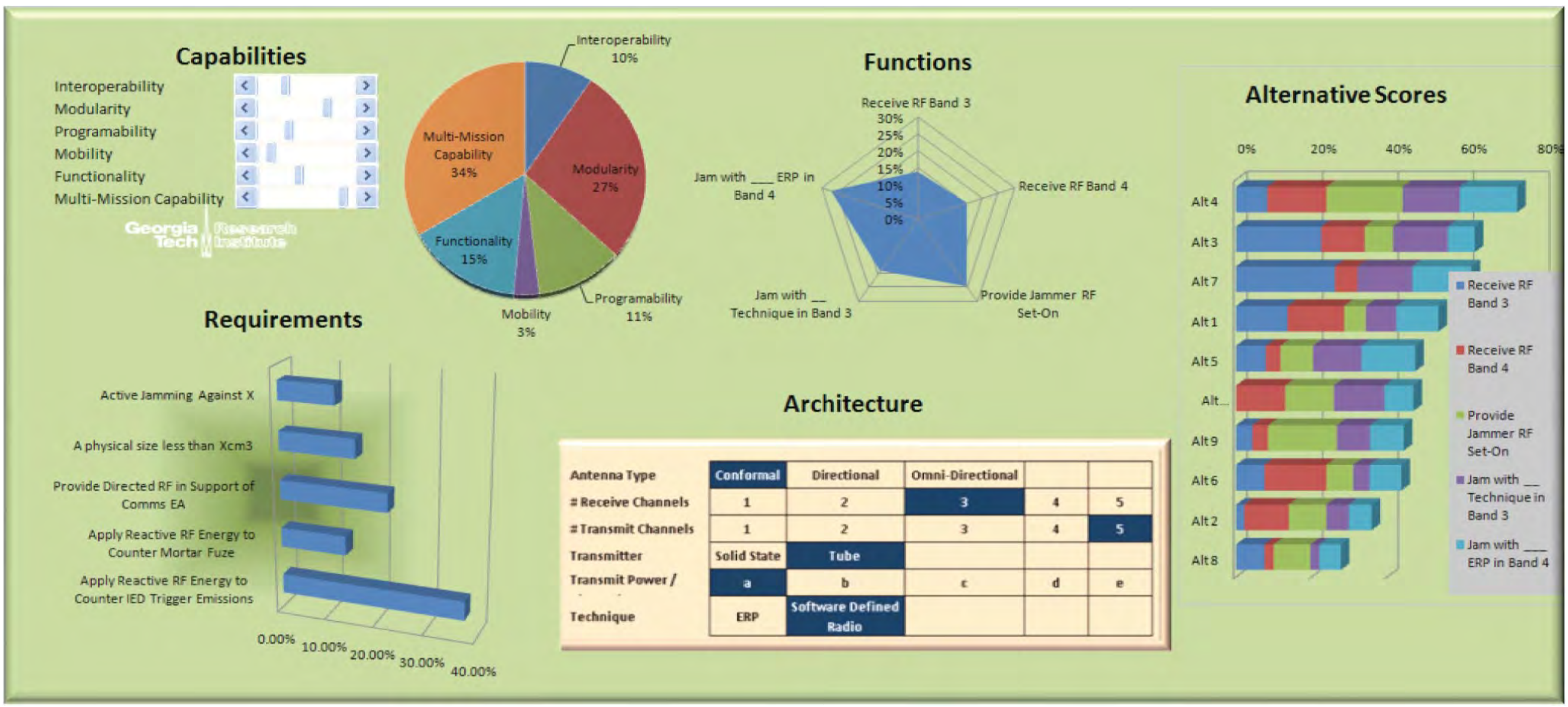


Bringing Modeling & Simulation Forward in the Decision Making Process


MPC VEHICLE PERFORMANCE GENERATION TOOL
Configuration Inputs
Armor Density Inputs
Performance Results
Save Custom Armor
Roof
Rear
Right/Left Sides
Nose
Belly
Default Settings
Advanced Inputs/Outputs
Save/Load Vehicle
Export Vehicles to VCT
Transportability Results
Sensitivity Analysis
Mass and Geometry Results



- **GTRI IEWS Program Support**
  - ✓ **IEWS Counter RC-IED Technology Discovery**
  - **Pre-AoA planning**
  - **Provide Subject Matter Expertise as necessary**


Capabilities
Interoperability
Modularity
Programability
Mobility
Functionality
Multi-Mission Capability
Georgia Tech Research Institute
Interoperability 10%
Multi-Mission Capability 34%
Modularity 27%
Functionality 15%
Mobility 3%
Programability 11%
Functions
Receive RF Band 3
30%
25%
20%
15%
10%
5%
0%
Receive RF Band 4
Provide Jammer RF Set-On
Jam with __ Technique in Band 3
Jam with ___ ERP in Band 4
Alternative Scores
0%
20%
40%
60%
Alt 4
Alt 3
Alt 7
Alt 1
Alt 5
Alt...
Alt 9
Alt 6
Alt 2
Alt 8
Receive RF Band 3
Receive RF Band 4
Provide Jammer RF Set-On
Jam with __ Technique in Band 3
Jam with ___ ERP in Band 4
Requirements
Active Jamming Against X
A physical size less than Xcm3
Provide Directed RF in Support of Comms EA
Apply Reactive RF Energy to Counter Mortar Fuze
Apply Reactive RF Energy to Counter IED Trigger Emissions
0.00%
10.00%
20.00%
30.00%
40.00%
Architecture
Antenna Type | Conformal | Directional | Omni-Directional
Receive Channels | 1 | 2 | 3 | 4 | 5
Transmit Channels | 1 | 2 | 3 | 4 | 5
Transmitter | Solid State | Tube
Transmit Power / | a | b | c | d | e
Technique | ERP | Software Defined Radio

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See also our work in RT21 and RT24 ➡

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SYSTEMS ENGINEERING Research Center

Model-Based Systems Engineering Using SysML

Excavator Testbed (2007-2009)

Abstract

This presentation highlights Phase 1 results from a modeling & simulation effort that integrates design and assessment using SysML. An excavator testbed illustrates interconnecting simulation models with associated diverse system models, design models, and manufacturing models. We then overview Phase 2 work-in-process including a mobile robotics testbed and associated SysML-driven operations demonstration.

The overall goal is to enable advanced model-based systems engineering (MBSE) in particular and model-based X (MBX) [1] in general. Our method employs SysML as the primary technology to achieve multi-level multi-fidelity interoperability, while at the same time leveraging conventional modeling & simulation tools including mechanical CAD, factory CAD, spreadsheets, math solvers, finite element analysis (FEA), discrete event solvers, and optimization tools.

This Part 1 presentation overviews the project context and several specific components. Part 2 focuses on manufacturing aspects including factory design, process planning, and throughput simulation.

This work is sponsored by several organizations including Lockheed and Deere and is part of the Modeling & Simulation Interoperability Team [2] in the INCOSE MBSE Challenge (with applications to mechatronics as an example domain).

[1] The X in MBX includes engineering (MBE), manufacturing (MBM), and potentially other scopes and contexts such as model-based enterprises (MBE).
[2] *http://www.pslm.gatech.edu/projects/incose-mbse-msi/*

Citations

- RS Peak, CJJ Paredis, LF McGinnis (2009-04) Model-Based SE Using SysML—Part 1: Integrating Design and Assessment M&S. NDIA M&S Committee Meeting, Arlington, Virginia.
- LF McGinnis (2009-04) Model-Based SE Using SysML—Part 2: Integrating Manufacturing Design and Simulation. NDIA M&S Committee Meeting, Arlington, Virginia.
- Main team web page: *http://www.pslm.gatech.edu/projects/incose-mbse-msi/*
- These publications: *http://eislab.gatech.edu/pubs/seminars-etc/2009-04-ndia-ms/*

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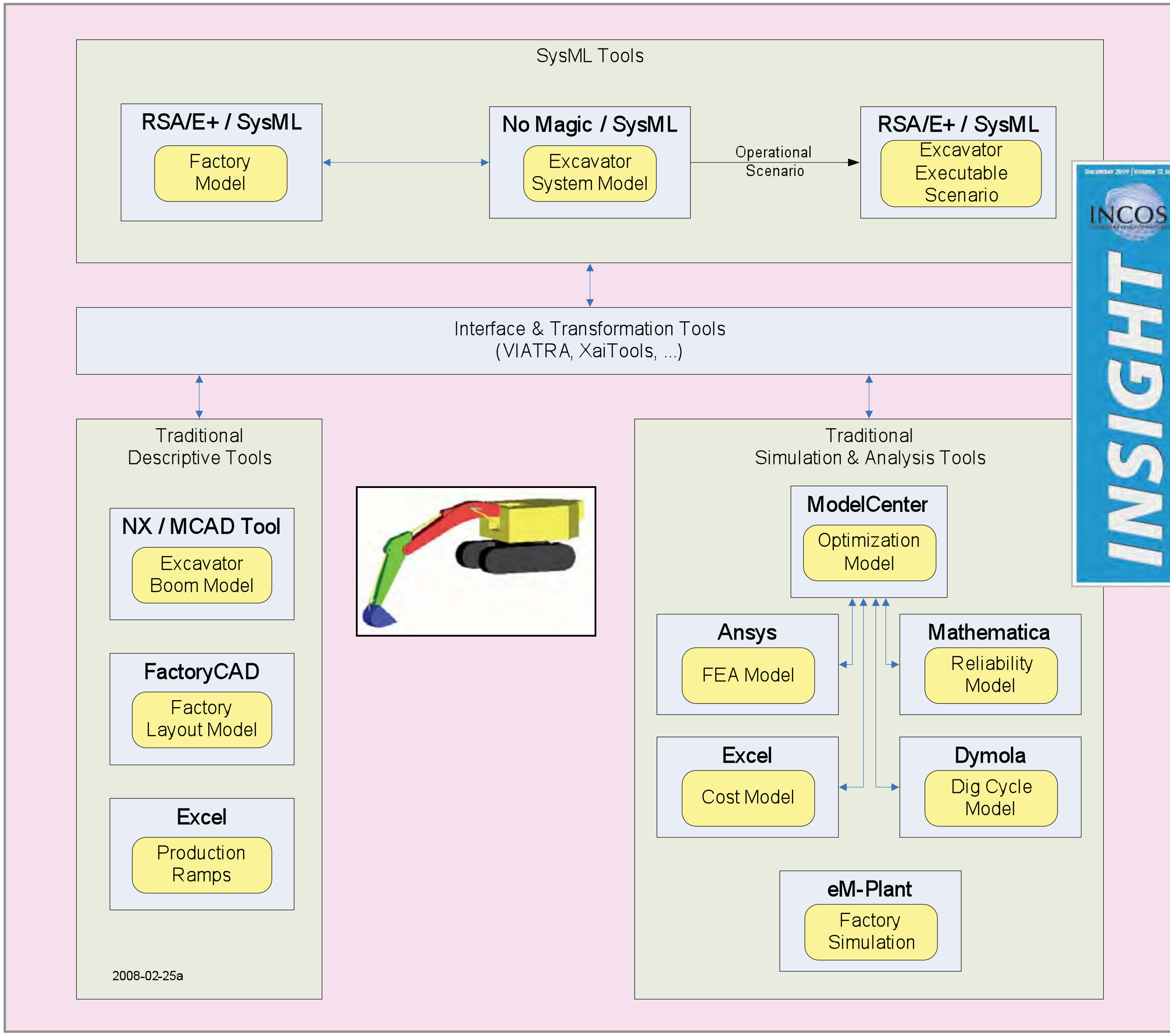
Excavator Modeling & Simulation Testbed

Tool Categories View

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INCOSE

INSIGHT

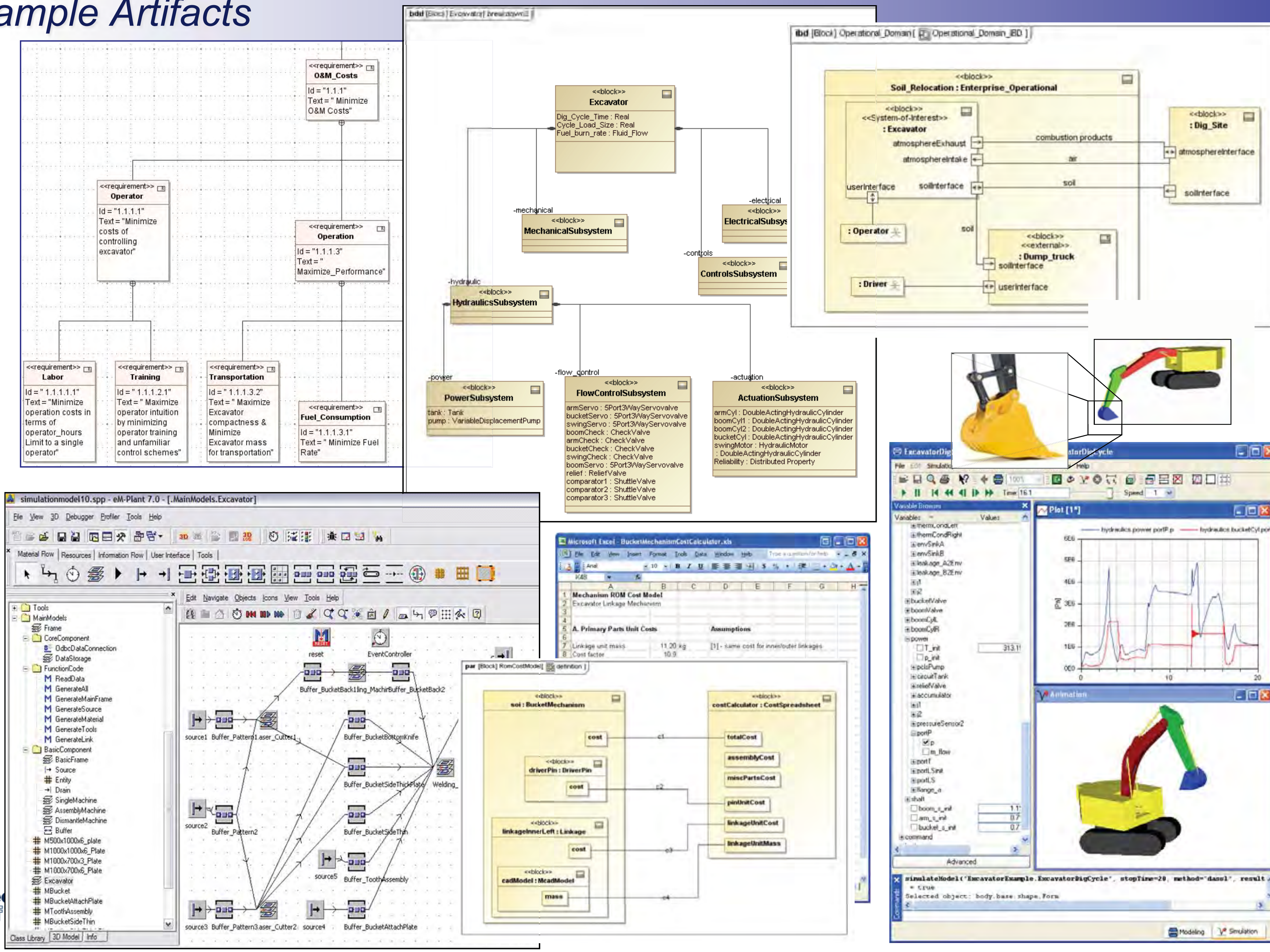
What's Inside

SPECIAL FEATURE

Model-Based Systems Engineering:
The New Paradigm

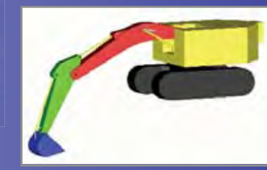
Excavator Modeling & Simulation Testbed

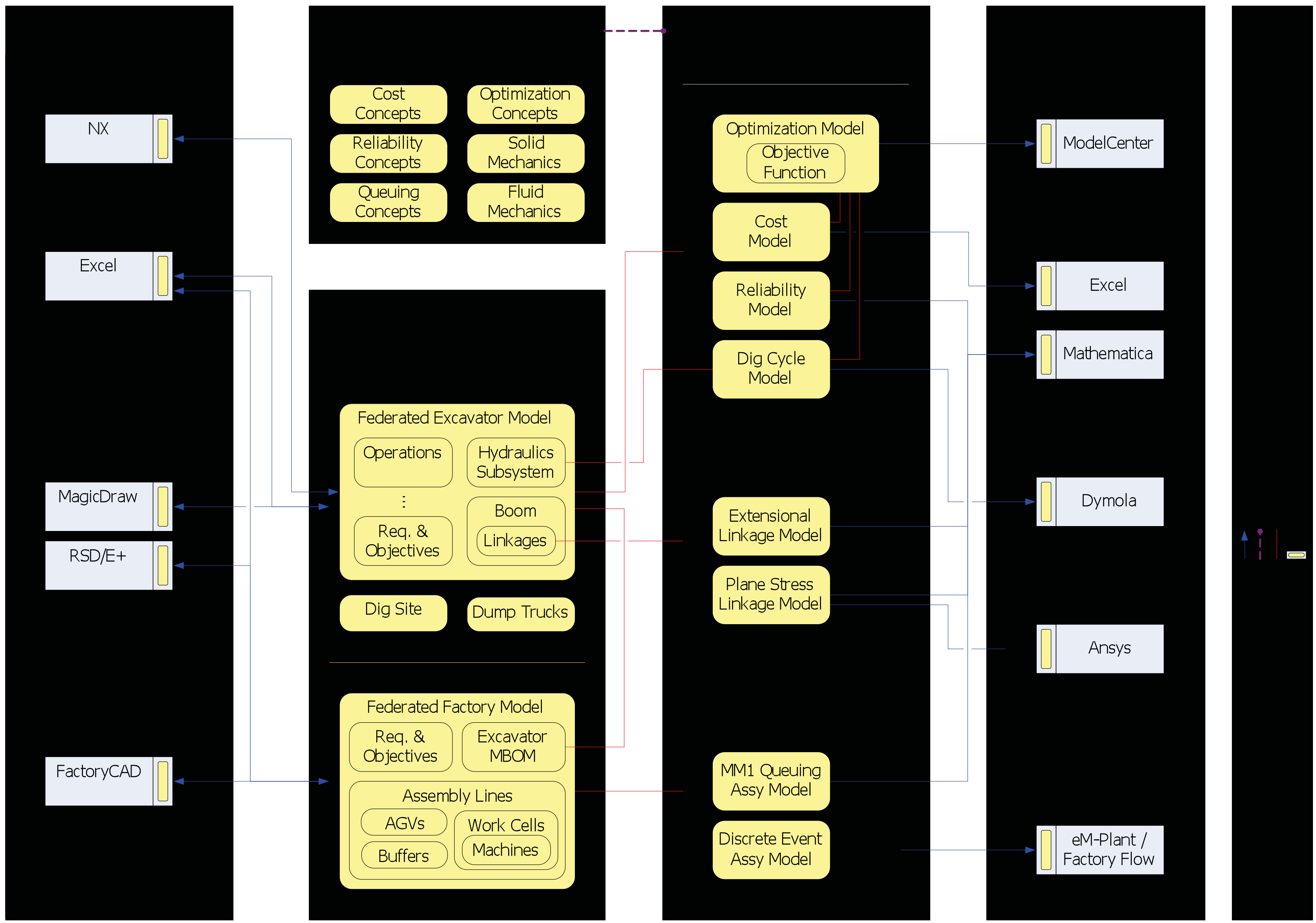
Sample Artifacts



Excavator Modeling & Simulation Testbed

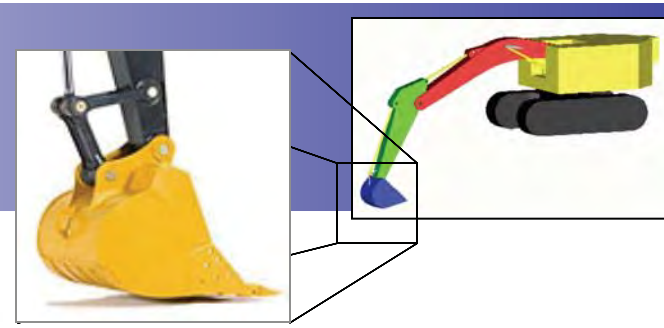
Interoperability Patterns View (MSI Panorama per MIM patterns)

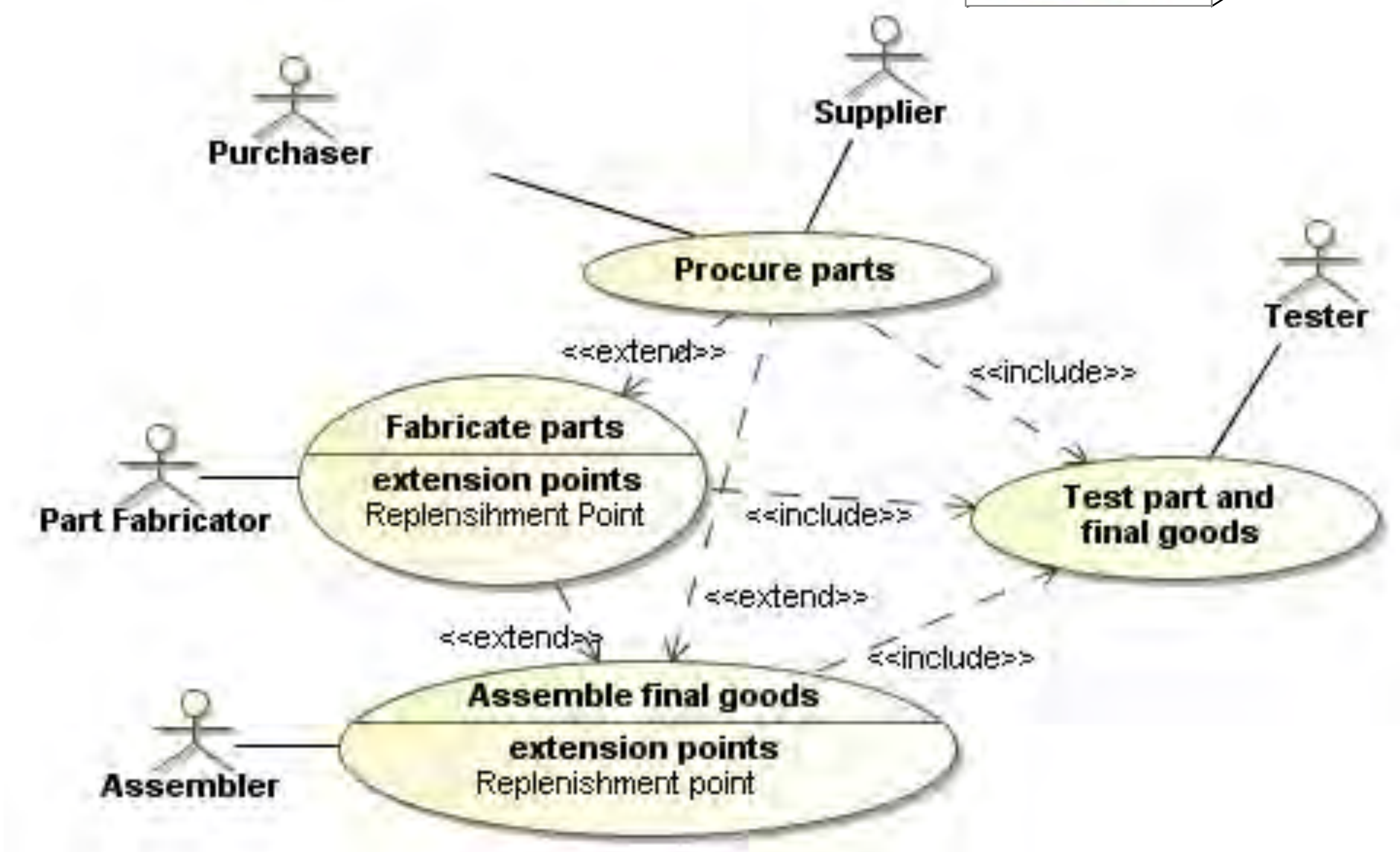




Manufacturing Use Cases

[McGinnis et al.]





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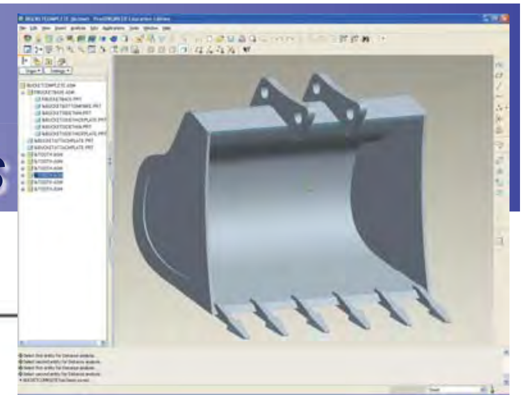
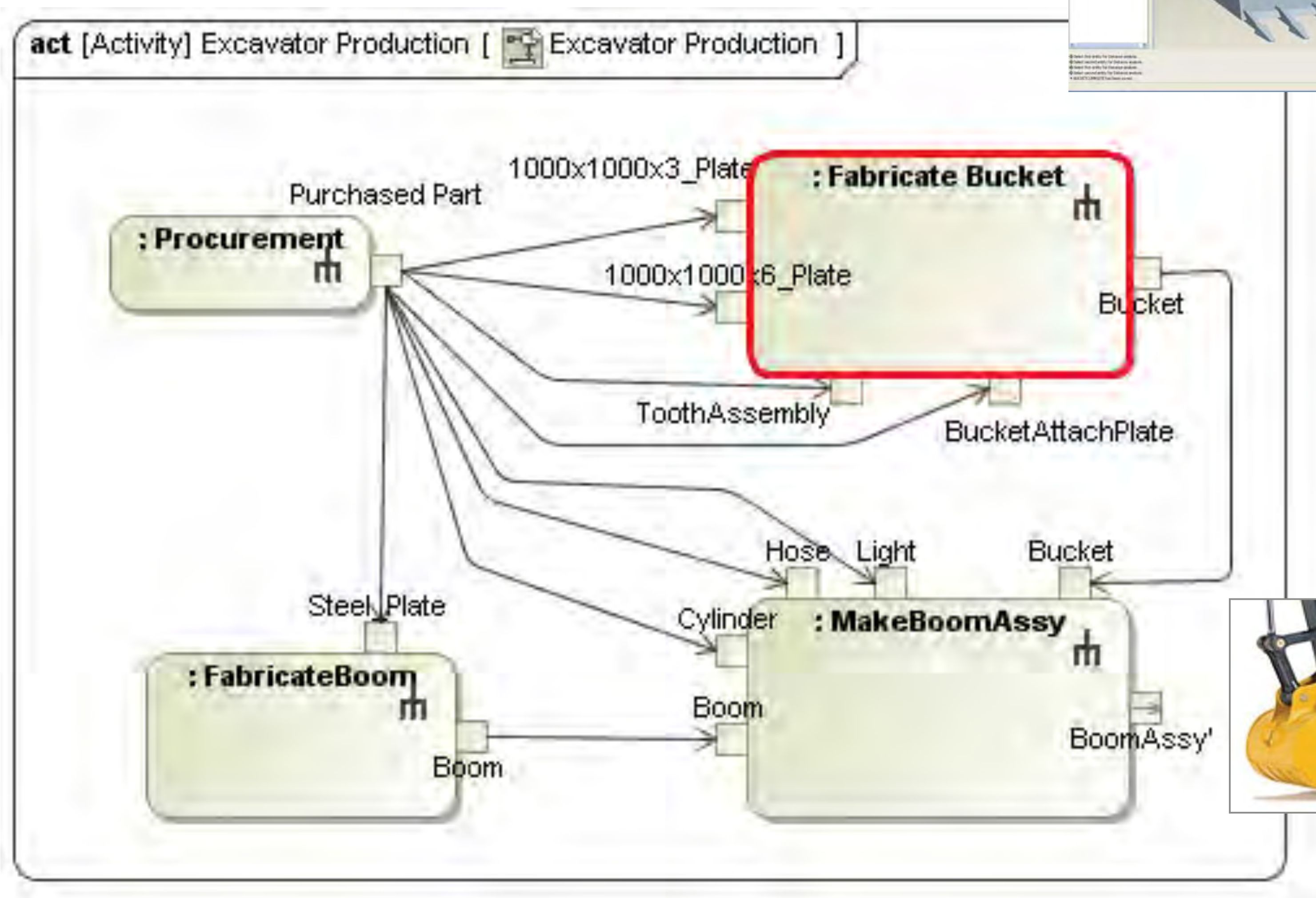
Process Planning Model

Functional modeling style using SysML activities

[McGinnis et al.]





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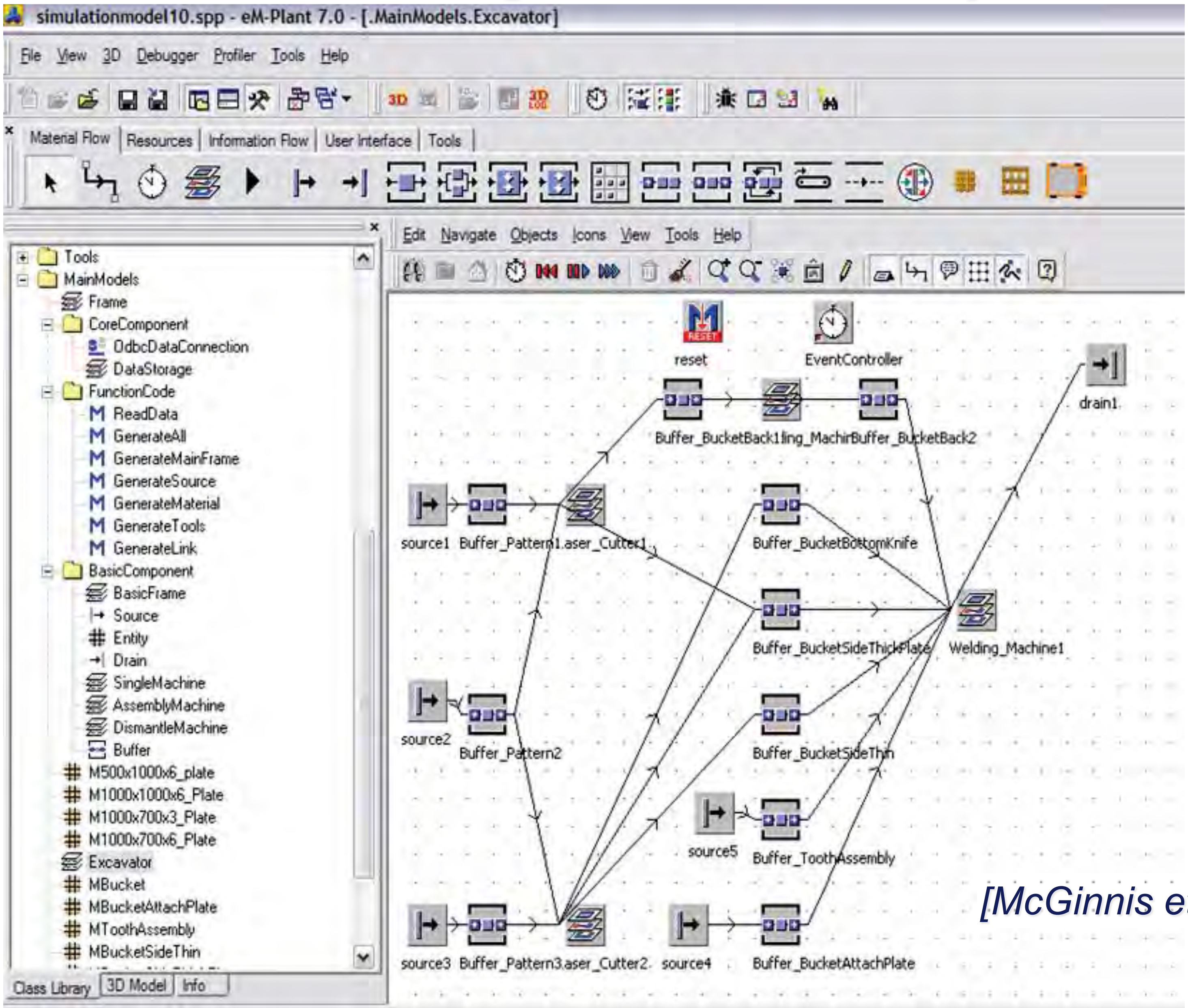
eM-Plant Simulation

Discrete event model auto-generated from SysML



[McGinnis et al.]

Exploration of System Architectures

CENTER FOR COMPACT AND EFFICIENT FLUID POWER

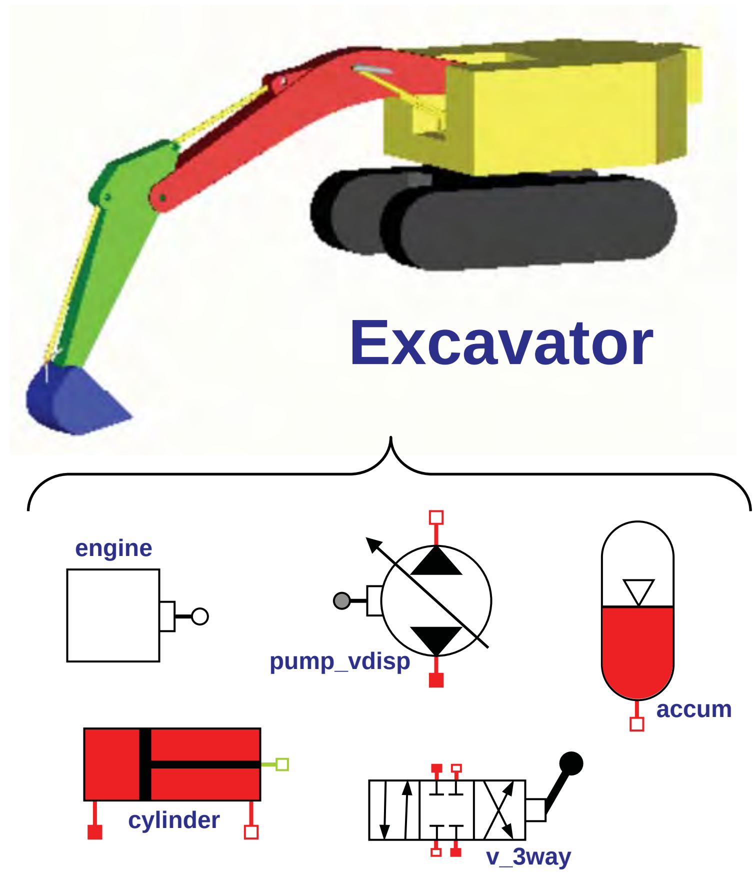
Problem Statement

Given:

- Component models
- Objectives / preferences

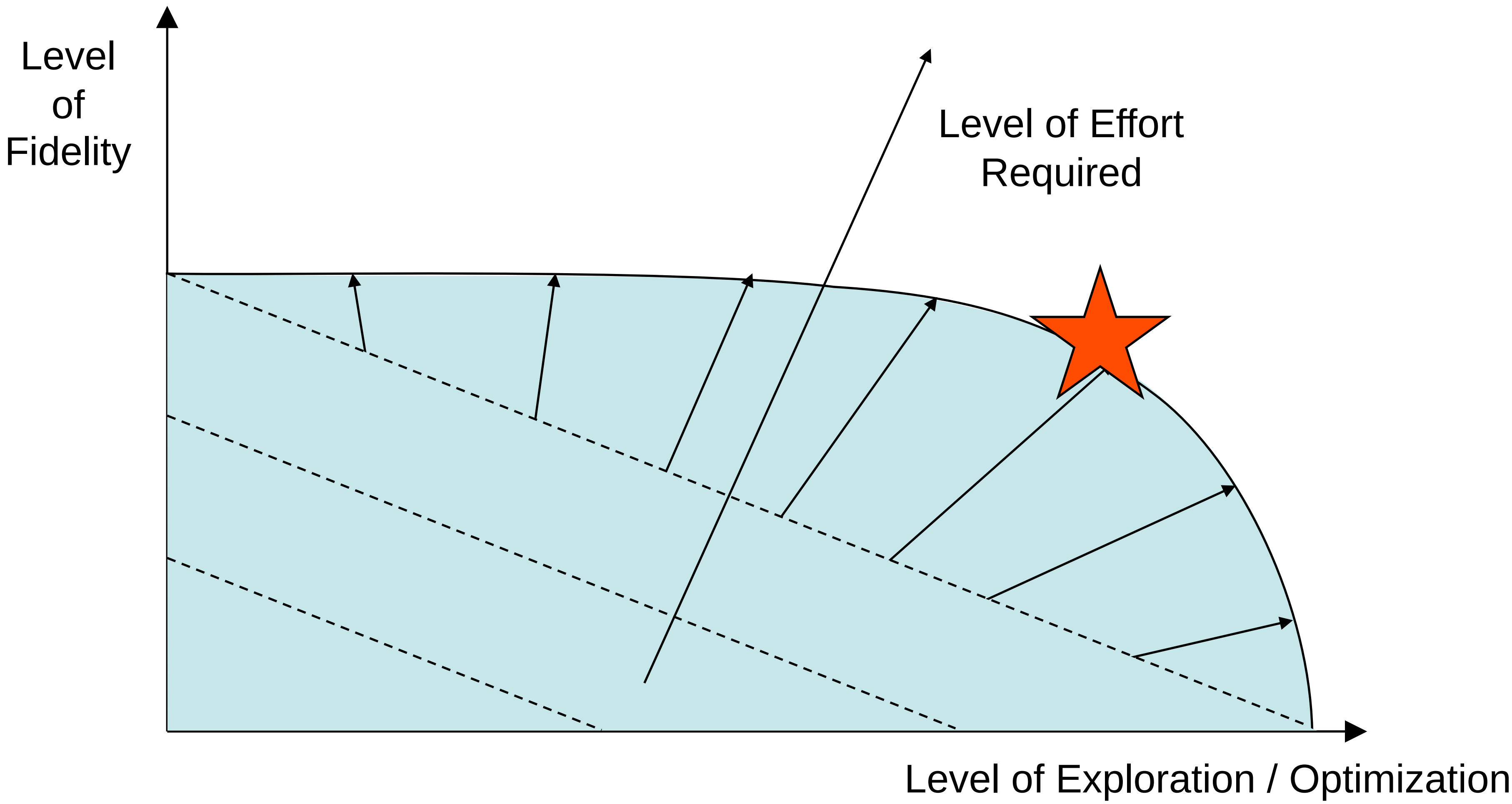
Find:

- Best system architecture
- Best component parameters
- Best controller

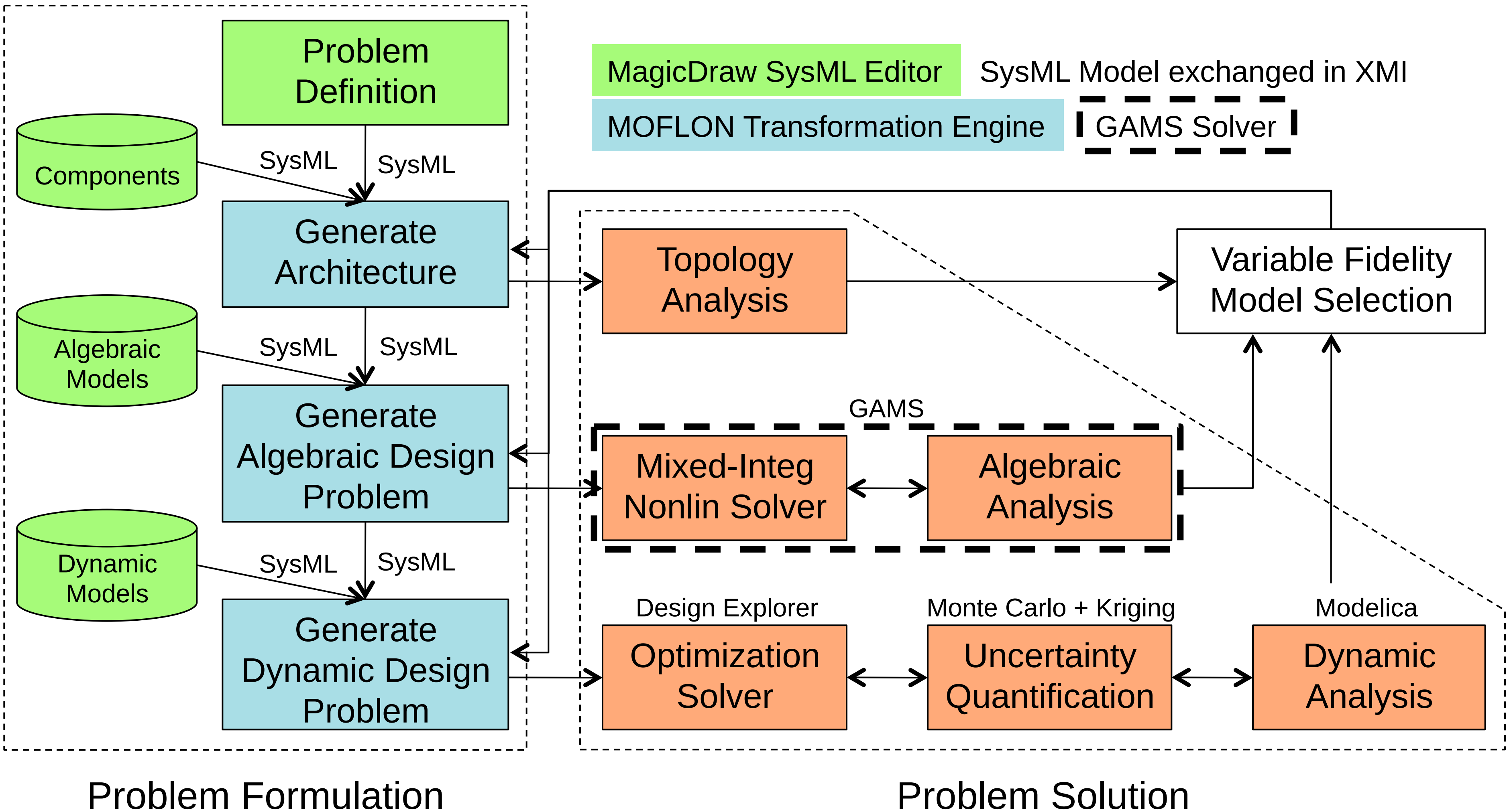


How to connect and size these?

Designer's Dilemma
M&S Risk/Benefit vs. Cost



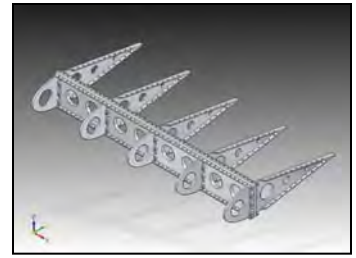
Architecture Exploration Framework



Both Problem Formulation and Problem Solution phases are implemented in ModelCenter

SysML Parametrics

Peak et al.



- Road scanning system using unmanned aerial vehicle (UAVs)
- UAV-based missile interceptor system trade study
- Space systems (tutorials): orbit planning; mass/cost roll-ups
- Space systems (studies/pilots): FireSat (INCOSE SSWG), ...
- Space systems (actuals): science merit function, ...
- Environmentally-conscious energy systems / smart grid
- Manufacturing “green-ness” / sustainability assessments
- Regional water management systems (e.g. South Florida)

...

- Mechanical part design and analysis (FEA)

...

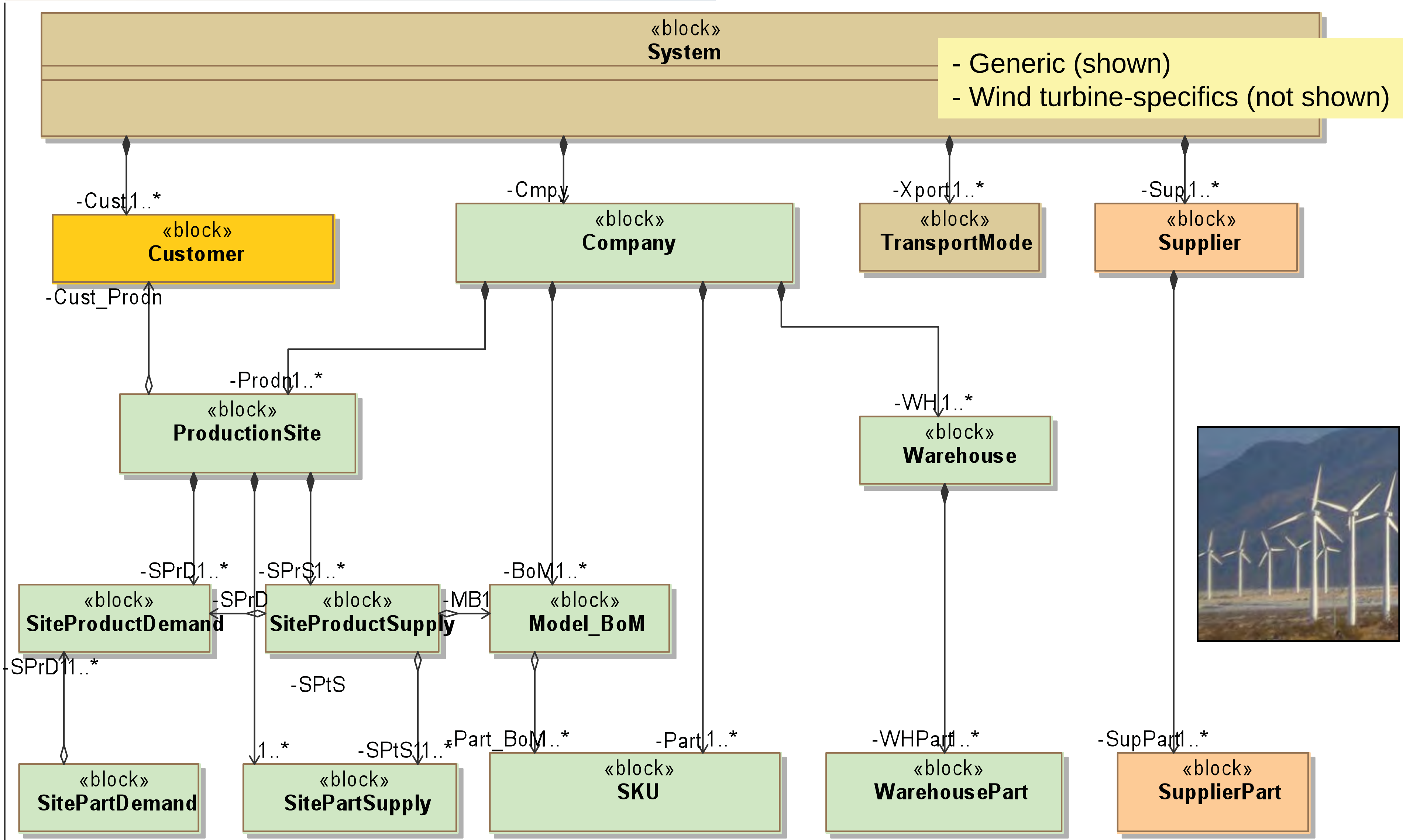
- Wind turbine supply chain management
- Insurance claims processing and website capacity model
- Financial model for small businesses
- Banking service levels model

...

Next-Generation Spreadsheet Technology++
(object-oriented, multi-dimensional, ...)

SysML Model: Global Supply Chain Mgt. & Optimization

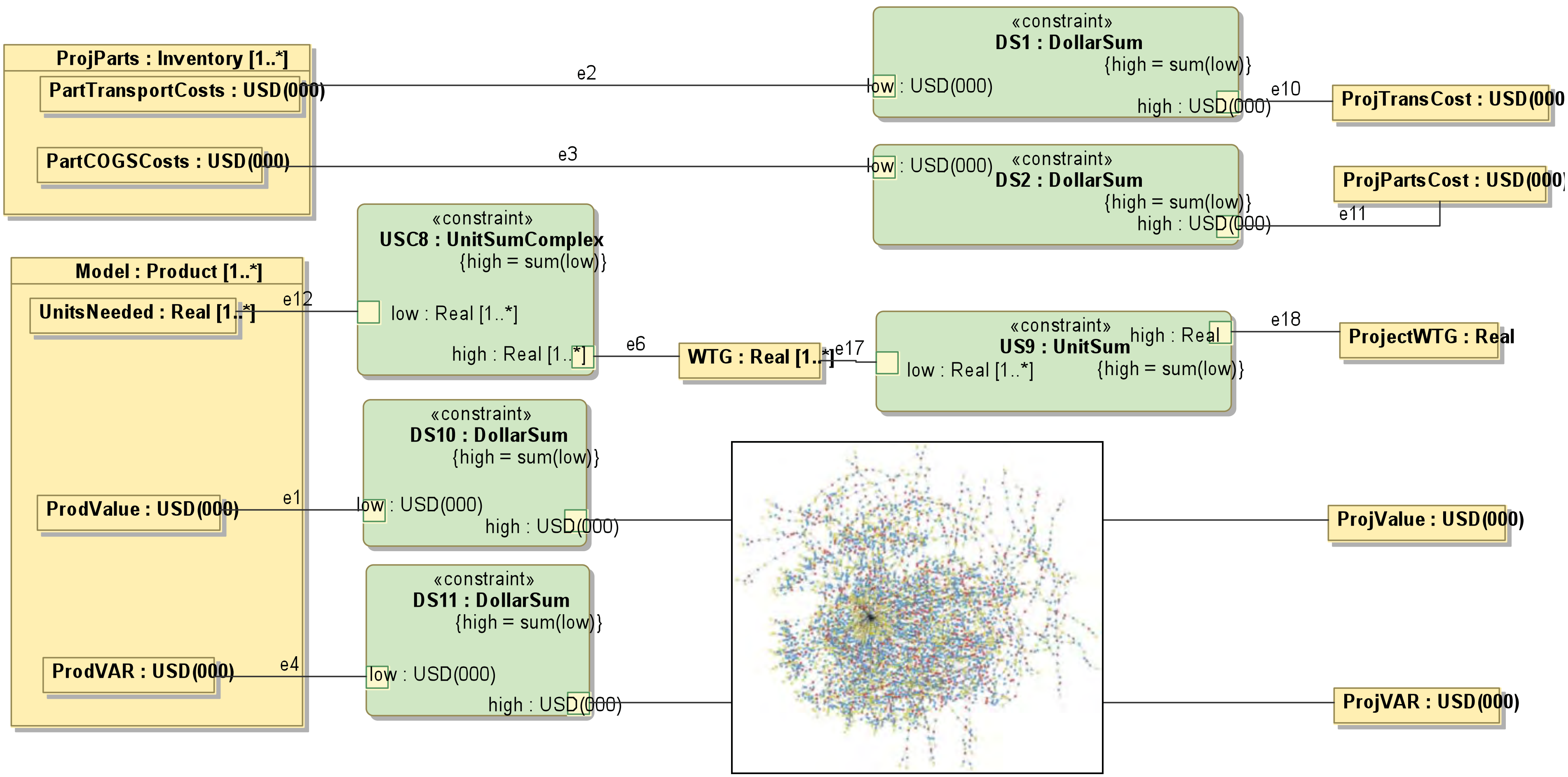
supply chain metrics (per-week): capacity, cost, lateness, risk, ...



Supply Chain Model – SysML Parametrics

Connect to Optimization Models, Compute Value-at-Risk

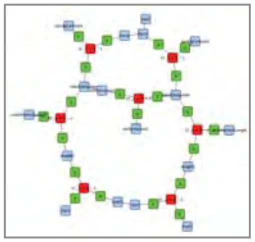
Ex. Given 100's of product orders and sourcing plans for the next 12 months, what percent of my business is at-risk if Supplier X does not deliver, or if Part Y becomes obsolete?



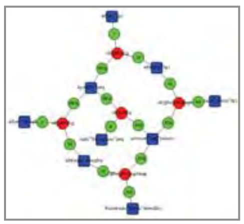
Model "DNA Signatures" Using SysML Parametrics

Panorama Tool by Andy Scott (Undergrad Research Asst.) and Russell Peak (Director, Modeling & Simulation Lab)
Examples as of ~9/2009 — Low/Medium Complexity

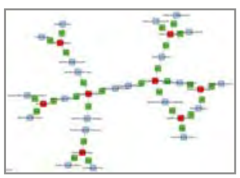
a. Snowman



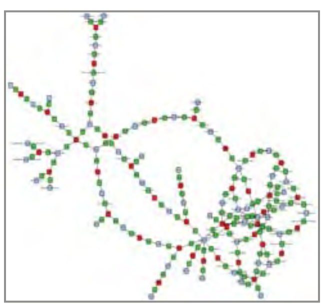
b. Mini Snowman



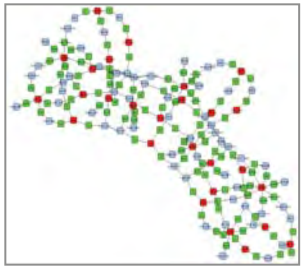
c. Snowflake



d. Mouse

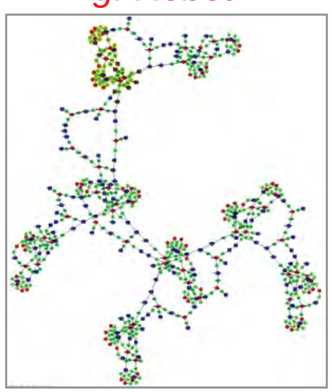


e. Cactus



f. ?

g. Robot



Test: Match the actual model titles (below) to their "DNA signatures" with imagined titles (left).

__g__ 1. South Florida water mgt. (hydrology) model

__a__ 2. 2-spring physics model

__e__ 3. 3-year company financial model

__c__ 4. UAV road scanning system model

__b__ 5. Car gas mileage model

__d__ 6. Airframe mechanical part model

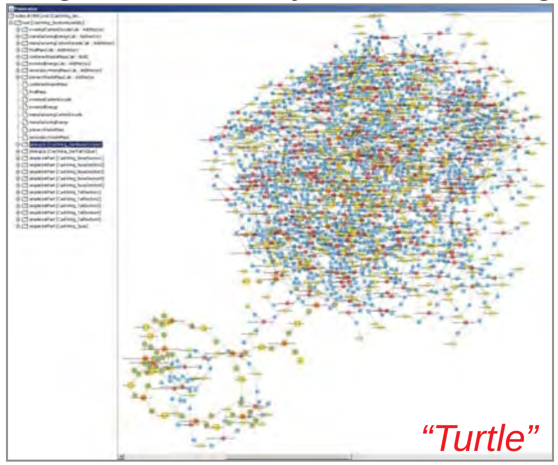
__f__ 7. Design verification model
(automated test for two Item 6. designs)

Recent Models: ~Medium Complexity

supply chain metrics

"Galaxy with Black Hole"

mfg. sustainability: airframe wing



"Turtle"

electronics recycling network

"Tumbleweed"

mfg. sustainability: automotive transmissions

"Turtle Bird"

"Angler Fish"

Georgia Institute of Technology

SysML/MBSE Curriculum & Formats

Statistics as of Sept 2010 — www.pslm.gatech.edu/courses

- Full-semester Georgia Tech academic courses
  - ISYE / ME 8813 & 4803: Since Fall 2007 (~95 students total)
- Industry short courses
  - Collaborative development & delivery with InterCAX LLC
  - Multiple [offerings,~students] and formats since Aug 2008
    - » SysML 101 [14,~260]; SysML 102 (hands-on) [12,~205]
  - Modes: » Onsite at industry/government locations
    - » Open enrollment via Georgia Tech (Atlanta, DC, Orlando, Vegas, ...)
    - » Web-based “live” since Apr 2010
  - Coming soon: 201/202, 301/302 (int/adv concepts, OCSMP prep, ...)
- Georgia Tech Professional Masters academic courses
  - Professional Masters in Applied Systems Engineering *www.pmase.gatech.edu*
  - ASE 6005 SysML-based MBSE course - Summer 2010
  - ASE 6006 SE Lab (SysML-based system design project) - Fall 2010

Contents

- Introduction
- Selected SE-related efforts
  - Professional Masters in SE (PMASE)
    Bishop, et al.
  - Tennenbaum Institute (TI)
    Bodner, Rouse, et al.
    See also our work in RT16 and RT25
  - GTRI SE Initiative
    Ender, et al.
  - Aerospace Systems Design Lab (ASDL)
    Mavris, et al.
  - Model-Based SE Center (MBSEC)
    McGinnis, Paredis, Peak, et al.
    See also our work in RT21 and RT24
- Summary

Georgia Institute of Technology

SYSTEMS ENGINEERING Research Center

Georgia Tech as part of SERC

- Pleased with collaboration in SERC to date
- Looking forward to new opportunities in SERC together